RESEARCH ARTICLE



First report and molecular characterization of the dagger nematode, *Xiphinema* oxycaudatum (Nematoda, Dorylaimidae) from South Africa

Fisayo Y. Daramola¹, Rinus Knoetze², Antoinette Swart^{3,4}, Antoinette P. Malan¹

I Department of Conservation Ecology and Entomology, Private Bag X1, Matieland 7602, Stellenbosch, South Africa 2 Plant Protection Division, Agriculture Research Council (ARC) Infruitec-Nietvoorbij, Private Bag X5026, Stellenbosch 7599, South Africa 3 Nematology Unit, Biosystematics Division, ARC-Plant Protection Research Institute, Private Bag X134, Queenswood 0121, South Africa 4 Department of Zoology, University of Johannesburg, PO Box 524, Auckland Park, Johannesburg 2006, South Africa

Corresponding author: Fisayo Y. Daramola (fdaramola@sun.ac.za)

Academic editor: Sergei Subbotin Received 9 April 2019 Accepted 13 October 2019	Published 3 December 2019
	!

Citation: Daramola FY, Knoetze R, Swart A, Malan AP (2019) First report and molecular characterization of the dagger nematode, *Xiphinema oxycaudatum* (Nematoda, Dorylaimidae) from South Africa. ZooKeys 894: 1–17. https://doi.org/10.3897/zooKeys.894.35281

Abstract

Plant-parasitic nematodes of the genus *Xiphinema* Cobb, 1913 comprise a complex group of nematode species, some of which are important vectors of plant viruses. During a field survey to determine the soil health of an abandoned honeybush (*Cyclopia genistoides*) monoculture, a high density of the dagger nematode, *Xiphinema oxycaudatum* Lamberti & Bleve-Zacheo, 1979 (Nematoda, Dorylaimidae), was observed in soil around the roots of honeybush plants in an abandoned farmland at Bereaville, an old mission station in the Western Cape province of South Africa. Soil samples were taken from the rhizosphere of plants and nematodes were extracted from the soil using a modified extraction tray method. Specimen of the dagger nematodes were processed for scanning electron microscopy, morphological and molecular analysis. Molecular profiling of the nematode species was done in order to give an accurate diagnosis and to effectively discriminate the nematode from other species within the *Xiphinema americanum* group. Phylogenetic analysis based on the D2D3 expansion segment of the 28S gene supported a close relationship of species within the *americanum* group, however, the protein-coding cytochrome oxidase (*cox1*) of the mitochondrial gene provided a useful tool for distinguishing the nematode from other species within the group. This study represents the first report of *X. oxycaudatum* from South Africa.

Keywords

coxI, D2D3, honeybush, molecular identification

Copyright Fisayo Y. Daramola et al. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Dagger nematodes, belonging to the *Xiphinema americanum*-group, are economically important nematodes that may cause damage to agricultural crops, by means of direct feeding on plant roots and in transmitting plant viruses. *Xiphinema oxycaudatum* Lamberti & Bleve-Zacheo, 1979 (Nematoda, Dorylaimidae) is a polyphagous and cosmopolitan nematode, which was first described from the rhizosphere of oil palm, *Elaies guineensis* in Nigeria (Lamberti and Bleve-Zacheo 1979). A high population of this nematode species were found in soil around honeybush (*Cyclopia genistoides*), in an abandoned farmland (-34.0516, 19.5174) at Bereaville in the Western Cape province, South Africa.

Although many nematode species in the *X. americanum*-group are widespread in distribution, *X. oxycaudatum* is localized in Africa with a few reports from Asia and South America (Lamberti et al. 2000; Fadaei et al. 2003; Oliveira et al. 2003; Chen et al. 2005). In South Africa, *Xiphinema* species have been listed as one of the most common and abundant plant parasitic nematodes causing damage on grapevines and woody plants (Fourie et al. 2017). However, only a few species belonging to the *Xiphinema americanum*-group have been reported in the country, some of these include; *X. americanum*, *X. brevicolle*, *X. diffusum*, *X. incognitum*, and *X. pachtaicum* (Lamberti et al. 1995, 2002).

Honeybush is an exclusive African herbal tea with a distinctive honey aroma and it is a rich source of compounds with antimutagenic properties (Kokotkiewicz and Luczkiewics 2009). There is an increasing demand for honeybush production in South Africa, due to increased awareness of the health benefits obtainable from this unique tea (SAHTA 2011).

In this study, the dagger nematodes found in soil around honeybush were identified with a combination of traditional morphological characterization and molecular techniques, based on the D2D3 expansion segment of the 28S gene and the proteincoding cytochrome oxidase (*coxI*) of the mitochondrial gene.

Methods

Sampling, nematode isolation, and processing

Soil samples were collected from three plots on the honeybush farmland, with five composite samples taken from each plot. Samples were taken from the rhizosphere of the plants, a depth of about 8 cm into the soil. Nematodes were extracted from the soil using a modified Whitehead and Hemming (1965) tray method and examined under a high-power compound microscope. Nematode specimens from a previously identified population of *Xiphinema americanum* Cobb, 1913 from a grapevine farm in the Western Cape was also included in the study. Nematodes were counted using a stereomicroscope and specimens collected for morphological study, scanning electron microscopy (SEM), and for molecular characterization of nematode species.

Light and scanning electron microscope observations

For light microscopy, nematode specimens were mounted on glass slides and observed under a compound microscope. Morphological characters were measured and light micrographs were taken with a Zeiss Axioskop 40 compound microscope equipped with a drawing tube. Adult females and juveniles were observed. Some of the morphometric features that were measured include total body length, oesophageal length, body diameter, stylet lengths (odontostyle and odontophore), lip region diameter, distance of basal guide ring from anterior, distance from anterior end to the vulva, width at vulva, and the tail length (Table 2). These measurements were used to calculate the characters; a, b, c, c' and V.

Table 1. Primer combination.

Primer code	Direction	Sequence (5'-3')	Amplified gene	References
D2A	Forward	ACA AGT ACC GTG AGG GAA AGT TG	28S rRNA	Nunn 1992
D3B	Reverse	TCG GAA GGA ACC AGC TAC TA		Nunn 1992
ITS1	Forward	TTGATTACGTCCCTGCCCTTT	ITS rRNA	Vrain et al. 1992
P28S	Reverse	TTTCACTCGCCGTTACTAAGG-		Vrain et al. 1992
CO1F	Forward	GATTTTTTGGKCATCCWGARG	COI	He et al. 2005
CO1R	Reverse	CWACATAATAAGTATCATG	COI	
XIPHR1	Reverse	ACAATTCCAGTTAATCCTCCTACC	COI	Lazarova et al. 2006
XIPHR2	Reverse	GTACATAATGAAAATGTGCCAC	COI	Lazarova et al. 2006

Table 2. Morphometrical data of *Xiphinema oxycaudatum* from South Africa. Measurements are in μ m, except where stated otherwise, in the form of: mean \pm standard deviation (range).

	Female	Pre-adult	Stage before pre-adult
n	11	6	1
L (mm)	$1.80 \pm 10.52 \; (1.60 {-} 1.94)$	1.42 ± 8.79 (1.33–1.52)	128.5
a	46.87 ± 4.37 (39.9–55.3)	37.46 ± 2.90 (33.6–40.9)	42.8
b	6.14 ± 0.56 (4.8–6.9)	4.93 ± 0.78 (3.5–5.7)	5.2
c	50.34 ± 2.96 (45.4–55.3)	37.28 ± 4.48 (29.9–42.2)	37.3
c'	$1.43 \pm 0.08 (1.3 - 1.6)$	$1.58 \pm 0.10 \ (1.4 - 1.7)$	1.6
V	49.82 ± 1.44 (47.8–52.4)	_	-
Odontostyle length	78.41 ± 5.12 (71-84)	64.9 ± 2.84 (61–68)	55
Odontophore length	56.14 ± 5.4 (46-66)	47.5 ± 0.84 (47-49)	43
Total stylet length	135.55 ± 5.41 (129.5–149.5)	112 ± 3.33 (111–117)	98
Replacement odontostyle length	_	78.78 ± 3.87 (74-85)	59.5
Anterior to guide ring	67.36 ± 2.84 (64–73)	55.5 ± 2.89 (50.5-58-73)	51.5
Tail length	35.82 ± 2.74 (31-41)	37.00 ± 4.70 (31-44.5)	34.5
h (hyaline portion of tail); also J	12.91 ± 1.61 (10.5–15.5)	9.92 ± 1.02 (9-11)	11
h % (hyaline portion/tail length)	36.08 ± 3.85 (29-40.3)	26.93 ± 1.95 (23.7-29)	31.9
Lip region diameter	12.86 ± 0.87 (11.5-13.5)	11.5 ± 0.54 (11–12)	11
Lip region height	5.86 ± 0.32 (5.5-6.5)	5.42 ± 0.38 (5-6)	4.5
Body diameter at guide ring	28.64 ± 1.80 (26-31.5)	25.75 ± 2.95 (23.5-31.5)	24
Body diameter at base of pharynx	36.20 ± 2.52 (33-42)	34.67 ± 4.03 (33-41)	29
Body diameter at vulva or mid-body for juvenile	39.18 ± 2.57 (36.5–44)	37.90 ± 5.19 (31–44)	30
Body diameter at anus	25.18 ± 1.97 (20.5-27.5)	23.42 ± 2.25 (20-26)	21
Body diameter at beginning of hyaline	13.50 ± 1.22 (11.5–16)	10.67 ± 0.61 (10-11.5)	9
portion of tail	$102.05 \pm (7.27)((7.214))$	55 70	
Pre-rectum length	$103.63 \pm 4/.5/(4/-214)$	33;70	-
Kectum length	$20.14 \pm 4.61 (12 - 31.5)$	$23.13 \pm /.49 (1/-34)$	-
Vagina length	$14.68 \pm 1.01 (12.5 - 16)$	—	-

Specimen samples for SEM were handpicked, fixed overnight in 2% Glutaraldehyde and dehydrated in increasing concentrations of ethanol. The nematode specimens were chemically dried with Hexamethyldisilizane (HMDS) in a fume hood and kept in a desiccator overnight. Nematodes were mounted on double-sided carbon tapes on Al stubs and were sputter coated with Pd/Au at a thickness of 100Å layer for 10 min.

A Zeiss Merlin FESEM (Carl Zeiss Microscopy, USA) was used to generate electron images at 3kV accelerating voltage using InLens SE and SE2 detection and a probe current of 100–150 pA. Images were captured in TIF format using a pixel averaging noise reduction algorithm.

DNA extraction, PCR, and sequencing

DNA was extracted from single adult female nematodes using a modified method of Nguyen (2007). The polymerase chain reaction (PCR) to confirm the identity of the nematode specie was carried out by the amplification of the internal transcribed spacer (ITS) region, the D2D3 expansion segment of the 28S gene of the ribosomal DNA, and the portion of the cytochrome oxidase (cox1) gene of the mitochondrial DNA. PCR of the ITS region was carried out as described by Chen et al. 2005 using KAPA2G 40 Robust HotStart ReadyMix (KAPA Biosystems) with the primer combination of S-ITS1 (5'-TTGATTACGTCCCTGCCCTTT-3') and 28S (5'-TTTCACTCGC-CGTTACTAAGG-3'). Amplification was carried out in a thermal cycler with the following cycling condition; 1 cycle at 94 °C for 4 min, followed by 30 cycles at 94 °C for 30 sec, 52 °C for 30 sec, and 72 °C for 2 min 30 sec, and ending with one cycle at 72 °C for 7 min and finally kept at 4 °C. PCR amplification of the D2-D3 expansion segments of the 28S rDNA gene was carried out with the primer set D2A (5'-ACA AGT ACC GTG AGG GAA AGT TG-3') and D3B (5'-TCG GAA GGA ACC AGC TAC TA-3') with the cycling condition of 4 min at 94 °C, followed by 35 cycles of 1 min at 94 °C, 1 min at 55 °C, and 1 min 30 sec at 72 °C, and a final extension at 72 °C for 10 min (Orlando et al. 2016). The portion of the partial coxI of the mitochondrial gene was amplified using a primer combination of the forward primer, COIF (5'-GATTTTTTGGKCATCCWGARG-3') with the reverse primer, XIPHR2 (5'-GTACATAATGAAAATGTGCCAC-3') as described by Lazarova et al. (2006). The thermal condition includes 1 cycle of 94°C for 1 min, 50 °C for a further 1 min and 72 °C for 2 min. This was followed by 40 cycles of 94 °C for 1 min, 45 °C for 1 min and 72 °C for 2 min. PCR was ended with a final extension phase of 94 °C for 1 min, 45 °C for 1 min and 72 °C for 5 min.

Sequence and phylogenetic analysis

PCR products were purified using the Nucleo-Fast Purification System (Macherey Nagel, Waltham, Massachusetts, USA). Sequencing of the purified DNA was performed in both directions with the Big Dye Terminator V1.3 sequencing kit, followed

by the use of electrophoresis on the 3730× 1DNA Analyser (Applied Biosystems) at the DNA Sequencing Unit (Central Analytical Facilities, Stellenbosch University). The Software CLC Main Workbench 7.3 (http://www.clcbio.com) was used for sequence assembly and editing. Newly obtained partial *coxI* sequences of *X. oxycaudatum* and *X. americanum* were deposited on the GenBank database with accession numbers MK211480 and MK956813 respectively. DNA sequences obtained for the D2D3 expansion segment of *X. oxycaudatum* was also deposited with accession numbers MK947997, MK966417, and MK988554.

The newly obtained DNA sequences were used for BLASTN (Altschul et al. 1997) comparison against GenBank sequences. DNA sequences from the top BLASTN matches, and other nematode sequences, were downloaded from GenBank and aligned using Multiple Alignment using Fast Fourier Transform (MAFTT).

The evolutionary history of the *coxI* region of the mitochondrial gene and D2D3 expansion segment of the 28S gene was inferred using the maximum parsimony (MP). The most parsimonious tree is shown. Evolutionary analyses were conducted in MEGA X version 10.0.5 (Kumar et al. 2018) and the confidence intervals for the various branching patterns in the trees were measured using bootstraps (Felsenstein 1985) with 1000 replicates. Estimates of the evolutionary divergence between sequences was done using pairwise distance analysis.

Results

Xiphinema oxycaudatum was observed in high numbers from samples taken from the abandoned honeybush farmland with a mean population density of about 510/250 cm³ soil.

Observations with SEM provided detailed information on some intrinsic features of the nematode such as the stirrup-shaped amphidial pouch, slit-like aperture, caudal pores and vagina opening (Fig. 1).

The morphological features of the nematodes are similar to those described from Nigeria (Lamberti and Bleve-Zacheo 1979; Bos and Loof 1983). Both adult females and juveniles were observed. The habitus of the nematodes are spiral or C-shaped with a head that is slightly offset. Adult females are between $1600-1800 \mu m$ long. They are more ventrally curved at the posterior end than the anterior. The vulva is located slightly above 50% of the body length; the ovary is amphi-didelphic with long oviduct and short uteri. The tail is conoid with bluntly rounded terminus. The juvenile stages are similar to adult females, but with a smaller body size. They also possess more pointed and sharper conoid tails. No male was found.

Description

Female: Body strongly curved ventrally into close C-shape. Cuticle 2.7 µm wide at mid-body, 6.5 µm at dorsal side of tail, radial striations visible on tail end. Lip region demarcated from body by slight depression (Fig. 2). Position of pharyngeal gland nuclei



Figure 1. Scanning electron micrographs of *Xiphinema oxycaudatum* **A–C** head region with stirrup-shaped amphidial pouch and slit-like aperture, vulva opening and tail showing a caudal pore. Scale bars: 2 µm.



Figure 2. Light microscopy of *Xiphinema oxycaudatum* **A–D** head region, female reproductive system with didelphic ovary, tail region and vulva. Scale bars: 10 µm (**A**, **C**, **D**), 20 µm (**B**).

and outlets (as percentage of bulb length): DO = 9.21 (6.5–11); DN = 15.05 (10.1–18.2); DN–DO = 5.83 (3.6–7.3); SN1 = 59.07 (49.3–67.8); SO = 64.54 (49.3–74.3); SN1–SO = 5.42 (0–11); SN2 = 62.86 (59.1–69.3); SN2–SO = 11.25 (5–18.3). Neck region 288.75 \pm 20.16 (265–310) µm long; cardia small, hemispherical to conoid in shape. Female reproductive system typical of *X. americanum* lineage (ovaries with symbionts, long oviducts, short uteri), each branch about two corresponding vulva diameters long. Tail conoid, dorsally convex, ventrally slightly arcuate with rounded terminus, two caudal pores on each lateral side.

Relationship

The specimens from South Africa agree well with the type description of *X. oxycaudatum* (Table 2) but are slightly longer (1.6–1.94 mm vs 1.5–1.7 mm); the vulva is situated more anterior in one specimen (47.8% vs 51–54%) and have a wider head region (11.5–13.5 μ m vs 9–10 μ m). However, the South African specimens are closer to the description of *X. oxycaudatum* from Iran (Fadaei et al. 2003) especially in the body length (1.6–1.9 mm in Iranian specimens) and more anterior position of vulva in some females (45.5–54% in Iranian specimens). The wider head region in the South African specimens are considered to be an intraspecific variation. The pre-adult stage juvenile from South Africa agrees well with the description of this stage described from Iran (Fadaei et al. 2003). One juvenile was found, which apparently falls in a stage before the pre-adult juvenile. It can be distinguished from the pre-adult stage, by the shorter replacement odontostyle (59 μ m vs 74–84 μ m in pre-adult juvenile). The specimens from South Africa are also near *X. peruvianum* Lamberti & Bleve-Zacheo, 1979, but can be distinguished by the shorter odontostyle (71–84 μ m vs 85–92 μ m and the shape of the tail (gradually tapered, conoid vs not so gradually tapered, almost subdigitate).

The phylogenetic relationships within the X. americanum-group species inferred from the analysis of D2D3 expansion segments of 28S and the partial mitochondrial coxI gene using MP are given in Figures 3 and 4 respectively. The D2D3 alignment was 710 base pairs long and included 59 X. americanum-group sequences with two outgroup sequences (X. index and Longidorus crataegi). Phylogenetic analysis of the D2D3 expansion region revealed a high similarity of almost 100% with some species in the *americanum*-group. Nearly identical sequences were obtained from the studied species, with interspecific divergence ranging from 0 to 0.25%. The MP tree showed two supported clades. Clade I (72%) includes: X. pachtaicum, X. incertum, X. pachydermum, X. parapachydermum, Xiphinema sp., X. simile, X. browni, and other nematode species. Clade II (100%) comprised of X. brevicalle species complex (Orlando et al. 2016): X. citricolum, X. americanum, X. californicum, X. rivesi, X. laevistriatum, and other species. Relationship within this clade was not well resolved. Intra-specific variation with about 2-3 indel events was also observed in the X. oxycaudatum sequences. The genetic relationship of the newly obtained sequences with reference sequences obtained from the National Centre for Biotechnology Information (NCBI) is illustrated in Figure 3.



Figure 3. Phylogenetic relationship within species of the *Xiphinema americanum*-group, based on analysis of the D2D3 regions with maximum parsimony (MP) using *Xiphinema index* and *Longidorus crataegi* as outgroups. Newly obtained sequence is indicated by bold letters.



Figure 4. Phylogenetic relationship within species of the *Xiphinema americanum*-group, based on analysis of the *coxI* regions with maximum parsimony (MP), using *Pratylenchus bolivianus* and *Caenorhabditis elegans* as outgroups. Newly obtained sequences are indicated by bold letters.

Species delimitation of *X. oxycaudatum* within the *X. americanum* group was achieved by analysing the *coxI* sequence alignment which comprised of 66 *X. americanum* group sequences and two other sequences, *Pratylenchus bolivianus* and *Caenorhabditis elegans* as outgroups. The alignment length was 298 base pairs long. Although there was no available sequence of the partial *coxI* gene of *X. oxycaudatum* on the NCBI database for comparison, the sequence showed a similarity of 86.19% and 82.48% with *X. peruvianum* and *X. rivesi* respectively. The pair-wise distance of *X. oxycaudatum* to the closely related Brazilian population of *X. peruvianum* is 245 base pairs differences (Table 3). Newly obtained *X. americanum* sequence showed a high similarity of 98.84% to the South African isolate (AM086690) with only four nucleotide differences. Estimates of the evolutionary divergence between the newly obtained sequence and some closely related ones is shown in Table 3. The number of base differences per sequence from between sequences are indicated.

Phylogenetic analysis of the aligned sequences revealed five major subclades within the studied *americanum*-group. They include: *X. americanum*, *X. californicum*, *Xiphinema* sp., *X. brevicolle* complex, and *X. pachtaicum*. *Xiphinema oxycaudatum* was closely related to *Xiphinema* sp. (Iran) and the Brazilian population of *X. peruvianum*. Within the 50% majority rule consensus MP tree, no significant difference was obtained in the two closely related species. However, sequences obtained from the *coxI* mitochondrial gene clearly discriminates *X. oxycaudatum* from other species within the *X. americanum*-group. The genetic relationship of this sequence with reference sequences obtained from the NCBI is illustrated in Figure 4.

Discussion

Precise identification of nematode species and knowledge of their distribution is important for effective phytosanitary and management options. Species identification of nematodes within the *Xiphinema americanum* group is often difficult and complicated due to overlapping of morphological features and phenotypic plasticity. The taxonomy of this group of nematodes is often regarded as controversial and subjective (Luc et al. 1998; Orlando et al. 2016), and there is a possibility to confuse and misidentify species within the group.

Some key morphological features that have been frequently used as diagnostic keys for differentiating between species within the *Xiphinema americanum* group include the lip region, odontostyle length, position of C, tail shape, and length (Lamberti and Bleve-Zacheo 1979; Lamberti and Carone 1991). However, in more recent times, identification has been done in combination with molecular tools with indications of mitochondrial marker cytochrome oxidase subunit 1 (*coxI*) as a barcode for species identification and a tool for resolving the complexity in identifying cryptic *americanum* species (Palomares-Rius et al. 2017).

Although the molecular analysis, based on the D2D3 region of the nematodes species in the present study revealed low interspecific variation in the nematodes within the *X. americanum* group, two distinct clades were evident from the phylogenetic tree.

The	
<i>1a americanum</i> group.	
he <i>Xiphinen</i>	
s within 1	
seduences	
ely related	
some close	
<i>binema oxycaudatum</i> and :	mences are shown.
s between Xip	m hetween sec
f COI region	sequence fro
. Pairwise distances of	of base differences per s
Table 3.	number c

12

	,	e	•		·		t		-	•	•	•		;	,	ļ	\$	\$	ć	č	ć	ę	è	è	è	Į	é	ę	ę	ć	
Species 1 X oxyca udatum_(South_Africa_M	-	4	c 🗌	4	\sim	•	-	0	-			7	6		٩ 	-	2I	2	07	17	77	C7	77	6	07	7	Q7	Q	8	10	
KZ11480) KZ11480 7 X rivesi (IISA Florida KX263104)	98					+	\top	+	+	+	_	_	_																		
3 Xiphinema_sp_(USA_Florida XX263101)	66	52									-																				
4 X tarjanense_(USA_Florida_ AM086694)	103	45	32																												
5 Xiphinema_sp(lran_MK 202796)	105	56	66	56				\vdash	-	-	-																				
6 Xgeorgianum_(USA_Florida_ AM086695)	106	56	65	56	65																										
7 Xincognitum_(China_AM086705)	107	68	63	58	65	72		-	-	-																					
8 Xbrevicolle_(Russia_KX263107)	107	76	68	62	62	72	55	-	-	-	-																				
9 Xrivesi_(Spain_JQ990060)	110	53	47	53	57	75	61	70																							
10 Xlambertii_(Czech_Republic_H M163208)	112	77	74	62	72	75	63	62 7	73																						
11 Xbrevicolle_(Brazil_AM086707)	118	69	70	74	69	81	66	77 7	77 8	22																					
12 Xluci_(Spa in_KY816627)	120	65	70	63	67	63	78	81 6	51 7	4 8	2																				
13 Xtaylori_(Slovakia_AM086703)	120	69	66	70	61	69	71	43 7	72 7	71 8	1 7.	_																			
14 X citricolum_(USA_Florida _AM086693)	122	61	58	59	57	67	68	67 (28	1 2	9 5	9 7:	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~																		
15 Xflorida e_(USA_Florida_ AM086696)	127	69	72	64	72	64	82	81	8 8	22	2 6	4 8	1 63																		
16 Xrivesi_(USA_Arkansa s_ AM086697)	128	69	70	65	70	99	84	20 2	74 8	35 8	5 6	2	1 69	9																	
17 Xdiffusum_(China_AM086701)	120	62	65	61	63	67	69	54 6	57 7	1 7	9 7(6 5(5 71	88	86																
18 Xdiffusum_(Brazil_AM086699)	122	63	64	58	62	64	65	50 6	57 7	0 7	6 7	4 5,	5 71	83	81	Ξ															
19 Xasta regiense_(Spain_KP268977)	132	113	108	113	102	116	103	105 1	16 16	05 1()6 11	2 10	6 115	9 122	122	116	116														
20 Xsimile_(Slova kia_AM086708)	135	94	105	106	84	108	67	102 5	6 86	11(96 80	9 10	1 97	104	103	101	106	123													
21 Xperuvianum_(Brazil_AM086712)	245	211	212	243	203	247	250 2	218 2	30 2	59 25	52 23	33 25	0 25() 250	248	3 243	245	241	247												
22 Xperuvianum_(USA_ Georgia_ AM086692)	272	234	241	255	224	265	268	242 2	54 2	79 2(57 25	58 26	54 260	5 269	265	263	266	256	264	72											
23 Xamerica num_(South_Africa_M K956813)	98	48	52	47	57	58	59	58	56 6	22 2	4 5	0 6	4 32	58	61	58	58	67	94	236	240										

	Species	-	2	3	4	5	9	~	8	6	0 1	1 1	2 1	3 1	4 1	5 1	6 1	1	8 1	9 2(0 2	1 22	2	3 24	1 25	26	27	28	29	30	31	1
24	Xamerica num_(South_Africa] AM086690)	119	57	59	53	60	64	67	63 (52	22	33 5	2 9	1 3	4 6	2 6	9 6	00	3 11	4 9	8 24	8 26	8									I
25	Xamericanum_(USA_Florida	273	243	244	260	234	284 2	279 2	47 2	66 2	86 2	82 2	56 2.	74 2;	74 27	72 27	72 27	9 27	7 26	57 27	8 26	0 29	1 23	9 27	9							1
26	Xamerica num_(USA_California ZX263065)	226	238	241	216	229	235 2	228 2	39 2	44 2	43 2.	39 2	36 2	32 21	28 22	26 22	26 23	3 23	32 23	6 23	3 22	14 24	6 20	5 23:	2 20							1
27	Xamerica num_(USA_California ZX26305 7)	232	247	249	221	235	247 2	239 2	45 2	50 2	53 2.	48 2	42 2	38 2	36 25	36 2	36 24	3 24	£2 24	65 23	9 22	24	9 21	3 24	9	47						I
28	Xamerica num_(USA_Alabama_K X263058)	244	242	247	226	230	244	242 2	145 2	44 2	59 2	46 2	48 2,	43 24	43 24	<u>46 2</u> 2	<u>14</u> 24	4 24	46 24	65 23	2 6	5 33	3 22	3 24	7 27	1 26	2 26	~				1
29	Xamerica num_(USA_California 2 	247	237 :	243	227	225	245 2	241 2	43 2	45 2	59 2	50 2,	49 2,	46 2	<u>44 24</u>	£7 2,	£5 24	7 24	<u>f9 25</u>	61 23	9 9	3 22	8 22	3 24	8 27	1 25	7 250	5 35				I
30	Xamerica num_(USA_California	250	242	247	232	230	250 2	248 2	51 2	50 2	65 2	52 2:	54 2	<u>49</u> 2 ²	49 25	52 25	50 25	0 25	52 25	0 24	3 6	5 33	4 22	9 25	3 27	4 26	2 26	0	36			1
31	Xamerica num_(USA_California 2 _KX263063)	253	242	247	235	230	253 2	251 2	51 2	53 2	68 2	55 2:	57 2:	52 2;	52 25	55 25	53 25	3 25	55 25	52 24	9 9	5 3:	5 23	2 25	6 27	7 26	2 26	30	37	0		
32	Xina equale_(Czech_Republic_H 163207)	264	249	258	258	233	279 2	270 2	2 2	86 2	87 2	78 2.	72 2	72 24	65 26	57 20	57 26	9 2(59 28	33 27	0 25	9 29	0 24	1 27	2 76	66	67	279	28]	282	285	ا ما

X. oxycaudatum was separated in a group from other *Xiphinema* species with a strong statistical support. This was also evident from previous studies where low interspecific variation within the *X. americanum*-group has been reported (He et al. 2005; Orlando et al. 2016). They indicated that *X. americanum*-group species formed two highly supported clades, *X. americanum* and *X. pachtaicum* (sensu Lamberti and Ciano 1993). Oliveira et al. (2004) also obtained nearly identical result with analysis of the 18 rDNA sequences where species belonging to the *X. americanum*-group formed a single group separated from the other *Xiphinema* species. He however suggested that 18S rDNA does not provide a useful marker to discriminate *Xiphinema* in the *americanum* group at the species level. This was also confirmed by Zasada et al. (2014), who showed that 18S rDNA sequence data did not provide taxonomic clarity among some populations of *X. americanum*. In the present study, the sequences obtained from the ITS region were of poor quality and were not used for phylogenetic analysis.

The protein coding mitochondrial gene, cytochrome oxidase subunit I (*coxI*), has been described as a reliable and preferred molecular barcode and a useful tool for highlighting the intra-specie variation within some species of *X. americanum*-group (Lazarova et al. 2006; Gutiérrez-Gutiérrez et al. 2012; Lazarova et al. 2016; Orlando et al. 2016; Palomares-Rius et al. 2017). In the present study, *coxI* gene was used to reconstruct the phylogenetic relationship within the species; thus, in combination with morphological identification, it provided a useful tool for delimitation and discrimination of *X. oxycaudatum* from other species within the *americanum*-group.

This study represents the first report of *X. oxycaudatum* in association with honeybush in South Africa. The South African population is both morphometrically and genetically similar to *X. peruvianum*. Meza et al. (2011) indicated that a high homology exists between Chile population of *X. peruvianum* and *X. oxycaudatum* identified from Taiwan. The South African population are similar to *X. peruvianum* but are distinguished by their shorter odontostyle and tail shape. This nematode species has been reported in association with a wide range of cultivated plants from Nigeria, Kenya, Iran, Pakistan, Brazil, and Taiwan (Lamberti and Bleve-Zacheo 1979; Bos and Loof 1983; Coomans and Heyns 1997; Fadaei et al. 2003; Oliveira et al. 2003; Chen et al. 2005). Our record of *X. oxycaudatum*, in association with *Cyclopia* spp. from South Africa, will add a new record to this list.

Nematodes belonging to the *Xiphinema americanum*-group are cosmopolitan in their distribution and have phytopathological importance with some species being implicated as vectors of important plant viruses. High numbers of *X. oxycaudatum* that were recorded from the honeybush farmland in South Africa could have resulted from high multiplication rate of nematodes due to availability of a suitable host, presence of some attractants in the soil, and some edaphic factors. The occurrence of *X. oxycaudatum* in such high density recorded in this study is disturbing and suggests that a damage potential may exist, which could have future implications on the budding honeybush tea industry.

To our knowledge, this will be the first documented report of the occurrence of *X*. *oxycaudatum* in South Africa.

Acknowledgements

The authors would like to thank Chantelle Girgan for her contribution to photography and Rhoda Malgas for her expert advice.

The financial assistance of the Human resources for Industry Programme (THRIP: TP14062571871) and the National Research Foundation (NRF) (grant no: 99679) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF.

References

- Altschul SF, Madden TL, Schäffer AA, Zhang J, Zhang Z, Miller W, Lipman DJ (1997) Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. Nucleic Acids Research 25(17): 3389–3402. https://doi.org/10.1093/nar/25.17.3389
- Bos WS, Loof PAA (1983) Nigerian species of the genus *Xiphinema* Cobb, 1913 (Nematoda: Dorylaimida): part I. Nematologica 30: 395–418. https://doi.org/10.1163/187529284X00301
- Chen D, Fang N, Yen J, Cheng Y, Tsay T (2005) Differentiation of the *Xiphinema americanum* group nematodes *X. brevicollum*, *X. incognitum*, *X. diffusum* and *X. oxycaudatum* in Taiwan by morphometrics and nuclear ribosomal DNA sequences. Nematology 7: 713–725. https://doi.org/10.1515/helmin-2015-0068
- Coomans A, Heyns J (1997) Three species of the *Xiphinema americanum*-group (Nematoda: Longidoridae) from Kenya. Nematologica 43: 259–274. https://doi. org/10.1163/005025997X00021
- Fadaei AA, Coomans A, Kheiri A (2003) Three species of the *Xiphinema americanum* lineage (Nematoda: Longidoridae) from Iran. Nematology 5: 453–461. https://doi. org/10.1163/156854103769224430
- Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39: 783–791. https://doi.org/10.1111/j.1558-5646.1985.tb00420.x
- Fourie H, Spaull VW, Jones RK, Daneel MS, De Waele D (2017) Nematology in South Africa: A View from the 21st Century. Springer, Cham, Switzerland, 569 pp. https://doi. org/10.1007/978-3-319-44210-5
- Gutiérrez-Gutiérrez C, Cantalapiedra-Navarrete C, Decraemer W, Vovlas N, Prior T, Palomares-Rius JE, Castillo P (2012) Phylogeny, diversity, and species delimitation in some species of the *Xiphinema americanum*-group complex (Nematoda: Longidoridae), as inferred from nuclear and mitochondrial DNA sequences and morphology. European Journal of Plant Pathology 134: 561–597. https://doi.org/10.1007/s10658-012-0039-9
- He Y, Subbotin SA, Rubtsova TV, Lamberti F, Brown DJF, Moens M (2005) A molecular phylogenetic approach to Longidoridae (Nematoda: Dorylaimida). Nematology 7: 111–124. https://doi.org/10.1163/1568541054192108
- Kokotkiewicz A, Luczkiewics M (2009) Honeybush (*Cyclopia* sp.) a rich source of compounds with high antimutagenic properties. Fitoterapia 80: 3–11. https://doi.org/10.1016/j.fitote.2008.11.001

- Kumar S, Stecher G, Li M, Knyaz C, Tamura K (2018) MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Molecular Biology and Evolution 35: 1547– 1549. https://doi.org/10.1093/molbev/msy096
- Lamberti F, Bleve-Zacheo T (1979) Studies on *Xiphinema americanum sensu lato* with descriptions of fifteen new species (Nematoda, Longidoridae). Nematologia Mediterranea 7: 51–106.
- Lamberti F, Carone M (1991) A dichotomous key for the identification of species of *Xiphinema* (Nematoda: Dorylaimida) within the *X. americanum*-group. Nematologia Mediterranea 19: 341–348.
- Lamberti F, Molinari S, Moens M, Brown DJF (2000) The *Xiphinema americanum* group. I. Putative species, their geographical occurrence and distribution, and regional polytomous identification keys for the group. Russian Journal of Nematology 8: 65–84.
- Lazarova SS, Malloch G, Oliveira CMG, Hübschen J, Neilson R (2006) Ribosomal and mitochondrial DNA analyses of *Xiphinema americanum*-group populations. Journal of Nematology 38: 404–410.
- Lazarova S, Peneva V, Kumari S (2016) Morphological and molecular characterisation, and phylogenetic position of *X. browni* sp. n., *X. penevi* sp. n. and two known species of *Xiphinema americanum*-group (Nematoda, Longidoridae). ZooKeys 574: 1–42. https://doi. org/10.3897/zookeys.574.8037
- Luc M, Coomans A, Loof PAA, Baujard P (1998) The Xiphinema americanum-group (Nematoda: Longidoridae). 2. Observations on Xiphinema brevicollum Lordello & daCosta, 1961 and comments on the group. Fundamental and Applied Nematology 21: 475–490. http:// hdl.handle.net/1854/LU-180033
- Meza P, Aballay E, Hinrichsen P (2011) Molecular and morphological characterization of species within the *Xiphinema americanum*-group (Dorylaimida: Longidoridae) from the central valley of Chile. Nematology 13: 295–306. https://doi.org/10.1163/138855410X518498
- Nguyen KB (2007) Methodology, morphology and identification. In: Nguyen KB, Hunt DJ (Eds) Entomopathogenic Nematodes: Systematics, Phylogeny and Bacterial Symbionts. Brill Leiden, Brill, 59–119. https://doi.org/10.1163/ej.9789004152939.i-816
- Nunn GB (1992) Nematode molecular evolution: an investigation of evolutionary patterns among nematodes based upon DNA sequences. PhD Thesis, University of Nottingham, Nottingham.
- Oliveira CMG, Brown DJF, Neilson R, Monteiro AR, Ferraz LCCB, Lamberti F (2003) The occurrence and geographic distribution of *Xiphinema* and *Xiphidorus* species (Nematoda, Longidoridae) in Brazil. Helminthologia 40: 41–54.
- Oliveira CMG, Hübschen J, Brown DJF, Ferraz LCCB, Wright F, Neilson R (2004) Phylogenetic relationships among *Xiphinema* and *Xiphidorus* nematode species from Brazil inferred from 18S rDNA sequences. Journal of Nematology 36: 153–159.
- Orlando V, Chitambar JJ, Dong K, Chizhov VN, Mollov D, Bert W, Subbotin S (2016) Molecular and morphological characterisation of *Xiphinema americanum*-group species (Nematoda: Dorylaimida) from California, USA, and other regions, and co-evolution of bacteria from the genus *Candidatus xiphinematobacter* with nematodes. Nematology 18(9): 1015–1043. https://doi.org/10.1163/15685411-00003012

- Palomares-Rius JE, Cantalapiedra-Navarrete C, Archidona-Yuste A, Subbotin SA, Castillo P (2017) The utility of mtDNA and rDNA for bar-coding and phylogeny of plant-parasitic nematodes from Longidoridae (Nematoda, Enoplea). Scientific Reports 7(10905):1–12. https://doi.org/10.1038/s41598-017-11085-4
- South African Honeybush Tea Association (2011) A profile of the South African honeybush tea market value chain. Department of Agriculture, Forestry and Fishers, Republic of South Africa, 6–9.
- Vrain TC, Wakarchuk DA, Levesque CA, Hamilton RI (1992) Intraspecific rDNA restriction fragment length polymorphism in the *Xiphinema americanum*-group. Fundamental and Applied Nematology 15: 563–573. http://www.documentation.ird.fr/hor/fdi:40261
- Zasada IA, Peetz AB, Howe DK, Wilhelm LJ, Cheam D, Denver DR, Smythe AB (2014) Using mitogenomic and nuclear ribosomal sequence data to investigate the phylogeny of the Xiphinema americanum species complex. PLoS ONE 9: e90035. https://doi.org/10.1371/ journal.pone.0090035
- Zeng Y, Ye W, Zhang Z, Sun H, Yong L, Huang Y, Zhao K, Liang H, Kerns J (2016) Morphological and molecular characterization of *Xiphinema* species from Shenzhen, China. Helminthologia 53: 62–75. https://doi.org/10.1515/helmin-2015-0068

RESEARCH ARTICLE



Muangnua arborea, a new semislug (Gastropoda, Stylommatophora, Helicarionidae, Durgellininae) from Loei Province, northeastern Thailand

Chanidaporn Tumpeesuwan¹, Sakboworn Tumpeesuwan^{1,2}

l Department of Biology, Faculty of Science, Mahasarakham University, Kantharawichai District, Maha Sarakham, 44150 Thailand **2** Palaeontological Research and Education Centre, Mahasarakham University, Kantharawichai District, Maha Sarakham, 44150 Thailand

Corresponding author: Sakboworn Tumpeesuwan (stumpeesuwan@yahoo.com)

Academic editor: Martin Haase Received 17 July 2019 Accepted 23 October 2019 Published 3 December 201	9
http://zoobank.org/4F021747-1CAE-4D14-BC22-7A7DA21B647A	

Citation: Tumpeesuwan C, Tumpeesuwan S (2019) *Muangnua arborea*, a new semislug (Gastropoda, Stylommatophora, Helicarionidae, Durgellininae) from Loei Province, northeastern Thailand. ZooKeys 894: 19–32. https://doi.org/10.3897/zooKeys.894.38327

Abstract

Muangnua arborea Tumpeesuwan & Tumpeesuwan, **sp. nov.**, is described, based on specimens deposited in the land snail collection of Mahasarakham University, Thailand. This species is the second described in the genus *Muangnua*, for which colour pictures of the living semislug in natural habitats, scanning electron microscope photos of the radula, and anatomy of the mature specimens were studied and presented for the first time for this genus. Keys to genera of Southeast Asian slug-like semislugs and species of *Muangnua* are provided.

Keywords

Durgellini, Loei, Na Haeo, new species, semi-slug, slug, taxonomy, Thailand

Introduction

Muangnua Solem, 1966 is a genus of helicarionid semislug with its shell reduced to a partially calcified cap having only a single remnant of coiling and that is completely covered by fused shell laps. The mantle lobes form a large cephalic shield reaching nearly to its eyes. Based on the external morphology, *Muangnua* looks similar to the

genus *Parmarion* Fischer 1856. *Muangnua limax* Solem, 1966 is the sole species in the genus, which was collected by B. Degerbol on 8 November 1958 from Doi Suthep in Chiang Mai Province, northern Thailand, at 1100 m above mean sea level. Since its discovery, no additional information on the species has been published (Panha 1996; Vorajuk 2000; Hemmen and Hemmen 2001; Nabhitabhata 2009).

During the project 'Landsnails of Na Haeo Area', specimens and photographs of our previous expedition in Loei Province in 2011 were re-examined, and a second species of the genus *Muangnua* was discovered from the land snail assemblage of Phu Suan Sai sandstone mountain (Fig. 1), which is approximately 250 km southeast from Doi Suthep (the type locality of *M. limax*). This suggests that the genus has evolved at a high altitude and might be distributed over a wide area, and further new species in the genus from other high altitudes might be discovered in the future.

Material and methods

Living specimens were collected on 24–25 October 2011 from trunks, twigs, and leaves, etc. of monocotyledon and dicotyledon plants in an evergreen forest on sandstone hills at Phu Suan Sai, Na Haeo District, Loei Province, northeastern Thailand (Fig. 1). Snails were photographically documented in the natural sandstone habitat (Figs 2, 3), collected, drowned in water, and preserved in 70% ethanol to study their genital system and radula morphology. Adult shells were counted for whorl number and measured for shell height (SH) and shell width (SW), using digital vernier calipers. Adult snails were dissected to examine their genital system under a stereo microscope for description. Radula were extracted from the buccal mass and examined under a scanning electron microscope at the Centre for Scientific and Technological Equipment, Suranaree University of Technology, Thailand. The examined specimens were deposited in the land snail collection of the Natural History Museum, Mahasarakham University, Thailand (NHMSU).

Results

Order Stylommatophora A. Schmidt, 1855 Superfamily Helicarionoidea Bourguignat, 1877 Family Helicarionidae Bourguignat, 1877 Subfamily Durgellinae Godwin-Austen, 1888 Tribe Durgellini Godwin-Austen, 1888

Genus Muangnua Solem, 1966

Type species. *Muangnua limax* Solem, 1966.

Diagnosis (based on type material studied by Solem (1966)). Shell reduced, having only one remnant of coiling, which in living semislug is completely covered by fused shell



Figure 1. Map of type locality (circle is type locality of *Muangnua limax*; star is type locality of *Muang-nua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov.) (modified from GinkgoMaps-project http://www.ginkgomaps.com).

laps. Mantle lobes form large cephalic shield reaching base of tentacles. Tail long and slender, with hooked caudal horn. Posterior visceral hump rounded, resting in V-shaped body groove. Jaw thin, without median projection or sculpture. Radula possesses tricuspid central, lateral, and marginal teeth. Genitalia, was studied from juvenile specimen, therefore, epiphallus cannot be differentiated. Free oviduct short, vagina rather long, dart apparatus, and other accessory penial organs absent; gametolytic sac (= spermatheca in Solem, 1966) long, finger-like, reaching two-thirds of way to albumen gland; atrium rather short.

Remarks. The genus *Muangnua* was originally placed in the family Helicarionidae and tribe Durgelli by Solem (1966), after which Vaught (1989) moved it to the family Ariophantidae (Table 1). Panha (1996), Hemmen and Hemmen (2001), and Nabhitabhata (2009) followed Vaught's classification. Schileyko (2002) also follows Vaught (1989), but he placed genus *Muangnua* into the subfamily Ariophantinae and tribe Ariophantini (Table 1). Recently, Bouchet and Rocroi (2005) and Bouchet et al. (2017) moved the tribe Durgellini into the subfamily Durgellinae (Helicarionidae). In this study, we followed Bouchet and Rocroi's classification. Among the three genera of long elongate, small Southeast Asian semislugs (Parmarion P. Fischer, 1856; Muangnua Solem, 1966; and Laocaia Kuzminykh, 1999), their external morphology is very similar, but they possess many different characters. Parmarion frequently covers their ear-shaped shell with a mantle lobe, whereas Muangnua and Laocaia always cover their finger nail-shaped shell and triangular shaped shell, respectively, with their mantle lobe. The caudal horn overhangs in *Muangnua* and *Laocaia* but does not overhang in Parmarion. The postero-dorsal midline keel is present in Parmarion and Muangnua whereas it is present or absent in Laocaia.

Muangnua arborea Tumpeesuwan & Tumpeesuwan, sp. nov.

http://zoobank.org/DE9258DC-692D-4AF1-891E-18C98D78EABC Figs 2–9

Material examined. *Holotype.* (Fig. 4) Thailand: Loei Province, Phu Suan Sai sandstone mountain, in small valley of Suan Pa Na Po, type locality covered by evergreen forest with dense undergrowth of bamboo and banana, 17°27'55"N, 100°55'30"E; at 940–960 m above mean sea level, 24–25 October 2011; C. Tumpeesuwan, S. Tumpeesuwan, and member of MSU malacology laboratory leg.; NHMSU-00019. *Paratypes.* Seven adults and three juveniles, same data as for holotype: NHMSU-00020.

Etymology. Specific epithet "arborea" derived from Latin word "arboreus" meaning "of trees" referring to the habitat of this new semislug species.

Differential diagnosis. (Table 2) *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. differs from *Muangnua limax* Solem, 1966 by its body coloration. Head

Authors		Tax	a	
-	Family	Subfamily	Tribe	Genus
Solem (1966)	Helicarionidae	Ariophantinae	Durgellini	Muangnua
Vaught (1989)	Ariophantidae	Macrochlamydinae	-	Muangnua
Panha (1996)	Ariophantidae	-	-	Muangnua
Hemmen and Hemmen (2001)	Ariophantidae	-	_	Muangnua
Schileyko (2002)	Ariophantidae	Ariophantinae	Ariophantini	Muangnua
Bouchet and Rocroi (2005)	Helicarionidae	Durgellinae	Durgellini	-
Nabhitabhata (2009)	Ariophantidae	Macrochlamydinae	-	Muangnua
Bouchet et al. (2017)	Helicarionidae	Durgellinae	Durgellini	-

Table 1. Classification of Muangnua Solem, 1966.

of *M. arborea* with three black or pale black strips, for which each lateral side of head possesses lighter stripes from base of lower tentacle back to base of cephalic shield, a darker mid-dorsal line from anterior extremity among tentacles back to one-third of body length under cephalic shield (Figs 3–6), whereas, mid-dorsal line black strips absent in *M. limax*. There are various sizes of white spots crowded on fringe and keel of living *M. arborea*, which causes remarkable white "Y" stripe on postero-dorsal side of foot (missing in preserved specimens), whereas, preserved specimen of *M. limax* possesses three black strips on postero-dorsal side of foot, a darker stripes on mid-dorsal keel, and two lighter stripes on both lateral sides.

Description. *Body:* Body is slender, elongated (Figs 2–6). Body length 37.1–45.3 mm and body width 10.2–10.4 mm when slightly retracted. Foot narrow, posterior part of foot laterally depressed and forms steep keel structure (Figs 2B–D, 3–6) tapering posteriorly. Tail long with hooked, caudal horn (Fig. 6B), tail length almost equal to half of length of posterior end of visceral hump to anterior end of head. Posterior lobe of visceral hump rounded, resting in "V" shaped body groove on top of foot (Figs 5, 6). Mantle lobes and shell laps fused and forming large cephalic shield, completely covering shell and visceral hump.

Coloration: Primary color of anterior body is light-ocher-brownish and gradually changes to brown or dark brown at posterior of body. Head possesses two pairs of tentacles (=ommatophores in Dedov et al. 2019). Lower tentacle is short and same color as head. Upper tentacle is black colored at base and gradually changes to lightocher-brownish at top of tentacle, which contrasts with black eye spot on top of tentacle. Head with three black or pale black strips, for which each side of head possesses lighter stripes from base of lower tentacle back to base of cephalic shield and under its edge, a darker mid-dorsal line from anterior extremity among both tentacles back to one-third of body length under cephalic shield (Figs 3–6). Whole body has pattern of irregularly-dispersed various-sized white spots. Visceral hump with two short vague, pale brown lateral strips (Figs 3A, 5, 6A). Posterior lobe of visceral hump sitting in dark brown to pale black V-shaped depression on postero-dorsal side of foot.

Character	Ta	xa
	M. limax	M. arborea
Body		
Mid-dorsal line	Absent	Present
Lateral stripe	Present	Absent
Radula		
Rows	120	> 123
Teeth/row	179	> 44
Genitalia		
Free oviduct	Present (short)	Absent
Vagina	Rather long	Very long
Gametolytic sac	Reaching two-thirds way to albumen gland	Reaching about half way to albumen gland

Table 2. Comparison of morphological characters between *Muangnua limax* Solem, 1966 and *Muang-<i>nua arborea* Tumpeesuwan & Tumpeesuwan sp. nov.



Figure 2. *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. **A** in natural habitat, evergreen forest along small stream valley on sandstone mountain at type locality, in which new species was found on monocot leaf (indicated by white arrow) **B** close-up view of specimen (indicated by arrow in **A**) **C** new species in resting position on tree trunk **D** new species on dicot leaf.



Figure 3. *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. **A** in natural habitat, after waking from resting position on bamboo leaf **B** revealing protective behavior on banana leaf.



Figure 4. *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. dissected holotype specimen NHMSU-00019 **A** lateral left **B** lateral right **C** dorsal **D** ventral. Photograph by: Benchawan Nahok.



Figure 5. *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. external morphology and coloration of body with visceral hump and V-shaped dorsal groove, **A** mature snail **B** immature snail.

Fringe of V-shaped depression connects to steep keel on postero-dorsal side of foot. Various sizes of white spots crowded on fringe and keel, which causes remarkable white "Y" stripe on postero-dorsal side of foot; posterior extremity of this white Y-shaped stripe connects to white caudal horn.

Shell (Fig. 7): Reduced to partially calcified cap having no coiling, shell length 7.1–7.4 mm, SW 5.1–5.5 mm., apex not prominent, shell shape similar to human finger nail, white calcified plate covered by transparent pale brown periostracum, normally sloughs off in preserved specimens (Fig. 7). In living semislug, its shell is always completely enclosed by fused shell laps.

Radula (Fig. 8): According to old specimens preserved since 2011, edge of radula plates macerated and breaks down during radula extraction process. Although, we choose the best specimens from several individuals, nevertheless, most of the marginal teeth were lost or incomplete. Radula plate long ribbon-shape, comprised of at least 123 rows of teeth. Each row composed of more than 44 teeth. Central teeth isosceles triangle, tricuspid, very large broad base, mesocone long lancelate, ectocones prominent but short, not reaching nearly to edge of base plate. First lateral teeth with small



Figure 6. *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. **A** colour pattern variation within population **B** close-up view of caudal horn (indicated by arrow).



Figure 7. Shell of *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. (paratype NHM-SU-00020) A external view B internal view C periostracum removed from shell of preserved specimen.

entocone appearing on mesocone shaft, ectocone large and plump on outer side of cusps. Laterals have basal plate elongated, increasing as entoconal size increases and ectocone rapidly decreases in size. By 20th tooth, teeth sub-equally bicuspid, as entocone becomes smaller than mesocone and ectocone reduced to a small side cusp.

Genitalia morphology (Fig. 9): Atrium rather short. Penis large and stout, peanut-shape, internally with short cylindrical muscular verge, which attaches to inner surface of penis at proximal end (connected to distal end of epiphallus); inner surface sculpture of penis can be divided into 2 types: upper portion around verge covered with numerous small tubercles, and lower portion covered with transverse folds (Fig. 9B, C); epiphallus length equal to penis, dumbbell-shape; vas deference inserts to epiphallus apically. Vagina very long and slender tube, prostate gland very small and encloses uterus, albumen gland small, hermaphroditic duct convoluted. Dart apparatus (amatorial organ) and other accessory penial organs absent. Gametolytic sac long, finger-like, reaching about half way to albumen gland.

Discussion. According to the most recent information, this species is known only from the type locality. They were found only on plants (Fig. 2), which is normally on the leaves of monocot plants, such as bamboo, banana, etc. (Fig. 3). In the resting stage, this animal normally holds onto the leaves or trunks of plants by inverting their tail and



Figure 8. Radula morphology of *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. (paratype NHMSU-00020) **A** radula plate (ribbon-like radula in middle of picture) **B** central tooth (arrow) and lateral teeth **C** close-up view of left side of radula **D** close-up view of middle part of radula **E** close-up view of left side of radula showing marginal teeth **F** close-up view of right side of radula.

attaching its end to the left side of their head, making their body U-shaped (Fig. 2C). This new species has a similar protective behavior to that described by Dedov et al. (2019) for *Laocaia simovi* and Wiktor (2002) for *Cryptaustenia saltatoria* and *Cryptaustenia obesa*. If they are touched or caught, they will quickly flip, wag, and twist their foot to escape from the predator (Fig. 3B). In addition, for some semislugs in the resting stage, we found them near their fecal matter (Fig. 3A), which might suggest this animal has homing behavior, and they will return to sleep in the same position every day.



Figure 9. Reproductive anatomy of *Muangnua arborea* Tumpeesuwan & Tumpeesuwan, sp. nov. (paratype NHMSU-00020), **A** genitalia **B** inner part of penis **C** after verge inverted. Abbreviations: hd = hermaphroditic duct, ag = albumen gland, vd = vas deferens, ep = epiphallus, er = epiphallic retractor, p = penis, ve = verge, at = atrium, gs = gametolytic sac, ut = uterus, v = vagina, pr = prostate gland.

According to Schilthuizen and Liew (2008) a semislug is defined as snails with a partially visible shell that, due to their rather small shell, cannot withdraw its body into its shell. *Muangnua* is a slug-like semislug possessing a reduced shell having only

one remnant coil that is always covered by a mantle lobe. There are many species of semislug described and recorded from South and Southeast Asia (Blanford and Godwin-Austen 1908), including, *Girasia* Gray, 1855 from Himalaya and Assam (India), *Cryptogirasia* Cockerell, 1898 from Naga Hills (India), from Western Ghat (India) and Ceylon (Sri Lanka), *Austenia* Nevill, 1878 from the Himalaya, Assam (India) and Burma (Myanmar), *Parmarion* P. Fischer, 1856 from South China to Java (Indonesia), *Minyongia* Godwin-Austen, 1916 from Assam (India), and *Myotesta* Collinge, 1901 from North Vietnam. Of these genera, only *Austenia* and *Parmarion* are known in Thailand. *Austenia doisutepensis* Solem, 1966 has a short body and 1²/₃ to 2 whorls; therefore, its mantle lobes and shell laps cannot cover all the shell surface and leave much of the shell exposed (snail-like semislugs). *Parmarion martensi* Simroth, 1893 has an elongated body, in which the small ear-shape reduced shell is frequently covered by mantle lobes and shell laps (slug-like semislugs). We provide below keys for identifying the genera of slug-like semislugs and species of *Muangnua* in Southeast Asia.

Key to genera of Southeast Asian slug-like semislugs

1	Ear-shaped shell frequently covered by mantle lobe; Caudal horn not over-
	hanging Parmarion
_	Finger nail or triangular shape shell always covered by mantle lobe; Caudal
	horn overhanging
2	Finger nail-shaped shell; gametolytic sac long cylindrical tube Muangnua
_	Triangular shaped shell with thin seam periostracum; gametolytic sac stalk
	short and stout or moderately long and slender

Key to species of genus Muangnua

	Muanonya arborea sp. nov.
_	Head with mid-dorsal line; tail without lateral stripe
1	Head without mid-dorsal line; tail with lateral stripe Muangnua limax

Acknowledgements

We would like to thank Benchawan Nahok for providing photographs of Holotype and SEM. We wish to express sincere thanks to Kitti Tanmuangpak, Chamaiporn Worachak, Ariya Hoompuay, Jittapa Ounchareon, and Jutatip Tippanet for helping with our fieldwork. We are indebted to Nual-anong Wichaikul, the Centre for Scientific and Technological Equipment of Technology Suranaree University for her help with sample processing and SEM work. We are deeply grateful to The Biodiversity Heritage Library (https://www. biodiversitylibrary.org/) for previous literature made available to us. Special thanks to Jolyon Dodgson for kindly checking the manuscript. We are deeply thankful to Barna Páll-Gergely, Liew Thor-Seng, and Chris Glasby for their valuable comments and suggestions. This research was Financially Supported by Mahasarakham University Grant Year 2018 (6105050/2561). Animal Care and Use Protocol Review No. IACUC-MSU-0023/2017.

References

- Blanford WT, Godwin-Austen HH (1908) The Fauna of British India, Ceylon and Burma. Taylor and Francis, London, 311 pp.
- Bouchet P, Rocroi JP (2005) Classification and Nomenclature of Gastropod Families. Malacologia 47(1–2): 1–397.
- Bouchet P, Rocroi JP, Hausdorf B, Kaim A, Kano Y, Nützel A, Parkhaev P, Schrödl M, Strong EE (2017) Revised classification, nomenclator and typification of gastropod and monoplacophoran families. Malacologia 61(1–2): 1–526. https://doi.org/10.4002/040.061.0201
- Bourguignat JR (1877) Description de deux nouveaux genres algériens, suivies d'une classificationdes familles et des genres de Mollusques terrestres et fluviatiles du système européen. Bulletin de la Sociéte des Sciences Physiques et Naturelles de Toulouse 3(1): 49–101.
- Cockerell TDA (1898) Note on Mariaella dussumieri. Nautilus 12(1): 9-10.
- Collinge WE (1901) Description of some new species of slugs collected by Mr. H. Fruhstorfer. The Journal of Malacology 8: 118–121.
- Dedov I, Schneppat U, Vu MQ, Huy NQ (2019) A new semislug of the genus Laocaia (Gastropoda, Pulmonata, Helicarionidae) from Vietnam. ZooKeys 846: 19–30. https://doi. org/10.3897/zookeys.846.34372
- Fischer P (1856) Actes de la Société Linnéenne de Bordeaux 20: 395.
- Godwin-Austen HH (1888) Land and freshwater Mollusca of India, including South Arabia, Baluchistan, Afghanistan, Kashmir, Nepal, Burmah, Pegu, Tenasserim, Malay Peninsula, Ceylon, and other islands of the Indian Ocean. Supplementary to Messrs. Theobald and Hanley's Conchologia Indica 1(6): 207–257.
- Godwin-Austen HH (1916) Zoological results of the Abor Expedition, 1911-12 Mollusca, VI. Records of the Indian Museum 8: 547–559. [pls. 45–48]
- Gray JE (1855) Catalogue of Pulmonata or Air-breathing Mollusca in the collection of the British Museum (Part 1). London, 192 pp.
- Hemmen J, Hemmen C (2001) Aktualisierte Liste der terrestrischen Gastropoden Thailand. Schriften zur Malakzoologie 18: 35–70.
- Kuzminykh AA (1999) A new genus and two new species of land snails of the Family Ariophantidae from North Vietnam. Ruthenica 9: 47–50.
- Nabhitabhata J (2009) Checklist of Mollusca Fauna in Thailand. Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand, 576 pp.
- Nevill G (1878) Hand list of Mollusca in the Indian Museum, Calcutta (Part I). Gastropoda, 338 pp. https://doi.org/10.5962/bhl.title.11957
- Panha S (1996) A checklist and classification of the terrestrial pulmonate snails of Thailand. Walkerana 8(19): 31–40.

- Schileyko AA (2002) Treatise on recent terrestrial pulmonate molluscs. 9. Helicarionidae, Gymnarionidae, Rhysotinidae, Ariophantidae. Ruthenica, Supplement 2(10): 1167–1307.
- Schileyko AA (2003) Treatise on recent terrestrial pulmonate molluscs. 10. Ariophantidae, Ostracolethaidae, Ryssotidae, Milacidae, Dyakiidae, Staffordiidae, Gastrodontidae, Zonitidae, Daudebardiidae, Parmacellidae. Ruthenica, Supplement 2(10): 1309–1466.
- Schilthuizen M, Liew TS (2008) The slugs and semi-slugs of Sabah, Malaysia Borneo (Gastropoda, Pulmonata: Veronicellidae, Rathouisiidae, Ariophantidae, Limacidae, Philomycidae). Basteria 27: 287–306.
- Solem A (1966) Some non-marine mollusks from Thailand, with notes on the classification of the Helicarionidae, Spolia Zoologica Musei Hauniensis 24: 7–110. [pls. 1–3]
- Vaught KC (1989) A classification of the living Mollusca. American Malacologist, Inc., Melbourne, 189 pp.
- Vorajuk C (2000) Taxonomic revision of semi-slugs in Thailand and some parts of neighboring countries. Unpublished Thesis, Department of Biology, Faculty of Science, Chulalongkorn University, Bangkok, 119 pp.
- Wiktor A (2002) Terrestrial gastropods of the Province of Madang in Papua-New Guinea (Part II) – Two species of *Cryptaustenia* Cockerell, 1898 (Pulmonata: Helicarionidae) new to the science. Folia Malacologica 10(4): 225–231. https://doi.org/10.12657/folmal.010.014



Variation in the number of testicular follicles and ovarioles among 18 lacewing species of the families Myrmeleontidae, Ascalaphidae, and Nemopteridae (Insecta, Neuroptera, Myrmeleontiformia)

Valentina G. Kuznetsova¹, Anna Maryańska-Nadachowska², Gadzhimurad N. Khabiev³, Gayane Karagyan⁴, Victor A. Krivokhatsky¹

 Zoological Institute, Russian Academy of Sciences, Universitetskaya emb. 1, 199034, St. Petersburg, Russia
Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Sławkowska 17, 31-016, Kraków, Poland 3 Prikaspiyskiy Institute of Biological Resources, Dagestan Scientific Centre, Russian Academy of Sciences, M. Gadzhieva street 45, 367025, Makhachkala, Russia 4 Scientific Center of Zoology and Hydroecology NAS RA, P. Sevak 7 Yerevan 0014, Armenia

Corresponding author: Valentina Kuznetsova (valentina_kuznetsova@yahoo.com)

Academic editor: S. Grozeva	Received 3 October 2019	Accepted 30 October 2019	Published 3 December 2019
http://zoobank.org/0B3730C2-B49C-4C49-8C6A-48F3C4A39701			

Citation: Kuznetsova VG, Maryańska-Nadachowska A, Khabiev GN, Karagyan G, Krivokhatsky VA (2019) Variation in the number of testicular follicles and ovarioles among 18 lacewing species of the families Myrmeleontidae, Ascalaphidae, and Nemopteridae (Insecta, Neuroptera, Myrmeleontiformia). ZooKeys 894: 33–51. https://doi. org/10.3897/zookeys.894.47040

Abstract

The representatives of the lacewing families Myrmeleontidae, Ascalaphidae, and Nemopteridae (the suborder Myrmeleontiformia) were studied with reference to the number of testicular follicles in males and the number of ovarioles in females. We have found that the number of follicles is highly variable, at least in the first two families. In the comparatively more fully explored family Myrmeleontidae, the species studied have three to several hundred follicles per testis, the dominant values being six and five. In Ascalaphidae, two main patterns were revealed: testes with a low number of follicles (six and twelve per testis) and testes with multiple follicles (several dozens). Moreover, differences in the follicle number were often observed both between males of the same species and different testes of a male. In Nemopteridae, considered a sister group to the [Myrmeleontidae + Ascalaphidae] clade, the testes in males were found to consist of six or five follicles each. This implies that a low number of follicles, most likely six, is an ancestral trait in Myrmeleontiformia. All other numbers are thus the derived traits and are probably due to a simple oligomerization or a simple polymerization, the latter process having been very intensive in the evolution of the suborder. Conversely, females were found to have ten ovarioles per ovary in each of the three families studied.

Copyright Valentina G. Kuznetsova et al. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords

Antlions, owlflies, spoonwings, testes, number of follicles, ovaries, number of ovarioles

Introduction

Many studies have been conducted on the internal reproductive organs in insects (see review books: Matsuda 1976; Büning 1994; Chapman 2013; Klowden 2013). It was shown that the gross morphology of both male and female reproductive systems is, for the most part, similar in different insects. In males, it is generally constituted by a pair of testes formed by a variable number of seminiferous tubules known as the testicular follicles, accessory glands, seminal vesicles, ejaculatory duct and ejaculatory bulb. The number of follicles, where development of initial diploid spermatogonia to fully differentiated haploid spermatozoa takes place, is closely related to sperm production by an insect. Follicles can vary in number from one per testis, e.g., in some psocids (Golub 2003), psyllids (Maryańska-Nadachowska et al. 2001a), true bugs (Castanhole et al. 2012), wasps and ants (Palomeque et al. 1990; Fiorillo et al. 2008), dipterans (Hassan et al. 2017) and beetles (Schubert et al. 2017), to a few dozens and even hundred per testis. For example, some grasshoppers (Acrididae) have up to 100 follicles in each of the paired testes whereas some Hymenoptera have up to 300 follicles per testis (Chapman 2013). The most common numbers in most insects seem to range from four to ten. The number of follicles is usually constant, symmetrical in the male (at least in cases of lower numbers), and species-specific. Moreover, some higher-level insect taxa show the same or close numbers of follicles in different species. For example, about two thirds of psyllids (Hemiptera: Psylloidea) have two follicles per testis; however, some subfamilies of the families Carsidaridae (Carsidarinae) and Psyllidae (Rhinocolinae, Spondyliaspidinae) are characterized by one follicle per testis (Maryańska-Nadachowska et al. 2001a). In true bugs (Hemiptera: Heteroptera), the number of follicles varies from one to seven per testis with, however, greater proportions of species showing seven follicles (Leston 1961; Akingbohungbe 1983). In bees (Hymenoptera: Apoidea), the number of follicles is predominantly three or four per testis (Moreira et al. 2008). In great majority of Antliophora (Diptera + Mecoptera + Siphonaptera), the testis consists of a single follicle or if there are several (three to five) follicles, they are fused medially into a simple, undivided sac, which also may be regarded as a single follicle (Sinclair et al. 2007; Chapman 2013).

In females, the internal reproductive organs are generally presented by a pair of ovaries formed by a variable number of ovarian tubes termed the ovarioles (comparable with the testicular follicles in the male) and connected via a pair of lateral oviducts to a median oviduct, ending in the vagina and genital opening. Each ovariole contains sequentially developing egg chambers at progressively advanced stages of oogenesis. Overall, two basic types of ovarioles (ovaries) are distinguished in insects, the panoistic and meroistic ones (Büning 1994; Bilinski 1998). In the panoistic ovary, all germline cells differentiate into oocytes, whereas in the meroistic ovary, some of the germline cells differentiate into oocytes, while others become nurse cells (trophocytes). The meroistic ovaries in turn may be of either a polytrophic or a telotrophic type depending on the spatial relations between the oocyte and the nurse cells within the ovariole. In the polytrophic ovarioles, each oocyte possesses its own group of trophocytes and is connected to them by intercellular bridges. In the telotrophic ovarioles, trophocytes remain in the trophic chamber and are connected to oocytes in the vitellarium by long nutritive cords. In insects, ovariole architecture is related to both phylogeny and life history (Štys and Biliński 1990; Büning 1993, 1994, 2005, 2006; Bilinski 1998). Ovarioles are known to vary considerably in number in different taxa, ranging from one in each of the paired ovaries, e.g. in some apterygotes, beetles and aphids, to approximately 1000, e.g. in termite queens, coccids, and some beetles (Büning 1994; Gillot 2005; Klowden 2013; Faille and Pluot-Sigwalt 2015). The most common numbers in most insects range from four to ten per ovary (Klowden 2013) and coincide thus with those of testicular follicles in males. The number of ovarioles is controlled differently across various insect groups (Hodin 2009). In some taxa, this pattern is genetically fixed being highly invariant. For example, females of almost all Lepidoptera, including many macro- and micro-moths and butterflies, have four ovarioles per ovary (Hodin 2009; Zhang et al. 2017). By contrast, in the approximately 13,000 known species of grasshoppers, ovariole number varies largely, from four to 297 per ovary (Stauffer and Whitman 1997). Likewise, in Coleoptera, ovariole number varies from one to 1000 in the ovary (Büning 1994). Specifically, among as little as 20 ground beetle species (from six genera) of the tribe Trechini (Carabidae) ovariole number extends from one to seven per ovary (Faille and Pluot-Sigwalt 2015). Besides, ovariole number can show substantial interspecific and interpopulation variation being influenced by different factors such as, e.g., environmental differences or a particular way of life (Taylor and Whitman 2010; Faille and Pluot-Sigwalt 2015).

Information on the ovaries and testes is of significance in questions dealing with insect development, life cycles, reproductive biology, evolution, taxonomy, and phylogeny. A significant body of literature on the subject has been published to date (e.g., Akingbohungbe 1983; Emeljanov and Kuznetsova 1983; Kuznetsova 1985; Glowacka et al. 1995; Maryańska-Nadachowska et al. 1996, 2001a, 2001b, 2006; Kubrakiewicz et al. 1998; Emeljanov et al. 2001; Kuznetsova et al. 2002, 2009; Wieczorek and Wojciechowski 2003; Fereira et al. 2004; Büning 2005; Wieczorek 2006; Sinclair et al. 2007; Papáček and Soldán 2008; Tworzydło et al. 2010; Mróz and Wojciechowski 2011; Dias et al. 2013; Green 2014; Faille and Pluot-Sigwalt 2015). Unfortunately, studies dealing with follicles and ovarioles mostly concern single species, and comparative data across multiple species of a group are still rare. Nevertheless, as shown in some publications, the number of testicular follicles can provide an informative taxonomic and phylogenetic character at different levels among higher taxa. More specifically, follicle number appeared constant at the taxonomic levels of tribes and/or subfamilies within the hemipteran families Delphacidae and Dictyopharidae (Auchenorrhyncha), with the changes in this character being correlated with their evolution (Kuznetsova 1985; Kirillova 1989; Kuznetsova et al. 2009). Several studies on the jumping plant lice (Hemiptera: Psylloidea) indicated a taxonomic and phylogenetic significance of the number of follicles showing them as reliable synapomorphies of the higher-level taxa (Maryańska-Nadachowska et al. 2001a, b). Moreover, differences in the follicle number have helped to discover hidden species within the psyllid genus *Cacopsylla* Ossiannilsson, 1970 (Psyllidae) (Kuznetsova et al. 2012) and the hymenopteran genus *Neoponera* Emery, 1901 (Formicidae) (Barcellos et al. 2015).

Neuroptera (lacewings) are an ancient and highly heterogeneous order of holometabolous insects, also known as Planipennia, containing 5803 species described in 16 families (Oswald 2016). The state of knowledge of testes and ovaries in lacewings is very poor and inadequate. Though limited to a few species, the results currently available show that the testis of the neuropteran males may comprise one, five, 40 or "numerous" follicles (Brauer 1854; Stitz 1909; Quartey and Kumar 1973; Matsuda 1976; Walker et al. 1994; De Jong 2011). As it appears from a series of more recent original papers (Kubrakiewicz 2002; Garbiec and Kubrakiewicz 2012; Garbiec et al. 2016; Vacacela et al. 2017), the ovary of the neuropteran females may include from eight to 24 ovarioles, and their ovarioles are of the meroistic-polytrophic type. Neuroptera are one of the oldest holometabolous insect orders with this type of ovaries (Garbiec and Kubrakiewicz 2012).

The present study was focused on the number of follicles and ovarioles in lacewings of the families Myrmeleontidae (antlions), Ascalaphidae (owlflies), and Nemopteridae (spoonwings). Myrmeleontidae comprise the most species-rich and most widespread neuropteran family, with over 1500 valid extant species in 191 genera (Stange 2004). The closely related Ascalaphidae are a moderately speciose family encompassing approximately 400 valid extant species assigned to approximately 65 genera, with wide distributional range in tropical and temperate areas of the world (Sekimoto and Yoshizawa 2007). Extant Nemopteridae encompass 146 valid species worldwide distributed between two subfamilies, Nemopterinae (spoon- and ribbon-wings, 98 species) and Crocinae (thread-wings, 48 species) (Sole et al. 2013). All these families, together with another two small extant families, Psychopsidae (silky lacewings) narrowly distributed in Australasia, Asia, and Africa, and Nymphidae (split-footed lacewings), endemic to the Australasian region, make up a derived monophyletic clade within Neuroptera, the suborder Myrmeleontiformia (Aspöck et al. 2001, 2003; Grimaldi and Engel 2005; Badano et al. 2016; Song et al. 2019).

Materials and methods

Insect samples

Lacewings were collected from May to October 2013–2018 in the Republic of Armenia, the Eastern Caucasus by G. Karagyan, T. Ghrejyan, I. Stepanjan, and A. Dantchenko, in the Republic of Dagestan, the North-East Caucasus, Russia by G. Khabiev
and E. Ilyina, and in the Astrakhan region, Russia by E. Ilyina. Adult males and females were fixed in 3:1 (ethanol: acetic acid) fixative and then stored at 4 °C until required. Collection sites, sampling dates, and the number of studied specimens are given in Table 1. Species identification was made by G. Khabiev and/or V. Krivokhatsky. Voucher specimens have been deposited in the insect collections of Zoological Institute RAS (St. Petersburg, Russia).

Microscopic observation of gonads

The current study is part of a larger research project on Neuroptera, their cytogenetics and evolution. For the last decade, we have prepared dozens of cytological preparations to study the karyotypes and male meiosis of lacewings represented by a quite wide taxonomic range (Kuznetsova et al. 2015, 2016). For those purposes, the insects were fixed in the Carnoy fixative (ethanol and glacial acetic acid, 3:1), the gonads were then dissected out of the abdomen in a drop of 45% acetic acid on a microscope slide and squashed. Before squashing for the subsequent chromosome analyses, the testicular follicles of the male and the ovarioles of the female were carefully separated from each other and counted under a stereomicroscope SZX7, Olympus. Those data became a basis for the present paper. While estimating the variation of the number of follicles per testis and ovarioles per ovary, we calculated the arithmetic mean and its standard deviation (SD) in a given set of data.

Results

In males, the internal reproductive organs were found to locate in the area of abdominal segments IV to VIII (depending of the species and the stage of development of the individual) and consist of the various parts commonly found in insects, including two symmetrical testes with various numbers of follicles, seminal vesicles, efferent ducts, accessory glands and the ejaculatory duct. Within the testis, follicles connect each other at the base, each follicle being enclosed in a yellow to red scrotal sheath. In females, the internal reproductive organs usually occupy the area of abdominal segments II to III and consist of a pair of ovaries, a pair of lateral oviducts, a common central oviduct, accessory glands, and a spermatheca. Within the ovary, the ovarioles are transparent and join each other by the terminal filaments. The investigation of the complete structure of the reproductive organs falls outside the scope of our study, which has almost exclusively focused on the number of follicles in males and the number of ovarioles in females.

Overall 18 species belonging to 15 genera of the families Myrmeleontidae (14 species, eleven genera, five subfamilies), Ascalaphidae (two species, two genera, one subfamily), and Nemopteridae (two species, two genera, one subfamily) were explored. All species, except *Euroleon nostras* (Geoffroy in Fourcroy, 1785) (Myrmeleontidae) and

Table	١.	Numbe	er of	ftesticula	r follicles	and	ovarioles	in N	/lyrmele	contidae,	, Ascal	aphidae,	and	Nemo	pteridae.

	Taxon	Number of males and	Number of follicles in each of	Number of ovarioles in each of	Place and date of collection	Reference
		females studied	the paired testes	the paired ovaries		
Myrn	neleontidae					
Palpa 1.	irinae Palpares libelluloides (Linnaeus, 1764)	6ð	305/* 267/378 351/396 346/319 312/472	_	Russia, Dagestan, Makhachkala, May 2013	Present study
2.	Palpares sp.	:9,	<u>337/338</u> 40/40	-	Ghana, Legon	Quartey and Kumar 1973
Acan	thaclisinae	1				
3.	Acanthaclisis occitanica (Villers, 1789)	18	50/51	-	Russia, Dagestan, Makhachkala, July 2015	Present study
		19	-	10/10	Armenia, Azat Reserve, June 2017	
Nemo	oleontinae		[r	. 1	
4.	Creoleon plumbeus (Olivier, 1811)	6 <u></u> °	6/6 (3) 5/6 (1) 5/*(1) 5/5 (1)	-	Russia, Dagestan, Gazard Cala, July 2015	Present study
		1♀	-	10/10	Armenia, Ararat prov., Lanjar 18.08.2016	
5.	Creoleon griseus (Klug in Ehrenberg, 1834)	1♀	-	10/10	Armenia, Yerevan, 15.08.2016	Present study
6.	Distoleon tetragrammicus (Fabricius, 1798)	4ð	4/4 (1) 4/5 (1) 5/5 (2)	-	Russia, Dagestan, Makhachkala, Karaman, 2016	Present study
		19	-	10/10	Russia, Dagestan, Makhachkala, July 2015	
7.	Delfimeus irroratus (Olivier, 1811)	1♀	-	10/10	Armenia, Ararat prov., env. Dashtakar, 6.08.2016	Present study
8.	<i>Neuroleon lukhtanovi</i> Krivokhatsky, 1996	13	5/5	-	Russia, Dagestan, Chirkata, 15.07.2013	Present study
9.	Neuroleon sp.	?♀	-	10/10	Ghana, Legon	Quartey and Kumar 1973
10.	<i>Macronemurus</i> <i>bilineatus</i> Brauer, 1868	3♂	5/* 6/5 5/5	-	Russia, Dagestan, Makhachkala, June 2013	Present study
Myrn	necaelurinae	i		1		
11.	Nohoveus zigan H. Aspöck, U. Aspöck et	13	9/9	-	Armenia, Goravan, 31.05. 2017	Present study
	Hölzel, 1980	10	-	10/10	Armenia, Armavir prov., Yervandashat, 21.09.2016	
12.	Myrmecaelurus trigrammus (Pallas,	6ේ	9/9 (5) 9/10 (1)	-	Russia, Astrakhan reg., Tinaki, 9.07.2016	Present study
	1771)	26්	10/10 (10) 10/8 (3) 10/* (8)	-	Russia, Dagestan, Makhachkala, June-July 2013	
		59	11/7 (1) 8/8 (2) 9/* (1) 6/6 (1)	10/10	Russia, Dagestan, Makhachkala, June-July 2013	
13.	<i>Myrmecaelurus solaris</i> Krivokhatsky, 2002	3♀		10/10	Russia, Dagestan	Present study
Myrn	neleontinae					
14.	<i>Myrmeleon inconspicuus</i> Rambur, 1842	43	6/6 (2) 6/5 (1) 5/5 (1)	-	Russia, Astrakhan reg., Tinaki, 9.07.2016	Present study

	Taxon	Number of males and	Number of follicles in each of	Number of ovarioles in each of	Place and date of collection	Reference
		females studied	the paired testes	the paired ovaries		
15.	<i>Myrmeleon immanis</i> Walker, 1853	3්	5/5	-	Russia, Dagestan, Makhachkala, July 2015	Present study
16.	<i>Myrmeleon formicarius</i> Linneaus, 1767	? <u>\</u>	5/5	-	?	Stitz 1909
17.	Euroleon nostras	2්	3/3	-	Russia, Dagestan	Present study
	(Geoffroy in Fourcroy, 1785)	?¢	_	10/10	SW Poland	Garbiec and Kubrakiewicz 2012
Ascal	aphidae					
Ascal	aphinae					
18.	Libelloides macaronius kolyvanensis (Laxmann,	13	12/12 (at least)	_	Armenia, Aygedzor, 4.06.2017	Present study
	1770)	3♀	-	10/10		
18a.	<i>Libelloides macaronius macaronius</i> (Scopoli, 1763)	?ð	6/6**	-	Germany, Kalenderberge	Brauer 1854 (as <i>Ascalaphus macaronius/</i> <i>hungaricus</i>)
19.	<i>Ascalaphus</i> Fabr. cf. <i>africanus</i> (McLachlan, 1871)	;¢	_	10/10	Ghana, Peduase (Accra district)	Quartey and Kumar 1973 [<i>Ascalaphus</i> sp. = <i>Ascalaphus</i> Fabr. cf. <i>africanus</i> (McL.)]
20.	Bubopsis hamata (Klug in Ehrenberg, 1834)	2්	33/56 50/44	-	Russia, Dagestan, Chirkata	Present study
Nemo	opteridae		1		<u>I</u>	
Nemo	opterinae					
21.	<i>Lertha ledereri</i> (Sélys- Longchamps, 1866)	2්	6/6	-	Armenia, Goravan, August, 2017	Present study
22.	Nemoptera sinuata Olivier, 1811	2්	6/6	-	Armenia, Aygedzor, 4.06.2017	Present study
		48	6/6	-	Armenia, Meghri, Artsvakar, 2017	
		2♀	-	10/10	Armenia, Azat Reserve, 2017	
23.	<i>Palmipenna</i> cf. <i>pilicornis</i> Tjeder, 1967	?ð	5/5	-	South Africa, Biedouw Valley, Namaqualand (Cape Province)	Walker et al. 1994
24.	<i>Palmipenna aeoleoptera</i> Picker, 1987	32♂	5/5	_	South Africa, Biedouw Valley, Namaqualand (Cape Province)	Walker et al. 1994

*Another testis was not found;

" In the original paper, the number of follicles is questioned.

Libelloides macaronius (Scopoli, 1763) (Ascalaphidae) examined previously in respect to the number of ovarioles (Garbiec and Kubrakiewicz 2012) and the number of follicles (Brauer 1854), respectively, were studied for the first time.

Myrmeleontidae

Palparinae

Six adult males of *Palpares libelluloides* (Linnaeus, 1764) were available for examination. Their bean-shaped testes were encapsulated each by the yellow scrotal membrane. In a sample of eleven testes examined (Table 1), the number of follicles varied in the range of 267–472 (mean 347.4, SD 54.18).

Acanthaclisinae

An adult male and an adult female of *Acanthaclisis occitanica* (Villers, 1789) were examined. In males, the bean-shaped testes were enclosed by the yellow sheath. We counted 51 follicles in one testis and 50 follicles in another testis of the male. In the female, the paired ovaries consisted each of the ten transparent ovarioles.

Nemoleontinae

Six species from five genera were studied, namely, *Creoleon plumbeus* (Olivier, 1811) (6Å, 1♀), *C. griseus* (Klug in Ehrenberg, 1834) (1♀), *Distoleon tetragrammicus* (Fabricius, 1798) (4Å, 1♀), *Delfimeus irroratus* (Olivier, 1811) (1♀), *Neuroleon lukhtanovi* Krivokhatsky, 1996 (1Å), and *Macronemurus bilineatus* Brauer, 1868 (3Å). In males, testes were spindle-shaped and yellow in color. In all studied species, regardless of the tribe they belong, the number of follicles per testis varied between six and four (Table 1). In the male of *N. lukhtanovi* each of the testes comprised five follicles. In males of *C. plumbeus*, *D. tetragrammicus* and *M. bilineatus*, a variation of the follicle number was observed both between conspecific males and/or between different testes of a male. Specifically, eleven testes checked in *C. plumbeus* consisted each of five or six follicles (mean 4.6, SD 0.52), and five testes examined in *M. bilineatus* consisted each of four or five follicles (mean 5.8, SD 0.45). Each of the four species studied in respect to the ovary structure, *Creoleon plumbeus*, *C. griseus*, *D. tetragrammicus*, and *Delfimeus irrotatus*, displayed ten transparent ovarioles per ovary.

Myrmecaelurinae

Three species from two genera of the tribe Myrmecaeluruni were studied, namely, *Novoheus zigan* H. Aspöck, U. Aspöck & Hölzel, 1980 (13, 12), *Myrmecaelurus tri-grammus* (Pallas, 1771) (323, 52), and *M. solaris* Krivokhatsky, 2002 (32). In males, testes were spindle-shaped and yellow to orange in color. The only studied male of *N. zigan* displayed nine follicles per testis. In two geographically distant populations of *M. trigrammus* (Russia: Astrakhan region and Dagestan), a variation in the follicle number was observed between different males and different testes of a male (Table 1). Overall, in a sample of 53 testes examined the number of follicles varied in the range of 6–11 (mean 9.42, SD 0.99). Each of the three species studied in respect to the ovary structure, *N. zigan*, *M. trigrammus*, and *M. solaris*, displayed ten transparent ovarioles per ovary.

Myrmeleontinae

Three species from two genera were studied, namely, *Myrmeleon inconspicuus* Rambur, 1842 (4 \Im), *M. immanis* Walker, 1853 (3 \Im), and *Euroleon nostras* (2 \Im). In males, testes were spindle-shaped and yellow to orange in color. Testes of *M. immanis* comprised each five follicles in each of the males explored. In *M. inconspicuus*, a variation was observed between both males and different testes of a male (Table 1). Specifically, of

the eight testes dissected, four had six follicles, two had five follicles, and two had six and five follicles, respectively (mean 5.62, SD 0.52). In *E. nostras*, each of the males had three follicles per testis.

Ascalaphidae

Ascalaphinae

Two species from two genera were studied, namely, *Libelloides macaronius kolyvanensis* (Laxmann, 1770) (1 \checkmark , 3 \bigcirc) and *Bubopsis hamata* (Klug in Ehrenberg, 1834) (2 \circlearrowright). Unfortunately, in the male of *L. m. kolyvanensis* we were unable to calculate exactly the number of follicles; however, there were no less than twelve follicles in each of the testes. Every female had ten transparent ovarioles per ovary. In *B. hamata*, one male had approximately 33 and 56 follicles in different testes, whereas the other one had approximately 44 and 50 follicles in different testes (mean 45,75, SD 9,8).

Nemopteridae

Nemopterinae

Two species from two genera were studied, namely, *Lertha ledereri* (Sélys-Longchamps, 1866) (2 $^{\circ}$) and *Nemoptera sinuata* Olivier, 1811 (6 $^{\circ}$, 2 $^{\circ}$). In both species, males had six follicles in each of the paired testes. The testes were spindle-shaped and light yellow in color. The females of *N. sinuata* had ten transparent ovarioles per ovary.

Discussion

A summary of all information currently available on the number of follicles and ovarioles in the lacewing species of the families Myrmeleontidae, Ascalaphidae, and Nemopteridae, derived mainly from the present study but also from five other studies conducted at different times by different researchers, is presented in Table 1. To our knowledge, no species of Psychopsidae and Nymphidae, the two other families of the suborder Myrmeleontiformia, have yet been studied in respect to testes and ovaries.

The general morphology of male and female internal reproductive system

As mentioned above, we did not study the internal reproductive organs of males and females in depth. In species under study, the male and female reproductive organs seem to correlate with those figured by Quartey and Kumar (1973) for *Palpares* sp., *Neuroleon* sp. and *Ascalaphus* sp. (= *Ascalaphus* Fabr. cf. *africanus* (McLachlan, 1871),

by Walker et al. (1994) for *Palmipenna* spp. (Nemopteridae), and by Brauer (1854) for *Ascalaphus macaronius/hungaricus* (= *Libelloides macaronius macaronius* (Scopoli, 1763); see Krivokhatsky et al. 2018 for synonymy).

Testicular follicles

More two-thirds of all hitherto studied species (Table 1) were found to have relatively low number of follicles per testis lying in the range between three (Euroleon nostras) and eleven, the latter number having been revealed in only one of the 53 testes examined in the polymorphic for this trait species Myrmecaelurus trigrammus. Both species belong to the family Myrmeleontidae, in which 14 species from eleven genera and five subfamilies were studied. Low numbers (3-11) were found in the subfamilies Nemoleontinae, Myrmecaelurinae, and Myrmeleontinae, but not in Palparinae and Acanthaclisinae. In the Palparinae, males of Palpares sp. and P. libelluloides showed 40 and 347.4 (on average) follicles per testis, respectively (Table 1). In the only studied male of Acanthaclisis occitanica (Acanthaclisinae) 50 and 51 follicles were counted in different testes. In the family Nemopteridae, all the four studied species in three genera, Lertha Navás, 1910, Nemoptera Latreille, 1802, and Palmipenna Tjeder, 1967, were found to have low numbers, namely, six in the first two genera and five in the last one. The family Ascalaphidae seems to display a rather wide margin of the follicle numbers, although the existing data are scarce and partly controversial. We found that the two studied males of Bubopsis hamata have a relatively high number of follicles, 45,75 (in average) per testis. On the other hand, Libelloides macaronius macaronius and L. m. kolyvanensis showed a relatively low number of follicles although their actual number remained uncertain for both. According to Brauer (1854), males of L. m. macaronius possess approximately six follicles per testis; however, in the only studied male of L. m. kolyvanensis we were able to count at least twelve follicles in each of the testes. It is worth noting that many species showed a variation in the follicle number between both different males and even different testes of a male, this being equally true for species with high and low number of follicles. It is interesting that a variability of the follicles number was likewise reported in some species of Raphidioptera (snakeflies) and Megaloptera (alderflies and dobsonflies), the two other orders of the superorder Neuropterida (Neuropteroidea) (Stitz 1909).

In the majority of genera, the only species was unfortunately studied. The exceptions are the genera *Palpares* Rambur, 1842 and *Palmipenna*, each with two explored species, and *Myrmeleon* Linnaeus, 1767 with three studied species. An important point is that in every case, the congeneric species share similar trends, namely, *Palpares* spp. have high numbers (40 and higher) while the two other genera have low numbers (five and/or six).

Note that the species differing significantly in the number of follicles seem to have no evident ecological, physiological, and developmental differences; then, it is not quite clear what could be the cause of such a wide variety of testes. It may be that the variation in follicle number manifests adaptation to the male abdomen size and, then, one might expect that the larger the insect the more follicles it has. Indeed, males of *Palpares libelluloides, Acanthaclisis occitanica*, and *Bubopsis hamata*, the three species characterized by numerous follicles, have very voluminous (long and/or thick) abdomens. Moreover, *P. libelluloides* showing the highest number of follicles, 267–472 per testis (mean 347.4, SD 54.18), is known as the largest species in the antlion fauna of Russia: in males, the abdomen (together with ectoprocts) can reach 45 mm in length (Krivokhatsky 2011).

Working with aphids, Blackman (1987) introduced the possibility that the reduction of the number of testicular follicles is related to the transfer of spermatogenesis to early larval stages. Our observation is that in the neuropteran males, meiosis does generally occur in the very young individuals. Nevertheless, this is equally true for species with both high and low number of follicles.

Thus, our study resulted in the discovery of many novel values of the follicle number in Myrmeleontiformia. Our results also indicate that the limits of the variation in the follicle number are very broad, much more than previously known both for this group and the order Neuroptera as a whole. However, the mechanisms underlying the diversity of the follicle number in the group must be explored further.

Ovarioles

In all hitherto studied species of the families Myrmeleontidae (ten species, eight genera), Ascalaphidae (two species, two genera), and Nemopteridae (one species), ovaries were found to consist of ten ovarioles each (Brauer 1854; Stitz 1909; Quartey and Kumar 1973; Garbiec and Kubrakiewicz 2012; present paper). The same ovarian structure was considered the most characteristic of the Neuroptera as a whole (Garbiec and Kubrakiewicz 2012). It should be noted, however, that the number of ovarioles per ovary is known to vary significantly (8–20) within the green lacewing family Chrysopidae (the suborder Hemerobiiformia) and even in the species of the genus *Chrysopa* Leach, 1815 (Vacacela et al. 2017).

The number of ovarioles in ovaries does not show a correlation with the female abdomen size, at least in the families studied here, considering that the same ovary structure was observed in all species, including relatively large *Acanthaclisis occitanica*. However, relevant data on other large species, such as *Palpares libelluloides*, are absent.

Large female insects were postulated to tend having comparatively higher potential fecundity (Berger et al. 2008). Moreover, the number of ovarioles per ovary is suggested to play a direct role in the number of eggs produced by a female and largely determines potential fecundity of an insect (Sarikaya et al. 2012). Even so, we can infer that in the neuropteran females the number of ovarioles is not the key factor responsible for their fecundity. An interesting avenue for future research would be to test whether there is a correlation between the size of ovarioles and the number of oocytes produced by these ovarioles, on the one hand, and the fecundity, on the other hand, in neuropteran females. Hodin (2009) suggested that plasticity in the number of ovarioles might be more prevalent for organisms living in fluctuating environments. In

Myrmeleontidae and Ascalaphidae, the larvae are known to be underground inhabitants, mostly psammophilous (Mansell 1999). It is conceivable, that there is a certain relationship between this lifestyle and the stability of the ovary structure. In this context, the above-mentioned variation of the number of ovarioles in chrysopids (Vacacela et al. 2017) may be related to the open lifestyle of their larvae.

The evolutionary changes of testes and ovaries in Myrmeleontiformia

We have shown that lacewings, at least in the families Myrmeleontidae, Ascalaphidae, and Nemopteridae, are highly conservative in the number of ovarioles in females, and, conversely, highly diverse in the number of testicular follicles in males. It is assumed that testes and ovaries of insects were initially arranged by segments, and they fell into a common seminal duct or oviduct, respectively, on each side of the abdomen. The evolutionarily initial number of follicles per testis as well as ovarioles per ovary is therefore suggested to be seven as the number of the pregenital segments in adult males and females (Sharov 1966; Emeljanov et al. 2001). Since all so far studied species of the Myrmeleontiformia have ten ovarioles per ovary, it is likely that this pattern is a characteristic feature of the suborder as a whole. This character gives thus additional support for the monophyly of Myrmeleontiformia substantiated both by morphological and genomic data (Aspöck et al. 2001, 2003; Badano et al. 2016; Song et al. 2019). Taken seven ovarioles per ovary as an ancestral state of this character, the occurrence of ovaries with ten ovarioles might represent a result of a simple polymerization.

Despite a great variability of the follicle number among Myrmeleontiformia, at least in Myrmeleontidae and Ascalaphidae, the majority of studied species have relatively low numbers, three to eleven, with an apparent mode of 6-5 follicles per testis. Moreover, only these two numbers were discovered in the family Nemopteridae considered a sister-group of the [Myrmeleontidae + Ascalaphidae] clade (see for review Song et al. 2019). Taking into account that no testes with seven follicles are presently known in Myrmeleontiformia (likewise in Neuroptera as a whole), either six or five follicles per testis could be considered a plesiomorphic condition in Myrmeleontiformia. At present, it is tempting to believe that the testis with six follicles represents the ancestral character state, since it is the only pattern encountered in each of the three families explored. Both lower and higher numbers are, thus, the derived traits in Myrmeleontiformia. In the evolution of the families Myrmeleontidae and Ascalaphidae, the processes leading to increasing the follicle number were intensive. In these families, the number of follicles has increased up to 40-56 in some species (Palpares sp., Acanthaclisis occitanica, Bubopsis hamata) and further still has dramatically increased up to several hundred in *Palpares libelluloides*. It is of interest that the species of the genus *Palpares* have significantly different number of testicular follicles even though it is high in both cases. We can speculate, based on the currently available data, that the increasing of the follicle number in Ascalaphidae and Myrmeleontidae is the result of homoplasy, and the polymerization of the follicles has thus independently occurred in these two families (Fig. 1).



Figure 1. The proposed ancestral numbers of follicles per testis (white circles) and ovarioles per ovary (black circles) and limits of their variation across the families Myrmeleontidae, Ascalaphidae, and Nemopteridae (Myrmeleontiformia)

Conclusions

Overall, the data presented here show that testes and ovaries demonstrate quite different evolutionary trends within the families Myrmeleontidae, Ascalaphidae, and Nemopteridae. The variable number of testicular follicles suggests that this structure is evolutionarily rather labile and, conversely, the number of ovarioles is invariable in these families and probably in the suborder Myrmeleontiformia as a whole. Our knowledge of testes and ovaries in this group as well as in Neuroptera as a whole is currently very limited. These key reproductive traits need in a further detailed study based on the extensive and broadly representative taxon sampling.

Acknowledgements

We thank A. Dantchenko (Moscow, Russia), E. Ilyina (Makhachkala, Russia), T. Ghrejyan and I. Stepanyan (Erevan, Armenia) for collecting some specimens. We thank Prof. Alexi Popov (Sofia, Bulgaria) for his valuable comments on the manuscript. The study was performed within the state research projects No AAAA-A19-119020790106-0 (VK) and No AAAA-A19-119020690082-8 (VKr). Partial financially supported by the research grant from the Russian Foundation for Basic Research (No 19-54-18002) and by the Presidium of the Russian Academy of Sciences, Program № 41 "Biodiversity of natural systems and biological resources of Russia" (VK).

References

- Akingbohungbe AE (1983) Variation in testis follicle number in the Miridae (Hemiptera: Heteroptera) and its relationship to the higher classification of the family. Annals of the Entomological Society of America 76: 37–43. https://doi.org/10.1093/aesa/76.1.37
- Aspöck U, Plant JD, Nemeschkal HL (2001) Cladistic analysis of Neuroptera and their systematic position within Neuropterida (Insecta: Holometabola: Neuropterida: Neuroptera). Systematic Entomology 26: 73–86. https://doi.org/10.1046/j.1365-3113.2001.00136.x
- Aspöck U, Aspöck H, Haring E (2003) Phylogeny of the Neuropterida morphological evidence and the molecular advocatus diaboli. Entomologische Abhandlungen 61: 157–158.
- Badano D, Aspöck U, Aspöck H, Cerretti P (2016) Phylogeny of Myrmeleontiformia based on larval morphology (Neuropterida: Neuroptera). Systematic Entomology 42: 94–117. https://doi.org/10.1111/syen.12200
- Barcellos MS, Martins LC, Cossolin JF, Serrão JE, Delabie JH, Lino-Neto J (2015) Testes and spermatozoa as characters for distinguishing two ant species of the genus *Neoponera* (Hymenoptera: Formicidae). Florida Entomologist 98: 1254–1256. https://doi. org/10.1653/024.098.0441
- Berger D, Walters L, Gotthard K (2008) What limits insect fecundity? Body size- and temperature-dependent egg maturation and oviposition in a butterfly. Functional Ecology 22: 523–529. https://doi.org/10.1111/j.1365-2435.2008.01392.x
- Bilinski S (1998) Introductory remarks. Folia Histochemica et Cytobiologica 36(4): 143-145.
- Blackman RL (1987) Reproduction, cytogenetics and development. In: Minks AK, Harrewijn P (Eds) Aphids: Their Biology, Natural Enemies and Control. 2. Elsevier, Amsterdam, 163–195.
- Brauer F (1854) Beiträge zur Kenntniss des inneren Baues und der Verwandlung der Neuropteren (Ascalaphus macaronius Scop., Myrmeleon tetragrammicus Pallas, Fabr., Burm.). Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien 4 (1852): 463–472. [Separate: S. 1–9]
- Büning J (1993) Germ cell cluster formation in insect ovaries. International Journal of Insect Morphology and Embryology 22: 237–253. https://doi.org/10.1016/0020-7322(93)90013-Q
- Büning J (1994) The Insect Ovary. Ultrastructure, Previtellogenic Growth and Evolution. Chapman & Hall, London, 400 pp. https://doi.org/10.1007/978-94-011-0741-9
- Büning J (2005) The telotrophic ovary known from Neuropterida exists also in the myxophagan beetle *Hydroscapha natans*. Development Genes and Evolution 215: 597–607. https://doi. org/10.1007/s00427-005-0017-8
- Büning J (2006) Ovariole structure supports sistergroup relationship of Neuropterida and Coleoptera. Arthropod Systematics and Phylogeny 64(2): 115–126.
- Castanhole MM, Pereira LL, de Souza HV, Itoyama MM (2012) Spermatogenesis of riffle bugs, *Rhagovelia whitei* and *Rhagovelia* sp. (Veliidae), and backswimmers *Martarega* sp. (Notonectidae). Genetics and Molecular Research 11(3): 2003–2020. https://doi. org/10.4238/2012.August.6.5

- Chapman RF (2013) The Insects: Structure and Function. 5th ed. Cambridge University Press, New York, 788 pp. [Chapter 12, 282–312: male; Chapter 13, 313–343: female]
- De Jong GD (2011) Observations on the biology of *Polystoechotes punctatus* (Fabricius) (Neuroptera: Ithonidae): Adult trophic status, description of the male reproductive system, and associations with mites. Proceedings of the Entomological Society of Washington 113(3): 291–298. https://doi.org/10.4289/0013-8797.113.3.291
- Dias FA, Gandara AC, Queiroz-Barros FG, Oliveira RL, Sorqine MH, Braz GR, Oliveira PL (2013) Ovarian dual oxidase (Duox) activity is essential for insect eggshell hardening and waterproofing. Journal of Biological Chemistry 288(49): 35058–35067. https://doi. org/10.1074/jbc.M113.522201
- Emeljanov AF, Kuznetsova VG (1983) The number of seminal follicles as a phylogenetic and taxonomic feature in the Dictyopharidae (Hemiptera) and other leafhoppers. Zoologich-eskii Zhurnal 62: 1583–1586. [In Russian, English abstract]
- Emeljanov AF, Golub NV, Kuznetsova VG (2001) Evolutionary transformation of testes and ovaries in booklice, birdlice, and sucking lice (Psocoptera, Phthiraptera: Mallophaga, Anoplura). Entomologicheskoe Obozrenie 80(3): 557–577. [in Russian; English transl. in Entomological Review 81(7): 767–785]
- Faille A, Pluot-Sigwalt D (2015) Convergent reduction of ovariole number associated with subterranean life in beetles. PLoS ONE 10(7): e0131986. https://doi.org/10.1371/journal.pone.0131986
- Fereira A, Abdalla FC, Kerr WE, Da Cruz-Landim C (2004) Comparative anatomy of the male reproductive internal organs of 51 species of bees. Neotropical Entomology 33(5): 569–576. https://doi.org/10.1590/S1519-566X2004000500005
- Fiorillo BS, Lino-Neto J, Báo SN (2008) Structural and ultrastructural characterization of male reproductive tracts and spermatozoa in fig wasps of the genus *Pegoscapus* (Hymenoptera, Chalcidoidea). Micron 39(8): 1271–1280. https://doi.org/10.1016/j.micron.2008.03.005
- Garbiec A, Kubrakiewicz J (2012) Differentiation of follicular cells in polytrophic ovaries of Neuroptera (Insecta: Holometabola). Arthropod Structure and Development 41(2): 165– 176. https://doi.org/10.1016/j.asd.2011.12.003
- Garbiec A, Kubrakiewicz J, Mazurkiewicz-Kania M, Simiczyjew B, Jędrzejowska I (2016) Asymmetry in structure of the eggshell in *Osmylus fulvicephalus* (Neuroptera: Osmylidae): an exceptional case of breaking symmetry during neuropteran oogenesis. Protoplasma 253(4): 1033–1042. https://doi.org/10.1007/s00709-015-0860-z
- Gillot C (2005) Entomology. Springer, Canada, 831 pp.
- Glowacka E, Kuznetsova VG, Maryańska-Nadachowska A (1995) Testis follicle number in psyllids (Psylloidea, Homoptera) as an anatomical feature in studies of systematic relations within the group. Folia biologica (Krakow) 43(3–4): 115–124.
- Golub NV (2003) The reproductive system of Psocoptera. Entomologicheskoe Obozrenie 82(1): 90–101 [in Russian; English translation in Entomological Review 83(1): 4–15.
- Green DA (2014) Developmental and genetic mechanisms of ovariole number evolution in Drosophila. PhD Thesis, Cambridge: Harvard University. http://nrs.harvard.edu/urn-3:HUL.InstRepos:12274190

- Grimaldi D, Engel M (2005) Evolution of the Insects. Cambridge University Press, New York and Cambridge, 755 pp.
- Hassan MI, Amer MS, Hammad KM, Gabarty A, Tharwat A, Selim TA (2017) Latent effect of gamma irradiation on reproductive potential and ultrastructure of males' testes of *Culex pipiens* (Diptera; Culicidae). Journal of Radiation Research and Applied Sciences 10: 44–52. https://doi.org/10.1016/j.jrras.2016.11.003
- Hodin J (2009) She shapes events as they come: plasticity in female insect reproduction. In: Whitman DW, Ananthakrishnan TN (Eds) Phenotypic Plasticity of Insects: Mechanisms and Consequences. Science Publishers, Enfield, 423–521. https://doi.org/10.1201/b10201-12
- Kirillova VI (1989) The anatomy of the male reproductive system in Homoptera (Cicadinea, Delphacidae) and the use of its structure in the taxonomy of the family. Zoologicheskii Zhurnal 68: 143–148. [in Russian, English abstr.]
- Klowden MJ (2013) Male reproductive systems. Physiological Systems in Insects. University of Idaho, Moscow, 203–214. https://doi.org/10.1016/B978-0-12-415819-1.00004-0
- Krivokhatsky VA (2011) Antlions (Neuroptera: Myrmeleontidae) of Russia. KMK Scientific Press Ltd, St. Petersburg-Moscow, 334 pp. [In Russian]
- Krivokhatsky VA, Bagaturov MF, Prokopov GA (2018) Owlflies (Neuroptera: Ascalaphidae) of Crimea and allied taxa from the West Palaearctic. Caucasian Entomological Bulletin 14(Suppl.): 41–72. https://doi.org/10.23885/18143326201814S4172
- Kubrakiewicz J (2002) Extrachromosomal rDNA amplification in the oocytes of *Polystoechotes punctatus* (Fabricius) (Insecta-Neuroptera-Polystoechotidae). Arthropod Structure and Development 31(1): 23–31. https://doi.org/10.1016/S1467-8039(02)00014-2
- Kubrakiewicz J, Jedrzejowska I, Biliński SM (1998) Neuropteroidea different ovary structure in related groups. Folia Histochemica et Cytobiologica 36: 179–187.
- Kuznetsova VG (1985) Phylogenetic analysis of chromosome variability and karyosystematics of Cicadina of the family Dictyopharidae (Homoptera, Auchenorrhyncha). Entomologicheskoe Obozrenie 64: 539–553. [in Russian; English transl. in Entomological Review 65(2): 88–106]
- Kuznetsova VG, Nokkala S, Shcherbakov D (2002) Karyotype, reproductive organs, and pattern of gametogenesis in *Zorotypus hubbardi* Caudell (Insecta: Zoraptera, Zorotypidae), with discussion on relationships of the order. Canadian Journal of Zoology 80: 1047– 1054. https://doi.org/10.1139/z02-074
- Kuznetsova VG, Maryańska-Nadachowska A, Emeljanov AF (2009) A contribution to the karyosystematics of the planthopper families Dictyopharidae and Fulgoridae (Hemiptera: Auchenorrhyncha). European Journal of Entomology 106: 159–170. https://doi. org/10.14411/eje.2009.019
- Kuznetsova VG, Labina ES, Shapoval NA, Maryańska-Nadachowska A, Lukhtanov VA (2012) Cacopsylla fraudatrix sp. n. (Hemiptera: Psylloidea) recognised from testis structure and mitochondrial gene COI. Zootaxa 3547: 55–63. https://doi.org/10.11646/zootaxa.3547.1.5
- Kuznetsova VG, Khabiev GN, Krivokhatsky VA (2015) Chromosome numbers in antlions (Myrmeleontidae) and owlflies (Ascalaphidae) (Insecta, Neuroptera). ZooKeys 538: 47–61. ttps://doi.org/10.3897/zookeys.538.6655

- Kuznetsova VG, Khabiev GN, Anokhin BA (2016) Cytogenetic study on antlions (Neuroptera: Myrmeleontidae): first data on telomere structure and rDNA location. Comparative Cytogenetics 10(4): 647–656. https://doi.org/10.3897/CompCytogen.v10i4.10775
- Leston D (1961) Testis follicle number and the higher systematics of the Miridae (Hemiptera-Heteroptera). Proceedings of the Zoological Society of London 137: 89–106. https://doi. org/10.1111/j.1469-7998.1961.tb06163.x
- Mansell MW (1999) Evolution and success of antlions (Neuropterida: Neuroptera, Myrmeleontidae). Stapfia 60: 49–58.
- Maryańska-Nadachowska A, Kuznetsova VG, Yang Ch-T, Woudstra IH (1996) New data on karyotypes and the number of testicular follicles in the psyllid families Aphalaridae, Psyllidae, Carsidaridae and Triozidae (Homoptera, Psylloidea). Caryologia 49(3–4): 279–285. https://doi.org/10.1080/00087114.1996.10797372
- Maryańska-Nadachowska A, Taylor GS, Kuznetsova VG (2001a) Meiotic karyotypes and structure of testes in males of 17 species of Psyllidae: Spondyliaspidinae (Hemiptera: Psylloidea) from Australia. Australian Journal of Entomology 40: 349–356. https://doi.org/10.1046/ j.1440-6055.2001.00230.x
- Maryańska-Nadachowska A, Kuznetsova VG, Taylor GS (2001b) Meiotic karyotypes and structure of testes in males of 12 species of Psyllidae: Acizziinae, Carsidaridae and Triozidae (Hemiptera: Psylloidea) from Australia. Australian Journal of Entomology 40: 357–364. https://doi.org/10.1046/j.1440-6055.2001.00231.x
- Maryańska-Nadachowska A, Kuznetsova VG, Gnezdilov VM (2006) Variability in the karyotypes, testes and ovaries of planthoppers of the families Issidae, Caliscelidae, and Acanaloniidae (Hemiptera: Fulgoroidea). European Journal of Entomology 103: 505–513. https:// doi.org/10.14411/eje.2006.066
- Matsuda R (1976) Morphology and Evolution of the Insect Abdomen. With special reference to developmental patterns and their bearings upon systematics. Pergamon Press, Oxford, New York, Toronto, Sydney, Paris & Frankfurt, 534 pp.
- Moreira PA, Araújo VA, Zama U, Lino-Neto J (2008) Morphology of male reproductive system in three species of *Trypoxylon (Trypargilum)* Richards (Hymenoptera: Crabronidae). Neotropical Entomology 37(4): 429–435. https://doi.org/10.1590/S1519-566X2008000400012
- Mróz E, Wojciechowski W (2011) The systematic position the tribe Stenodemini (Heteroptera: Cimicomorpha: Miridae: Mirinae) in the light of the male internal reproductive system. Journal of Natural History 45(25–26): 1563–1588. https://doi.org/10.1080/00222933.2 011.559595
- Oswald JD (2016) LDL Neuropterida Species of the World (version Oct 2013). In: Roskov Y, Abucay L, Orrell T, Nicolson D, Flann C, Bailly N, Kirk P, Bourgoin T, DeWalt RE, Decock W, De Wever A (Eds) Species 2000 & ITIS Catalogue of Life, 31st October 2016. Species 2000 Naturalis, Leiden. https://www.catalogueoflife.org/col [accessed 5 May 2016]
- Palomeque T, Cano MA, Chica E, Diaz de la Guardia R (1990) Spermatogenesis in *Tapinoma nigerrimum* (Hymenoptera, Formicidae). Cytobios 62: 71–80.

- Papáček M, Soldán T (2008) Structure and development of the reproductive system in Aphelocheirus aestivalis (Hemiptera: Heteroptera: Nepomorpha: Aphelocheiridae). Acta Entomologica Musei Nationalis Pragae 48(2): 299–318.
- Quartey SQ, Kumar R (1973) Structure of the alimentary and reproductive organs of some adult Neuroptera. Insect Systematics and Evolution 4: 91–99. https://doi.org/10.1163/187631273X00110
- Sarikaya DP, Belay AA., Ahuja A, Dorta A, Green DA, Extavour CG (2012) The roles of cell size and cell number in determining ovariole number in *Drosophila*. Developmental Biology 363(1): 279–289. https://doi.org/10.1016/j.ydbio.2011.12.017
- Schubert LF, Krüger S, Moritz GB, Schubert V (2017) Male reproductive system and spermatogenesis of *Limodromus assimilis* (Paykull, 1790). PLoS ONE 12(7): e0180492. https:// doi.org/10.1371/journal.pone.0180492
- Sekimoto S, Yoshizawa K (2007) Discovery of the genus Suhpalacsa Lefebvre (Neuroptera: Ascalaphidae: Ascalaphinae) in Japan, with description of a new species. Entomological Science 10: 81–86. https://doi.org/10.1111/j.1479-8298.2006.00201.x
- Sharov AG (1966) Basic arthropodian stock with special reference to insects. International series of monographs in pure and applied biology. (Division: Zoology) 30: 1–271.
- Sinclair BJ, Borkent A, Wood DM (2007) The male genital tract and aedeagal components of the Diptera with a discussion of their phylogenetic significance. Zoological Journal of the Linnean Society 150: 711–742. https://doi.org/10.1111/j.1096-3642.2007.00314.x
- Sole CL, Scholtz CH, Ball JB, Mansell MW (2013) Phylogeny and biogeography of southern African spoon-winged lacewings (Neuroptera: Nemopteridae: Nemopterinae). Molecular Phylogenetics and Evolution 66: 360–368. https://doi.org/10.1016/j.ympev.2012.10.005
- Song N, Li X-X, Zhai Q, Bozdoğan H, Yin X-M (2019) The mitochondrial genomes of Neuropteridan insects and implications for the phylogeny of Neuroptera. Genes 10(2): 1–108. https://doi.org/10.3390/genes10020108
- Stange LA (2004) A systematic catalog, bibliography and classification of the world antlions (Insecta: Neuroptera: Myrmeleontidae). Memoirs of the American Entomological Institute 74: 1–565.
- Stauffer TW, Whitman DW (1997) Grasshopper Oviposition. In: Gangwere SK, Muralirangan MC, Muralirangan M (Eds) The Bionomics of Grasshoppers, Katydids and their Kin. CAB International, Wallingford, 231–280.
- Stitz H (1909) Zur Kenntnis des Genitalapparats der Neuropteren. Zoologische Jahrbücher. Abteilung für Anatomie und Ontogenie der Tiere 27: 377–448. https://doi.org/10.5962/ bhl.part.21341
- Štys P, Biliński S (1990) Ovariole types and the phylogeny of hexapods. Biological Reviews 65: 401–429. https://doi.org/10.1111/j.1469-185X.1990.tb01232.x
- Taylor BJ, Whitman DW (2010) A test of three hypotheses for ovariole number determination in the grasshopper *Romalea microptera*. Physiological Entomology 35: 214–221. https:// doi.org/10.1111/j.1365-3032.2010.00732.x
- Tworzydło W, Biliński SM, Kocárek P, Haas F (2010) Ovaries and germline cysts and their evolution in Dermaptera (Insecta). Arthropod Structure and Development 39(5): 360–368. https://doi.org/10.1016/j.asd.2010.05.004

- Vacacela HE, Alvarez-Zapat A, Gonzales AC, Martins EF, Martinez LC, Serrão JE (2017) Anatomy and histology of the alimentary canal and ovarioles of *Ceraeochrysa cubana* adults. Bulletin of Insectology 70(2): 181–188. http://www.bulletinofinsectology.org/
- Walker MH, Picker MD, Leon B (1994) Eversible abdominal vesicles and some observations of the male reproductive system of the spoon wing lacewing *Palmipenna* (Neuroptera: Nemopteridae). Journal of Morphology 219(1): 47–58. https://doi.org/10.1002/ jmor.1052190107
- Wieczorek K (2006) Anatomical investigations of the male reproductive system of five species of Calaphidinae (Hemiptera, Aphidoidea). Insect Systematics and Evolution 37: 457– 465. https://doi.org/10.1163/187631206788831434
- Wieczorek K, Wojciechowski W (2003) The use of the structure of the male reproductive system of aphids (Hemiptera, Aphidoidea) in their phylogeny. Aphids and other Homopterous Insects 9: 173–180.
- Zhang Z, Men L, Peng Y, Li J, Deng A, Chen Y, Liu X, Ma R (2017) Morphological differences of the reproductive system could be used to predict the optimum *Grapholita molesta* (Busck) control period. Scientific Reports 7(8198): 1–14. https://doi.org/10.1038/ s41598-017-08549-y

RESEARCH ARTICLE



DNA barcodes reveal 63 overlooked species of Canadian beetles (Insecta, Coleoptera)

Mikko Pentinsaari¹, Robert Anderson², Lech Borowiec³, Patrice Bouchard⁴, Adam Brunke⁴, Hume Douglas⁴, Andrew B.T. Smith², Paul D. N. Hebert¹

I Centre for Biodiversity Genomics, 50 Stone Road East University of Guelph, Guelph, ON, N1G 2W1, Canada 2 Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, ON, K1P 6P4, Canada 3 Department of Biodiversity and Evolutionary Taxonomy, University of Wrocław, Przybyszewskiego 65, 51-148 Wrocław, Poland 4 Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, ON, K1A 0C6, Canada

Corresponding author: Mikko Pentinsaari (mpentins@uoguelph.ca)

Academic editor: A. Smith	Received 5 July 2019	Accepted 25 October 2019	Published 4 December 2019				

Citation: Pentinsaari M, Anderson R, Borowiec L, Bouchard P, Brunke A, Douglas H, Smith ABT, Hebert PDN (2019) DNA barcodes reveal 63 overlooked species of Canadian beetles (Insecta, Coleoptera). ZooKeys 894: 53–150. https://doi.org/10.3897/zookeys.894.37862

Abstract

This study demonstrates the power of DNA barcoding to detect overlooked and newly arrived taxa. Sixtythree species of Coleoptera representing 25 families are studied based on DNA barcode data and morphological analysis of the barcoded specimens. Three of the species involve synonymies or previous taxonomic confusion in North America, while the first Canadian records are published for 60 species. Forty-two species are adventive in North America, and 40 of these adventive species originate from the Palaearctic region. Three genera are recorded from the Nearctic region for the first time: *Coelostoma* Brullé, 1835 (Hydrophilidae), *Scydmoraphes* Reitter, 1891 (Staphylinidae), and *Lythraria* Bedel, 1897 (Chrysomelidae). Two new synonymies are established: *Mycetoporus triangulatus* Campbell, 1991 (Staphylinidae) is a junior synonym of *Mycetoporus reichei* Pandellé, 1869, **syn. nov.** while *Bledius philadelphicus* Fall, 1919 (Staphylinidae) is a junior synonym of *Bledius gallicus* (Gravenhorst, 1806), **syn. nov.** The previously suggested move of *Ctenicera tigrina* (Fall, 1901) to the genus *Pseudanostirus* Dolin, 1964 (Elateridae) is formalized, resulting in *Pseudanostirus tigrinus* (Fall, 1901), **comb. nov.**

Keywords

DNA barcoding, new species records, adventive species

Table of contents

Introduction	55
Materials and methods	56
Material	56
Tissue sampling and DNA barcode sequencing	57
Identification and validation of the new Canadian species records	58
Species accounts	58
Availability of data	59
Results	59
Gyrinidae	62
Carabidae	62
Hydrophilidae	62
Leiodidae	64
Staphylinidae	66
Scarabaeidae	86
Clambidae	87
Scirtidae	89
Throscidae	92
Elateridae	96
Cantharidae	97
Dermestidae 1	02
Ptinidae 1	02
Erotylidae 1	.03
Cryptophagidae1	05
Phalacridae 1	05
Nitidulidae 1	.08
Coccinellidae 1	.09
Corylophidae 1	14
Mycetophagidae 1	16
Ciidae 1	16
Mordellidae 1	19
Zopheridae 1	19
Tenebrionidae 1	20
Chrysomelidae 1	.22
Curculionidae 1	.27
Discussion 1	34
Acknowledgements 1	36
References 1	37
Supplementary material 1 1	50

55

Introduction

Since being proposed as a standardized approach for identifying unknown specimens to species-level (Hebert et al. 2003) DNA barcoding has become a global research effort. By May 2019, the Barcode of Life Data Systems (BOLD, http://boldsystems. org/; Ratnasingham and Hebert 2007)) contained more than 7 million DNA barcode records. The utility of DNA barcodes for biosecurity and for the detection of invasive species was recognized soon after their initial proposition (Armstrong and Ball 2005). In New Zealand, DNA barcoding has been adopted as a routine tool for screening for new potential pest species in certain insect taxa (Armstrong 2010). Invasive species are one of the most important threats to biodiversity worldwide (Bellard et al. 2016; Maxwell et al. 2016). They are also responsible for major economic losses to agriculture and forestry; invasive species are estimated to cause between \$100-200 billion in losses annually in the United States of America alone (Pimentel 2011). Timely detection and accurate identification of new adventive species is important for efficient monitoring and management of potential pests. However, if an adventive species belongs to a taxonomically difficult or neglected group of morphologically similar species, it can remain undetected for decades (deWaard et al. 2010; Jendek et al. 2015).

Among the 8,302 species of Coleoptera known from Canada, 639 are adventive (Brunke et al. 2019). A series of publications by Klimaszewski et al. (2010, 2012, 2013, 2015, 2017) provides both diagnostic features and overviews of the ecology and known North American distribution of these species. While Europe has been and still is a major source of these species because of the intensive trade and ship traffic across the Atlantic, the proportion of Asian species has recently increased as a consequence of increased trade with this region (Klimaszewski et al. 2012). The establishment of Palaearctic species in North America is likely facilitated by the climatic similarity of the regions (Klimaszewski et al. 2013).

The beetle fauna of North and Central Europe has recently been DNA barcoded extensively (Pentinsaari et al. 2014; Hendrich et al. 2015; Rougerie et al. 2015). These barcode reference libraries provide an efficient tool for the detection of adventive European beetle species in other parts of the world, particularly for those taxonomic groups where the native fauna is poorly known. Detection of species shared between continents is greatly facilitated by the Barcode Index Number (BIN) system (Ratnasingham and Hebert 2013). The BIN system was created primarily as an interim taxonomic framework for the COI barcode records on BOLD which lack species level identifications. However, comparison between BINs and Linnaean species names has proved highly useful in uncovering misidentifications, synonymies, and overlooked species diversity (e.g., Landry et al. 2013). In European Coleoptera, BINs showed a perfect 1:1 correspondence to known species in ca. 90% of the studied species (Pentinsaari et al. 2014; Hendrich et al. 2015).

The Canadian arthropod fauna has been extensively sampled for DNA barcoding over the past decade, both in the field and in natural history collections (see e.g., Gwiazdowski et al. 2015, Hebert et al. 2016, Bouchard et al. 2017, Steinke et al. 2017). A joint analysis of all available European and Canadian beetle data allows rapid screening for species shared between continents on a wide taxonomic scale. Such screening in equivalent barcode libraries of Lepidoptera has revealed multiple new species records and synonymies (Landry et al. 2013), as well as previously overlooked species lineages (Mutanen et al. 2012).

This paper reports the first Canadian records for 60 species of beetles, which were initially detected based on DNA barcoded specimens, and resolves previous taxonomic confusion in three more species. Twenty-one species represent native North American taxa recently arrived or previously overlooked in Canada. Forty-two species are adventive, and at least four are potential pests. Two species described from North America were found to be synonyms of Palaearctic species and hence are now properly recognized as adventive to the Nearctic region. We provide morphological diagnoses and illustrations for all adventive species, and for those 12 native North American species for which they are not readily available elsewhere.

Materials and methods

Material

This publication is based on the analysis of more than 130,000 DNA barcode records from Europe and Canada. The combined dataset of European and Canadian Coleoptera was screened for intercontinentally shared species. As part of the cleaning and validation process of a barcode reference library for Canadian Coleoptera, representative specimens of Canadian Barcode Index Number (BIN) clusters lacking species-level identifications were retrieved for morphological analysis. After identification and validation of new species records and synonyms, 1168 DNA barcode records (sequence length \geq 400 bp) representing 63 species were selected for publication. Most (1147) of these records derive from freshly collected specimens obtained through projects coordinated by the Centre for Biodiversity Genomics, University of Guelph (CBG) such as the Canadian National Parks Malaise Program (http://biodiversitygenomics.net/projects/cnp/), the School Malaise Trap Program (Steinke et al. 2017, https://malaiseprogram.com/), and BIObus collecting trips across Canada (https://biobus.ca/). As these specimens are stored pinned or in ethanol in the CBG voucher archive, they were available for morphological study and species assignment once barcode sequences were available. The three specimens of Attagenus smirnovi Zhantiev, 1973 were submitted for DNA barcoding through the LifeScanner citizen science initiative (http://www.lifescanner.net/) and are stored in the CBG voucher specimen archive. One of the DNA barcoded specimens of Contacyphon kongsbergensis (Munster, 1924) is stored in the Wallis-Roughley Museum of Entomology (JBWM). As part of our effort to construct a DNA barcode reference library for Canadian beetles, we analyzed 15,811 specimens of beetles held in the Canadian National Collection of Insects, Arachnids, and Nematodes (CNC). Although sequence recovery from the CNC samples was lower than with freshly collected material, their analysis provided a wide set of well-identified reference specimens (Bouchard

et al. 2017). Seventeen of the successfully sequenced CNC specimens were found to represent new species for Canada, and are included in the dataset published here.

In addition to the barcoded material, we examined 303 specimens without DNA barcode data to obtain a more detailed understanding of the Canadian distribution of some of the newly detected species. Of these additional specimens, 257 are deposited in CNC, five in the University of Guelph Insect Collection (**DEBU**), four in the Canadian Museum of Nature (**CMNC**), and two in the Field Museum of Natural History, Chicago. Thirty-two additional records of *Notaris scirpi* (Fabricius, 1793) are from specimens deposited in the private insect collections of Claude Chantal (**CCCH**), Stéphane Dumont (**CSDU**), Pierre de Tonnancour (**CPTO**), and Robert Vigneault (**CRVI**). Three additional records of *Carpelimus elongatulus* (Erichson, 1839) are from specimens in the private insect collection of Reginald Webster (**RWC**).

Tissue sampling and DNA barcode sequencing

The tissue sampling protocol varied according to the origin of the material and size of the specimen. A single leg was detached from each CNC specimen and it was placed in a well in a 96-well microplate pre-filled with 10 μ l of 96% ethanol. Each CNC specimen was also photographed, and the resultant image was uploaded to BOLD along with the label data. The specimens archived at the CBG were processed in two ways. Small specimens (body length < 6 mm) were placed into a well in a 96 well microplate for DNA extraction. Following DNA extraction, the microplates were refilled with ethanol and the specimens were stored in the microplates in the CBG voucher specimen archive. Larger specimens were either pinned or preserved in ethanol, and a single leg was used for DNA extraction. Photography of each specimen is not a standard element in the workflow because a million specimens are processed yearly at CBG. Instead, representative specimens of new Barcode Index Numbers (BINs, Ratnasingham and Hebert 2013) are retrieved from the archive for photography once specimens have been assigned to a BIN.

DNA extraction, PCR amplification, and Sanger sequencing of the COI barcode region were performed for all specimens at the Centre for Biodiversity Genomics, using standard protocols optimized for large-scale generation of COI barcode data. For detailed descriptions of the protocols, see Ivanova et al. (2006) and deWaard et al. (2008, 2018). For most specimens, a cocktail of the Folmer primers (Folmer et al. 1994) and LepF1 & LepR1 (Hebert et al. 2004) was used in the first PCR amplification attempt. When resources allowed it, specimens for which the initial PCR amplification failed were reanalyzed using primer sets that targeted 307 bp and 407 bp amplicons (Hajibabaei et al. 2006). Bidirectional sequencing was the rule prior to 2013, but subsequent sequences were often obtained through unidirectional analysis. Details on the PCR and sequencing protocol for each specimen are provided in the public BOLD dataset (see Availability of data below).

Identification and validation of the new Canadian species records

All COI barcode sequences on BOLD which fulfill quality criteria (< 1% ambiguous bases; no reading frame shifts, chimeras or obvious contaminations) are automatically assigned into BINs. The founding member sequence of a new BIN cluster must be at least 500 bp long, but shorter sequences (min. 300 bp) can be assigned into existing clusters. A detailed description of the clustering algorithm and the associated informatics workflow is provided by Ratnasingham and Hebert (2013). In short, all sequences are initially clustered based on a fixed threshold of 2.2% divergence (uncorrected p-distance). These initial clusters are then refined by Markov clustering to generate the final BINs. The clustering algorithm is run regularly on BOLD, and new BINs are generated and existing BINs may be split or merged as new sequence data are added.

The new adventive species were initially detected because Canadian specimens shared a BIN assignment with their European counterparts. When available, at least five Canadian voucher specimens were then morphologically examined to confirm the identification. Most of the extensions in the known range of native North American species were detected and validated in the same way, i.e., Canadian specimens were found to share BINs with identified specimens from the United States. A few taxa were encountered during the validation of a DNA barcode reference library for Canadian Coleoptera when representative specimens from BINs lacking a species-level identification were retrieved for morphological analysis. Only those species for which voucher specimens were available and could be reliably validated are included in this paper.

Species accounts

The brief sections on diagnostic information in this paper detail only the most relevant morphological characters for distinguishing each newly detected species from its closest relatives in North America. Due to the variety of beetle taxa covered, these sections cannot employ a completely uniform format. To provide some consistency, the terminology employed and the order in which the characters are presented follows Lawrence et al. (2011). For native North American species with good diagnoses readily available in existing literature, we simply provide references to those diagnoses. In addition to the diagnostic information, we briefly summarize the current Canadian records as well as the distribution of the species outside Canada. Finally, we provide brief ecological data, and consider collecting methods for each species. The order of the families and genera in the species treatments follows Bousquet et al. (2013). Species are ordered alphabetically within genera. We follow Wheeler and Hoebeke (2009) in our use of terms related to non-native species. All distance measures between DNA barcode sequences are reported as uncorrected p-distance (i.e., the proportion of differing nucleotides in pairwise comparisons of sequences).

Availability of data

Detailed collection information for each specimen, including both DNA barcoded material and other specimen records, as well as GenBank accession numbers for the barcode sequences, are provided in the Suppl. material 1: Table S1. All sequences, details on PCR and sequencing primers, photographs (if available) and full collection data for the DNA barcoded specimens are available through a public dataset on BOLD (DS-NEW-COL18, https://doi.org/10.5883/DS-NEWCOL18). The public BIN pages for each species can be accessed through the BOLD dataset, or by entering the BIN URIs provided in each species account (e.g., BOLD:AAP7843) in the search field of the public BIN portal: http://boldsystems.org/index.php/Public_BarcodeIndexNumber_Home

Results

The higher classification of the new species, and the research projects and collections from which the specimens originate, are summarized in Table 1. Detailed accounts of each species are provided below. The original distribution, habitat preferences, and possible pest status of the adventive species are summarized in Table 2.

Table 1. Summary of the higher classification of the studied species and the projects and institutions from which the specimens originate. Abbrevations: SMP: School Malaise Program; CNP & OPPMP: Canadian National Parks & Ontario Provincial Parks Malaise programs; CNC: Canadian National Collection of Insects, Arachnids, and Nematodes.

Family	Subfamily	Species	SMP	CNP&	BioBus	Other	CNC	Other public
				OPPMP		CBG		& private
						projects		collections
Gyrinidae	Enhydrinae	Dineutus emarginatus			×			
Carabidae	Harpalinae	Anisodactylus caenus					×	
Hydrophilidae	Sphaeridiinae	Coelostoma orbiculare				×		
Leiodidae	Leiodinae	Leiodes polita				×		
Staphylinidae	Pselaphinae	Bibloplectus minutissimus				×		
	Tachyporinae	Mycetoporus reichei	×	×				
		Tachyporus atriceps	×	×	×	×		
	Aleocharinae	Amischa decipiens	×			×		
		Atheta vaga				×		
	Aleocharinae	Myllaena infuscata				×		
	Oxytelinae	Bledius gallicus		×		×		
		Carpelimus elongatulus			×	×		×
	Scydmaeninae	Stenichnus collaris			×	×		
		Stenichnus scutellaris	×	×	×	×		
		Scydmoraphes minutus		×		×		
		Scydmaenus rufus				×		
	Paederinae	Lathrobium geminum			×			
		Lathrobium lineatocolle		×		×		
		Medon apicalis				×		
		Medon ripicola		×				
		Pseudomedon obscurellus		×				
Scarabaeidae	Melolonthinae	Phyllophaga implicita			×			

Family	Subfamily	Species	SMP	CNP&	BioBus	Other	CNC	Other public
-	-	-		OPPMP		CBG		& private
						projects		collections
Clambidae	Calyptomerinae	Calyptomerus dubius	×			×		
	Clambinae	Clambus simsoni	×					
Scirtidae	Scirtinae	Contacyphon kongsbergensis			×	×		×
		Contacyphon obscurellus		×	×			
		Contacyphon fuscescens		×	×	×		
Throscidae	Throscinae	Aulonothroscus distans	×	×		×		
		Trixagus carinifrons		×		×		
		Trixagus meybohmi	×			×		
Elateridae	Dendrometrinae	Pseudanostirus tigrinus		×				
Cantharidae	Cantharinae	Dichelotarsus lapponicus		×				
	Malthininae	Malthodes pumilus		×	×			
Dermestidae	Attageninae	Attagenus smirnovi				×		
Ptinidae	Dorcatominae	Petalium incisum				×		
Erotylidae	Cryptophilinae	Cryptophilus obliteratus	×			×		
	, , , , , , , , , , , , , , , , , , ,	Cryptophilus propinquus				×		
Cryptophagidae	Cryptophaginae	Henoticus mycetoecus		×				
Phalacridae	Phalacrinae	Acylomus ergoti	×	×	×	×		
		Olibrus liquidus	×					
Nitidulidae	Epuraeinae	Epuraea unicolor			×	×		
Coccinellidae	Chilocorinae	Chilocorus renipustulatus	×					
	Coccinellinae	Nephus bisignatus					×	
		Scymnus rubromaculatus	×			×		
Corylophidae	Corylophinae	Orthoperus corticalis				×		
Mycetophagidae	Mycetophaginae	Litargus connexus	×					
Ciidae	Ciinae	Cis boleti				×		×
		Cis glabratus			×			
Mordellidae	Mordellinae	Mordellistena militaris		×				
Zopheridae	Colydiinae	Lasconotus subcostulatus		×			×	
Tenebrionidae	Alleculinae	Isomira angusta			×			
Chrysomelidae	Galerucinae	Chaetocnema hortensis	×	×		×	×	
		Longitarsus lewisii	×					
		Lythraria salicariae				×		
		Scelolvperus liriophilus		×				
Curculionidae	Brachvcerinae	Notaris scirpi					×	×
	Baridinae	Ampeloglypter sesostris				×	×	
		Centrinopus helvinus	×					
	Ceutorhynchinae	Ceutorhynchus inaffectatus				×		
	- · · · · · · · · · · · · · · · · · · ·	Ceutorhynchus mutabilis		×			×	
	Cryptorhynchinae	Peracalles pectoralis			×			
	Entiminae	Exomias trichopterus				×		
	Scolvtinae	Ambrosiodmus rubricollis		×	×			

Table 2. Summary of the original distribution, habitats, and possible pest status of the adventive species.

Family Species		Original	Habitat	Possible pest status	
		distribution			
Cantharidae	Itharidae Malthodes pumilus Palaearctic Dry meadows, warm forest edges, larvae		-		
			probably in dead wood as predators		
Chrysomelidae	Chaetocnema hortensis	Palaearctic	On various species of Poaceae	Recorded as a minor pest of	
				wheat and barley in Europe	
	Longitarsus lewisii	Palaearctic	On Plantago spp., especially P. major	-	
	Lythraria salicariae	Palaearctic	In wetlands on Lysimachia spp.	-	
Ciidae	Cis boleti	Palaearctic	On polypore fungi, mainly Trametes spp.	-	
	Cis glabratus	Palaearctic	On polypore fungi, main host: Fomitopsis	-	
			pinicola		
Clambidae	Calyptomerus dubius	Palaearctic	In decaying plant material	-	
	Clambus simsoni	Australian	In decaying plant material	-	

Family	Species	Original distribution	Habitat	Possible pest status
Coccinellidae	Chilocorus renipustulatus	Palaearctic	Deciduous forests, feeds on scale insects	_
	Scymnus rubromaculatus	Palaearctic	Dry, warm habitats, mainly found on	_
	5		Brassicaceae, feeds on aphids	
Corylophidae	Orthoperus corticalis	Palaearctic	Deciduous forests, in fungus-infested dead wood	_
Curculionidae	Notaris scirpi	Palaearctic	On Scirpus and Carex in various wet habitats	-
	Exomias trichopterus	Palaearctic	Eurytopic, polyphagous, often found in	Potential pest of berry
			orchards and gardens	crops. Recorded as a pest of
				strawberry, raspberry and
				black chokeberry in Europe.
	Ceutorhynchus	Palaearctic	On Hesperis matronalis (also H. tristis in	-
	inaffectatus		Europe)	
	Ambrosiodmus rubricollis	Palaearctic	Ambrosia feeder, polyphagous	Potential pest of various
				deciduous and coniferous
				trees.
Dermestidae	Attagenus smirnovi	Afrotropical	Larval development mainly (exclusively?)	Pest of various organic
			indoors in temperate areas	materials of animal origin
Erotylidae	Cryptophilus obliteratus	Palaearctic	In decaying plant material	-
	Cryptophilus propinquus	Palaearctic	In decaying plant material	-
Hydrophilidae	Coelostoma orbiculare	Palaearctic	Aquatic, mainly in eutrophic ponds	-
Leiodidae	Leiodes polita	Palaearctic	Eurytopic, in forests, heaths, gardens, etc.,	-
			larval development probably in subterranean	
			fungi	
Mycetophagidae	Litargus connexus	Palaearctic	In deciduous and mixed forests in fungus- infested dead wood	_
Nitidulidae	Epuraea unicolor	Palaearctic	Decaying and fermenting fruit, tree sap, fungal fruiting bodies, etc.	_
Phalacridae	Olibrus liquidus	Palaearctic	Prefers dry, warm habitats, larval development	-
			in flowers of Asteraceae, exact host plants	
			preferences not known	
Staphylinidae	Amischa decipiens	Palaearctic	Eurytopic, in various, usually moist habitats	-
	Atheta vaga	Palaearctic	Eurytopic, in decaying organic material, often in bird nests	_
	Myllaena infuscata	Palaearctic	At margins of standing and running water	_
	Bledius gallicus	Palaearctic	Moist soil at river banks, edges of fields, etc.	_
	Carpelimus elongatulus	Palaearctic	Various moist habitats	-
	Lathrobium geminum	Palaearctic	Moist, open habitats	-
	Lathrobium lineatocolle	Palaearctic	Riparian habitats and wet meadows	-
	Medon apicalis	Palaearctic	Exact breeding habitat unknown, collected	-
Staphylinidae	Medon ripicola	Palaearctic	Unknown, possibly deep litter or mammal	
· · · · · · · · · · · · · · · · · · ·			burrows	
	Pseudomedon obscurellus	Palaearctic	Wetlands, in decaying organic matter	
	Bibloplectus minutissimus	Palaearctic	Collected in flood debris and along river banks	
			in Europe, exact microhabitat unknown	
	Scydmaenus rufus	Palaearctic	Eurytopic, found in forest edges, parks,	
			gardens, floodplains and fields	
	Scydmoraphes minutus	Palaearctic	Associated with ants	
	Stenichnus collaris	Palaearctic	Various moist habitats	
	Stenichnus scutellaris	Palaearctic	Forests, forest edges, gardens	
	Mycetoporus reichei	Palaearctic	Eurytopic, in various terrestrial habitats	
	Iachyporus atriceps	Palaearctic	Eurytopic, mainly in disturbed habitats in Canada	
Throscidae	Trixagus carinifrons	Palaearctic	Prefers dry, warm habitats, larval development	
			probably in soil on fungi (possibly mycorrhizal fungi)	
	Trixagus meybohmi	Palaearctic	Larval development probably in soil on fungi (possibly mycorrhizal fungi)	

Gyrinidae

Dineutus emarginatus (Say, 1825) BOLD:ABX0942

Distribution. Native to the Nearctic region. Widespread in the eastern United States (Gustafson and Miller 2015).

Canadian records. ONTARIO: Charleston Lake Provincial Park, 22-Jun-2015 (2 exx, CBG); Charleston Lake Provincial Park, 25-Jun-2015 (2 exx, CBG).

Diagnostic information. See Gustafson and Miller (2015).

Bionomic notes. Recorded from a variety of lotic and lentic freshwater habitats (Gustafson and Miller 2015). The Canadian adult specimens were hand-collected at a boat launch site on the shore of Charleston Lake, and two larvae matched to the adults by barcode sequences were collected with a dip net at a different site in the same lake.

Carabidae Harpalinae Harpalini

Anisodactylus caenus (Say, 1823) BOLD:AAZ2908

Distribution. Native to the Nearctic region. Widespread in the United States, recorded from all states bordering southern Ontario (Bousquet 2012).

Canadian records. ONTARIO: Point Pelee National Park, 08-Jun-2000 (1 ex, CNC). **Diagnostic information.** See Lindroth (1968) or Bousquet (2010).

Bionomic notes. This species occurs in deciduous forests on moist soil (Larochelle and Lariviere 2003). The Canadian specimen was caught with a UV light trap on a forest trail in Point Pelee National Park.

Comments. As only a single specimen was captured, it is uncertain whether this species is truly established in Canada.

Hydrophilidae Sphaeridiinae Coelostomatini

Coelostoma orbiculare (Fabricius, 1775) BOLD:AAF3894 Figure 1



Figure I. Coelostoma orbiculare (Fabricius), habitus, L. Borowiec. Scale bar: 1.0 mm.

Distribution. Native to the Palaearctic region. Widespread and common in Europe, distributed across Eurasia to the Russian Far East and Japan (Hansen 1987, 2004). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Cambridge, 01-Jun-2015 (1 ex, CBG); Hartington, 18-Apr-2017 (1 ex, CBG).

Diagnostic information (based on Hansen 1987). Body length 4.0–4.8 mm. Habitus short and wide, convex, as in Fig. 1. Black, with the pronotal margins sometimes narrowly red-brown. Antennae with nine antennomeres and a loosely built club with three antennomeres. Base of antennae concealed in dorsal view by the expanded lateral margin of the head. Eyes emarginate. Elytra with sharply impressed sutural striae reaching from apex at least to middle. Tarsomere 1 of meso- and metatarsi longer than tarsomere 2. Abdominal ventrite 1 without medial carina.

Bionomic notes. This species is found in stagnant fresh water. It prefers eutrophic ponds with dense vegetation, and mainly occurs in shallow water at the edges (Hansen 1987). One of the two Canadian specimens was collected as a larva in a leaf litter sample from a wetland, the other (an adult) was sifted from leaf litter close to a lake shore.

Comments. This is the first record of the genus *Coelostoma* Brullé, 1835 in the Nearctic region. *Coelostoma orbiculare* leads to couplet 28 in Van Tassell's (2001) key to North American genera of Hydrophilidae together with the genera *Dactylosternum* Wollaston, 1854 and *Phaenonotum* Sharp, 1882. It can be distinguished from *Dactylosternum* by the absence of a longitudinal carina on the first abdominal ventrite (present in *Dactylosternum*), and from *Phaenonotum* by the presence of distinct sutural striae on the elytra (absent in *Phaenonotum*).

Leiodidae Leiodinae Leiodini

Leiodes polita (Marsham, 1802) BOLD:AAO1258 Figure 2

Distribution. Native to the Palaearctic region. Widespread in Europe, also recorded from North Africa and Caucasus (Daffner 1983; Perreau 2004). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Puslinch Township, 15-Aug-2010 to 22-Aug-2010 (1 ex, CBG); Guelph, 18-Aug-2010 (1 ex, CBG).

Diagnostic information (based on Daffner 1983). Body length 2.2–4 mm. Habitus as in Fig. 2A. Red-brown or yellow-brown, head, pronotum and the sutural and lateral margins of elytra sometimes darkened. Antennae long, with a strongly transverse, darkened club, last antennomere narrower than antennomere 10. Head normally with four punctures in transverse series. Basal margin of pronotum sinuate laterally. Mesoventrite with a long, low and evenly curved medial carina, not reaching the transverse carina and without excavation anteriorly. Metaventrite approximately as long as abdominal ventrites 1 and 2 combined. Elytra with regular, strongly and densely punctate striae, interstitial punctures sparse. Elytra not transversely strigose or strongly microsculptured. Elytral stria 9 separated from side margin at basal third, forming a subhumeral row of punctures. Protibiae only moderately widened towards apex. Metafemora in both sexes with an apical projection at both inner and outer margins, projections stronger in males (Fig. 2B). Male metatibiae bent inward starting from the basal third. Male genitalia as in Fig. 2C, D.



Figure 2. *Leiodes polita* (Marsham) **A** habitus L. Borowiec **B** male left metafemur, dorsal view **C** aedeagus, ventral view **D** aedeagus, lateral view. Scale bars: 1.0 mm (**A**), 0.5 mm (**B**), 0.2 mm (**C**, **D**).

Bionomic notes. This eurytopic species is found in forests, forest edges, heaths, gardens etc. in Europe (Koch 1989b). The Canadian specimens were collected with Malaise traps in suburban residential areas in southern Ontario.

Comments. *Leiodes polita* leads to *L. quebecensis* Baranowski, 1993 in the key to North American species of *Leiodes* (Baranowski 1993). It can be distinguished by the sinuate basal margin of the pronotum (straight in *L. quebecensis* and related species), differently formed projections of the metafemora, and the male genitalia.

Staphylinidae Pselaphinae Trichonychini

Bibloplectus minutissimus (Aubé, 1833) BOLD:AAO0615 Figure 3

Distribution. Native to the West Palaearctic region, widespread in Europe (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Peterborough, 24-May-2015 to 30-May-2015 (1 ex, CBG); Markham, 24-Jun-2017 to 25-Jun-2017 (1 ex, CBG).

Diagnostic information. Body length 0.9–1.1 mm. Habitus as in Fig. 3A. Female apical tergite with distinctive projection (Fig. 3A). Aedeagus as in Fig. 3B (Löbl 1960).

Bionomic notes. Pearce (1957) writes that this species can be collected from the base of grasses and under stones along sandy river banks and in flood debris in Britain. Unlike other European (Pearce 1957) or North American (Owens and Carlton 2017) species of the genus, it does not occur in deep leaf litter or damp moss. Both Pearce (1957) and Besuchet (1955) state that the species is infrequently collected but this may be due to the extremely small size and unknown microhabitat requirements. One of the Canadian specimens was collected with a Malaise trap on farmland, the other was extracted from soil and leaf litter from a mixed habitat of farmland and forest.

Comments. Only female specimens were available from the Nearctic, but they share identical barcode haplotypes with a specimen of *Bibloplectus minutissimus* sampled from Germany. They were also morphologically consistent with the diagnostic characters listed above. In the Palaearctic fauna, females of this species can be recognized by a combination of small size, pale body, temples clearly longer than eyes, and apical tergite produced into a long spine (Besuchet 1955). In the Nearctic region, males are needed for an accurate morphological identification (see Chandler 1990; Owens and Carlton 2017) as many undescribed species are still expected.

Tachyporinae Mycetoporini

Mycetoporus reichei Pandellé, 1869 BOLD:ABW4933 Figure 4

= Mycetoporus triangulatus Campbell, 1991, syn. nov.

Distribution. Native to the West Palaearctic region and broadly distributed (Schülke and Smetana 2015). Adventive in the Nearctic region (Massachusetts, New Hamp-



Figures 3, 4. 3 *Bibloplectus minutissimus* (Aubé) **3A** habitus **3B** aedeagus, ventral view, re-drawn from Löbl (1960) **4** *Mycetoporus reichei* Pandellé **4A** habitus **4B** aedeagus, ventral and lateral view, M. Kocian. Scale bars: 0.25 mm (**3A**), 0.1 mm (**3B**), 1.0 mm (**4A**), 0.2 mm (**4B**).

shire, and Wisconsin, United States, and Ontario, Quebec, and New Brunswick, Canada) (Campbell 1991, as *M. triangulatus*).

Canadian records (DNA barcoded specimens). ONTARIO: Orangeville, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Owen Sound, 21-Aug-2014 to 04-Sep-2014 (1 ex, CBG).

Additional Canadian records. See Campbell (1991) and Brunke et al. (2014) for details of earlier records from Canada and United States (as *M. triangulatus*).

Diagnostic information. Body length: 3.1–4.3 mm. Habitus as in Fig. 4A. Ocular puncture of head located at inner edge of eye. Discal pronotal punctures absent. Elytral disc with only one row of punctures, and elytral microsculpture only distinct in apical half. Aedeagus as in Fig. 4B.

Bionomic notes. In the Nearctic, Campbell (1991) reported this species from a vole nest, spruce litter, car net, flood debris, and from a deciduous forest. Brunke et al. (2014) collected this species (as *M. triangulatus*) from soybean fields and their adjacent hedgerows in Ontario, Canada. The barcoded Canadian specimens were collected with Malaise traps, one in a suburban residential area and the other in grassland habitat.

Comments. Campbell (1991) described *Mycetoporus triangulatus* and stated that it is "almost certainly introduced" but was unable to match it to Palaearctic species available for study. The Palaearctic species of *Mycetoporus* were only recently revised to

include the complex sclerites of the internal sac (e.g., Schülke 2012b) and the Nearctic fauna had not been reviewed since. The Finnish specimens in the BIN are identified as *M. clavicornis* (Stephens, 1832), a close relative of *M. reichei*. These specimens may be misidentified (they were identified by MP before the presence of *M. reichei* in Finland was detected) and need to be re-examined.

Tachyporinae Tachyporini

Tachyporus atriceps **Stephens**, **1832** BOLD:ABX2484, BOLD:ACL8080 Figure 5

Distribution. Native to the Palaearctic region, where it is widespread (Schülke 2012b). Adventive in the Nearctic region (British Columbia, Ontario, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island, Canada).

Canadian records (DNA barcoded specimens). BRITISH COLUMBIA: BURNABY, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG). ONTARIO: Ancaster, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG); Ausable-Bayfield Conservation Authority, 30-Jun-2015 (1 ex, CBG); Cambridge, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Cambridge, 24-Apr-2015 to 01-May-2015 (49 exx, CBG); Carillon Park, 06-May-1982 (2 ex, CNC); Courtice, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG); Guelph, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Guelph, 23-Sep-2013 to 04-Oct-2013 (2 exx, CBG); Guelph, 26-Sep-2014 to 29-Sep-2014 (1 ex, CBG); Hartington, 04-Oct-2017 (1 ex, CBG); Mississauga, 24-May-2016 to 26-May-2016 (1 ex, CBG); Point Pelee National Park, 06-Jul-2015 (1 ex, CBG); Puslinch Township, 19-Sep-2010 to 27-Sep-2010 (2 exx, CBG); Puslinch Township, 24-Oct-2010 to 31-Oct-2010 (1 ex, CBG); Red Rock, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG); Rondeau Provincial Park, 09-Jul-2015 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (13 exx, CBG); Rouge National Urban Park, 15-Sep-2013 (1 ex, CBG); Stayner, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG). QUEBEC: Forillon National Park, 16-Sep-2013 to 23-Sep-2013 (2 exx, CBG). NEW BRUNSWICK: Florenceville-Bristol, 22-Sep-2014 to 03-Oct-2014 (3 exx, CBG); Fredericton, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG). Nova SCOTIA: Cape Breton Highlands National Park, 13-Sep-2013 to 20-Sep-2013 (1 ex, CBG); Hubbards, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG). PRINCE EDWARD IS-LAND: Prince Edward Island National Park, 11-Sep-2013 to 18-Sep-2013 (1 ex, CBG).

Additional Canadian records. ONTARIO: Carillon Park, 06-May-1982 (2 exx, CNC); Renfrew County, 4 km SE Cobden, 15-Sep-1980 (1 ex, CNC); Wentworth County, Stoney Creek, 03-Mar-1973 (1 ex, CNC). QUEBEC: Montreal, 07-Sep-1984 (1 ex, CNC). NOVA SCOTIA: Halifax, 1988 (1 ex, CNC).

Diagnostic information. Body length 2.4–3.6 mm. Habitus as in Fig. 5A. Head black, strongly contrasting with pronotum, elytra with either medial and ovoid lateral markings across disc or disc nearly entirely darkened (Fig. 5B). Elytral chaetotaxy as



Figures 5, 6. 5 *Tachyporus atriceps* Stephens 5A habitus 5B elytral chaetotaxy (re-drawn from Assing and Schülke 2012) and pattern variability 5C aedeagus, ventral view, M. Schülke, modified. Abbreviations: OD outer discal row, MD middle discal row, ID inner discal row, S sutural row 6 *Amischa decipiens* (Sharp) 6A habitus 6B spermatheca, re-drawn from Muona (1990). Scale bars: 1.0 mm (5A; 6A), 0.5 mm (5B, C), 0.1 mm (6B).

in Fig. 5B, with sutural row of punctures and three rows of discal punctures, with two punctures in inner discal row. Aedeagus as in Fig. 5C.

Bionomic notes. This species occurs in a variety of moist to very dry microhabitats (Schülke 2012b). In the Nearctic, this species occurs in disturbed habitats. It was collected by Brunke et al. (2014) in soybean fields and adjacent hedgerows in Ontario (misidentified as *T. canadensis* Campbell, 1979, to which it is similar). The barcoded specimens were collected in suburban residential areas and protected land adjacent to cities, mainly with Malaise or pitfall traps. Some of the barcoded specimens are larvae extracted from soil or leaf litter.

Comments. *Tachyporus atriceps* has the same elytral chaetotaxy as *T. borealis* Campbell, 1979, *T. nimbicola* Campbell, 1979, and *T. canadensis* Campbell, 1979 but can be separated from the first two by the elytra with discal markings. *Tachyporus canadensis* has a dark red-brown head, bright yellow pronotum, and either a pair of narrow linear lateral dark markings (and medial darkening) or entirely immaculate elytra, while *T. atriceps* has a deep black head, slightly darkened (dingy yellow-orange) pronotum and lateral elytral markings that are ovoid or entirely fused with the medial marking to form a broad darkened area over much of the elytra. The internal sac sclerite of *T. atriceps* is similarly shaped to *T. nimbicola* and *T. borealis* (cane-shaped, Fig. 5C) while *T. canadensis* possesses a characteristic arc-shaped sclerite that is not hooked. *Tachyporus atriceps* appears to be common in at least southern Canada and has been present in the Nearctic since at least 1973. This species was probably recently introduced, or has only recently become widespread and common, as it was not detected by Campbell (1979). *Tachyporus atriceps* is split into two closely clustered BINs which show no differences in morphology, including male genitalia.

Aleocharinae Athetini

Amischa decipiens (Sharp, 1869) BOLD:ABA6362 Figure 6

Distribution. Native to the Palaearctic region, occurring broadly in Europe and also reported from the Canary Islands, Tunisia, Turkey, and Mongolia (Schülke and Smetana 2015). Adventive in the Nearctic region (British Columbia and Ontario, Canada).

Canadian records. BRITISH COLUMBIA: Abbotsford, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Burnaby, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG); Port Coquitlam, 20-Apr-2015 to 08-May-2015 (1 ex, CBG); Surrey, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG). ONTARIO: Aylmer, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG); Brantford, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Cambridge, 20-Apr-2015 to 08-May-2015 (1 ex, CBG); Chesley, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Ethel, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Georgian Bay Islands National Park, 28-

Apr-2013 to 03-May-2013 (1 ex, CBG); Hagersville, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Hagersville, 23-Sep-2013 to 04-Oct-2013 (1 ex, CBG); Little Britain, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG); London, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG); London, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Manitowaning, 21-Sep-2015 to 02-Oct-2015 (5 exx, CBG); Milverton, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Napanee, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Perth East, 23-Sep-2013 to 04-Oct-2013 (1 ex, CBG); St. Thomas, 22-Sep-2014 to 03-Oct-2014 (10 exx, CBG); Stayner, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG); Teeswater, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Stayner, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG); Teeswater, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Walkerton, 22-Apr-2013 to 03-May-2013 (2 exx, CBG); Walkerton, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Walkerton, 22-Apr-2014 to 03-Oct-2014 (2 exx, CBG); Walkerton, 22-Apr-2013 to 03-May-2013 (2 exx, CBG); Walkerton, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Walkerton, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Walkerton, 22-Sep-2014 to 03-Oct-2013 (1 ex, CBG); Whitby, 23-Sep-2013 to 04-Oct-2013 (1 ex, CBG).

Diagnostic information. Body length: 2.0–2.2 mm. Habitus as in Fig. 6A. Tergite VII in both sexes without a distinct notch. Spermatheca as in Fig. 6B.

Bionomic notes. This eurytopic species is usually found in moist microhabitats such as leaf litter and moldy hay (Koch 1989a). Good (1995) reported this species from agricultural fields and grasslands in Ireland. Most of the barcoded Canadian specimens were collected with Malaise traps in suburban residential areas.

Comments. One of the most distinctive species of this difficult genus, *A. decipiens* can be recognized by tergite VII lacking a notch in both sexes and by the distinctive spermatheca that bears an elongate capsule (Fig. 6B) (Muona 1990). In at least some parts of its European range (e.g., Ireland), the species is considered to be parthenogenetic (Williams 1969; Good 1995). All examined voucher specimens from the Nearctic were females, suggesting that this species is also parthenogenetic in North America. The genus *Amischa* in North America is unrevised and all Nearctic specimens that cannot be matched to Palaearctic *A. analis* (Gravenhorst, 1802) or *A. decipiens* should be treated as unidentifiable pending a comprehensive study. An examination of all North American types was outside the scope of this study and should ideally be accompanied by further DNA sequencing work of both Nearctic and Palaearctic *Amischa*.

Atheta vaga (Heer, 1839)

BOLD:AAP6199 Figure 7

Distribution. Native to the Palaearctic region, widespread in Europe and reported from Algeria, Tunisia, East and West Siberia, and Mongolia (Schülke and Smetana 2015). Adventive in the Nearctic region (California, United States, and Nova Scotia, Canada).

Canadian records. Nova Scotia: Halifax, 30-May-2013 to 06-Jul-2013 (2 exx, CBG).

Diagnostic information. Body length 2.5–2.8 mm. Habitus as in Fig. 7A. Aedeagus as in Fig. 7B. Spermatheca as in *Atheta fanatica* Casey (Fig 7D).



Figures 7, 8. 7A Atheta vaga (Heer), habitus 7B Atheta vaga, aedeagus, lateral view 7C Atheta fanatica Casey, aedeagus, lateral view 7D Atheta fanatica, spermatheca 8 Myllaena infuscata Kraatz 8A habitus 8B aedeagus, ventral view 8C aedeagus, lateral view 8D spermatheca 8B–D V. Assing. Scale bars: 1.0 mm (7A), 0.2 mm (7B–D), 0.5 mm (8A), 0.1 mm (8B–D).
Bionomic notes. Palm (1970) wrote that the species is common at sap runs on trees, on carrion, in fungi, in compost, and in the nests of birds, including ravens and birds of prey. It consistently occurs in a wide variety of bird nests in Europe (Hicks 1959). Its sister species, native Nearctic *A. fanatica* Casey, 1910, apparently lives in the same way (Klimaszewski et al. 2018) and has been collected in artificial owl nest boxes (Majka et al. 2006, Webster et al. 2009). The Canadian specimens were collected with a Malaise trap in a forested part of Point Pleasant Park in Halifax, Nova Scotia.

Comments. First reported from North America by Muona (1984) from California (without specimen data including date). This is the first record from eastern North America and for Canada. Populations in eastern and western North America may represent separate introductions, and dissection and sequencing of further material may reveal a more detailed introduction history. With the exception of its native sister species, *A. fanatica, A. vaga* can be easily recognized by the shape of the median lobe in lateral view and spermatheca. It can be distinguished from *A. fanatica* by the less strongly sinuate tubus of the median lobe in lateral view (compare with Fig. 7C). The spermathecae of the two species are identical. The close relationship and separate species status of the two species is confirmed by two well-separated BINs. Although the two examined vouchers from Canada are females, we are confident of their identity based on identical DNA barcode haplotypes shared with European material of *A. vaga. Atheta fanatica* forms a separate BIN cluster (BOLD:ACL9881) which shows ca. 10% divergence from *A. vaga*.

Aleocharinae Myllaenini

Myllaena infuscata Kraatz, 1853 BOLD:AAX2901 Figure 8

Distribution. Native to the western Palaearctic region, widely distributed in Europe but rare in the north (Palm 1968) and also reported from India (Kashmir) (Schülke and Smetana 2015), though many of these records need confirmation (Assing 2018). It has previously been reported as occurring in the Nearctic region by Schülke and Smetana (2015) but this is probably based on an erroneous synonymy of North American *M. immunda* Casey with this species in older literature. Klimaszewski (1982) corrected the synonymy, and *M. immunda* is now considered a synonym of *M. arcana* Casey, 1911. The true *M. infuscata* is reported here as adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Rouge National Urban Park, 15-Sep-2013 (1 ex, CBG).

Diagnostic information. Body length 1.2–1.5 mm. Habitus as in Fig. 8A. Aedeagus as in Fig. 8B, C. Spermatheca as in Fig. 8D.

Bionomic notes. *Myllaena infuscata* occurs in both exposed and shaded microhabitats along the margins of still and running water (Reid 1991). The Canadian specimen was extracted from soil and leaf litter collected near the mouth of Rouge River.

Comments. Myllaena infuscata is distinctive in the Nearctic fauna for its spermathecal shape, which forms concentric circular coils (Fig. 8D). The median lobe of the aedeagus in lateral view is also distinctive among species in North America (Fig. 8B, C). Within the western Palaearctic fauna, only *M. minuta* has similar genitalia but differs in the shape of the median lobe in lateral view. The single female from Ontario bears the characteristic spermatheca and its corresponding barcode sequence falls within the BIN associated with *M. infuscata*, rather than *M. minuta*, its similar sister species. It is unknown whether this is a recent introduction to North America or if its small size has impeded its detection.

Oxytelinae Blediini

Bledius gallicus (Gravenhorst, 1806)

BOLD:AAH0142 Figure 9

= Bledius philadelphicus Fall, 1919, syn. nov.

Distribution. Native to the Palaearctic region, trans-Palaearctic (Schülke 2012a). Adventive in the Nearctic region (Maryland, Massachusetts, New Jersey, New York, and Pennsylvania, United States, and Ontario, Quebec, New Brunswick, and Newfoundland, Canada (Herman 1972, Bousquet et al. 2013, as *B. philadelphicus*).

Canadian records (DNA barcoded specimens). ONTARIO: Georgian Bay Islands National Park, 19-Aug-2013 to 27-Aug-2013 (1 ex, CBG); Grundy Lake Provincial Park, 13-Jul-1995 (1 ex, CNC); Hamilton, 21-Jul-2017 (3 exx, CBG). QUEBEC: Montreal, 19-Aug-1981 (1 ex, CNC).

Additional Canadian records. See Herman (1972) for a list of earlier records from Canada and the United States (as *B. philadelphicus*).

Diagnostic information. Body length: 3.7–4.8 mm. Habitus as in Fig. 9A, B. Male sternite VII as in Fig. 9D. Aedeagus as in Fig. 9C.

Bionomic notes. Palm (1961) (as synonym *B. fracticornis*) states that this species can be found in half-moist sand, gravel, clay or mineral soil mixed with humus, with or without vegetation cover. In Central Europe, this species occurs on sandy to muddy river banks, and also in damp field edges (Schülke 2012a). Three of the CBG specimens were collected at a UV light at a forest edge, one was caught in a Malaise trap in a forested peninsula.

Comments. *Bledius gallicus* can be recognized within Herman's (1972) 'semiferrugineus group' using the following combination of characters: last segment of meta-



Figures 9, 10. 9 *Bledius gallicus* (Gravenhorst) **9A** habitus, black elytra, L. Borowiec **9B** habitus, redbrown elytra, L. Borowiec **9C** aedeagus, ventral view, VL = ventral lamella M. Schülke **9D** male sternite VII **10** *Carpelimus elongatulus* (Erichson) **10A** habitus **10B** aedeagus, ventral view, H. Schillhammer. Scale bars: 1.0 mm (**9A, B; 10A**), 0.2 mm (**9C**), 0.2 mm (**9D**), 0.25 mm (**10B**).

tarsus in dorsal view gradually expanded to apex, male sternite VII emarginate, with membranous lobe but emargination not bordered by a pair of spines, pronotum with midlongitudinal groove. The species will key easily to *B. philadelphicus* Fall, 1919 in Herman's (1972) key and we here consider these two species synonyms. Specimens in

the CNC identified as *B. philadelphicus* by Lee Herman and included in his revision of the '*semiferrugineus* group' (Herman 1972) were dissected and revealed to be *B. gallicus*. The description of *Bledius philadelphicus* in Herman (1972) corresponds to that of *B. gallicus* in Schülke (2012a), including the characteristic male sternite VII (though the membranous part is slightly deeper in both Nearctic and Palaearctic populations than indicated by the illustration). *Bledius gallicus* is closely related to the Palaearctic *B. femoralis* (Gyllenhal, 1827) (Schülke 2012a). The two species have extremely similar aedeagi, differing only in the apex of the ventral lamella (Fig. 9C) (acute in *B. femoralis* and broadly truncate in *B. gallicus*). These two species are more easily separated by the shape of male sternite VII (Schülke 2012a).

Based on the specimens available at the CNC and reported by Herman (1972), *B. gallicus* has been in North America for quite a long time, since at least as early as 1910, when Fall (1910) first described *B. philadelphicus* as *B. dissimilis* (not Erichson 1840, preoccupied name replaced by Fall (1919)). The earliest Canadian specimens are from the 1920s.

Oxytelinae Oxytelini

Carpelimus elongatulus (Erichson, 1839) BOLD:AAW4293

Figure 10

Distribution. Native to the Palaearctic region, distributed from western Europe to the Baikal region of Russia (Schülke 2012a). Adventive in the Nearctic region (Ontario, Quebec, and New Brunswick, Canada).

Canadian records (DNA barcoded specimens). ONTARIO: Ausable-Bayfield Conservation Authority, 30-Jun-2015 (1 ex, CBG); Indian Point Provincial Park, 28-Jul-2015 (1 ex, CBG); Puslinch Township, 09-May-2010 (1 ex, CBG).

Additional Canadian records. ONTARIO: Guelph, 10-Apr-2009, (2 exx, DEBU); Minesing Swamp, 26-Jan-2008 (1 ex, DEBU). QUEBEC: Dorval, 10-Oct-1975, (1 ex, FMNH); Sainte-Foy, 27-May-1976, (1 ex, FMNH). NEW BRUNSWICK: Charlotte County, 05-Jun-2008 (1 ex, RWC); Jackson falls, 22-May-2010, (1 ex, RWC); Musquash, 07-May-2006 (1 ex, RWC).

Diagnostic information. Body length: 2.0–2.6 mm. Habitus as in Fig. 10A. Aedeagus as in Fig. 10B.

Bionomic notes. This species occurs on banks of waterways, wet meadows, agricultural fields and in damp leaf litter (Schülke 2012a). The Canadian specimens were collected with Malaise traps in forests and extracted from leaf litter from a wetland and a river bank.

Comments. As the Nearctic *Carpelimus* have not been revised in modern times, it is currently necessary to dissect males to match with published illustrations of the aedeagus (see Webster et al. 2016). Although only female voucher specimens from the Nearctic were available for study, they easily key to *C. elongatulus* in Schülke

(2012a) and two of the barcoded Canadian specimens share identical haplotypes with European specimens of *C. elongatulus*. Similar but much smaller Palaearctic species such as *C. subtilis* are represented in BOLD and form separate BINs deeply divergent from *C. elongatulus*.

Scydmaeninae Cyrtoscydmini

Stenichnus collaris (Müller & Kunze, 1822) BOLD:ABA1519

Figure 11

Distribution. Native to the western Palaearctic region, widely distributed in Europe (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Peterborough, 31-May-2015 to 06-Jun-2015 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (2 exx, CBG).

Diagnostic information. Body size: 1.55–1.70 mm. Habitus as in Fig. 11A. Ae-deagus as in Fig. 11B.

Bionomic notes. Koch (1989a) reports that this species is found in moist forests, forest edges and gardens among leaves and fungi, in dead wood, and at sap flows. One of the Canadian specimens was collected with a Malaise trap on farmland, the other two with pitfall traps in grassland and a river bank.

Comments. As the Nearctic *Stenichnus* fauna remains unrevised, it is only possible to associate Nearctic specimens with Palaearctic species through dissected males or barcodes. The Canadian specimens share identical barcode haplotypes with European material, and the identification was verified by examination of the male genitalia.

Stenichnus scutellaris (Müller & Kunze, 1822)

BOLD:AAN9916 Figure 12

Distribution. Native to the western Palaearctic region, widespread in Europe (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Cambridge, 07-May-2015 to 14-May-2015 (5 exx, CBG); Cambridge, 15-Jul-2017 (15 exx, CBG); Cambridge, 25-May-2015 to 01-Jun-2015 (1 ex, CBG); Cambridge, 25-May-2015 to 31-May-2015 (4 exx, CBG); Cambridge, 29-Apr-2015 to 07-May-2015 (1 ex, CBG); Guelph, 13-May-2017 (1 ex, CBG); Guelph, 22-Apr-2013 to 03-May-2013 (2 exx, CBG); Guelph, 22-Apr-2017 (1 ex, CBG); Kitchener, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Mississauga, 15-Sep-2015 to 17-Sep-2015 (3 exx, CBG); Owen Sound, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Pickering, 24-Jun-2017 to 25-Jun-2017 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (7 exx, CBG); Rouge National Urban Park,



Figures 11, 12. 11 *Stenichnus collaris* (Müller & Kunze) 11A habitus, L. Borowiec 11B aedeagus, dorsal view 12 *Stenichnus scutellaris* (Müller & Kunze) 12A habitus, L. Borowiec 12B aedeagus, dorsal view. Scale bars: 0.5 mm (11A; 12A), 0.1 mm (11B; 12B).

11-Jun-2013 to 18-Jun-2013 (1 ex, CBG); Rouge National Urban Park, 15-Sep-2013 (1 ex, CBG); Rouge National Urban Park, 24-Jun-2017 (1 ex, CBG); Rouge National Urban Park, 29-Apr-2013 to 03-May-2013 (1 ex, CBG); Warsaw, 05-May-2014 to 23-May-2013 (1 ex, CBG); Whitby, 22-Apr-2013 to 03-May-2013 (1 ex, CBG).

Diagnostic information. Body length: 1.4–1.5 mm. Habitus as in Fig. 12A. Male profemur widened apicad to form an abrupt 90° angle in dorsal view. Aedeagus as in Fig. 12B.

Bionomic notes. This species lives in leaf litter and dead wood (Koch 1989a). It is mostly collected in forests or at forest edges, occasionally in wetlands and grasslands

(Koch 1989a). Most Canadian specimens were collected using Malaise traps, pitfall traps, or by sifting leaf litter. Most specimens were collected in disturbed forest fragments but some were from grasslands and wetlands.

Comments. As the Nearctic *Stenichnus* fauna remains unrevised, it is only possible to associate Nearctic specimens with Palaearctic species through dissected males or barcodes. The Canadian specimens share identical barcode haplotypes with European material, and the identification was verified by examination of the male genitalia. The modified male profemur of *S. scutellaris* is unique among the Central European fauna (Franz and Besuchet 1971). Without a revision of the Nearctic fauna, it is not possible to know whether other North American species also possess this character.

Scydmaeninae Scydmaenini

Scydmaenus rufus Müller & Kunze, 1822

BOLD:AAO4392 Figure 13

Distribution. Native to the western Palaearctic region, widespread in Europe and also reported from Algeria, Tunisia, and Lebanon (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Guelph, 17-Sep-2017 (6 exx, CBG).

Diagnostic information. Body length: 1.4 mm. Habitus as in Fig. 13A. Aedeagus as in Fig. 13B.

Bionomic notes. This eurytopic species occurs along forest edges and in parks, gardens, floodplains, and fields (Koch 1989a). The Canadian specimens were sifted from a compost heap.

Comments. As the Nearctic *Scydmaenus* fauna remains unrevised, it is only possible to associate Nearctic specimens with Palaearctic species through dissected males or barcodes. Three of the Canadian specimens share identical barcode haplotypes with European material, and the identification was verified by examination of the male genitalia.

Scydmaeninae Glandulariini

Scydmoraphes minutus (Chaudoir, 1845) BOLD:AAO3241 Figure 14

Distribution. Native to the Palaearctic region, widespread in Europe and also reported from the Russian Far East (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).



Figures 13, 14. 13 *Scydmaenus rufus* Müller & Kunze 13A habitus, L. Borowiec 13B aedeagus, ventral view 14 *Scydmoraphes minutus* (Chaudoir) 14A habitus 14B aedeagus, ventral view. Scale bars: 0.5 mm (13A; 14A), 0.1 mm (13B; 14B).

Canadian records. ONTARIO:Georgian Bay Islands National Park, 30-Jul-2013 to 06-Aug-2013 (1 ex, CBG); Peterborough, 30-Jul-2015 (1 ex, CBG).

Diagnostic information. Body length: 1.15–1.30 mm. Habitus as in Fig. 14A. Head without supraantennal notches or frontal impression, submentum with lateral sutures broadly separated. Pronotum setose, laterally margined, with a transverse groove at the base. Aedeagus as in Fig. 14B.

Bionomic notes. This species is associated with ants, especially species of the *Formica rufa* Linnaeus, 1761 group, and *Lasius fuliginosus* (Latreille, 1798) and *L. brunneus* (Latreille, 1798) in Europe (Franz and Besuchet 1971). Koch (1989a) reports *S. minutus* with *Lasius* ants in hollow trees, under loose bark and in fallen logs. The Canadian specimens were collected with Malaise traps, one in a forested peninsula and the other on farmland.

Comments. The genus *Scydmoraphes* Reitter, 1891 is here reported for the first time from North America. It was distinguished recently from the similar Nearctic genus *Parascydmus* Casey, 1897 (Jałoszynski 2019), and it does not appear to be an obvious synonym of the other similar Nearctic genus *Brachycepsis* Brendel, 1889. A detailed systematic study of the Nearctic glandulariine genera is warranted. The genus *Scydmoraphes* (with a single species in the Nearctic region) may be recognized within the Nearctic fauna of Glandulariini by the unique combination of a transverse groove on the base of the pronotum, which is margined laterally (Fig. 14A), submentum with lateral sutures broadly separated, and head dorsally lacking frontal impression and supraantennal notches (Jałoszynski 2019). In habitus, *Scydmoraphes* is similar to *Brachycepsis* and *Parascydmus* but can be easily recognized by the transverse pronotal groove.

The following couplets from O'Keefe (2001) were modified to include *Scydmo-raphes*:

19a (18)	Base of pronotum with transverse groove (Fig. 14A)
	Scydmoraphes minutus
-	Base of pronotum with only impressed basal foveae 19b
19b (19a)	Pronotum with 4 basal foveae (fig. 42.20); scutellum large; often light to
	dark brown in color Brachycepsis
-	Pronotum with 6 basal foveae (fig. 43.20); scutellum minute; often black
	in colorParascydmus

Paederinae Paederini

Lathrobium geminum Kraatz, 1857 BOLD:AAX0181 Figure 15

Distribution. Native to the Palaearctic region, distributed from Europe to the Far East of Russia (Schülke and Smetana 2015). Adventive in the Nearctic region (British Columbia, Canada).

Canadian records. BRITISH COLUMBIA: Gulf Islands National Park Reserve, 17-Jun-2014 to 22-Jun-2014 (2 exx, CBG).

Diagnostic information. Body length: 8.0–9.0 mm. Habitus as in Fig. 15A. Female sternite VIII elongate and truncate apically, as in Fig. 15D. Aedeagus distinctive in lateral view, as in Fig. 15B, C.

Bionomic notes. In Central Europe, this is a common species in unforested, humid microhabitats such as wetlands, shorelines, agricultural fields, gardens, and heath (Assing 2012). The Canadian specimens were collected in a wetland adjacent to a lake, one with pitfall traps and the other by Berlese funnel extraction.

Comments. The voucher specimens from North America are, unfortunately, females but share identical barcode haplotypes with Palaearctic specimens of *L. geminum*



Figures 15, 16. 15 *Lathrobium geminum* Kraatz 15A habitus, L. Borowiec 15B aedeagus, lateral view V. Assing 15C aedeagus, ventral view V. Assing 15D female sternite VIII, modified from Assing and Schülke (2012) 16 *Lathrobium lineatocolle* Scriba 16A aedeagus, lateral view, V. Assing 16B female sternite VIII, V. Assing. Scale bars: 2.0 mm (15A), 0.5 mm (15B–D), 0.5 mm (16A, B).

from Germany and Finland. North American vouchers key to *L. geminum* in Assing (2012) and female sternite VIII is consistent with the shape described for this species. As the Nearctic fauna of *Lathrobium* is unrevised, comparisons with North American species are not yet possible.

Lathrobium lineatocolle Scriba, 1859 BOLD:ACL0909 Figure 16

Distribution. Native to the Palaearctic region, widespread in Europe and reported from China, Iran, Turkey, and the Russian Far East (Schülke and Smetana 2015). Adventive in Canada (Ontario).

Canadian records. ONTARIO: Rouge National Urban Park, 29-Apr-2013 to 03-May-2013 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (1 ex, CBG).

Diagnostic information. Female sternite VIII elongate to narrow, scarcely emarginate apex, as in Fig. 16B. Aedeagus distinctive in lateral view, as in Fig. 16A.

Bionomic notes. In Central Europe, this species occurs mostly in riparian habitats and in wet meadows (Assing 2012). One of the Canadian specimens was collected with a Malaise trap in a forest patch; the other was caught in a riverside pitfall trap.

Comments. As the Nearctic fauna of *Lathrobium* is unrevised, comparisons with North American species are not yet possible.

Medon apicalis (Kraatz, 1857)

BOLD:ACC4101 Figure 17

Distribution. Native to the western Palaearctic region, widespread in Europe and also reported from Algeria, Morocco, Turkey, the Canary Islands, and Madeira (Schülke and Smetana 2015). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Guelph, 30-Jun-2018 (1 ex, CBG).

Diagnostic information. Body length: 3.8–4.6 mm. Habitus as in Fig. 17A. Male sternite VII as in Fig. 17C. Aedeagus as in Fig. 17B.

Bionomic notes. This species has been collected in a variety of habitats in Europe, but the breeding habitat requirements are unknown (Assing 2006). Most specimens have been collected in flight (car nets, flight interception traps) (Assing 2006). Specimens have also been collected from stream edges, haystacks, woodland and at light (Assing 2006). This species is less likely to occur in the nests of small mammals than other species of the genus (Assing 2006). The Canadian specimen was collected at a UV light in a mixed forest.

Comments. A single female voucher from Canada was available for study and, while males would normally be necessary to confirm a positive identification in *Medon*, its barcode sequence is identical to German and Austrian specimens of *M. apicalis*. All similar, widespread Palaearctic species that could be confused with *M. apicalis* (*M. ripicola* (Kraatz, 1854), *M. brunneus* (Erichson, 1839), *M. fusculus* (Mannerheim, 1830)) are represented in BOLD and form distinct BIN clusters. The female voucher was also morphologically compared to representatives of all widespread western Palaearctic *Medon* species and was consistent with the variability of body proportions, punctation and color of *M. apicalis*. Four species known from the southwestern Palaearctic are closely related to *M. apicalis* and cannot be reliably distinguished by external characters: *M. perniger* Coiffait, 1978 (Italy and extreme southern parts of France and Switzerland); *M. maronitus* (Saulcy, 1864) (Greece to Turkmenistan); *M. sericellus* Fairmaire, 1860 (North Africa) and *M. beydaghensis* Fagel, 1969 (Turkey) (Assing 2004, 2006). None of these species are currently rep-



Figures 17–19. 17 *Medon apicalis* (Kraatz) 17A habitus 17B aedeagus, ventral and lateral view, V. Assing 17C male sternite VII, V. Assing 18 *Medon ripicola* (Kraatz) 18A habitus 18B aedeagus, ventral and lateral view, V. Assing 18C male sternite VII, V. Assing 19 *Pseudomedon obscurellus* (Erichson) 19A habitus 19B aedeagus, lateral view, V. Assing 19C male sternite VIII, V. Assing. Scale bars: 1.0 mm (17A; 18A; 19A), 0.2 mm (17B, C; 18B, C; 19B, C).

resented on BOLD. Although one or more of these species might share a BIN with *M. apicalis*, the Ontario specimen has an identical DNA barcode haplotype to specimens from Germany and Austria where *M. apicalis* is the only known representative of this species group. As the Nearctic fauna of *Medon* is unrevised, comparisons with North American species are not yet possible. Recognizing this species in the Nearctic region requires dissected males or DNA barcoding.

Medon ripicola (Kraatz, 1854)

BOLD:AAO2230 Figure 18

Distribution. Native to the western Palaearctic region, widespread in Europe and also reported from Algeria, Morocco, Turkey, and Madeira (Schülke and Smetana 2015). Adventive in the Nearctic region (Nova Scotia, Canada).

Canadian records. NOVA SCOTIA: Cape Breton Highlands National Park, 10-May-2013 to 21-May-2013 (1 ex, CBG).

Diagnostic information. Body length: 3.7–4.2 mm. Habitus as in Fig. 18A. Male sternite VII as in Fig. 18C. Aedeagus as in Fig. 18B.

Bionomic notes. This species is rarely collected in the Palaearctic, with its breeding microhabitat unknown (probably in deeper litter or mammal burrows). In Central Europe, specimens have been collected mostly in wetlands (floodplains, ponds), in flood debris, mole nests, and deeper deciduous leaf litter (Assing 2012). Palm (1963) wrote that this species was rarely collected in Scandinavia: once in Sweden under pebbles on the seashore and in Denmark under seaweed. Its occasional but typical appearance near water suggests that heavy rains may flood out the breeding microhabitat and deposit the beetles elsewhere (e.g., flood debris). The collection of *M. ripicola* on northern European seashores suggests a potential mechanism for introduction to the Canadian Maritimes through ocean commerce. The Canadian specimen was collected with a Malaise trap in a riverside forest.

Comments. A single female voucher from Canada was available for study and, while males would normally be necessary to confirm a positive identification in *Medon* by morphology, its barcode sequence clustered within the European material of *M. ripicola* with only two nucleotide sites differing from the nearest European specimen. All similar Palaearctic species that could be confused with *M. ripicola* (*M. apicalis* (Kraatz, 1857), *M. brunneus* (Erichson, 1839), *M. fusculus* (Mannerheim, 1830)) are represented in BOLD in separate BIN clusters. The female voucher was also morphologically compared to representatives of all Palaearctic *Medon* species and was consistent with the body proportions, punctation and color of *M. ripicola*. As the Nearctic fauna of *Medon* is unrevised, useful comparisons with North American species are not yet possible. Recognizing this species in the Nearctic region is reliably accomplished, at present, using dissected males or DNA barcoding.

Pseudomedon obscurellus (Erichson, 1840)

BOLD:AAO1043 Figure 19

Distribution. Native to the western Palaearctic region, widespread in Europe and also reported from Algeria, Morocco, Madeira, Tunisia, Cyprus, and Turkey (Schülke and Smetana 2015). Adventive in the Neotropical region (Chile; Assing 2009) and the Nearctic region (Nova Scotia, Canada).

Canadian records. Nova Scotia: Cape Breton Highlands National Park, 07-Jun-2013 to 24-Jun-2013 (1 ex, CBG).

Diagnostic information. Body length: 3.0–3.4 mm. Habitus as in Fig. 19A. Male sternite VIII as in Fig. 19C. Aedeagus as in Fig. 19B.

Bionomic notes. This species inhabits wetlands and can be collected from rotting organic matter (Assing 2012). The Canadian specimen was collected at the same site and in the same Malaise trap as the *M. ripicola* specimen.

Comments. A single female voucher from Canada was available for study and, while males would normally be necessary to confirm a positive identification in *Pseudomedon*, its barcode sequence is identical to German specimens of *P. obscurellus*. The morphologically similar Palaearctic species *P. obsoletus* forms a separate BIN cluster (BOLD:ABY0636). The female voucher from Canada also was consistent with the typical coloration of *P. obscurellus* given by Assing (2012). As the Nearctic fauna of *Pseudomedon* is unrevised, comparisons with North American species are not yet possible. Recognizing this species in the Nearctic region is reliably accomplished, at present, using dissected males or DNA barcoding.

Due to taxonomic confusion until the 1970s, reports of *Pseudomedon obscurellus* and *P. obsoletus* from regions outside of the Palaearctic need re-confirmation (Assing 2009, Klimaszewski et al. 2013). The record of *P. obsoletus* from British Columbia from Hatch (1957) is doubtful and likely refers to *P. obscurellus* as it was described as being partly dark rufous, a color more typically associated with this species (Assing 2012). To our knowledge, this is the first verified record of any Palaearctic *Pseudomedon* species from the Nearctic.

Scarabaeidae Melolonthinae Melolonthini

Phyllophaga implicita (Horn, 1887)

BOLD:AAC5184

Distribution. Native to North America. Occurs across most of the Mississippi River drainage basin in the United States (Luginbill and Painter 1953).

Canadian records. ONTARIO: Point Pelee National Park, 05-Jun-2008 (1 ex, CBG). **Diagnostic information** (partially based on Luginbill and Painter 1953). Body length 14.5–17.0 mm. Dorsal surface pale to dark brown, moderately shiny (not pruinose or iridescent), glabrous, and without scales. Clypeus emarginate. Antennae with nine antennomeres. See Luginbill and Painter (1953) for images of habitus and genitalia.

Bionomic notes. Adults have been observed on numerous plants including *Tilia* L., *Fagus* L., *Betula* L., *Ulmus* L., *Lonicera* L., *Acer* L., *Platanus* L., *Rosa* L., *Juglans* L., *Salix* L. and cultivated legumes (Luginbill and Painter 1953). The Canadian specimen was collected in a mixed forest close to the shore of Lake Erie using an ultraviolet light.

Comments. It is not surprising to find a range extension of this species into Canada considering the widespread distribution in eastern North America and the apparent broad range of host plants. Since only a single specimen was collected in Canada it is difficult to assess how firmly established this species is. There are hundreds of species of *Phyllophaga* with a similar overall appearance; therefore, it is crucial to use the male or female genitalia for morphological species identifications.

Clambidae Calyptomerinae

Calyptomerus dubius (Marsham, 1802) BOLD:AAP9145 Figure 20

Distribution. Native to the Palaearctic region, widespread in Central Europe and around the Mediterranean (Endrödy-Younga 1961, Löbl 2006). Adventive in the Afrotropical region (South Africa), the Australian region (Australia) (Endrödy-Younga 1974) and in the Nearctic region (British Columbia, Canada).

Canadian records. BRITISH COLUMBIA: Abbotsford, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Vancouver, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Victoria, 03-Sep-2014 to 10-Sep-2014 (1 ex, CBG).

Diagnostic information (based on Endrödy-Younga 1961). Body length 1.1– 1.6 mm. Habitus as in Fig. 20A. Red-brown, with the edges of pronotum and elytra paler. The antennal groove forms a continuous and even curve with the side of the frons in front of the eyes. Lateral edges of pronotum bluntly angled. Pubescence on the dorsal surface long and sparse. Elytra angled apicolaterally and truncate at the hind margin. Aedeagus as in Fig. 20B.

Bionomic notes. This species is known from decaying plant material. It has been collected from dead, fungus-infested logs of deciduous trees, leaf litter, composts, moldy hay, etc. (Koch 1989b). The Canadian specimens were collected with Malaise traps in residential areas.



Figures 20, 21. 20 *Calyptomerus dubius* (Marsham) 20A habitus, L. Borowiec 20B aedeagus, dorsal view 21 *Clambus simsoni* Blackburn 21A habitus 21B aedeagus, ventral view. Scale bars: 0.5 mm (20A; 21A), 0.2 mm (20B), 0.1 mm (21B).

Comments. *Calyptomerus oblongulus* (Mannerheim, 1853) is the only other representative of this genus known from North America. It is larger than *C. dubius* (body length 1.8–2.0 mm), with a rounded angle between the antennal groove and the lateral margin of frons, rounded lateral edges of pronotum, evenly curved (not truncate) ely-tral hind margins, shorter and denser pubescence on the dorsal surface, and different male genitalia (Endrödy-Younga 1961).

Clambinae

Clambus simsoni Blackburn, 1902 BOLD:AAO0037 Figure 21

Distribution. Native to the Australian region. Described from Australia, where the species is widespread and common (Endrödy-Younga 1990). Also recorded from New Zealand (Johnson 1997). Adventive in the Afrotropical region (South Africa), the Palae-arctic region (British Isles and Central Europe; Endrödy-Younga 1990, Johnson 1997, Meybohm 2004, Löbl 2006), and the Nearctic region (British Columbia, Canada).

Canadian records. BRITISH COLUMBIA: West Vancouver, 20-Apr-2015 to 08-May-2015 (1 ex, CBG).

Diagnostic information (based on Endrödy-Younga 1990 and Johnson 1997). Body length 1.0–1.2 mm. Habitus as in Fig. 21A. Pale red-brown, with head and anterior part of pronotum darkened. Lateral angles of head narrowly rounded, rectangular, a line drawn between the angles level with the posterior margin of eyes. Dorsal surface without microsculpture. Apical part of elytra with large punctures. Pubescence of elytra relatively long and sparse, individual setae only a little longer than distance between seta-bearing punctures. Aedeagus as in Fig. 21B, penis finely serrate laterally in the apical quarter.

Bionomic notes. This species is known from decaying plant material. It has been collected from heaps of cut grass, heaps of shredded bark, and (in New Zealand) from tree fungi (Johnson 1997). The Canadian specimen was collected with a Malaise trap in a suburban residential area.

Comments. Morphologically, *Clambus simsoni* is most reliably identified by its characteristic male genitalia. The Canadian specimen is a male which shares an identical barcode sequence with a specimen sampled from Germany. In Endrödy-Younga's (1981) key to the New World species of *Clambus, C. simsoni* leads to *C. spangleri* Endrödy-Younga in couplet 14. *Clambus simsoni* is slightly larger (*C. spangleri* is 0.8–0.9 mm according to Endrödy-Younga), and the pubescence on the dorsal surface is sparser than in *C. spangleri*.

Scirtidae Scirtinae

Contacyphon fuscescens (Klausnitzer, 1976) BOLD:ACX3673 Figure 22

Distribution. Native to North America. Described from New York State (Ithaca) (Klausnitzer 1976).

Canadian records. YUKON TERRITORY: Kluane National Park and Reserve, 15-Jul-2014 to 24-Jul-2014 (1 ex, CBG). BRITISH COLUMBIA: Naikoon Provincial Park, 24-Jun-2014 to 03-Jul-2014 (4 exx, CBG); Naikoon Provincial Park, 13-Jul-2014 to 31-Jul-2014 (5 exx, CBG); Naikoon Provincial Park, 08-Aug-2014 to 15-Aug-2014 (4 exx, CBG). ONTARIO: Puslinch Township, 12-Jun-2010 to 19-Jun-2010 (1 ex, CBG); Short Hills Provincial Park, 26-May-2014 to 09-Jun-2014 (4 exx, CBG); Short Hills Provincial Park, 23-Jun-2014 to 07-Jul-2014 (1 ex, CBG).

Diagnostic information (based on Klausnitzer 1976). Body length 2.5–3.0 m. Dark brown, basal margin of the pronotum and elytral suture a little paler. Head with granulate punctation, pronotal punctation fine, elytra a little more coarsely punctate than pronotum. Elytra with longitudinal ribs. Male tergite VIII and IX as in Fig. 22C. Aedeagus as in Fig. 22A, B.

Bionomic notes. The Canadian specimens were collected with Malaise traps in wetlands and close to open water in forests and farmland.

Comments. *Contacyphon fuscescens* belongs to the *C. coarctatus* group of species. It is most reliably identified by the male genitalia. The identification of the Canadian specimens is based on dissected male representatives of the BIN.

Contacyphon kongsbergensis (Munster, 1924)

BOLD:AAJ3307 Figure 23

Distribution. Holarctic. Recorded from across the Palaearctic region, from Western Europe to the Russian Far East (Klausnitzer 2006). In North America, apparently previously known only from Alaska (Kalsin Bay, Kodiak (Nyholm 1972)). This record was overlooked by Bousquet et al. (2013).

Canadian records. BRITISH COLUMBIA: Smithers, 28-Jul-2014 to 05-Aug-2014 (4 exx, CBG). ALBERTA: Jasper National Park, 02-Aug-2010 to 05-Aug-2010 (1 ex, CBG). MANITOBA: Churchill, 05-Aug-2005 (1 ex, CBG); Churchill, 18-Aug-2006 (1 ex, JBWM); Churchill, 21-Jul-2007 (2 exx, CBG); Riding Mountain National Park, 16-Jul-2012 to 23-Jul-2012 (1 ex, CBG).

Diagnostic information (based on Nyholm 1972 and Lohse 1979). Body length 2.7–3.2 mm. Reddish or yellowish brown, head usually darker than pronotum and elytra. Head and pronotum with dense, coarse, granulate punctation. Elytra densely punctate. Male sternite IX and accessory sclerite as in Fig. 23C. Aedeagus as in Fig. 23A, B.

Bionomic notes. This species is known from acidic *Sphagnum* bogs (Nyholm 1972). Most Canadian specimens were collected with Malaise traps; also collected with light traps and by sweep netting.

Comments. Contacyphon kongsbergensis is morphologically most reliably identified by its genitalia. The lack of a modern revision of North American Contacyphon prevents detailed comparison with related species.



Figures 22–24. 22 *Contacyphon fuscescens* (Klausnitzer) 22A aedeagus, dorsal plate 22B aedeagus, ventral plate 22C male tergite 8 and 9 23 *Contacyphon kongsbergensis* (Munster) 23A aedeagus, dorsal plate 23B aedeagus, ventral plate 23C male sternite 9 and accessory sclerite 24 *Contacyphon obscurellus* (Klausnitzer) 24A aedeagus, dorsal plate 24B aedeagus, ventral plate 24C male sternite 9 24D male tergite 9. Scale bars: 0.2 mm (22A–C; 23A–C), 0.5 mm (24A–D).

Contacyphon obscurellus (Klausnitzer, 1976) BOLD:AAG7260, BOLD:ACP0631, BOLD:ACP0632 Figure 24

Distribution. Native to North America. Described from New York State (Adirondack, Long Lake) (Klausnitzer 1976).

Canadian records. ONTARIO: Georgian Bay Islands National Park, 30-Jul-2013 to 06-Aug-2013 (1 ex, CBG); Guelph, 30-Jun-2018 (1 ex, CBG); Perth, 03-Jul-2014 to 17-Jul-2014 (1 ex, CBG); Warsaw, 04-Jul-2014 to 18-Jul-2014 (1 ex, CBG). New BRUNSWICK: Kouchibouguac National Park, 19-Aug-2009 (1 ex, CBG). Nova Sco-TIA: Cape Breton Highlands National Park, 14-Jul-2013 to 19-Jul-2013 (1 ex, CBG); Cape Breton Highlands National Park, 19-Jul-2013 to 26-Jul-2013 (1 ex, CBG); Cape Breton Highlands National Park, 02-Aug-2013 to 09-Aug-2013 (1 ex, CBG); Kejimkujik National Park, 08-Aug-2013 to 22-Aug-2013 (1 ex, CBG). NEWFOUNDLAND: Gros Morne National Park, 25-Jun-2013 to 02-Jul-2013 (1 ex, CBG); Gros Morne National Park, 09-Jul-2013 to 16-Jul-2013 (1 ex, CBG); Gros Morne National Park, 09-Jul-2013 to 20-Jul-2013 (9 exx, CBG); Gros Morne National Park, 10-Jul-2013 to 20-Jul-2013 (47 exx, CBG); Gros Morne National Park, 11-Jul-2013 (1 ex, CBG); Gros Morne National Park, 12-Jul-2013 (2 exx, CBG); Gros Morne National Park, 15-Jul-2013 (1 ex, CBG); Gros Morne National Park, 17-Jul-2013 (1 ex, CBG); Gros Morne National Park, 22-Aug-2013 to 27-Aug-2013 (1 ex, CBG); Terra Nova National Park, 24-Jul-2013 to 30-Jul-2013 (3 exx, CBG).

Diagnostic information (based on Klausnitzer 1976). Body length 2.4 mm. Brown, elytral suture pale brown, antennae and legs yellow-brown. Male sternite IX and tergite IX as in Fig. 24C, D. Aedeagus as in Fig. 24A, B.

Bionomic notes. The Canadian specimens were collected in conifer and mixed forests, mainly with Malaise traps.

Comments. *Contacyphon obscurellus* belongs to the *C. variabilis* group of species. It is most reliably identified by its genitalia. The species is split into three closely clustered BINs, which show no obvious morphological differences. The identification of the Canadian specimens is based on dissected male representatives of these BINs.

Throscidae

Aulonothroscus distans Blanchard, 1917 BOLD:ABA9083

Distribution. Native to North America. Blanchard (1917) listed records from Massachusetts, New York and North Carolina.

Canadian records. ONTARIO: Balsam Lake Provincial Park, 02-Jun-2014 to 16-Jun-2014 (1 ex, CBG); Cambridge, 21-May-2015 to 27-May-2015 (1 ex,

CBG); Cambridge, 25-May-2015 to 31-May-2015 (1 ex, CBG); Cambridge, 04-Jun-2015 to 11-Jun-2015 (3 exx, CBG); Cambridge, 18-Jun-2015 to 24-Jun-2015 (1 ex, CBG); Elizabethtown-Kitley, 14-May-2010 to 18-May-2010 (1 ex, CBG); Elizabethtown-Kitley, 28-May-2010 to 30-May-2010 (2 exx, CBG); Georgian Bay Islands National Park, 04-Jun-2013 to 11-Jun-2013 (1 ex, CBG); Georgian Bay Islands National Park, 11-Jun-2013 to 18-Jun-2013 (1 ex, CBG); Georgian Bay Islands National Park, 18-Jun-2013 to 26-Jun-2013 (3 exx, CBG); Georgian Bay Islands National Park, 26-Jun-2013 to 30-Jun-2013 (2 exx, CBG); Georgian Bay Islands National Park, 30-Jul-2013 to 06-Aug-2013 (2 exx, CBG); Georgian Bay Islands National Park, 06-Aug-2013 to 19-Aug-2013 (1 ex, CBG); Georgian Bay Islands National Park, 03-Sep-2013 to 10-Sep-2013 (2 exx, CBG); Guelph, 17-Oct-2013 (1 ex, CBG); Hanover, 30-Jul-2014 to 13-Aug-2014 (1 ex, CBG); Rouge National Urban Park, 04-Jun-2013 to 11-Jun-2013 (1 ex, CBG); Rouge National Urban Park, 11-Jun-2013 to 18-Jun-2013 (6 exx, CBG); Rouge National Urban Park, 02-Jul-2013 to 09-Jul-2013 (1 ex, CBG); Rouge National Urban Park, 23-Jul-2013 to 30-Jul-2013 (1 ex, CBG); Rouge National Urban Park, 20-Aug-2013 to 27-Aug-2013 (1 ex, CBG); Rouge National Urban Park, 26-May-2014 to 03-Jun-2014 (3 exx, CBG); Rouge National Urban Park, 03-Jun-2014 to 10-Jun-2014 (2 exx, CBG); Rouge National Urban Park, 10-Jun-2014 to 17-Jun-2014 (3 exx, CBG); Rouge National Urban Park, 17-Jun-2014 to 24-Jun-2014 (3 exx, CBG); Rouge National Urban Park, 25-May-2014 to 01-Jul-2014 (1 ex, CBG); Rouge National Urban Park, 01-Jul-2014 to 08-Jul-2014 (1 ex, CBG); Rouge National Urban Park, 08-Jul-2014 to 15-Jul-2014 (1 ex, CBG); Rouge National Urban Park, 22-Jul-2014 to 29-Jul-2014 (2 exx, CBG); Rouge National Urban Park, 29-Jul-2014 to 05-Aug-2014 (1 ex, CBG); Rouge National Urban Park, 12-Aug-2014 to 19-Aug-2014 (1 ex, CBG); Rouge National Urban Park, 19-Aug-2014 to 26-Aug-2014 (1 ex, CBG); Rouge National Urban Park, 16-Sep-2014 to 23-Sep-2014 (1 ex, CBG); Rouge National Urban Park, 30-Sep-2014 to 07-Oct-2014 (1 ex, CBG); Thousand Islands National Park, 01-Jun-2012 to 08-Jun-2012 (2 exx, CBG); Thousand Islands National Park, 07-Jul-2012 to 13-Jul-2012 (1 ex, CBG); Thousand Islands National Park, 08-Jun-2012 to 15-Jun-2012 (1 ex, CBG); Thousand Islands National Park, 22-Jun-2012 to 29-Jun-2012 (1 ex, CBG); Thousand Islands National Park, 25-May-2012 to 01-Jun-2012 (1 ex, CBG); Waterloo, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG).

Diagnostic information (based on Blanchard 1917). Body length 2.6–3.0 mm. Piceous brown. Eyes with a small semicircular emargination. Head with longitudinal carinae separate and slightly diverging on the frons. Prosternal striae entire.

Bionomic notes. The Canadian specimens were collected with Malaise traps, mostly in deciduous or mixed forests.

Comments. The shallow semicircular emargination of the eyes separates this species from the other known North American species of *Aulonothroscus* (Blanchard 1917).

Trixagus carinifrons (Bonvouloir, 1859) BOLD:ABW4548

Figure 25

Distribution. Native to the Palaearctic region. Widespread in Europe, also recorded from the Russian Far East (Leseigneur 2007). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Guelph, 01-Aug-2013 to 08-Aug-2013 (3 exx, CBG); Guelph, 15-Aug-2013 to 22-Aug-2013 (1 ex, CBG); Guelph, 29-Aug-2013 to 05-Sep-2013 (1 ex, CBG); Guelph, 30-Sep-2013 to 04-Oct-2013 (1 ex, CBG); Rouge National Urban Park, 28-May-2013 to 04-Jun-2013 (1 ex, CBG); Rouge National Urban Park, 18-Jun-2013 to 25-Jun-2013 (4 exx, CBG); Rouge National Urban Park, 27-Aug-2013 to 03-Sep-2013 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2014 to 10-Jun-2014 (1 ex, CBG); Rouge National Urban Park, 29-Jul-2014 to 05-Aug-2014 (2 exx, CBG); Rouge National Urban Park, 05-Aug-2014 (2 exx, CBG); Rouge National Urban Park, 05-Aug-2014 (4 exx, CBG).

Diagnostic information (based on Leseigneur 1998, 2005). Body length 2.5– 3.0 mm. Habitus as in Fig. 25A. Eyes deeply emarginate. Head with longitudinal carinae which converge towards the vertex. Sides of pronotum sinuate in males, slightly or not sinuate in females. Elytral apex in males with a fringe of hairs longer than the lateral pubescence, often hidden under the elytra and not visible without removal of the abdomen. Aedeagus as in Fig. 25B.

Bionomic notes. In Europe, this species is usually found in dry, warm habitats: heaths, forest edges, gravel pits, etc. (Koch 1989b). The Canadian specimens were collected in Malaise traps in a patch of forest and on a lawn between buildings on the University of Guelph campus.

Comments. The genus *Trixagus* includes several overlooked and probably undescribed species in Canada based on DNA barcode data and initial studies of male genitalia of the barcoded material (Bouchard et al. 2017, MP unpublished data). Until the genus is revised, the two Palaearctic *Trixagus* species reported here are most reliably identified using DNA barcodes or male genitalia.

Trixagus meybohmi Leseigneur, 2005 BOLD:ACC5051 Figure 26

Distribution. Recently described, distribution not yet thoroughly known. Apparently widespread in Europe (Leseigneur 2005, Mertlik and Leseigneur 2007, Silfverberg 2010, Rassi et al. 2015). Adventive in the Nearctic region (British Columbia, Ontario, Quebec, and Nova Scotia, Canada).



Figures 25, 26. 25 *Trixagus carinifrons* (Bonvouloir) 25A habitus, L. Borowiec 25B aedeagus 26 *Trixagus meybohmi* Leseigneur 26A habitus 26B aedeagus. Scale bars: 1.0 mm (25A; 26A), 0.5 mm (25B; 26B).

Canadian records. BRITISH COLUMBIA: North Vancouver, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG); Vancouver, 20-May-2014 to 26-May-2014 (2 exx, CBG); Vancouver, 03-Jun-2014 to 10-Jun-2014 (1 ex, CBG); Vancouver, 12-Aug-2014 to 19-Aug-2014 (2 exx, CBG); Vancouver, 26-Aug-2014 to 02-Sep-2014 (1 ex, CBG); Vancouver, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); West Vancouver, 21-Sep-2015 to 02-Oct-2015 (12 exx, CBG). ONTARIO: Dundas, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Toronto, 21-Sep-2015 to 02-Oct-2015 (3 exx, CBG). QUEBEC: Montreal, 19-Sep-2014 to 26-Sep-2014 (1 ex, CBG). Nova Scotia: Point Pleasant Park, 25-May-2013 to 01-Jun-2013 (1 ex, CBG); Point Pleasant Park, 06-Jul-2013 to 13-Jul-2013 (2 exx, CBG); Point Pleasant Park, 06-Jul-2013 to 13-Jul-2013 (2 exx, CBG); Point Pleasant Park, 03-Aug-2013 to 10-Aug-2013 (9 exx, CBG); Point Pleasant Park, 10-Aug-2013 to 17-Aug-2013 (7 exx, CBG); Point Pleasant Park, 17-Aug-2013 to 24-Aug-2013 (6 exx, CBG); Point Pleasant Park, 24-Aug-2013 to 31-Aug-2013 (4 exx, CBG); Point Pleasant Park, 31-Aug-2013 to 07-Sep-2013 (1 ex, CBG); Point Pleasant Park, 07-Sep-2013 to 14-Sep-2013 (2 exx, CBG).

Diagnostic information (based on Leseigneur 2005). Body length 2.4–3.2 mm. Habitus as in Fig. 26A. Eyes deeply emarginate. Head with slender longitudinal carinae, which are parallel or slightly converging towards the vertex. Sides of pronotum not or only slightly sinuate, slightly angulate in males, rounded or weakly angulate in females. Elytral apex in males with a fringe of long setae (setae as long as antennomere 11), which can be tucked under the elytra and may not be visible without removal of the abdomen. Aedeagus as in Fig. 26B.

Bionomic notes. The Canadian specimens were collected with Malaise traps in city parks and suburban residential areas.

Comments. Until the North American species of *Trixagus* are revised, *T. meybohmi* is most reliably identified using DNA barcodes or male genitalia.

Elateridae Dendrometrinae Prosternini

Pseudanostirus tigrinus (Fall, 1901), comb. nov. BOLD: ACU2924

Distribution. Native to North America. Previously known only from the United States, where the species is known from areas near Lake Tahoe in California (Fall 1901). CNC has additional specimens collected in northern Oregon and near Lake Tahoe in Nevada.

Canadian record (DNA barcoded specimen). BRITISH COLUMBIA: Gulf Islands National Park Reserve, 30-May-2014 to 08-Jun-2014 (1 ex, CBG).

Additional Canadian record. BRITISH COLUMBIA: Parksville, 11-Apr-2018 (1 ex, CNC).

Diagnostic information (based on Brown 1936). Body length 9.0–11.2 mm. Antennae with antennomeres 3 and 5 of equal length. Pronotum black, with pubescence pale except for two to circular patches of dark setae on each side. Elytra red-brown with pale setae, with band of darker setae surrounding scutellar shield and three angulate transverse bands of dark setae extending from suture to epipleura.

Bionomic notes. *Pseudanostirus tigrinus* has been collected by beating *Pseudotsuga* Carrière on a grassy hillside with *Quercus garryana* Douglas ex Hook. trees. Other specimens have been collected in Malaise and funnel traps also in semi-open woodland with *Arbutus* L. and *Pseudotsuga* trees in warm-summer Mediterranean climate areas. The barcoded specimen was collected with a Malaise trap in a coastal mixed forest.

Comments. This species was described as *Corymbites tigrinus* Fall, 1901. Brown (1936) placed this species in *Ludius* Berthold, 1827 as *Ludius tigrinus* (Fall, 1901), part of the *L. triundulatus* species group. Lane (1948) found that *Ludius* Eschscholtz, 1829 was a synonym of *Elater* Linnaeus, 1758 and transferred all North American *Ludius* to *Ctenicera* Latreille, 1829. Johnson (2002) indicated that all species of Brown's *tri-undulatus* group should be transferred to *Pseudanostirus* but did not formally present any new combinations. This combination has not been used previously in the scientific literature. Therefore the resulting combination *Pseudanostirus tigrinus* (Fall, 1901) is used here for the first time.

Pseudanostirus tigrinus is similar to *P. nebraskensis* (Bland, 1863). Its independent placement in a separate BIN cluster supports the validity of *P. tigrinus*.

Cantharidae Cantharinae Podabrini

Dichelotarsus lapponicus (Gyllenhal, 1810) BOLD:ACD1483 Figure 27

Distribution. Previously only recorded from the Palaearctic region. A northern species, found in Norway, Sweden, and Finland, and across the northern Palaearctic to the Russian Far East and Japan (Hokkaido) (Kazantsev and Brancucci 2007; Silfverberg 2010; Rassi et al. 2015). Probably Holarctic and previously overlooked in North America.

Canadian records. YUKON TERRITORY: Ivvavik National Park, 17-Jun-2014 to 23-Jun-2014 (3 exx CBG); Ivvavik National Park, 23-Jun-2014 to 29-Jun-2014 (16 exx, CBG).

Diagnostic information (based on Kazantsev 1998). Body length 7–10 mm. Habitus as in Fig. 27A. Dark brown to black, basal antennomeres, mandibles and usually clypeus (at least at the margins) yellow. Legs variably yellow, usually at least the profemora yellow. Third antennomere in males ca. 1.5 times as long as the second. Pronotum as wide as long or slightly wider than long, with sides concave before acute



Figures 27, 28. 27 *Dichelotarsus lapponicus* (Gyllenhal) 27A habitus 27B aedeagus, ventral view (everted endophallus removed) 27C aedeagus, lateral view (everted endophallus removed) 27D endophallus, lateral view 28 *Malthodes pumilus* (Brébisson), habitus, L. Borowiec. Scale bars: 2.0 mm (27A), 0.5 mm (27B–D), 0.3 mm (28).

hind angles. All tarsal claws in both sexes with a broad, blunt basal tooth, no claws deeply cleft. Aedeagus as in Fig. 27B–D, with dorsal plate with apical notch.

Bionomic notes. In Northern Finland, this species is found both above and below the treeline, usually in wetlands (MP, pers. obs.). The Canadian specimens were collected with a Malaise trap on tundra close to the Arctic treeline.

Comments. The remote arctic collecting locality suggests that this species is more likely to be Holarctic than adventive from the Palaearctic region. The legs and basal antennomeres of the Canadian specimens are darker and the body length is slightly smaller compared to North European material we examined (including the DNA barcoded Finnish specimens with which the Canadian specimens share the BIN cluster). The male genitalia and shape of the pronotum show no differences between the European and Canadian specimens. Based on the identification keys, descriptions and figures by Fall (1927) and Fender (1961), D. lapponicus closely resembles D. piniphilus (Eschscholtz, 1830). The tarsal claw formula is the same and the shape of the pronotum is very similar in both species. The dorsal plate of the aedeagus has an apical notch in *D*. lapponicus (as in Fig. 27B), whereas in D. piniphilus it is apically truncate or subtruncate. The clypeus of *D. lapponicus* is usually vellow at least at the margins. The vellow color is more extensive in males in the material we have seen, and only faint red-brown spots are visible on the clypeus of some female specimens. The clypeus is black in D. piniphilus. Pelletier and Hébert (2014) state that D. lapponicus resembles D. perplexus (W.J. Brown, 1940), which is known from across boreal and arctic Canada, but D. perplexus is smaller (body length 5.0–6.5 mm) and has a different tarsal claw formula.

Malthininae Malthodini

Malthodes pumilus (Brébisson, 1835) BOLD:AAP7843 Figure 28

Distribution. Native to the Palaearctic region. Widespread in Europe, also recorded from Iran and Turkey (Kazantsev and Brancucci 2007). Adventive in the Nearctic region (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland, Canada).

Canadian records. BRITISH COLUMBIA: Mount Revelstoke National Park, 19-Jun-2014 to 26-Jun-2014 (15 exx, CBG); Mount Revelstoke National Park, 04-Jul-2014 to 09-Jul-2014 (22 exx, CBG); New Afton Mine, 06-Jun-2013 to 13-Jun-2013 (4 exx, CBG); New Afton Mine, 20-Jun-2013 to 27-Jun-2013 (1 ex, CBG); Vancouver, 03-Jun-2014 to 10-Jun-2014 (4 exx, CBG); Vancouver, 17-Jun-2014 to 24-Jun-2014 (1 ex, CBG); Yoho National Park, 25-Jun-2014 to 07-Jul-2014 (1 ex, CBG). ALBERTA: Banff National Park, 17-Jun-2012 (1 ex, CBG); Banff National Park,

19-Jun-2012 (1 ex, CBG); Banff National Park, 15-Jun-2012 to 20-Jun-2012 (1 ex, CBG); Elk Island National Park, 22-Jun-2012 to 29-Jun-2012 (1 ex, CBG); Elk Island National Park, 01-Jul-2012 (1 ex, CBG); Elk Island National Park, 02-Jul-2012 (1 ex, CBG); Elk Island National Park, 29-Jun-2012 to 03-Jul-2012 (17 exx, CBG); Elk Island National Park, 06-Jul-2012 to 13-Jul-2012 (8 exx, CBG); Jasper National Park, 04-Jul-2012 to 11-Jul-2012 (1 ex, CBG); Waterton Lakes National Park, 27-Jun-2012 to 04-Jul-2012 (3 exx, CBG); Waterton Lakes National Park, 10-Jul-2012 to 17-Jul-2012 (4 exx, CBG); Waterton Lakes National Park, 17-Jul-2012 to 24-Jul-2012 (3 exx, CBG). SASKATCHEWAN: Grasslands National Park, 29-Jun-2014 to 08-Jul-2014 (3 exx, CBG). MANITOBA: Riding Mountain National Park, 02-Jul-2012 to 09-Jul-2012 (10 exx, CBG). ONTARIO: Algonquin Provincial Park, 01-Jul-2014 to 15-Jul-2014 (2 exx, CBG); Bayview Escarpment Provincial Park, 29-May-2014 to 12-Jun-2014 (6 exx, CBG); Bayview Escarpment Provincial Park, 26-Jun-2014 to 10-Jul-2014 (1 ex, CBG); Bruce Peninsula National Park, 21-Jun-2012 to 28-Jun-2012 (2 exx, CBG); Bruce Peninsula National Park, 28-Jun-2012 to 07-Jul-2012 (3 exx, CBG); Bruce Peninsula National Park, 05-Jul-2012 to 12-Jul-2012 (3 exx, CBG); Bruce Peninsula National Park, 12-Jul-2012 to 18-Jul-2012 (2 exx, CBG); Elizabethtown-Kitley, 02-Jun-2010 to 04-Jun-2010 (1 ex, CBG); Elizabethtown-Kitley, 04-Jun-2010 to 06-Jun-2010 (1 ex, CBG); Elizabethtown-Kitley, 06-Jun-2010 to 08-Jun-2010 (1 ex, CBG); Elizabethtown-Kitley, 12-Jun-2010 to 14-Jun-2010 (1 ex, CBG); Elizabethtown-Kitley, 15-Jun-2011 to 20-Jun-2011 (2 exx, CBG); Frontenac Provincial Park, 05-Jun-2014 to 19-Jun-2014 (3 exx, CBG); Georgian Bay Islands National Park, 04-Jun-2013 to 11-Jun-2013 (1 ex, CBG); Georgian Bay Islands National Park, 11-Jun-2013 to 18-Jun-2013 (7 exx, CBG); Georgian Bay Islands National Park, 18-Jun-2013 to 26-Jun-2013 (6 exx, CBG); Guelph, 19-Jun-2015 to 26-Jun-2015 (1 ex, CBG); Hartington, 30-May-2017 (1 ex, CBG); Hartington, 13-Jun-2017 (2 exx, CBG); Hartington, 28-Jun-2017 (1 ex, CBG); Inverhuron Provincial Park, 25-Jun-2014 to 09-Jul-2014 (4 exx, CBG); Lion's Head Provincial Park, 26-Jun-2014 to 10-Jul-2014 (1 ex, CBG); Lower Madawaska River Provincial Park, 02-Jul-2014 to 16-Jul-2014 (2 exx, CBG); Murphy's Point Provincial Park, 05-Jun-2014 to 19-Jun-2014 (1 ex, CBG); Peterborough, 24-May-2015 to 30-May-2015 (1 ex, CBG); Peterborough, 07-Jun-2015 to 13-Jun-2015 (2 exx, CBG); Pinery Provincial Park, 25-Jun-2014 to 09-Jul-2014 (1 ex, CBG); Puslinch Township, 05-Jun-2010 to 12-Jun-2010 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (2 exx, CBG); Sandbanks Provincial Park, 05-Jun-2014 to 19-Jun-2014 (1 ex, CBG); Short Hills Provincial Park, 26-May-2014 to 09-Jun-2014 (1 ex, CBG); Sudbury, 08-Jun-2010 (1 ex, CBG); Thousand Islands National Park, 01-Jun-2012 to 08-Jun-2012 (1 ex, CBG); Thousand Islands National Park, 08-Jun-2012 to 15-Jun-2012 (5 exx, CBG); Thousand Islands National Park, 15-Jun-2012 to 22-Jun-2012 (3 exx, CBG). QUEBEC: Forillon National Park, 05-Jul-2013 to 15-Jul-2013 (4 exx, CBG); Forillon National Park, 15-Jul-2013 to 22-Jul-2013 (6 exx, CBG); Forillon National Park, 22-Jul-2013 to 30-Jul-2013 (4 exx, CBG); Forillon National Park, 28-Jun-2013

to 05-Jul-2013 (1 ex, CBG); Mingan Archipelago National Park Reserve, 02-Jul-2013 to 09-Jul-2013 (1 ex, CBG). New BRUNSWICK: Fundy National Park, 18-Jun-2013 to 25-Jun-2013 (1 ex, CBG); Fundy National Park, 02-Jul-2013 to 09-Jul-2013 (22 exx, CBG); Fundy National Park, 09-Jul-2013 to 16-Jul-2013 (33 exx, CBG); Fundy National Park, 16-Jul-2013 to 23-Jul-2013 (8 exx, CBG). NOVA SCOTIA: Cape Breton Highlands National Park, 14-Jul-2013 to 19-Jul-2013 (1 ex, CBG); Cape Breton Highlands National Park, 19-Jul-2013 to 26-Jul-2013 (1 ex, CBG); Kejimkujik National Park, 13-Jun-2013 to 20-Jun-2013 (1 ex, CBG); Kejimkujik National Park, 27-Jun-2013 to 05-Jul-2013 (1 ex, CBG); Sable Island National Park Reserve, 01-Jul-2014 to 14-Jul-2014 (3 exx, CBG). PRINCE EDWARD ISLAND: Prince Edward Island National Park, 03-Jul-2013 to 10-Jul-2013 (1 ex, CBG). NEWFOUNDLAND: Gros Morne National Park, 12-Jul-2013 (1 ex, CBG); Gros Morne National Park, 09-Jul-2013 to 16-Jul-2013 (109 exx, CBG); Gros Morne National Park, 09-Jul-2013 to 20-Jul-2013 (24 exx, CBG); Gros Morne National Park, 10-Jul-2013 to 20-Jul-2013 (6 exx, CBG); Gros Morne National Park, 23-Jul-2013 to 30-Jul-2013 (25 exx, CBG); Gros Morne National Park, 06-Aug-2013 to 13-Aug-2013 (2 exx, CBG); Terra Nova National Park, 25-Jun-2013 to 02-Jul-2013 (4 exx, CBG); Terra Nova National Park, 09-Jul-2013 to 16-Jul-2013 (37 exx, CBG); Terra Nova National Park, 24-Jul-2013 to 30-Jul-2013 (3 exx, CBG).

Diagnostic information (based on Wittmer 1979). Body length 1.3–1.5 mm. Habitus as in Fig. 28. Unicolorous dark brown to black, tarsi slightly paler. Mandibles with a finely serrate additional tooth on the inner surface. Male with the last ventrite long and narrow, deeply emarginate (almost to the middle), last visible tergite likewise deeply emarginate.

Bionomic notes. In Europe, this eurytopic species is usually found in dry, warm habitats such as exposed forest edges, dry meadows etc. (Koch 1989b). The larvae probably live in dead wood as predators (Koch 1989b). The Canadian specimens were collected in a variety of habitats, mainly forests, and mainly in Malaise traps.

Comments. The minute size distinguishes this species from all other Canadian species of *Malthodes* except for *M. parvulus* (LeConte, 1851) (Fender 1951, Pelletier and Hébert 2014). *Malthodes parvulus* is paler, with the first two antennomeres, pronotum, elytra and legs yellow (Pelletier and Hébert 2014). The structure of the terminal abdominal segments in males is also quite different between these species (see Fender (1951) or Pelletier and Hébert (2014) for figures of *M. parvulus*). However, all morphologically examined Canadian specimens of *M. pumilus* were females. It is probably a mainly parthenogenetic species, as males are rare in Europe as well (Wittmer 1979). The genitalia and modifications of the terminal abdominal segments of males are often crucial for morphological identification of *Malthodes* species (Fender 1951; Wittmer 1970). The extreme scarcity of males for morphological diagnosis combined with the lack of recent taxonomic work on the genus in North America probably explains why *M. pumilus* has remained undetected despite being apparently widespread and common across Canada.

Dermestidae Attageninae Attagenini

Attagenus smirnovi Zhantiev, 1973) BOLD:AAI7919 Figure 29

Distribution. Native to the Afrotropical region. Adventive in the Palaearctic region, first recorded from Europe in the 1960s (misidentified under various species names), distribution expanded in recent decades (Stengaard Hansen et al. 2012). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Toronto, 19-Jul-2016 (3 exx, CBG).

Diagnostic information (based on Peacock 1979, Halstead 1981, and Kalik 1992). Body length 2.3–4.0 mm. Habitus as in Fig. 29A, B. Dark brown to black with yellow pubescence, elytra red-brown in males, usually paler yellow-brown in females. Antennae and legs red-brown or yellow-brown. Male antennomere 11 slightly curved at the base, ca. four times longer than wide and ca. four times as long as the combined length of antennomeres 9 and 10. Female antennal club elongate, last antennomere not modified, ovoid. Propleurotrochantin exposed. Anterior ventral carina of mesofemur prominent and sharp, posterior carina weakly developed. Metacoxa reaching metepimeron.

Bionomic notes. This species is recorded from the nests of the Little swift (*Apus affinis* (J.E. Gray, 1830)) in Kenya (Peacock 1979). It is an indoor pest of various materials of animal origin in Europe (Stengaard Hansen et al. 2012). The Canadian specimens (two larvae and one adult female) were collected in an apartment in Toronto.

Comments. Vernacularly known as the brown carpet beetle. The coloration makes this species quite distinctive among *Attagenus* species recorded from Canada. Presence of adults and larvae in a home suggest establishment in Canada. It is unknown how large or viable Canadian populations of this species are.

Ptinidae Dorcatominae

Petalium incisum Ford, 1973 BOLD:ACX8800

Distribution. Native to North America. Widespread in eastern United States (White 1982; Arango and Young 2012).

Canadian records. ONTARIO: Burlington, 07-Aug-2014 to 20-Aug-2014 (1 ex, CBG); Cambridge, 15-Jul-2017 (4 exx, CBG); Guelph, 30-Jul-2017 (1 ex, CBG).

Diagnostic information. See Ford (1973) and Arango and Young (2012).



Figure 29. Attagenus smirnovi Zhantiev, habitus, L. Borowiec A male B female. Scale bar: 1.0 mm.

Bionomic notes. Ford (1973) reared this species from *Rhus toxicodendron* L. and *Robinia pseudoacacia* L. (probably from dead dry wood). One Canadian specimen was caught with a Malaise trap; the rest were collected by beating vegetation in deciduous and mixed forests.

Erotylidae Cryptophilinae Cryptophilini

Cryptophilus obliteratus Reitter, 1874 BOLD:AAP6170

Distribution. Native to the Palaearctic region (Asia). Adventive in the western Palaearctic region, recorded in Europe at least from Austria, Denmark, Germany, and France (Denux and Zagatti 2010). Adventive in the Nearctic region (Arkansas, Massachusetts, Maryland, Minnesota, and Wisconsin, United States (Esser 2017), and Ontario, Canada).

Canadian records. ONTARIO: Ailsa Craig, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Dunnville, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); London, 22-Apr-2013 to 03-May-2013 (2 exx, CBG); Orillia, 20-Apr-2015 to 08-May-2015 (1 ex, CBG); Peterborough, 05-Jul-2015 to 11-Jul-2015 (1 ex, CBG); Port Rowan, 22-Apr-2013

to 03-May-2013 (2 exx, CBG); Scarborough, 20-Apr-2015 to 08-May-2015 (1 ex, CBG); Whitby, 22-Apr-2013 to 03-May-2013 (5 exx, CBG).

Diagnostic information (based on Esser 2016). Body length ca. 2.5 mm. Color red-brown with more-or-less extensive black markings on the elytra, usually a transverse black band or black lateral spots. Lateral margins of pronotum rounded, more abruptly narrowed basally, concave just in front of the sharp, approximately right-angled hind angles. Meso- and metatibiae bent inwards in males. Parameres relatively shorter than in the other two species recorded from North America. For habitus and genital figures, see Esser (2016) and Jens Esser's homepage: http://cryptophagidae.de/ Cryptophilus-Erotylidae-pleasing-fungus-beetles/

Bionomic notes. This species has been collected from heaps of compost and garden waste in Germany (Franzen 1991). The Canadian specimens were collected with Malaise traps, mainly from suburban residential areas.

Comments. Esser (2017) reported *Cryptophilus obliteratus* from the United States and synonymized *Cryptophilus seriatus* Casey, 1924 (described from Massachusetts) with it. This species has obviously been present in North America for a long time, and Canadian records older than those reported here may well be found in collections.

Cryptophilus propinquus Reitter, 1874 BOLD:AAY6550

Distribution. This species was confused with *Cryptophilus angustus* (Rosenhauer, 1856) under the name *Cryptophilus integer* (Heer, 1841) until recently. Therefore, its distribution is not yet very well known. *Cryptophilus propinquus* was described from Japan, and has been recorded at least from Germany, India, Italy, Turkey, and the United States (Esser 2016, 2017). Adventive in the Nearctic region (Maryland, Minnesota, Mississippi, and Wisconsin, United States (Esser 2017), and British Columbia and Ontario, Canada).

Canadian records. BRITISH COLUMBIA: Victoria, 25-Jun-2014 to 02-Jul-2014 (1 ex, CBG); Victoria, 23-Jul-2014 to 30-Jul-2014 (2 exx, CBG). ONTARIO: Cambridge, 04-Jun-2015 to 11-Jun-2015 (1 ex, CBG); Guelph, 15-Jul-2010 to 01-Aug-2010 (1 ex, CBG); Guelph, 17-Sep-2017 (2 exx, CBG); Rouge National Urban Park, 15-Sep-2013 (1 ex, CBG).

Diagnostic information (based on Esser 2016). Body length ca. 2 mm. Redbrown without black markings on the elytra. Sides of pronotum evenly rounded in dorsal view, no concavity before blunt hind angles. Meso- and metatibiae dilated distally, sometimes with a blunt angle on the dorsal edge in males, but not bent ventrad in either sex. Parameres relatively longer than in *C. obliteratus*, but shorter than in *C. angustus*. For habitus and genital figures, see Esser (2016) and Jens Esser's homepage: http://cryptophagidae.de/Cryptophilus-Erotylidae-pleasing-fungus-beetles/

Bionomic notes. This species is found in decaying plant material, e.g., in compost heaps (Koch 1989b, Ruta et al. 2011). The DNA barcoded Canadian specimens were

collected in Malaise traps in suburban residential areas, in pitfall traps in forest fragments, and by sifting compost heaps.

Comments. Cryptophilus integer (Heer, 1841) is listed as occurring in Canada by (Bousquet et al. 2013), but Esser (2016, 2017) discovered that the name is not valid and refers specimens identified as *C. integer* to two different species: *C. propinquus* Reitter, 1874 and *C. angustus* (Rosenhauer, 1856) (= *C. simplex* (Wollaston, 1857)). Esser (2017) reported that both of these species occur in the Nearctic region but listed no records from Canada for either species. We found only *C. propinquus* among the DNA barcoded Canadian specimens, but not *C. angustus*.

Cryptophagidae Cryptophaginae Cryptophagini

Henoticus mycetoecus (Park, 1929) BOLD:ACK1696

Distribution. Native to North America. Described from Illinois (Park 1929), also recorded from Iowa (Downie and Arnett 1996).

Canadian records. ONTARIO: Rouge National Urban Park, 18-Jun-2013 to 25-Jun-2013 (1 ex, CBG).

Diagnostic information (based on Park (1929)). Body length 1.8–2.0 mm. More or less uniformly red-brown, with legs, antennae, and medial part of elytra paler. Lateral margins of pronotum serrate, sublateral carinae absent. Posterior of pronotum with two deep foveae connected by a distinct basal groove.

Bionomic notes. Park (1929) collected the type specimens from decaying fruiting bodies of the polypore fungus *Climacodon septentrionalis* (Fr.) P. Karst. in a sugar maple forest. The Canadian specimen was caught with a Malaise trap in a patch of forest.

Phalacridae Phalacrinae

Acylomus ergoti Casey, 1890 BOLD:AAH0135 Figure 30

Distribution. United States (Gimmel 2013). *Tinodemus grouvellei* Guillebeau, 1894, synonymized under *A. ergoti* by Gimmel (2013), was described from Michigan.

Canadian records. ONTARIO: Brantford, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG); Breslau, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Cambridge, 07-May-2015 to 14-May-2015 (3 exx, CBG); Cambridge, 14-May-2015 to 21-May-2015



Figures 30, 31. 30 *Acylomus ergoti* Casey 30A male metatibia, ventral view 30B aedeagus, dorsal view 30C tegmen, dorsal view 30D tegmen, lateral view 31 *Olibrus liquidus* Erichson, habitus, L. Borowiec. Scale bars: 0.2 mm (30A–D), 1.0 mm (31).

(1 ex, CBG); Cambridge, 25-May-2015 to 31-May-2015 (1 ex, CBG); Elizabethtown-Kitley, 30-Apr-2010 to 02-May-2010 (1 ex, CBG); Elizabethtown-Kitley, 09-May-2010 to 14-May-2010 (1 ex, CBG); Elizabethtown-Kitley, 14-May-2010 to 18-May-2010 (1 ex, CBG); Elizabethtown-Kitley, 30-May-2010 to 02-Jun-2010 (1 ex, CBG); Embro, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Georgian Bay Islands National Park, 06-May-2013 to 12-May-2013 (1 ex, CBG); Georgian Bay Islands National Park, 12-May-2013 to 23-May-2013 (9 exx, CBG); Georgian Bay Islands National Park, 30-Jul-2013 to 06-Aug-2013 (1 ex, CBG); Hagersville, 23-Sep-2013 to 04-Oct-2013 (1 ex, CBG); Hartington, 28-Jun-2017 (1 ex, CBG); London, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Mississauga, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG); Orangeville, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Peterborough, 31-May-2015 to 06-Jun-2015 (1 ex, CBG); Peterborough, 29-Jun-2015 to 02-Jul-2015 (1 ex, CBG); Point Pelee National Park, 02-May-2012 to 09-May-2012 (8 exx, CBG); Point Pelee National Park, 16-May-2012 to 23-May-2012 (10 exx, CBG); Point Pelee National Park, 27-Jun-2012 to 04-Jul-2012 (1 ex, CBG); Point Pelee National Park, 05-Sep-2012 to 12-Sep-2012 (1 ex, CBG); Rouge National Urban Park, 07-Jun-2013 (2 exx, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (10 exx, CBG); Rouge National Urban Park, 17Jun-2014 to 24-Jun-2014 (1 ex, CBG); Rouge National Urban Park, 08-Jul-2014 to 15-Jul-2014 (1 ex, CBG); Williamstown, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG). QUEBEC: Montreal, 24-Jul-2014 to 02-Aug-2014 (1 ex, CBG); Montreal, 19-Sep-2014 to 26-Sep-2014 (1 ex, CBG). New BRUNSWICK: Springfield, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG).

Diagnostic information (based on the redescription of *Tinodemus grouvellei* by Švec 2002). Body length 2.0 mm. Oval, dark brown, elytral suture and base of pronotum laterally paler. Legs, antennae and mouthparts red, ventral side orange. Head and pronotum without microsculpture. Scutellum and elytra finely and densely transversely strigose. Sutural stria of elytra present in the apical 5/8. Male metatibiae short and widened apically, twice as wide at apex as proximally, medio-apical spine ca. twice as long as metatarsomere 1, curved at apex (Fig. 30A). Female metatibiae not modified. Male genitalia as in Fig. 30B, C.

Bionomic notes. The Canadian specimens were collected in various habitats (grasslands, forests, wetlands, residential areas etc.), mainly with Malaise traps.

Comments. The lack of a modern species-level revision of *Acylomus* prevents detailed comparison to most other Nearctic species of *Acylomus*. The only other species of *Acylomus* previously known from Canada, *A. pugetanus* Casey, 1916, was redescribed by Steiner and Singh (1987). It is darker, especially ventrally, and has different male genitalia and no apparent sexual dimorphism in metathoracic leg structure. At least one more species of *Acylomus* (BOLD:ACM7465) occurs in Canada according to DNA barcode data and initial morphological analysis of the barcoded specimens, but we have not been able to identify it to species level.

Olibrus liquidus Erichson, 1845

BOLD:AAX0584 Figure 31

Distribution. Native to the Palaearctic region, widespread in Europe and North Africa (Švec 2007). Adventive in the Nearctic region (British Columbia, Canada).

Canadian records. BRITISH COLUMBIA: Burnaby, 20-Apr-2015 to 08-May-2015 (1 ex, CBG).

Diagnostic information (based on Thompson 1958; Vogt 1967b). Body length 1.9–2.6 mm. Habitus (Fig. 31) elongate-oval, narrower towards the elytral apex. Dark brown, elytra paler towards the apex, antennae, palpi and legs yellow-brown. Head and pronotum without microsculpture. Elytra fully covered by fine, net-like microsculpture in females, anterior third without microsculpture in males. Elytra with two sutural striae, which converge and usually meet towards the apex. Metaventrite densely and coarsely punctate, especially laterally. See Thompson (1958) for figures of the male genitalia (tegmen) and female ovipositor.

Bionomic notes. This species feeds on a variety of Asteraceae genera, usually in dry and warm habitats in Europe (Koch 1989b). The Canadian specimen was collected with a Malaise trap in a suburban residential area.

Comments. Lack of a modern revision of North American *Olibrus* prevents detailed comparison of *O. liquidus* to the native species. It is most reliably identified using male genitalia or DNA barcodes. Good illustrations of the genitalia are provided in volume 5, part 5b of the Handbooks for the Identification of British Insects (Thompson 1958).

Nitidulidae Epuraeinae Epuraeini

Epuraea unicolor (Olivier, 1790) BOLD:AAX8537 Figure 32

Distribution. Native and widespread in the Palaearctic region. Recorded from North Africa and all of Europe to the Russian Far East and Japan (Audisio 1993; Jelínek and Audisio 2007) One of the most common and abundant species of the genus in Europe (Audisio 1993). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Guelph, 01-Nov-2009 (1 ex, CBG); Guelph, 22-Apr-2017 (1 ex, CBG); Guelph, 06-Jun-2018 (3 exx, CBG); Guelph, 30-Jun-2018 (1 ex, CBG); Rouge National Urban Park, 03-Jun-2013 to 09-Jun-2013 (1 ex, CBG).

Diagnostic information (based on Audisio 1993). Body length 2.3–3.2 mm. Habitus elongate, subparallel, rather flattened (Fig. 32A). Color variable, body, legs, and antennae usually yellowish or red-brown, pronotum and elytra often laterally paler, antennal club usually darkened. Elytra variably darkened, with a rounded dark spot on each elytron at the apical third, or with more extensive, irregular but symmetric dark patterns. Antennae with club ca. 1.5 times as long as wide. Head with subcircular, moderately impressed punctation, punctures approximately the size of the ommatidia, separated by 0.5–0.6 times their diameter, interspace with fine microsculpture. Punctures on pronotum and elytra slightly larger, but with similar microsculpture and relative distance between them. Pronotum 1.45–1.65 times as wide as long, broadest in the basal third, abruptly narrowed towards the protruding hind angles, anterior edge with a deep, wide, trapezoidal emargination. Elytral apices separately broadly rounded. Metaventrite with a wide V-shaped emargination at the hind edge. Male mesotibia distally slightly widened, with a small tooth at the inner margin (Fig. 32B). Female mesotibia unmodified. Male genitalia as in Fig. 32C–E.

Bionomic notes. This species occurs in decaying and fermenting organic material (e.g., fruit, fruiting bodies of fungi, tree sap), under the bark of dead trees etc., probably feeding on the microbes decomposing these materials (Audisio 1993). Often found in anthropogenic habitats such as orchards, cultivated fields, and garbage dumps (Audisio 1993). The Canadian specimens were collected by sifting a compost heap in a suburban backyard, in a Malaise trap in a residential area, and in pitfall traps at a riverside in Rouge National Urban Park.


Figure 32. *Epuraea unicolor* (Olivier) **A** habitus, L. Borowiec **B** male mesotibia **C** penis **D** parameres, ventral view **E** parameres, lateral view. Scale bars: 1.0 mm (**A**), 0.2 mm (**B–E**).

Comments. The lack of a modern revision of North American *Epuraea* prevents detailed comparison to other Canadian species at the moment. *Epuraea unicolor* can be reliably separated by DNA barcodes from all other Palaearctic and Nearctic *Epuraea* species sampled so far. The diagnostic information above, in particular the male mesotibia and genitalia, should allow morphological identification.

Coccinellidae Coccinellinae Chilocorini

Chilocorus renipustulatus (Scriba, 1791) BOLD:AAO1521 Figure 33

Distribution. Native to the Palaearctic region. Widespread in Europe, also recorded from Siberia and the Russian Far East (Kovář 2007). Adventive in the Nearctic region (Ontario, Canada).



Figures 33, 34. 33 *Chilocorus renipustulatus* (Scriba) 33A habitus, L. Borowiec 33B median lobe (penis guide) and parameres, ventral view 33C penis (sipho), tip in lateral view 34 *Nephus bisignatus* (Boheman) 34A habitus, S. Karjalainen 34B median lobe (penis guide) and parameres, lateral view 34C penis (sipho), tip in lateral view. Scale bars: 1.0 mm (33A), 0.5 mm (33B; 34A), 0.2 mm (33C; 34B), 0.1 mm (34C).

Canadian records. ONTARIO: Hamilton, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG); Mississauga, 19-Sep-2016 to 30-Sep-2016 (3 exx, CBG); Windsor, 22-Sep-2014 to 03-Oct-2014 (1 ex, CBG).

Diagnostic information (based on Fürsch 1967 and Gordon 1985). Body length 4–5 mm. Habitus as in Fig. 33A. Black, shiny, with a single rounded or slightly transverse orange-red macula on each elytron, abdomen laterally and apically orange, medial part of first ventrite black. Pronotum without distinct microsculpture on disc. Male genitalia as in Fig. 33B, C.

Bionomic notes. The main habitat in Europe is broadleaf forest, and the preferred prey are scale insects, in particular *Chionaspis salicis* (Linnaeus, 1758) (Koch 1989b). The Canadian specimens were collected with Malaise traps in suburban residential areas.

Comments. *Chilocorus kuwanae* Silvestri, 1909, an East Asian species introduced to the United States and recorded from across the country (Gordon 1985; Hendrickson et al. 1991), was recently synonymized with *C. renipustulatus* by Bieńkowski (2018). According to Bieńkowski, male genitalia are similar throughout the distribution areas of both species. However, Bieńkowski did not study any type material. One of the Canadian specimens shares an identical barcode haplotype with specimens of *C. renipustulatus* from Germany and Finland, others are slightly divergent (p-distance to European material varies from 0.006 to 0.015). Unfortunately, no barcode data are available for *C. kuwanae*. No Canadian records have been previously published under either name.

Chilocorus renipustulatus is externally very similar to *Chilocorus stigma* (Say, 1835) and its closest relatives. It can be distinguished using the male genitalia and microsculpture of the pronotum. In *C. stigma* and allied species, the interspace between punctures on the disc of the pronotum is covered by finely engraved, netlike microsculpture. In *C. renipustulatus*, the interspace is smooth and shiny, with no visible microsculpture on disc. The orange maculae on the elytra are more transverse in *C. renipustulatus* than in *C. stigma* in the examined DNA barcoded Canadian material of these species, but the maculae are known to vary in size and shape in *C. renipustulatus* (Bieńkowski, 2018).

Coccinellinae Scymnini

Nephus bisignatus (Boheman, 1850) BOLD:ACD2027 Figure 34

Distribution. Previously known only from Europe, where the species is more common in the north and rather sporadic in the central and southern parts (Fürsch 1965; Kovář 2007; Silfverberg 2010; Rassi et al. 2015). Probably Holarctic and previously overlooked in North America.

Canadian records. NUNAVUT: Kugluktuk, 25-Jun-2010 (1 ex, CNC); Kugluktuk, 01-Jul-2010 (1 ex, CNC); Kugluktuk, 11-Jul-2010 (1 ex, CNC); Kugluktuk, 13-Jul-2010 (1 ex, CNC).

Diagnostic information (based on Fürsch 1965, 1967, 1987). Body length 1.5–2.0 mm. Habitus elongate-oval (Fig. 34A). Black, with the anterior edge of the pronotum and often the apical edge of the elytra narrowly brown. Each elytron with a single small, obscurely delimited red-brown spot close to the apex, sometimes very faintly visible. Antennae with nine antennomeres. Pronotum very finely punctate, with strong, netlike microsculpture. Postcoxal lines on first abdominal ventrite briefly parallel to the hind margin of the ventrite at the middle, with the apices curved forward laterally. Male genitalia as in Fig. 34B, C.

Bionomic notes. *Nephus bisignatus* prefers open, usually sandy habitats in Europe (Koch 1989b). The Canadian specimens were collected in mesic tundra with yellow pan and pitfall traps.

Comments. Nephus bisignatus belongs to subgenus Bipunctatus Fürsch, 1987, which is characterized by having only nine antennomeres (Fürsch 1987). All the previously recorded Canadian species have either ten or eleven antennomeres (Gordon 1976, 1985). The remote collecting localities in the arctic tundra indicate that this species is probably Holarctic and previously overlooked in North America rather than adventive from the Palaearctic region. Two subspecies are known from Europe (Kovář 2007), but we refrain from assigning the Canadian specimens to any subspecies. Among the Nearctic fauna, *N. bisignatus* resembles *N. georgei* (Weise, 1929), but has a narrower body outline and usually smaller and less conspicuous elytral spots. Nephus georgei also has ten antennomeres instead of nine. Gordon (1976) notes that specimens of *N. georgei* from the northern parts of the Northwest Territories are smaller and narrower compared to specimens from southern Canada and northern United States, and that the pale color pattern of the elytra is reduced in the northern specimens. Based on these notes, the arctic specimens of *N. georgei* may actually represent *N. bisignatus* and need to be re-examined.

Scymnus rubromaculatus (Goeze, 1777) BOLD:AAN9250

Figure 35

Distribution. Native to the Palaearctic region, widespread across Eurasia from western Europe to the Russian Far East (Kovář 2007). Adventive in the Nearctic region (Ontario and Nova Scotia, Canada).

Canadian records. ONTARIO: Barrie, 22-Apr-2013 to 03-May-2013 (1 ex, CBG); Burlington, 21-Jul-2017 (1 ex, CBG); Guelph, 06-Jun-2013 to 13-Jun-2013 (1 ex, CBG); Guelph, 20-Jun-2013 to 27-Jun-2013 (2 exx, CBG); Guelph, 01-Aug-2013 to 08-Aug-2013 (1 ex, CBG); Guelph, 15-Aug-2013 to 22-Aug-2013 (1 ex, CBG); Mississauga, 15-Sep-2015 to 17-Sep-2015 (1 ex, CBG); Mississauga, 19-Sep-2016 to 30-Sep-2016 (3 exx, CBG); Toronto, 19-Jun-2017 to 27-Jun-2017 (1 ex, CBG). Nova Scotta: Berwick, 20-Apr-2015 to 08-May-2015 (1 ex, CBG).



Figure 35. *Scymnus rubromaculatus* (Goeze) **A** female habitus, L. Borowiec **B** male habitus **C** median lobe (penis guide) and parameres, ventral view **D** median lobe (penis guide) and parameres, lateral view **E** penis (sipho), lateral view. Scale bars: 1.0 mm (**A**, **B**), 0.2 mm (**C**, **D**), 0.5 mm (**E**).

Diagnostic information (based on Fürsch 1967). Body length 1.8–2.3 mm. Habitus as in Fig. 35A, B. Color sexually dimorphic. Male: head, pronotum (apart from a black mediobasal spot), and legs yellow, otherwise black. Female: almost completely black with only the mouthparts, labrum and legs yellow. Femora often darkened. Post-coxal lines on 1st abdominal ventrite reaching the hind edge of the ventrite. Male genitalia as in Fig. 35C–E.

Bionomic notes. This species prefers dry, warm habitats in Europe and is found mainly on Brassicaceae, occasionally on trees and bushes (Koch 1989b). Most Canadian specimens were collected with Malaise traps in suburban areas.

Comments. Scymnus rubromaculatus leads to the couplets separating Scymnus americanus Mulsant, 1850, S. apicanus Chapin, 1973 and S. paracanus Chapin, 1973 in Gordon's keys to North American Scymnus (Gordon 1976, 1985). In S. rubromaculatus, the dorsal surface is more densely punctate and pubescent than in those three species, the hind margin of the elytra is slightly or not paler than the elytral disc, and the female has no pale markings on head (apart from labrum and mouthparts) or pronotum. The male genitalia differ: the apical hook of the penis (sipho), which is typical for S. americanus and related species, is absent in S. rubromaculatus.

Corylophidae Corylophinae Orthoperini

Orthoperus corticalis (Redtenbacher, 1845)

BOLD:ACC5439 Figure 36

Distribution. Native to the Palaearctic region. Widely distributed from Western Europe to Siberia (Bowestead 1999, 2007). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Cambridge, 29-Apr-2015 to 07-May-2015 (1 ex, CBG); Cambridge, 07-May-2015 to 14-May-2015 (1 ex, CBG); Cambridge, 21-May-2015 to 27-May-2015 (1 ex, CBG).

Diagnostic information (based on Bowestead 1999). Body length 0.8–1.0 mm. Habitus slightly elongate oval, strongly convex (Fig. 36A). Dark brown to black, antennal base and legs pale, five apical antennomeres dark brown. Pronotum finely punctate, often with a transverse row of larger punctures medioposteriorly, with isodiametric microsculpture throughout. Elytral punctation fine, punctures larger basally, interspaces with similar microsculpture as the pronotum, the microsculpture forming wavy transverse rows of cells especially basally. Sutural striae of elytra present only at the apex. Male metaventrite with an elongate depression medially, and a short median keel behind the depression, distance of the keel from hind edge of metaventrite ca. 1/12 of the length of the metaventrite (Fig. 36B). Aedeagus as in Fig. 36C, D.

Bionomic notes. This species is mainly known from deciduous forests. It has been collected from a variety of fungus species growing on dead logs, and under the bark of fungus-infested logs (Bowestead 1999, Rutanen 2015). The Canadian specimens were collected with a Malaise trap at the edge of a forest.

Comments. This is the second species of *Orthoperus* recorded as adventive in Canada: the Palaearctic *O. atomus* (Gyllenhal, 1808) is known from British Columbia in



Figures 36, 37. 36 *Orthoperus corticalis* (Redtenbacher) 36A habitus, L. Borowiec 36B male metaventrite 36C aedeagus, ventral view 36D aedeagus, lateral view 37 *Litargus connexus* (Geoffroy) 37A habitus, L. Borowiec 37B antenna. Scale bars: 0.25 mm (36A), 0.2 mm (36B–D), 0.5 mm (37A), 0.2 mm (37B).

Canada, and Washington and Oregon in the United States (Klimaszewski et al. 2015). *Orthoperus corticalis* is darker and slightly larger than *O. atomus*, with stronger punctation on the pronotum and elytral base and denser and more strongly impressed microsculpture (Bowestead 1999). Two native North American species are currently known from Canada: *O. scutellaris* LeConte, 1878 has small V-shaped scratches on the elytra instead of punctures, and *O. suturalis* LeConte, 1878 has fine but distinctly impressed sutural striae (only faintly visible close to the elytral apex in *O. corticalis*) (LeConte 1878, Downie and Arnett 1996).

Mycetophagidae Mycetophaginae Mycetophagini

Litargus connexus (Geoffroy, 1785) BOLD:AAK8818 Figure 37

Distribution. Native to the Palaearctic region. Widespread in Europe, also recorded from North Africa, and across the region to the Russian Far East and Japan (Nikitsky 2008). Adventive in the Nearctic region (British Columbia, Canada).

Canadian records. BRITISH COLUMBIA: Burnaby, 20-Apr-2015 to 08-May-2015 (1 ex, CBG).

Diagnostic information (based on Vogt 1967a). Body length 2.4–2.8 mm. Dorsal habitus elongate, sides of elytra almost parallel (Fig. 37A). Black, elytra with transverse, undulating yellow bands at the base and just beyond midlength, and a yellow sutural spot close to the elytral apex. Yellow markings variable, basal band frequently broken into separate spots. Antennomere 8 somewhat wider than long, terminal antennomere approximately as long as wide, structure of the antennal club as in Fig. 37B. Elytra with epipleura concave, descending towards the lateral edge.

Bionomic notes. This species is found in deciduous and mixed forests in fungusinfested dead wood (Koch 1989b). The Canadian specimen was collected with a Malaise trap in a suburban residential area.

Comments. The combination of the elongate and nearly parallel-sided body, color pattern of the elytra and structure of the antennae will distinguish *L. connexus* from all other *Litargus* species known from Canada. Parsons (1975) provides diagnoses and illustrations of the native North American species.

Ciidae Ciinae Ciini

Cis boleti (Scopoli, 1763) BOLD:AAJ3268 Figure 38

Distribution. Native to the Palaearctic region. Recorded across Eurasia from western Europe to the Russian Far East and Japan (Jelínek 2008). Adventive in the Nearctic region (Ontario, Canada).

Canadian records (barcoded specimens). ONTARIO: Guelph, 21-Aug-2017 (2 exx, CBG); Guelph, 21-Oct-2017 (2 exx, CBG);



Figures 38, 39. 38 *Cis boleti* (Scopoli) 38A habitus, L. Borowiec 38B pronotum 39A *Cis glabratus*, Mellié, female habitus, L. Borowiec 39B *Cis glabratus*, male head and pronotum 39C *Cis glabratus*, aedeagus 39D *Cis levettei* (Casey), aedeagus. Scale bars: 0.5 mm (38A, B; 39A, B), 0.2 mm (39C, D).

Additional Canadian records. ONTARIO: Horning's Mills, 08-Nov-2015 (1 ex, DEBU); Milton, 28-May-2002 (1 ex, DEBU).

Diagnostic information (based on Lohse 1967). Body length 2.8–4.0 mm. Habitus as in Fig. 38A. Dark brown to black (usually darker than in Fig. 38A). Pronotum more than 1.3 times wider than long, with concavities on disc (Fig. 38B). Lateral margins of pronotum widely deplanate and visible throughout in dorsal view. Elytra with dual punctation: larger punctures arranged in irregular rows, with the intervals finely and densely punctate. Elytral vestiture consists of short, stout bristles.

Bionomic notes. This species feeds on polypore fungi, mainly *Trametes* species growing on deciduous trees (Koch 1989b, Reibnitz 1999). The barcoded Canadian specimens were collected from polypore fruiting bodies in a mixed forest.

Comments. *Cis submicans* Abeille de Perrin, 1874 (= *C. pistoria* Casey, 1898) is the only other representative of the mainly Palaearctic *C. boleti* species group known from North America (Lopes-Andrade et al. 2016). *Cis boleti* is a robust species, broader and on average larger than *C. submicans*, with the pronotum at least 1.3 times wider than long. The pronotal disc of *C. boleti* has indentations on both sides of the midline. These indentations are very shallow in *C. submicans*. The pronotum is also more densely punctate in *C. boleti* than in *C. submicans*.

Cis glabratus Mellié, 1848

BOLD:AAJ3241 Figure 39

Distribution. Native to the Palaearctic region, widespread in Europe (Jelínek 2008). Common in northern Europe, mainly found in higher elevations in Central Europe (Reibnitz 1999, Rassi et al. 2015). Adventive in the Nearctic region (Nova Scotia, Canada).

Canadian records. NOVA SCOTIA: Cape Breton Highlands National Park, 21-Jul-2009 (1 ex, CBG).

Diagnostic information (based on Lohse 1967). Body length 1.5–2.0 mm. Redbrown to dark brown, habitus as in Fig. 39A. Clypeus in male with two large, broad teeth (Fig. 39B). Pronotum widest behind middle, distinctly tapering towards the front angles. Vestiture on pronotum fine and pale. Outer edge of protibia serrated. Male with a large abdominal fovea on 1st abdominal ventrite. Aedeagus as in Fig. 39C.

Bionomic notes. The main host fungus in Europe is *Fomitopsis pinicola* (Sw.) P. Karst. (Reibnitz 1999). The Canadian specimen was collected in a jack pine forest in Cape Breton Highlands National Park.

Comments. *Cis glabratus* is externally very similar to *C. levettei* (Casey, 1898) and leads to that species in the key to North American species (Lawrence 1971). The microscopic vestiture of the pronotum is longer and more conspicuous in *C. glabratus*, but the most reliable morphological differences are in the male genitalia (Fig. 39C, D). *Cis levettei* forms a separate BIN (BOLD:ACA7530) which is more closely clustered to other Palaearctic members of the *C. nitidus* species group (*C. castaneus* (Herbst, 1793), *C. jacquemartii* Mellié, 1848 and *C. lineatocribratus* Mellié, 1848) than to *C. glabratus*.

Mordellidae Mordellinae Mordellistenini

Mordellistena militaris LeConte, 1862 BOLD:ACE3572

Distribution. Native to the Nearctic region. Previously recorded at least from Indiana, New York, North Carolina, and Ohio in the United States (Liljeblad 1945; Downie and Arnett 1996).

Canadian records. ONTARIO: Point Pelee National Park, 27-Jun-2012 to 04-Jul-2012 (5 exx, CBG).

Diagnostic information. See Liljeblad (1945).

Bionomic notes. The Canadian specimens were collected with a Malaise trap in a savanna with *Opuntia* cacti and sparse woody vegetation.

Comments. The coloration and the ridges of the hind legs of the Canadian specimens match both the Liljeblad (1945) diagnosis and the photographs of LeConte's type specimen in the type database of the Museum of Comparative Zoology at Harvard University. Therefore, we consider this record reliable despite the lack of a modern revision of the North American *Mordellistena*.

Zopheridae Colydiinae Synchitini

Lasconotus subcostulatus Kraus, 1912 BOLD:ACU9668

Distribution. Native to the Nearctic region. Previously known from California, Idaho, Nevada, Oregon, Washington, South Dakota, Montana, and Nebraska in the United States (Lord et al. 2011–2013).

Canadian records (DNA barcoded specimen). SASKATCHEWAN: Grasslands National Park 21-May-2014 to 29-May-2014 (1 ex, CBG).

Additional Canadian records. BRITISH COLUMBIA: Aspen Grove, 20-Oct-1936 (5 exx, CNC); Merritt, 04-Jun-1922 (1 ex, CNC); Merritt, 08-Jun-1922 (2 exx, CNC); Merritt, 09-Jun-1922 (6 exx, CNC); Merritt, 10-Jun-1922 (1 ex, CNC); Merritt, 15-Jun-1922 (2 exx, CNC); Merritt, 18-Jun-1922 (1 ex, CNC); Merritt, 14-Sep-1923 (1 ex, CNC); Merritt, 03-Jun-1924 (1 ex, CNC); Merritt, 13-May-1925 (1 ex, CNC); Merritt, 25-Jul-1925 (1 ex, CNC); Olivier, 24-May-1958 (1 ex, CNC); Olivier, 12-Jun-1958 (10 exx, CNC); Olivier, 14-Jun-1958 (6 exx, CNC); Peachland, 19-Jul-1912

(1 ex, CNC); Peachland, 13-Jul-1919 (1 ex, CNC); Summerland, 25-Mar-1932 (16 exx, CNC); Summerland, 24-Sep-1932 (5 exx, CNC); Summerland, 7-Oct-1932 (1 ex, CNC); Summerland, 10-Oct-1932 (116 exx, CNC); Summerland, 11-Oct-1932 (5 exx, CNC); Summerland, 11-Nov-1932 (51 exx, CNC); Exact locality unknown, Sep-1923 (1 ex, CNC). SASKATCHEWAN: Crane Valley, 06-Oct-1914 (1 ex, CNC). MANITOBA: Aweme, 25-Jul-1919 (5 exx, CNC); Aweme, 31-Oct-1921 (1 ex, CNC); Onah, 24-Jul-1919 (5 exx, CNC).

Diagnostic information (based on Stephan 1989 and Lord et al. 2011–2013). Body length 2.5–2.8 mm. Pronotum with a central concave area covering 1/3 to 1/2 total width of pronotum, concave area bordered laterally by longitudinal raised ridges. Pronotum carinate anteriorly with double "U" shaped anterior margin. Elytral interstriae 5 more raised than other interstriae, forming a median concave area of the elytra typically on posterior half only. See Lord et al. (2011–2013) for a habitus photograph.

Bionomic notes. Hackwell (1973) reported that this species is associated with galleries of several species of bark beetles where it feeds on both fungi and bark beetles during larval development. Many of the CNC specimens were collected from pine trees (*Pinus contorta* Douglas ex Loudon, *P. monticola* Douglas ex D.Don, *P. ponderosa* Douglas ex C.Lawson). The DNA barcoded Canadian specimen was collected with a Malaise trap in a grassland.

Comments. The single DNA barcoded specimen from Saskatchewan (the only member of its BIN, with no closely clustered neighbors) was compared with specimens of this little-studied genus in the CNC. The identification of this specimen using data in Lord et al. (2011–2013) led to the further identification of several other Canadian specimens from British Columbia, Saskatchewan, and Manitoba. Examination of specimens collected 100 years ago in three provinces suggests that this species has long been part of the Canadian fauna.

Tenebrionidae Alleculinae Alleculini

Isomira angusta (Casey, 1891) BOLD:AAH0400 Figure 40

Distribution. Native to the Nearctic region. Previously known from Georgia and South Carolina in the United States (Bousquet et al. 2018).

Canadian records. ONTARIO: Point Pelee National Park, 23-Jun-2010 (2 exx, CBG).

Diagnostic information (based on Aalbu et al. 2002). Body length 5.5–6.0 mm. Ventral surface of tarsi densely, finely pubescent (Fig. 40A). Male with sternite VIII deeply bilobed apically (Fig. 40B), extending beyond posterior edge of abdominal ventrite 5.



Figure 40. *Isomira angusta* (Casey) A anterior tarsal pubescence B male sternite 8. Scale bars: 0.5 mm (A), 1.0 mm (B).

Bionomic notes. The Canadian specimens were collected with a UV light trap in a meadow patch in deciduous forest.

Comments. This species was originally described as the only member of the new genus *Tedinus* by Casey (1891). *Tedinus* was included as valid in the key to the genera of Alleculini by Aalbu et al. (2002) where it was separated from species of *Isomira* Mulsant, 1856 based on the characters listed above. In addition to the new Canadian record, three new U.S. state records were found among the DNA barcoded specimens:

FLORIDA: Destin, 25-Mar-1980 (1 ex, CNC). OKLAHOMA: Willis, 15-Apr-2009 (6 exx, CBG & CNC); Willis, 18-Apr-2009 (1 ex, CNC). Illinois: Pine Hills Field Station, 22-May-1967 (1 ex, CNC).

Chrysomelidae Galerucinae Alticini

Chaetocnema hortensis (Geoffroy, 1785) BOLD:AAM7650

Figure 41

Distribution. Native to the Palaearctic region, widespread across the region and common in many parts (Döberl 2010; Konstantinov et al. 2011). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. BRITISH COLUMBIA: Kelowna, 22-Sep-2014 to 03-Oct-2014 (2 exx, CBG); Revelstoke, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG). ONTARIO: Brampton, 19-Sep-2016 to 30-Sep-2016 (2 exx, CBG); Mississauga, 24-May-2016 to 26-May-2016 (1 ex, CBG); Mississauga, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG). Nova Scotia: Cape Breton Highlands National Park, 23-Jun-2013 to 29-Jun-2013 (1 ex, CBG); Elmwood, 01-Nov-2005 (1 ex, CBG); Kejimkujik National Park, 31-Jul-2009 (1 ex, CBG); Truro, 21-Sep-2015 to 02-Oct-2015 (2 exx, CBG). LABRADOR: Happy Valley-Goose Bay, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG). NewFOUND-LAND: Terra Nova National Park, 04-Jul-2009 (1 ex, CBG).

Diagnostic information (based on Konstantinov et al. 2011). Body length (excluding head) 1.8–2.1 mm. Habitus as in Fig. 41A, B. Pronotum and elytra with a bronze or green metallic lustre. Four basal antennomeres yellow, antennomere 2 sometimes partly brown, femora brown, tibiae yellow. Pronotal punctures separated by approximately their own diameter. The two innermost elytral rows of punctures on basal half confused, third through fifth rows confused or regular, sixth row confused. Elytral humeral callus well developed. Aedeagus as in Fig. 41C, D.

Bionomic notes. *Chaetocnema hortensis* has a wide range of host plants. It mainly feeds on various grasses (Poaceae), including cereal crop species (Koch 1992; Konstantinov et al. 2011). It has been recorded as a minor pest of wheat and barley in Europe (Pavlov 1960' Vappula 1965). Most of the barcoded Canadian specimens were collected with Malaise traps in suburban environments. A few records are from grassland and forest habitats in Canadian national parks.

Comments. Chaetocnema hortensis has previously been confused with C. borealis R. White, 1996 in Canada. We found that most Canadian specimens in CNC identified as C. borealis actually represent C. hortensis. The elytral punctation of the two species is similarly irregular basally. In C. borealis, the basal antennomeres are brown rather than pale yellow, and the dorsal surface has a blue rather than bronze or green lustre. The aedeagus is differently shaped in the two species (Fig. 41D, E).



Figure 41. *Chaetocnema hortensis* (Geoffroy) **A** male habitus, L. Borowiec **B** female habitus, L. Borowiec **C** *C. hortensis*, aedeagus, ventral view **D** *C. hortensis*, aedeagus, lateral view **E** *C. borealis* R. White, aedeagus, lateral view. Scale bars: 1.0 mm (**A**, **B**), 0.5 mm (**C–E**).

Based on comparison of the type specimens of *C. borealis* (deposited in CNC) with the diagnoses and figures in the recent revision of Palaearctic *Chaetocnema* species (Konstantinov et al. 2011), *C. borealis* is very similar to (and possibly synonymous with) the Palaearctic *C. sahlbergii* (Gyllenhal, 1827). Both species inhabit bogs and other types of wetlands (Koch 1992; White 1996). Records of *C. borealis* from agricultural fields and other drier habitats reported e.g., by Majka and LeSage (2010) probably represent *C. hortensis*.

Longitarsus lewisii Baly, 1874 BOLD:ACI5614 Figure 42

Distribution. Native to the Palaearctic region. Widespread in Europe, recorded throughout Eurasia to China and the Russian Far East (Döberl 2010). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Cornwall, 19-Sep-2016 to 30-Sep-2016 (5 exx, CBG).

Diagnostic information (based on Warchalowski 1996 and Rutanen and Martikainen 2014). Body length 1.7–2.3 mm. Habitus as in Fig. 42A, B, convex in dorsal view, sides of elytra rounded. Head brown, pronotum and elytra yellow-brown, elytral suture usually narrowly dark at least near midlength, legs pale, metafemora darker. Ventral side red-brown to black. Pronotum ca. 1.5 times wider than long, finely punctate. Elytra densely and finely punctate, punctures slightly larger around scutellum. Male with a narrow longitudinal impression at the middle of the last ventrite, ending in a small, sharply delimited round pit. Last ventrite of females unmodified or with a very weak impression. Penis in lateral view strongly bent towards dorsum at the apex (Fig. 42C, D).

Bionomic notes. This species feeds on *Plantago* species, especially *P. major* L. (Koch 1992, Rutanen and Martikainen 2014). In Finland, it is most often collected in dry, barren habitats (Rutanen and Martikainen 2014). The Canadian specimens were collected with a Malaise trap in a suburban residential area.

Comments. Longitarsus lewisii is closely related to L. pratensis (Panzer, 1794), another adventive species from the Palaearctic region (Warchalowski 1996, Rutanen and Martikainen 2014). Longitarsus lewisii is more rounded and convex, and on average slightly larger than L. pratensis (1.7–2.3 mm vs. 1.4–2.1 mm) (Warchalowski 1996). The elytral suture is not darkened in L. pratensis, and the hind femora are paler. However, color is variable in this species group, and the male genitalia and the modifications of the last ventrite are the best distinguishing characters. In males of L. pratensis, the impression of the last ventrite is broad, circular and less sharply delimited than in males of L. lewisii. The penis of L. pratensis is shorter than that of L. lewisii, and less strongly bent. Females of L. pratensis have an elongate-oval, shallow medial impression on the last ventrite. The preferred host plant of L. pratensis is *Plantago lanceolata* L., but both species use several species of *Plantago* (Koch 1992; Döberl 1994; Rutanen and Martikainen 2014).

Lythraria salicariae (Paykull, 1800) BOLD:AAO3219 Figure 43

Distribution. Native to the Palaearctic region. Widespread in Europe, scattered records in Asia to East Siberia and Japan (Döberl 2010). Adventive in the Nearctic region (Ontario, Canada).



Figure 42. *Longitarsus lewisii* Baly **A** male habitus, L. Borowiec **B** female habitus, L. Borowiec **C** aedeagus, ventral view **D** aedeagus, lateral view. Scale bars: 1.0 mm (**A**, **B**), 0.5 mm (**C**, **D**).

Canadian records. ONTARIO: Cambridge, 25-May-2015 to 31-May-2015 (1 ex, CBG); Pickering, 24-Jun-2017 to 25-Jun-2017 (1 ex, CBG).

Diagnostic information (based on Mohr 1966). Body length 1.8–2.3 mm. Habitus elongate-oval (Fig. 43A, B). Yellow-brown or red-brown, apical antennomeres and ventral side darkened, sometimes also head, pronotum, and elytral suture darker brown. Base of pronotum without lateral furrows or a transverse impression. Procoxal cavities closed behind. Elytral punctures arranged in regular striae. Metatibia without a subapical dilation or tooth on the outer margin.



Figure 43. Lythraria salicariae (Paykull), habitus, L. Borowiec A male B female. Scale bar: 1.0 mm.

Bionomic notes. *Lythraria salicariae* is found in various wetland and marshy shoreline habitats as well as in forest depressions (Koch 1992). The larvae develop on *Lysimachia* species, and the adults occasionally feed also on *Lythrum salicaria* L. (Koch 1992, Dolgovskaya et al. 2004). The Canadian specimens were collected with pan traps in a grassy wetland and a mixed habitat of agricultural fields and forest.

Comments. *Lythraria* Bedel, 1897 is a monotypic genus reported here for the first time from North America. *Lythraria salicariae* would be identified as *Pseudorthygia* Csiki, 1940 (couplet 75) using the key to genera of Galerucinae in Riley et al. (2002) based on its closed procoxal cavities, but *L. salicariae* is not as convex in lateral profile and has a more elongate body outline. Among previously recorded Canadian leaf beetles, the habitus of *L. salicariae* is somewhat similar to *Glyptina brunnea* Horn, 1889, but the procoxal cavities are open behind in *Glyptina*.

Galerucinae Luperini

Scelolyperus liriophilus Wilcox, 1965 BOLD:ABW1434

Distribution. Native to the Nearctic region. Widespread in eastern United States (Clark 1996).

Canadian records. QUEBEC: Forillon National Park, 05-Jul-2013 to 15-Jul-2013 (2 exx, CBG).

Diagnostic information. See Clark (1996).

Bionomic notes. This species has been collected from a wide variety of plant species (Clark 1996). The Canadian specimens were collected with a Malaise trap along a forest trail in Forillon National Park.

Curculionidae Brachycerinae Erirhinini

Notaris scirpi (Fabricius, 1793) BOLD:AAX5634 Figure 44

Distribution. Native to the Palaearctic region. Widespread in Europe, with scattered records in Asia to the Russian Far East and Japan (Alonso-Zarazaga et al. 2017). Adventive in the Nearctic region (Quebec, Canada).

Canadian records (DNA barcoded specimen). QUEBEC: Laval, 11-Jun-1997 (1 ex, CNC).

Additional Canadian records. QUEBEC: Gatineau, 25-May-2012 (1 ex, CPTO); Henryville, 14-Jun-2015 (1 ex, CNC); Henryville, 07-Jun-2017 (1 ex, CMNC); Henryville, 07-Jun-2017 (9 exx, CCCH); Henryville, 14-Jun-2017 (1 ex, CMNC); Laval, 5-Jun-2004 (2 exx, CSDU); Laval, 19-Apr-2013 (1 ex, CSDU); Laval, 22-Jun-2013 (1 ex, CSDU); Longueuil, 21-May-2016 (1 ex, CPTO); Oka, 01-Jul-2004 (1 ex, CRVI); Oka, 06-Jun-2011 (1 ex, CRVI); Oka, 19-Aug-2012 (1 ex, CMNC); Oka, 26-Aug-2012 (1 ex, CPTO); Oka, 01-Jun-2014 (1 ex, CRVI); Oka, 21-Jun-2016 (1 ex, CRVI); Oka, 13-Jul-2016 to 20-Jul-2016 (2 exx, CRVI); Oka, 22-Jul-2016 (1 ex, CRVI); Oka, 15-May-2018 to 31-May-2018 (1 ex, CRVI); Saint-Côme, 13-Jul-2013 (1 ex, CSDU); Saint-Lazare, 20-Jun-2012 (1 ex, CPTO); Saint-Lazare, 17-Sep-2012 (1 ex, CPTO); Saint-Lazare, 14-Jun-2013 (1 ex, CPTO); Saint-Lazare, 18-Jul-2017 (1 ex, CSDU); Terrasse-Vaudreuil, 01-Jun-2013 (1 ex, CNC); Terrasse-Vaudreuil, 11-Jun-2007 (1 ex, CPTO); Terrasse-Vaudreuil, 30-Jun-2014 (1 ex, CPTO); Varennes, 07-Jun-2011 (1 ex, CCCH).

Diagnostic information (based on Hoffmann 1958). Body length: 4.7–7.0 mm. Habitus as in Fig. 44. Oblong-oval, black or brown, dorsal pubescence of small piliform scales more or less regularly distributed, with a speckled color pattern formed by patches of paler scales. Rostrum elongate, narrow, curved, punctate-striate and carinate. Prothorax approximately as long as wide, sides rounded, punctation dense and deep, with median line slightly elevated anteriorly. Elytra rounded at humeri in dorsal view, sides subparallel until slightly beyond middle. Ventrally with lateral portions of abdomen, metanepisternum, metanepimeron, and lateral portion of metaventrite with dense cream-colored scales.



Figures 44, 45. 44 *Notaris scirpi* (Fabricius), habitus, L. Borowiec 45 *Centrinopus helvinus* Casey, habitus. Scale bar: 2.0 mm (44), 1.0 mm (45).

Bionomic notes. *Notaris scirpi* is oligophagous on *Scirpus* and *Carex* species in wet habitats (Koch 1992). Hoffmann (1958) notes that in France the species develops in the collar of *Carex acutiformis* Ehrh. and that adults can be collected in litter around wet areas.

Comments. These are the first records of *Notaris scirpi* from the Nearctic region. After the identification of the DNA barcoded specimen deposited in CNC, 37 additional specimens from various localities in Quebec were found in other collections. The earliest record is from 1997, and the species seems to be firmly established in Quebec. *Notaris scirpi* is easily distinguished from *Tournotaris bimaculatus* (Fabricius, 1787) and *Notaris puncticollis* (LeConte, 1876), the two most similar species already known from North America, by the dense cream-colored scales on the lateral portions of the abdomen, metanepisternum, metanepimeron, and lateral portion of the metaventrite.

Baridinae Madarini

Ampeloglypter sesostris (LeConte, 1876) BOLD:ADH7970

Distribution. Native to the Nearctic region. Previously recorded from Indiana, Michigan, Ohio, Pennsylvania, Illinois, Florida, and Missouri (O'Brien and Wibmer 1982; Saunders and Tobin 2000) but likely more widespread in eastern and midwestern United States (Riedl and Taschenberg 1984).

Canadian records (DNA barcoded specimens). ONTARIO: Pelee Island, 06-Jun-1982 (1 ex, CNC); Rouge National Urban Park, 25-Jun-2017 (1 ex, CBG).

Additional Canadian records. ONTARIO: Pelee Island, 26-Jun-1940 (1 ex, CNC); Pelee Island, 27-Jun-1940 (1 ex, CNC); Windsor, 30-May-2002 (1 ex, CMNC).

Diagnostic information (based on Blatchley and Leng 1916 and Anderson 2002). Body length: 2.7–3.0 mm. Body glabrous, shiny, elongate-oval, pale reddish brown throughout. Elytral interstriae flat. Femora not toothed. Tarsus with two claws connate at base.

Bionomic notes. This species feeds on *Vitis* L. species, and it is considered a minor pest in vineyards (Bouchard et al. 2005). The female oviposits above a stem node and hollows out additional cavities along the longitudinal axis of shoots of the host plants. The larva develops and feeds on tissues inside the shoot, causing it to swell and thereby inducing gall formation (Lasnier et al. 2019).

Comments. The red-brown *Ampeloglypter sesostris*, known commonly as the grape cane gallmaker, can be separated from the other two species in this genus in the United States and Canada by color: *A. ampelopsis* (Riley, 1869) and *A. longipennis* Casey, 1892 have a black integument.

Baridinae Apostasimerini

Centrinopus helvinus Casey, 1892 BOLD:ACX7906 Figure 45

Distribution. Native to the Nearctic and Neotropical regions. Recorded from eastern and north central United States, and southward to Nicaragua (O'Brien and Wibmer 1982).

Canadian records. ONTARIO: Waterloo, 21-Sep-2015 to 02-Oct-2015 (1 ex, CBG); Waterloo, 19-Sep-2016 to 30-Sep-2016 (1 ex, CBG).

Diagnostic information (based on Casey 1920 and Anderson 2002). Body length: 2.0–2.7 mm. Body dark red-brown to black, oval, covered dorsally with pale scales, oriented perpendicularly to body axis on pronotum, oriented longitudinally on elytra

(Fig. 45). Scales somewhat denser on elytral interstriae 3, 5, 7. Prothorax only slightly narrower than elytra in dorsal view. Scutellum densely covered with scales. Female with sharply defined longitudinal sulcus anterior to procoxae. Each procoxa in male with one anteriorly projecting spine-like process in front.

Bionomic notes. Kissinger (1964) mentioned that adults in this genus are found on flowers of Asteraceae. According to Blatchley and Leng (1916) *Centrinopus helvinus* was taken on sweetscented joe pye weed, *Eutrochium purpureum* (L.) E.E. Lamont. We are not aware of any additional biological information published on this species. The barcoded Canadian specimens were collected with a Malaise trap on farmland.

Comments. The genus *Centrinopus* Casey, 1892, which is in need of a taxonomic revision (Anderson 2002), contains six species in the eastern United States and is recorded here from Canada for the first time.

Ceutorhynchinae Ceutorhynchini

Ceutorbynchus inaffectatus Gyllenhal, 1837

BOLD:ACB0098 Figure 46

Distribution. Native to the Palaearctic region. Widespread in Europe, recorded east to Kazakhstan and West Siberia (Alonso-Zarazaga et al. 2017). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Guelph, 02-Jun-2018 (1 ex, CBG).

Diagnostic information (based on Lohse 1983). Body length 2.3–3.9 mm. Habitus as in Fig. 46A, appearing grey at low magnification due to the pale scales sparsely covering the black integument. Antennal funicle with seven antennomeres. Pronotum densely punctate, lateral tubercles absent. Elytra without apical calli, interstriae with narrow scales arranged in two or three longitudinal rows. Meso- and metafemora with small teeth. All tarsal claws with small basal tooth. Aedeagus as in Fig. 46B.

Bionomic notes. This species feeds on *Hesperis matronalis* L. and *H. tristis* L. (Brassicaceae) (Koch 1992). The larvae develop in the seed pods, the adults feed on leaves and other parts of the host plants (Koch 1992, Larsen et al. 1992). The Canadian specimen was collected by sweep netting vegetation along a recreational trail where *H. matronalis* is abundant.

Comments. Ceutorhynchus inaffectatus is similar in habitus to two other Palaearctic species adventive in North America: C. obstrictus (Marsham, 1802) and C. rapae Gyllenhal, 1837. These species have lateral pronotal tubercles, which are absent in C. inaffectatus. The combination of toothed femora, antennal funicle with seven antennomeres, pronotum lacking lateral tubercles and toothed tarsal claws will separate C. inaffectatus from native species of Ceutorhynchus. Hesperis matrona-



Figures 46–48. 46 *Ceutorhynchus inaffectatus* Gyllenhal 46A habitus, L. Borowiec 46B aedeagus 47 *Ceutorhynchus mutabilis* Dietz, habitus 48 *Exomias trichopterus* (Gautier des Cottes) 48A male habitus, L. Borowiec 48B female habitus, L. Borowiec. Scale bars: 1.0 mm (46A; 47; 48), 0.5 mm (46B).

lis (dame's rocket or purple rocket) is an invasive weed in North America (Francis et al. 2009), and the strictly specialized *C. inaffectatus* could potentially be useful in its biological control.

Ceutorhynchus mutabilis Dietz, 1896 BOLD:AAZ4085 Figure 47

Distribution. Native to the Nearctic region. This species is reported from Baja California, California, Oregon, Washington, Colorado, Kansas, and North Dakota in the United States (O'Brien and Wibmer 1982; Balsbaugh and Aarhus 1990).

Canadian records. BRITISH COLUMBIA: Radium, 24-Aug-1982 (2 exx, CNC); New Afton Mine, 20-Jun-2013 to 27-Jun-2013 (1 ex, CBG). Alberta: Calgary, 22-Jul-1976 (1 ex, CNC); Exact locality not specified, 20-Jun-1985 (1 ex, CNC); Exact locality not specified, 09-Jun-1990 (1 ex, CNC). SASKATCHEWAN: Grasslands National Park, 19-Jul-2012 to 26-Jul-2012 (1 ex, CBG). MANITOBA: Exact locality not specified, 24-Jul-1995 (1 ex, CNC).

Diagnostic information (based on Scheibner 1963). Body length: 2.4 mm. Habitus as in Fig. 47, body with black integument covered with white to pale brown scales. Antennal funicle with seven antennomeres. Combination of two types of scales on pronotum and elytra, some broadly oval, others expanding from base with a truncate apex. Elytra with dense patch of appressed oval scales posterior to scutellum. Metafemora lacking tooth. Tarsal claws each with a small basal tooth.

Bionomic notes. The natural history and host preferences of this little-studied species are unknown (Colonnelli 2004).

Comments. Although this genus is in need of a revision, the combination of character states listed above, in combination with the habitus photograph (Fig. 47), should lead to the correct identification. Studies describing the biology of this and other native species of *Ceutorhynchus* Germar, 1824 are badly needed.

Peracalles pectoralis (LeConte, 1876) BOLD:ACY2911

Distribution. Native to the Nearctic region. Anderson (2002) reports this species from Illinois, Indiana, Ohio, Kentucky, and Missouri in the United States.

Canadian records. ONTARIO: Point Pelee National Park, 06-Jul-2015 (1 ex, CBG); Point Pelee National Park, 16-Jun-2014 to 22-Jun-2014 (3 exx, CBG).

Diagnostic information (based on Anderson 2002). Body length: 3.0–3.3 mm. Body black, covered with broad, flat, appressed dark brown to pale scales, broadly oval in dorsal view. Antennal funicle with seven articles. Prosternum with deep longitudinal sulcus for reception of rostrum, sulcus extending posteriorly to anterior edge of mesoventrite. Elytra strongly convex in lateral view, with a single row of flat, apically truncate, erect scales on each interstria.

Bionomic notes. Adults in this genus occur in leaf litter (Anderson 2002). The Canadian specimens were collected from a marsh and a swampy forest using pan traps, pitfall traps and Berlese funnel extraction.

Comments. The genus *Peracalles* Kissinger, 1964 contains two species in the United States (Anderson 2002) and is recorded here in Canada for the first time.

Entiminae Sciaphilini

Exomias trichopterus (Gautier des Cottes, 1863) BOLD:ACZ1179 Figure 48

Distribution. Native to the Palaearctic region. Widespread in Central Europe (Alonso-Zarazaga et al. 2017). Adventive in the Nearctic region (Ontario, Canada).

Canadian records. ONTARIO: Rouge National Urban Park, 24-Jun-2017 to 25-Jun-2017 (1 ex, CBG).

Diagnostic information (based on Rheinheimer and Hassler 2013). Body length: 2.7–3.4 mm. Habitus as in Fig. 48A, B. Body brown to black, covered with fine semierect to erect setae, legs pale yellow to red-brown. Rostrum with shallow longitudinal depression dorsally. Globose elytra with humeral angles obsolete. Elytra lacking row of long setae near suture on posterior half.

Bionomic notes. This common European species is polyphagous on herbaceous plants (Balalaikins 2011) and could become a new pest of berry crops in Canada (see Kolov and Korotyaev 2017).

Comments. Exomias trichopterus is very similar in appearance to E. pellucidus pellucidus (Boheman, 1834), another adventive Palaearctic species which is common and widespread in North America. Both species were previously placed in the genus Barypeithes Jacquelin du Val, 1854. The former subgenus Exomias was elevated to the generic level by Borovec (2013). Exomias pellucidus pellucidus can be diagnosed primarily by the noticeably denser setae on their elytra, especially near the apex where an additional row of long setae is present along the elytral suture.

Scolytinae Xyleborini

Ambrosiodmus rubricollis (Eichhoff, 1875) BOLD:AAR3532

Distribution. Native to the eastern Palaearctic and Oriental regions (Knížek 2011). Adventive in Europe, Australia, and the Nearctic region (widespread in the United States; Ontario, Canada) (Knížek 2011; Gomez et al. 2018).

Canadian records. ONTARIO: Point Pelee National Park, 11-Jul-2012 to 18-Jul-2012 (1 ex, CBG); Point Pelee National Park, 16-Jun-2014 to 22-Jun-2014 (2 exx, CBG).

Diagnostic information (based on Gomez et al. 2018). Body length 2.4–2.6 mm. Pronotum with asperities covering entire surface. Elytral declivity with tubercles on interstriae 2 as large as those on interstriae 1 and 3.

Bionomic notes. Ambrosiodmus rubricollis uses symbiotic fungi to attack many genera of gymnosperm and dicot trees including species in the following Canadian genera: Abies Mill., Aesculus L., Alnus Mill., Carya Nutt., Cornus L., Fraxinus L., Ilex L., Juglans L., Morus L., Pinus L., Populus L., Prunus L., Quercus L., Rhus L. (Faccoli et al. 2009). One of the Canadian specimens was collected with a Malaise trap in a savanna, the two others were caught with pitfall traps in a swampy forest.

Comments. This is the only *Ambrosiodmus* species known from Canada, although two larger-bodied species are known from states bordering southern Ontario (Gomez et al. 2018). *Ambrosiodmus lewisi* (Blandford, 1984), and *A. tachygraphus* (Zimmermann, 1868) can be distinguished from *A. rubricollis* by their greater body lengths (3.6 to 4.0 mm).

Discussion

This study adds 60 new species to the Canadian beetle fauna and resolves taxonomic confusion in another three species. Among the 42 adventive species covered, 40 are native to the Palaearctic region. The remaining two species, Clambus simsoni and Attagenus smirnovi, are native to the Australian and Afrotropical regions respectively, but also occur in the Palaearctic as adventive species. Nephus bisignatus and Dichelotarsus *lapponicus* were previously known only from the Palaearctic region, but because they were collected in remote arctic localities in Canada, we consider it likely that they are Holarctic taxa whose occurrence in North America was previously overlooked. The remaining 19 new species are native to North America, and represent either previously overlooked occurrences in Canada, or recent range expansions. The fact that many new records of native species were of species that are difficult to identify by morphological methods suggests that most of these species have been long present in Canada but overlooked. Six species were found at Point Pelee, a forest and wetland area isolated from similar habitats in both United States and Canada, further suggesting that recent range extensions are an unlikely explanation for new Canadian records of these species. The fact that 54 of the 60 new species for Canada were found in general survey samples for insects clearly indicates that much more work is needed using specialized, taxonspecific collecting techniques to achieve a full inventory of the Coleoptera diversity in Canada. We also expect that increased insect survey activity in United States would recover records for many of the same adventive species there, plus additional species as-yet unrecorded from North America.

Species that are adapted to disturbed or ruderal habitats are more likely to be accidentally transported through human activities than species that require non-synanthropic habitats (Lockwood et al. 2013). Many of the adventive beetle species established in North America are strongly synanthropic and occur mainly in human-

disturbed habitats and settlements (Klimaszewski et al. 2010, 2012). Not surprisingly, most of the new adventive species we report here were found mainly or exclusively in Southern Ontario, which is Canada's most densely populated and biodiverse region, and in the Greater Vancouver area, the third largest metropolitan area in Canada and home to the busiest port in the country (also with high native insect diversity). Some of these adventive species have likely been present in Canada for a long time, but have been overlooked due to difficulties in morphological identification. Stenichnus scutellaris and Amischa decipiens are widespread and common in southern Ontario, while A. decipiens is also found in the Greater Vancouver area. Malthodes pumilus occurs from East to West in both suburban and natural environments. All three species represent genera that have received little or no taxonomic investigation in North America in recent decades. Others, such as Calyptomerus dubius, Clambus simsoni, Litargus connexus, and Olibrus liquidus, may have arrived more recently as they have only been found in one or a few urban localities, and some are only represented by singleton specimens in the Canadian DNA barcode data. Verifying that these species are well-established in Canada will require further monitoring and study of material in existing collections.

Most of the species newly recorded here that are shared between Europe and North America probably arrived into North America from Europe because they were discovered there first. Relatively few North American beetle species are known to occur as adventive in Europe, but more may well be uncovered especially in families where the Nearctic fauna is poorly known. Adventive insect species are sometimes described as new to science after arriving in a new area (Wheeler and Hoebeke 2009), as exemplified by the two new synonymies in Staphylinidae we establish in this study. New species are less likely to escape notice in Europe where the beetle fauna, including taxonomically challenging families such as Staphylinidae, is generally better known and more intensively studied compared to North America. Our analysis of European and Canadian DNA barcode data has uncovered at least one native North American species of Staphylinidae occurring as adventive in Europe and described as new from there. This synonymy will be formally established in a future publication. A geographically well represented DNA barcode dataset can provide information on the biogeography and distributional status (native vs. adventive) of species, and potentially identify the geographic origin of adventive or expansive species (Valade et al. 2009; Lees et al. 2011). A detailed analysis of the spatial genetic variation in all the species covered here is beyond the scope of the present paper but will be a subject of future studies.

It is noteworthy that 57 of our 60 new species records for Canada were discovered, in whole or in part, using material recently collected by the Centre for Biodiversity Genomics. In fact, only two of the new species were discovered based solely on specimens from the CNC (see Table 1). The CNC was once the primary source of new data on Canadian insect species, but it is no longer the depository for most specimens from general survey and inventory work across the country. For example, the 1,085,146 Canadian insect specimens analyzed by Hebert et al. (2016) are stored in the CBG voucher archive. To further illustrate this change in specimen accumulation, a complete inventory of the Canadian Scarabaeoidea in the CNC (ABTS, unpublished data) revealed that only 7% of the specimens in that institution were collected during the past 30 years. In contrast, 37% of the specimens in CNC were collected during the previous 30-year period (1959–1988). Inventories of Canadian Scarabaeoidea in most of the major entomological collections across the country show a similar overall pattern. Although general survey and inventory work is badly needed in Canada to detect the full diversity of the Coleoptera fauna, collecting efforts have significantly declined over the past 30 years. This leaves invasive species undetected and range expansions undiscovered for years longer than would have been the case when there were large-scale survey and inventory efforts (e.g., Northern Insect Survey; Lonsdale and Huber 2011). With the growing threat of invasive species through increasing global trade and the northward expansion of species due to the changing climate, ongoing collaborative survey and inventory efforts are needed to detect new species as they appear in Canada.

Bousquet et al. (2013) recorded 8237 Coleoptera species in Canada, an increase of almost 10% over a similar checklist published 22 years earlier (Bousquet 1991). The recent summary by Brunke et al. (2019) increased the number of Canadian beetle species to 8302. These increases are mainly due to progress in taxonomic research on Coleoptera species already present in Canada, but species recently establishing themselves in Canada also increased the count. The 60 species we report here as new for Canada increase the number of known beetle species in the country by another 0.7% compared to Brunke et al. (2019). Of these, the 40 new adventive species add 6.3% to the number of non-native Coleoptera known from Canada. Further new Canadian records and new synonymies in European and North American Coleoptera detected through DNA barcode data are currently being validated. Our study shows that DNA barcoding, combined with morphological validation of the voucher specimens, is a powerful tool for detecting and identifying overlooked or recently arrived species, both native and adventive (see also deWaard et al. 2009, Landry et al. 2013). Even though the species coverage of the European and Canadian DNA barcode reference libraries of beetles is still far from complete, our results undeniably demonstrate their usefulness for cataloguing regional biodiversity.

Acknowledgements

Josie Smith (Canadian Food Inspection Agency) provided the additional specimen of *Pseudanostirus tigrinus*. Collecting permits granted by the City of Guelph (Martin Neumann, Parks Operations and Forestry) to M. Pentinsaari led to the discovery of *Cis boleti* and *Medon apicalis*. Marko Mutanen (University of Oulu, Finland) provided European material of several species for comparison. Serge Laplante (Agriculture and Agri-Food Canada, Ottawa) helped in validating some of the identifications. Volker Assing (Hannover, Germany), Sami Karjalainen (Kirkkonummi, Finland), Matúš Kocian (Prague, Czech Republic), Harald Schillhammer (Natural History Museum Vienna, Austria), and Michael Schülke (Berlin, Germany) kindly allowed us to use their images in this publication. Anthony Davies (Agriculture and Agri-Food Canada, Ottawa) imaged many of the specimens and compiled the figure plates. Steve Paiero provided access to the University of Guelph Insect Collection. Claude Chantal (Varennes, Quebec), Stéphane Dumont (Montreal,

Quebec), Pierre de Tonnancour (Terrasse-Vaudreuil, Quebec), and Robert Vigneault (Oka, Quebec) provided additional specimen records of *Notaris scirpi* from their private collections. Reginald Webster (Charters Settlement, New Brunswick) and György Makranczy (Hungary) provided additional verified specimen records of *Carpelimus elongatulus*. All of the sequence analysis and processing of voucher specimens, as well as the CBG's collection program, were supported by grants from the Ontario Ministry of Research and Innovation, and from Genome Canada through Ontario Genomics in support of the International Barcode of Life (iBOL) project. Subsequent work to identify specimens and analyze data was enabled by the Canada First Research Excellence Fund through its support for the Food From Thought project at the University of Guelph. Michael Caterino and two anonymous reviewers provided helpful comments on a previous version of this manuscript.

References

- Aalbu RL, Triplehorn CA, Campbell JM, Brown KW, Somerby RE, Thomas DB (2002) Tenebrionidae Latreille, 1802. In: Arnett RH, Thomas MC, Skelley PE, Frank JH (Eds) American Beetles (Vol. 2). Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, 463–509. https://doi.org/10.1201/9781420041231.ch7
- Alonso-Zarazaga MA, Barrios H, Borovec R, Bouchard P, Caldara R, Colonnelli E, Gültekin L, Hlaváč P, Korotyaev B, Lyal CHC, Machado A, Meregalli M, Pierotti H, Ren L, Sánchez-Ruiz M, Sforzi A, Silfverberg H, Skuhrovec J, Trýzna M, Velázquez de Castro AJ, Yunakov NN (2017) Cooperative Catalogue of Palaearctic Coleoptera Curculionoidea. Monografías electrónicas SEA 8. Sociedad Entomológica Aragonesa S.E.A., Zaragoza, 729 pp. http:// graellsia.revistas.csic.es/index.php/graellsia/article/view/537/636
- Anderson RS (2002) Curculionidae Latreille, 1802. In: Arnett RH, Thomas MC, Skelley PE, Frank JH (Eds) American Beetles (Vol. 2). Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, 722–815.
- Arango RA, Young DK (2012) Death-watch and spider beetles of Wisconsin Coleoptera: Ptinidae. General Technical Report FPL-GTR-209. US Department of Agriculture, Forest Service, Forest Products Laboratory, Madison. https://doi.org/10.2737/FPL-GTR-209
- Armstrong K (2010) DNA barcoding: a new module in New Zealand's plant biosecurity diagnostic toolbox. EPPO Bulletin 40: 91–100. https://doi.org/10.1111/j.1365-2338.2009.02358.x
- Armstrong KF, Ball SL (2005) DNA barcodes for biosecurity: invasive species identification. Philosophical Transactions of the Royal Society of London. Series B, Biological sciences 360: 1813–1823. https://doi.org/10.1098/rstb.2005.1713
- Assing V (2004) A Revision of the *Medon* Species of the Eastern Mediterranean and Adjacent Regions (Insecta: Coleoptera: Staphylinidae: Paederinae). Bonner zoologische Beiträge 52: 33–82.
- Assing V (2006) A Revision of the Western Palaearctic *Medon*: the Species of the Atlantic Islands, the Western Mediterranean, and Europe, Except for the Southeast. Bonner zoologische Beiträge 54: 25–95.
- Assing V (2009) On the *Pseudomedon* species of the Palaearctic region (Coleoptera: Staphylinidae: Paederinae). Linzer biologische Beiträge 41: 1175–1189.

- Assing V (2012) Paederinae. In: Assing V, Schülke M (Eds) Die K\u00e4fer Mitteleuropas, Band 4 (2. Auflage). Spektrum Akademischer Verlag, Heidelberg, 380–383.
- Assing V (2018) On some *Myllaena* species in the East Mediterranean and Caucasus regions (Coleoptera: Staphylinidae: Aleocharinae). Linzer biologische Beiträge 50: 1015–1032.
- Audisio P (1993) Fauna d'Italia (Vol. 32): Coleoptera Nitidulidae Kateretidae. Edizione Calderini, Bologna, 971 pp.
- Balalaikins M (2011) On Latvian Entiminae (Coleoptera: Curculionidae): 2. Tribes Trachyphloeini Lacordaire, 1863 and Sciaphilini Sharp, 1891. Acta Zoologica Lithuanica 21: 253–262. https://doi.org/10.2478/v10043-011-0031-1
- Balsbaugh EU, Aarhus DG (1990) Checklist and new state records of Curculionidae (broad sense) (Coleoptera) for North Dakota. Journal of the Kansas Entomological Society 63: 227–236. https://www.jstor.org/stable/25085171
- Baranowski R (1993) Revision of the genus *Leiodes* Latreille of North and Central America. Entomologica Scandinavica Supplementum 41: 1–149.
- Bellard C, Cassey P, Blackburn TM (2016) Alien species as a driver of recent extinctions. Biology letters 12: 20150623. https://doi.org/10.1098/rsbl.2015.0623
- Besuchet C (1955) Monographie des *Bibloplectus* et *Pseudoplectus* paléarctiques. Bulletin de la Société Entomologique Suisse 28: 153–209.
- Bieńkowski AO (2018) Key for identification of the ladybirds (Coleoptera: Coccinellidae) of European Russia and the Russian Caucasus (native and alien species). Zootaxa 4472: 233– 260. /doi.org/10.11646/zootaxa.4472.2.2
- Blanchard F (1917) Revision of the Throscidae of North America (Coleoptera). Transactions of the American Entomological Society 43: 1–26.
- Blatchley WS, Leng CW (1916) Rhynchophora or Weevils of North Eastern America. The Nature Publishing Company, Indianapolis, 682 pp. https://doi.org/10.5962/bhl.title.1557
- Borovec R (2013) Sciaphilini. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 8). Brill, Leiden, 83, 377–386.
- Bouchard P, Lesage L, Goulet H, Bostanian NJ, Vincent C, Zmudzinska A, Lasnier J (2005) Weevil (Coleoptera: Curculionoidea) diversity and abundance in two Quebec vineyards. Annals of the Entomological Society of America 98: 565–574. https://doi.org/10.1603/0013-8746(2005)098[0565:WCCDAA]2.0.CO;2
- Bouchard P, Smith ABT, Douglas H, Gimmel ML, Brunke AJ, Kanda K (2017) Biodiversity of Coleoptera. In: Foottit RG, Adler PH (Eds) Insect Biodiversity: Science and Society. John Wiley & Sons Ltd, 337–417. https://doi.org/10.1002/9781444308211.ch11
- Bousquet Y (1991) Checklist of beetles of Canada and Alaska. Agriculture Canada, Ottawa, 430 pp.
- Bousquet Y (2010) Illustrated Identification Guide to Adults and Larvae of Northeastern North American Ground Beetles (Coleoptera, Carabidae). Pensoft Publishers, Sofia, 562 pp.
- Bousquet Y (2012) Catalogue of Geadephaga (Coleoptera: Adephaga) of America, north of Mexico. ZooKeys 245: 1–1722. https://doi.org/10.3897/zookeys.245.3416
- Bousquet Y, Bouchard P, Davies A, Sikes D (2013) Checklist of beetles (Coleoptera) of Canada and Alaska. Second edition. ZooKeys 360: 1–44. https://doi.org/10.3897/zookeys.360.4742

- Bousquet Y, Thomas DB, Bouchard P, Smith AD, Aalbu RL, Johnston MA, Steiner Jr. WE (2018) Catalogue of Tenebrionidae (Coleoptera) of North America. ZooKeys 728: 1–455. https://doi.org/10.3897/zookeys.728.20602
- Bowestead S (1999) A revision of the Corylophidae (Coleoptera) of the West Palaearctic Region. Muséum d'histoire naturelle, Genève, Geneva, 203 pp.
- Bowestead S (2007) Corylophidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 631–635.
- Brown WJ (1936) American species of *Ludius*; The *fallax* and *triundulatus* groups. The Canadian Entomologist 68: 99–107. https://doi.org/10.4039/Ent6899-5
- Brunke AJ, Bahlai CA, Klimaszewski J, Hallett RH (2014) Rove beetles (Coleoptera: Staphylinidae) in Ontario, Canada soybean agroecosystems: assemblage diversity, composition, seasonality, and habitat use. The Canadian Entomologist 146: 652–670. https://doi. org/10.4039/tce.2014.19
- Brunke AJ, Bouchard P, Douglas HB, Pentinsaari M (2019) Coleoptera of Canada. ZooKeys 819: 361–376. https://doi.org/10.3897/zookeys.819.24724
- Campbell JM (1979) A revision of the genus *Tachyporus* Gravenhorst (Coleoptera: Staphylinidae) of North America. Memoirs of the Entomological Society of Canada 111: 1–95. https://doi.org/10.4039/entm111109fv
- Campbell JM (1991) A revision of the genera *Mycetoporus* Mannerheim and *Ischnosoma* Stephens (Coleoptera: Staphylinidae: Tachyporinae) of North and Central America. Memoirs of the Entomological Society of Canada 123: 1–169. https://doi.org/10.4039/ent-m123156fv
- Casey TL (1891) Coleopterological notices, III. Annals of the New York Academy of Sciences 6: 9–214. https://doi.org/10.1111/j.1749-6632.1892.tb55403.x
- Casey TL (1920) Memoirs on the Coleoptera. The New Era Printing Company, Lancaster, 529 pp.
- Chandler DS (1990) The Pselaphidae (Coleoptera) of Latimer county, Oklahoma, with revisions of four genera from eastern North America. Part I. Faroninae and Euplectinae. Transactions of the American Entomological Society 115: 503–529.
- Clark SM (1996) The genus *Scelolyperus* Crotch in North America (Coleoptera: Chrysomelidae: Galerucinae). Insecta Mundi 10: 261–280. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1005&context=insectamundi.
- Colonnelli E (2004) Catalogue of Ceutorhynchinae of the world, with a key to genera (Insecta: Coleoptera: Curculionidae). Argania Editio, Barcelona, 124 pp.
- Daffner H (1983) Revision der paläarktischen Arten der Tribus Leiodini Leach (Coleoptera, Leiodidae). Folia Entomologica Hungarica 44: 9–163.
- Denux O, Zagatti P (2010) Coleoptera families other than Cerambycidae, Curculionidae sensu lato, Chrysomelidae sensu lato and Coccinelidae. Chapter 8.5. BioRisk 4: 315–406. https://doi.org/10.3897/biorisk.4.61
- deWaard JR, Humble LM, Schmidt BC (2010) DNA barcoding identifies the first North American records of the Eurasian moth, *Eupithecia pusillata* (Lepidoptera: Geometridae). Journal of the Entomological Society of British Columbia 107: 25–31. https://journal. entsocbc.ca/index.php/journal/article/view/11

- deWaard JR, Ivanova NV, Hajibabaei M, Hebert PDN (2008) Assembling DNA Barcodes. In: Martin CC (Ed.) Methods in Molecular Biology (Vol. 410): Environmental Genomics. Humana Press, 275–294. https://doi.org/10.1007/978-1-59745-548-0_15
- deWaard JR, Landry J-F, Schmidt BC, Derhousoff J, McLean JA, Humble LM (2009) In the dark in a large urban park: DNA barcodes illuminate cryptic and introduced moth species. Biodiversity and Conservation 18: 3825–3839. https://doi.org/10.1007/s10531-009-9682-7
- deWaard JR, Levesque-Beaudin V, DeWaard SL, Ivanova NV, McKeown JTA, Miskie R, Naik S, Perez KHJ, Ratnasingham S, Sobel CN, Sones JE, Steinke C, Telfer AC, Young AD, Young MR, Zakharov EV, Hebert PDN (2018) Expedited assessment of terrestrial arthropod diversity by coupling Malaise traps with DNA barcoding. Genome 62(3): 85–95. https://doi.org/10.1139/gen-2018-0093
- Döberl M (1994) Alticinae. In: Lohse GA, Lucht WH (Eds) Die Käfer Mitteleuropas, Band 14 (3. Supplementband). Goecke & Evers, Krefeld, 92–141.
- Döberl M (2010) Alticinae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 6). Apollo Books, Stenstrup, 491–563.
- Dolgovskaya MY, Konstantinov AS, Reznik SY, Spencer NR, Volkovitsh MG (2004) Flea beetles (Coleoptera: Chrysomelidae) associated with purple loosestrife, *Lythrum salicaria*, in Russia. In: Cullen JM, Briese DT, Kriticos DJ, Lonsdale WM, Morin L, Scott JK (Eds) Proceedings of the XI International Symposium on Biological Control of Weeds. CSIRO Entomology, Canberra, 96–101.
- Downie NM, Arnett RH (1996) The Beetles of Northeastern North America (Vol. 1, 2). Sandhill Crane Press, Gainesville, 1721 pp.
- Endrödy-Younga S (1961) Revision der Gattung *Calyptomerus* Redtb. (Coleoptera: Clambidae). Acta Zoologica Academiae Scientiarum Hungaricae 7: 401–412.
- Endrödy-Younga S (1974) A revision of the described Australian and New Zealand species of the family Clambidae (Coleoptera) with description of a new species. Records of the South Australian Museum 17: 1–10.
- Endrödy-Younga S (1981) The American species of the familia Clambidae (Coleoptera: Eucinetoidea). Entomologia Generalis 7: 33–67.
- Endrödy-Younga S (1990) A revision of the Australian Clambidae (Coleoptera: Eucinetoidea). Invertebrate Taxonomy 4: 247–280. https://doi.org/10.1071/IT9900247
- Esser J (2016) Über die Identität von *Cryptophilus integer* (Heer, 1841) (Coleoptera, Erotylidae). Entomologische Nachrichten und Berichte 60: 213–218.
- Esser J (2017) On the Nearctic *Cryptophilus* Reitter, 1874 (Coleoptera: Erotylidae). Linzer biologische Beiträge 49: 1133–1137.
- Faccoli M, Frigimelica G, Mori N, Petrucco Toffolo E, Vettorazzo M, Simonato M (2009) First record of *Ambrosiodmus* (Hopkins, 1915) (Coleoptera: Curculionidae, Scolytinae) in Europe. Zootaxa 2303: 57–60. https://doi.org/10.11646/zootaxa.2303.1.4
- Fall HC (1901) Notes on *Dichelonycha* and *Cantharis*, with descriptions of new species in othera [sic] genera. Transactions of the American Entomological Society 27: 277–310.
- Fall HC (1910) Miscellaneous notes and descriptions of North American Coleoptera. Transactions of the American Entomological Society 36: 89–197.
- Fall HC (1919) A Change of Names (Coleoptera). Entomological News 30: 1–26.

- Fall HC (1927) A review of the North American species of *Podabrus*. Entomologica Americana 8: 65–103.
- Fender KM (1951) The Malthini of North America (Coleoptera-Cantharidae). The American Midland Naturalist 46: 513–629. https://doi.org/10.2307/2421804
- Fender KM (1961) Family Cantharidae. In: Hatch MH (Ed.) Beetles of the Pacific Northwest. Part III: Pselaphidae and Diversicornia I. University of Washington Press, Seattle, 44–68.
- Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–299.
- Ford EJJ (1973) A revision of the genus *Petalium* LeConte in the United States, Greater Antilles, and the Bahamas (Coleoptera: Anobiidae). United States Department of Agriculture Technical Bulletin 1476: 1–40.
- Francis A, Cavers PB, Warwick SI (2009) The Biology of Canadian Weeds. 140. Hesperis matronalis L. Canadian Journal of Plant Science 89: 191–206. https://doi.org/10.4141/ CJPS08094
- Franz H, Besuchet C (1971) Scydmaenidae. In: Freude H, Harde KW, Lohse GA (Eds) Die K\u00e4fer Mitteleuropas, Band 3. Goecke & Evers, Krefeld, 271–303.
- Franzen B (1991) Vorläufige Mitteilung über eine Cryptophilus-Art neu für Mitteleuropa (Coleoptera: Languriidae). Mitteilungen der Arbeitsgemeinschaft Rheinischer Koleopterologen 1: 59–63.
- Fürsch H (1965) Die palaearktischen Arten der Scymnus-bipunctatus-Gruppe und die europäischen Vertreter der Untergattung Sidis (Col. Cocc.). Mitteilungen der Münchner Entomologischen Gesellschaft 55: 178–213.
- Fürsch H (1967) Coccinellidae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 7. Goecke & Evers, Krefeld, 227–278.
- Fürsch H (1987) Übersicht über die genera und Subgenera der Scymnini mit besonderer Berücksichtigung der Westpalaearktis (Insecta, Coleoptera, Coccinellidae). Entomologische Abhandlungen (Dresden) 51: 57–74.
- Gimmel ML (2013) Genus-level revision of the family Phalacridae (Coleoptera: Cucujoidea). Zootaxa 3605: 1–147. https://doi.org/10.11646/zootaxa.3605.1.1
- Gomez DF, Rabaglia RJ, Fairbanks KEO, Hulcr J (2018) North American Xyleborini north of Mexico: a review and key to genera and species (Coleoptera, Curculionidae, Scolytinae). ZooKeys 768: 19–68. https://doi.org/10.3897/zookeys.768.24697
- Good JA (1995) Habitat records of *Amischa* C.G. Thomson (Staphylinidae: Aleocharinae) from Ireland. Coleopterist 3: 77–79.
- Gordon RD (1976) The Scymnini (Coleoptera: Coccinellidae) of the United States and Canada: Key to genera and revision of *Scymnus, Nephus* and *Diomus*. Bulletin of the Buffalo Society of Natural Sciences 28: 1–362.
- Gordon RD (1985) The Coccinellidae (Coleoptera) of America north of Mexico. Journal of the New York Entomological Society 93: 1–912.
- Gustafson GT, Miller KB (2015) The New World whirligig beetles of the genus *Dineutus* Macleay, 1825 (Coleoptera, Gyrinidae, Gyrininae, Dineutini). ZooKeys 476: 1–135. https:// doi.org/10.3897/zookeys.476.8630

- Gwiazdowski RA, Foottit RG, Maw HEL, Hebert PDN, Imondi R, LaRocca G (2015) The Hemiptera (Insecta) of Canada: Constructing a reference library of DNA barcodes. PLoS ONE 10: e0125635. https://doi.org/10.1371/journal.pone.0125635
- Hackwell GA (1973) Biology of *Lasconotus subcostulatus* (Coleoptera: Colydiidae) with special reference to feeding behavior. Annals of the Entomological Society of America 66: 62–65. https://doi.org/10.1093/aesa/66.1.62
- Hajibabaei M, Janzen DH, Burns JM, Hallwachs W, Hebert PDN (2006) DNA barcodes distinguish species of tropical Lepidoptera. Proceedings of the National Academy of Sciences of the United States of America 103: 968–971. https://doi.org/10.1073/pnas.0510466103
- Halstead DGH (1981) Taxonomic notes on some *Attagenus* spp associated with stored products, including a new black species from Africa (Coleoptera: Dermestidae). Journal of Stored Product Research 17: 91–99. https://doi.org/10.1016/0022-474X(81)90007-2
- Hansen M (1987) 18 Fauna Entomologica Scandinavica The Hydrophiloidea (Coleoptera) of Fennoscandia and Denmark. EJ Brill, Copenhagen, 254 pp.
- Hansen M (2004) Hydrophilidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 2). Apollo Books, Stenstrup, 44–68.
- Hatch MH (1957) The beetles of the Pacific Northwest. Part II: Staphyliniformia. University of Washington Press, Seattle, 384 pp.
- Hebert PDN, Cywinska A, Ball SL, deWaard JR (2003) Biological identifications through DNA barcodes. Proceedings of the Royal Society of London. Series B: Biological Sciences 270: 313–321. https://doi.org/10.1098/rspb.2002.2218
- Hebert PDN, Penton EH, Burns JM, Janzen DH, Hallwachs W (2004) Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly *Astraptes fulgerator*. Proceedings of the National Academy of Sciences of the United States of America 101: 14812–14817. https://doi.org/10.1073/pnas.0406166101
- Hebert PDN, Ratnasingham S, Zakharov EV, Telfer AC, Levesque-Beaudin V, Milton MA, Pedersen S, Jannetta P, DeWaard JR (2016) Counting animal species with DNA barcodes: Canadian insects. Philosophical Transactions of the Royal Society of London. Series B, Biological sciences 371: e1001127. https://doi.org/10.1098/rstb.2015.0333
- Hendrich L, Morinière J, Haszprunar G, Hebert PDN, Hausmann A, Köhler F, Balke M (2015) A comprehensive DNA barcode database for Central European beetles with a focus on Germany: adding more than 3,500 identified species to BOLD. Molecular Ecology Resources 15: 795–818. https://doi.org/10.1111/1755-0998.12354
- Hendrickson RMJ, Drea JJ, Rose M (1991) A distribution and establishment program for *Chilocorus kuwanae* (Silvestri) (Coleoptera: Coccinellidae) in the United States. Proceedings of the Entomological Society of Washington 93: 197–200.
- Herman L (1972) Revision of *Bledius* and related genera. Part I. The *aequatorialis, mandibularis*, and *semiferrugineus* groups and two new genera (Coleopera, Staphylinidae, Oxytelinae). Bulletin of the American Museum of Natural History 149: 111–254.
- Hicks EA (1959) Check-list and Bibliography on the Occurrence of Insects in Birds' Nests. Iowa State College Press, Ames, 696 pp. https://doi.org/10.5962/bhl.title.6819
- Hoffmann A (1958) Faune de France 62. Coléoptères Curculionides. 3^{ème} partie. Fédération Française des Sociétés de Sciences Naturelles, Paris, 632 pp.

- Ivanova NV, deWaard JR, Hebert PDN (2006) An inexpensive, automation-friendly protocol for recovering high-quality DNA. Molecular Ecology Notes 6: 998–1002. https://doi. org/10.1111/j.1471-8286.2006.01428.x
- Jałoszynski P (2019) Notes on Nearctic genera *Catalinus* Casey and *Parascydmus* Casey (Coleoptera: Staphylinidae: Scydmaeninae). Zootaxa 4603: 145–158. https://doi.org/10.11646/ zootaxa.4603.1.7
- Jelínek J (2008) Ciidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 5). Apollo Books, Stenstrup, 55–62.
- Jelínek J, Audisio P (2007) Nitidulidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 459–491.
- Jendek E, Grebennikov VV, Bocak L (2015) Undetected for a century: Palaearctic Agrilus ribesi Schaefer (Coleoptera: Buprestidae) on currant in North America, with adult morphology, larval biology and DNA barcode. Zootaxa 4034: 1–112. https://doi.org/10.11646/ zootaxa.4034.1.5
- Johnson C (1997) *Clambus simsoni* Blackburn (Col., Clambidae) new to Britain with notes on its wider distribution. Entomologist's Monthly Magazine 133: 161–164.
- Johnson P (2002) Elateridae Leach, 1815. In: Arnett RHJ, Thomas MC, Skelley PE, Frank JH (Eds) American Beetles (Vol. 2). Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, 160–173.
- Kalik V (1992) Dermestidae. In: Lohse GA, Lucht WH (Eds) Die K\u00e4fer Mitteleuropas, Band 13 (2. Supplementband). Goecke & Evers, Krefeld, 83–86.
- Kazantsev SV (1998) Новые российские виды *Dichelotarsus* (Coleoptera, Cantharidae) [New Russian species of *Dichelotarsus* (Coleoptera, Cantharidae)]. Zoologicheskii zhurnal 77: 572–575.
- Kazantsev SV, Brancucci M (2007) Cantharidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 234–298.
- Kissinger DG (1964) Curculionidae of America north of Mexico. A key to genera. Taxonomic Publications, South Lancaster, 143 pp.
- Klausnitzer B (1976) Zur Kennits der Nordamerikanischen Arten der Gattung *Cyphon* Paykull (Col., Helodidae) (40. Beitrag zur Kennits der Helodidae). Polskie Pismo Entomologiczne 46: 439–453.
- Klausnitzer B (2006) Scirtidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 3). Apollo Books, Stenstrup, 316–323.
- Klimaszewski J (1982) Studies of Myllaenini (Coleoptera: Staphylinidae, Aleocharinae). 1. Systematics, phylogeny, and zoogeography of Nearctic *Myllaena* Erichson. The Canadian Entomologist 114: 181–242. https://doi.org/10.4039/Ent114181-3
- Klimaszewski J, Brunke AJ, Assing V, Langor DW, Newton AF, Bourdon C, Pelletier GA, Webster RP, Herman L, Perdereau L, Davies A, Smetana A, Chandler DS, Majka CG, Scudder GGE (2013) Synopsis of Adventive Species of Coleoptera (Insecta) Recorded from Canada. Part 2: Staphylinidae. Pensoft Publishers, Sofia, 360 pp.
- Klimaszewski J, Langor D, Batista R, Duval J-A, Majka CG, Scudder GGE, Bousquet Y (2012) Synopsis of Adventive Species of Coleoptera (Insecta) Recorded from Canada. Part 1: Carabidae. Pensoft Publishers, Sofia, 96 pp.

- Klimaszewski J, Langor D, Majka CG, Bouchard P, Bousquet Y, LeSage L, Smetana A, Sylvestre P, Pelletier G, Davies A, DesRochers P, Goulet H, Webster R, Sweeney J (2010) Review of Adventive Species of Coleoptera (Insecta) Recorded from Eastern Canada. Pensoft Series Faunistica No. 94. Pensoft Publishers, Sofia, 272 pp.
- Klimaszewski J, Langor DW, Hammond HEJ, Pelletier GA, Bousquet Y, Bourdon C, Webster RP, Borowiec L, Scudder GGE, Majka CG (2015) Synopsis of Adventive Species of Coleoptera (Insecta) Recorded from Canada. Part 3: Cucujoidea. Pensoft Publishers, Sofia, 172 pp.
- Klimaszewski J, Langor DW, Smith ABT, Hoebeke ER, Davies A, Pelletier GA, Douglas H, Webster RP, Bourdon C, Borowiec L, Scudder GGE (2017) Synopsis of Adventive Species of Coleoptera (Insecta) Recorded from Canada. Part 4: Scarabaeoidea, Scirtoidea, Buprestoidea, Byrrhoidea, Elateroidea, Derodontoidea, Bostrichoidea, and Cleroidea. Pensoft Publishers, Sofia, 215 pp.
- Klimaszewski J, Webster R, Langor D, Brunke AJ, Davies A, Bourdon C, Labrecque M, Newton AF, Dorval J-A, Frank JH (2018) Aleocharine Rove Beetles of Eastern Canada (Coleoptera, Staphylinidae, Aleocharinae): a Glimpse of Megadiversity. Springer, Cham, 879 pp.
- Knížek M (2011) Scolytinae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 7). Apollo Books, Stenstrup, 204–251.
- Koch K (1989a) Die Käfer Mitteleuropas, Ökologie (Vol. 1). Goecke & Evers Verlag, Krefeld, 440 pp.
- Koch K (1989b) Die K\u00e4fer Mitteleuropas, \u00f6kologie (Vol. 2). Goecke & Evers Verlag, Krefeld, 382 pp.
- Koch K (1992) Die K\u00e4fer Mitteleuropas, \u00f6kologie (Vol. 3). Goecke & Evers Verlag, Krefeld, 389 pp.
- Kolov SV, Korotyaev BA (2017) On establishing of two weevils (Coleoptera, Curculionidae: Entiminae) damaging fruit and berry crops in Southeastern Kazakhstan. Entomological Review 97: 404–405. https://doi.org/10.1134/S0013873817030149
- Konstantinov AS, Baselga A, Grebennikov VV, Prena J, Lingafelter SW (2011) Revision of the Palearctic *Chaetocnema* Species (Coleoptera: Chrysomelidae: Galerucinae: Alticini). Pensoft Publishers, Sofia, 363 pp.
- Kovář I (2007) Coccinellidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 568–631.
- Landry J-F, Nazari V, DeWaard JR, Mutanen M, Lopez-Vaamonde C, Huemer P, Hebert PDN (2013) Shared but overlooked: 30 species of Holarctic Microlepidoptera revealed by DNA barcodes and morphology. Zootaxa 3749(1): 1–93. https://doi.org/10.11646/ zootaxa.3749.1.1
- Lane MC (1948) Some generic corrections in the Elateridae- I. (Coleoptera). Proceedings of the Entomological Society of Washington 50: 179–182.
- Larochelle A, Lariviere M-C (2003) A Natural History of the Ground-beetles (Coleoptera: Carabidae) of America North of Mexico. Pensoft Publishers, Sofia, 584 pp.
- Larsen LM, Nielsen JK, Sørensen H (1992) Host plant recognition in monophagous weevils: Specialization of *Ceutorhynchus inaffectatus* to glucosinolates from its host plant *Hesperis matronalis*. Entomologia Experimentalis et Applicata 64: 49–55. https://doi. org/10.1111/j.1570-7458.1992.tb01593.x
- Lasnier C, McFadden-Smith W, Moreau D, Bouchard P, Vincent C (2019) Guide to the key arthropods of vineyards of Eastern Canada. Ottawa.
- Lawrence JF (1971) Revision of the North American Ciidae (Coleoptera). Bulletin of the Museum of Comparative Zoology at Harvard College 142: 419–522.
- Lawrence JF, Slipinski A, Seago AE, Thayer MK, Newton AF, Marvaldi AE (2011) Phylogeny of the Coleoptera based on morphological characters of adults and larvae. Annales Zoologici 61: 1–217. https://doi.org/10.3161/000345411X576725
- LeConte JL (1878) Descriptions of new species. In: Hubbard HG, Schwarz EA (Eds) The Coleoptera of Michigan. Proceedings of the American Philosophical Society 17: 593–626.
- Lees DC, Lack HW, Rougerie R, Hernandez-Lopez A, Raus T, Avtzis ND, Augustin S, Lopez-Vaamonde C (2011) Tracking origins of invasive herbivores through herbaria and archival DNA: the case of the horse-chestnut leaf miner. Frontiers in Ecology and the Environment 9: 322–328. https://doi.org/10.1890/100098
- Leseigneur L (1998) Throscidae. In: Lucht W, Klausnitzer B (Eds) Die Käfer Mitteleuropas, Band 15 (4. Supplementband). Spektrum Akademischer Verlag, Heidelberg, 222–231.
- Leseigneur L (2005) Description de *Trixagus meybohmi* n. sp. et note sur la morphologie des *Trixagus* du groupe *carinifrons* (Coleoptera, Throscidae). Bulletin de la Société ento-mologique de France 110: 89–96.
- Leseigneur L (2007) Throscidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 87–89.
- Liljeblad E (1945) Monograph of the family Mordellidae (Coleoptera) of North America, north of Mexico. Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 62. University of Michigan Press, Ann Arbor, 229 pp.
- Lindroth CH (1968) The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Part 5. Opuscula Entomologica Supplementum 33: 649–944.
- Löbl I (1960) Die tschechoslowakischen Arten der Gattung *Bibloplectus* Reitter (Col. Pselaphidae). Acta Societatis Entomologicae Čechosloveniae 57: 58–67.
- Löbl I (2006) Clambidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 3). Apollo Books, Stenstrup, 314–316.
- Lockwood JL, Hoopes MF, Marchetti MP (2013) Invasion Ecology (2nd ed.). Wiley-Blackwell, Chichester, 444 pp.
- Lohse GA (1967) Cisidae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 7. Goecke & Evers, Krefeld, 280–295.
- Lohse GA (1979) Helodidae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 6. Goecke & Evers, Krefeld, 249–263.
- Lohse GA (1983) Ceutorhynchinae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 11. Goecke & Evers, Krefeld, 180–253.
- Lonsdale O, Huber JT (2011) Insect Collections of Canada Series: Canadian National Collection of Insects, Arachnids & Nematodes, Ottawa. Newsletter of the Biological Survey of Canada 30: 15–40.
- Lopes-Andrade C, Webster RP, Webster VL, Alderson CA, Hughes CC, Sweeney JD (2016) The Ciidae (Coleoptera) of New Brunswick, Canada: New records and new synonyms. ZooKeys 573: 339–366. https://doi.org/10.3897/zookeys.573.7445

- Lord NP, Nearns EH, Miller KB (2011–2013) Ironclad ID: Tool for Diagnosing Ironclad and Cylindrical Bark Beetles (Coleoptera: Zopheridae) of North America north of Mexico. The University of New Mexico and Center for Plant Health Science and Technology, USDA, APHIS, PPQ. http://cerambycids.com/ironcladid/index.html
- Luginbill P, Painter HR (1953) May beetles of the United States and Canada. United States Department of Agriculture Technical Bulletin 1060: 1–102.
- Majka CG, Klimaszewski J, Lauff RF (2006) New Coleoptera records from owl nests in Nova Scotia, Canada. Zootaxa 1194: 33–47.
- Majka CG, LeSage L (2010) *Chaetocnema* flea beetles (Coleoptera: Chrysomelidae, Alticini) of the Maritime provinces of Canada. Journal of the Acadian Entomological Society 6: 34–38.
- Maxwell SL, Fuller RA, Brooks TM, Watson JEM (2016) Biodiversity: The ravages of guns, nets and bulldozers. Nature 536: 143–145. https://doi.org/10.1038/536143a
- Mertlik J, Leseigneur L (2007) The species of the family Throscidae (Coleoptera: Elateroidea) Czech and Slovak Republics. Elateridarium 1: 1–55.
- Meybohm H (2004) *Clambus lohsei* n. sp. aus der Umgebung von Hamburg (Coleoptera, Clambidae). Entomologische Blätter 100: 13–18.
- Mohr K-H (1966) Chrysomelidae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 9. Goecke & Evers, Krefeld, 95–280.
- Muona J (1984) Review of the Palearctic Aleocharinae also occuring in North America (Coleoptera: Staphylinidae). Entomologica Scandinavica 15: 227–231. https://doi. org/10.1163/187631284X00190
- Muona J (1990) The Fennoscandian and Danish species of the genus *Amischa* Thomson (Coleoptera, Staphylinidae). Entomologisk Tidsskrift 111: 17–24.
- Mutanen M, Hausmann A, Hebert PDN, Landry J-F, de Waard JR, Huemer P (2012) Allopatry as a Gordian knot for taxonomists: patterns of DNA barcode divergence in arctic-alpine Lepidoptera. PLoS ONE 7: e47214. https://doi.org/10.1371/journal.pone.0047214
- Nikitsky NB (2008) Mycetophagidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 5). Apollo Books, Stenstrup, 51–55.
- Nyholm T (1972) Die nordeuropäischen Arten der Gattung *Cyphon* Paykull (Coleoptera). Entomologica Scandinavica Supplementum 3: 1–100.
- O'Brien CW, Wibmer GJ (1982) Annotated checklist of the weevils (Curculionidae sensu lato) of North America, Central America, and the West Indies (Coleoptera: Curculionoidea). Memoirs of the American Entomological Institute 34: 1–382.
- O'Keefe ST (2001) Scydmaenidae Leach, 1815. In: Arnett RH, Thomas MC (Eds) American Beetles (Vol. 1). Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. CRC Press, Boca Raton, 259–267.
- Owens BE, Carlton CE (2017) Seven new species of *Bibloplectus* Reitter (Coleoptera: Staphylinidae: Pselaphinae) from Eastern United States with notes on distributions of previously described species. Zootaxa 4243: 139–152. https://doi.org/10.11646/zootaxa.4243.1.6
- Palm T (1961) Svensk Insektfauna 9. Skalbaggar, Coleoptera. Kortvingar: Fam. Staphylinidae, Häfte 2. Underfam. Oxytelinae, Oxyporinae, Steninae, Euaesthetinae. Entomologiska Föreningen i Stockholm, Stockholm, 126 pp.

- Palm T (1963) Svensk Insektfauna 9. Skalbaggar, Coleoptera. Kortvingar: Fam. Staphylinidae, Häfte 3. Underfam. Paederinae, Staphylininae. Entomologiska Föreningen i Stockholm, Stockholm, 168 pp.
- Palm T (1968) Svensk Insektfauna 9. Skalbaggar. Coleoptera, Kortvingar: Fam. Staphylinidae, Häfte 5. Underfam. Aleocharinae (*Deinopsis-Trichomicra*). Entomologiska Föreningen i Stockholm, Stockholm, 112 pp.
- Palm T (1970) Svensk Insektfauna 9. Skalbaggar. Coleoptera, Kortvingar: Fam. Staphylinidae, Häfte 6. Underfam. Aleocharinae (*Atheta*). Entomologiska Föreningen i Stockholm, Stockholm, 180 pp.
- Park O (1929) Taxonomic studies in Coleoptera, with notes upon certain species of beetles in the Chicago area, I. Journal of the New York Entomological Society 37: 429–436.
- Parsons CT (1975) Revision of Nearctic Mycetophagidae (Coleoptera). The Coleopterists Bulletin 29: 93–108.
- Pavlov IE (1960) Ecology of cereal-stem flea-beetles (Coleoptera, Chrysomelidae, Halticinae) and measures for their control [In Russian]. Entomologicheskoe Obozrenie 39: 775–795.
- Peacock ER (1979) *Attagenus smirnovi* Zhantiev (Coleoptera: Dermestidae) a species new to Britain, with keys to the adults and larvae of British *Attagenus*. Entomologist's Gazette 30: 131–136.
- Pearce EJ (1957) Coleoptera Pselaphidae. Handbooks for the identification of British insects (Vol. IV), part 9. Royal Entomological Society, London, 32 pp. http://www.royensoc. co.uk/sites/default/files/Vol04_Part09.pdf
- Pelletier GA, Hébert C (2014) The Cantharidae of Eastern Canada and Northeastern United States. Canadian Journal of Arthropod Identification 25: 1–246. https://doi.org/10.3752/ cjai.2014.25
- Pentinsaari M, Hebert PDN, Mutanen M (2014) Barcoding Beetles: A regional survey of 1872 species reveals high identification success and unusually deep interspecific divergences. PLoS ONE 9: e108651. https://doi.org/10.1371/journal.pone.0108651
- Perreau M (2004) Leiodidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 2). Apollo Books, Stenstrup, 133–203.
- Pimentel D (2011) Environmental and economic costs associated with alien invasive species in the United States. In: Pimentel D (Ed.) Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species. CRC Press, Boca Raton, 411–430. https://doi.org/10.1201/b10938-26
- Rassi P, Karjalainen S, Clayhills T, Helve E, Hyvärinen E, Laurinharju E, Malmberg S, Mannerkoski I, Martikainen P, Mattila J, Muona J, Pentinsaari M, Rutanen I, Salokannel J, Siitonen J, Silfverberg H (2015) Kovakuoriaisten maakuntaluettelo 2015 [Provincial List of Finnish Coleoptera 2015]. Sahlbergia 21: 1–164. http://www.luomus.fi/sites/default/files/sahlbergia/sahlbergia_21_S1_2015.pdf
- Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System (http://www. barcodinglife.org). Molecular Ecology Notes 7: 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x
- Ratnasingham S, Hebert PDN (2013) A DNA-based registry for all animal species: the Barcode Index Number (BIN) system. PLoS ONE 8: e66213. https://doi.org/10.1371/journal.pone.0066213

- Reibnitz J (1999) Verbreitung und Lebensräume der Baumschwammfresser Südwestdeutschlands (Coleoptera: Cisidae). Mitteilungen des Entomologischen Vereins Stuttgart 34: 3–74.
- Reid CAM (1991) Notes on distribution of *Myllaena* spp. (Col., Staphylinidae) in Buckinghamshire and north-east England. Entomologist's Monthly Magazine 127: 1–24.
- Rheinheimer J, Hassler M (2013) Die Rüsselkäfer Baden-Württembergs (2nd ed.). Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW), Ubstatdt-Weiher, 944 pp.
- Riedl H, Taschenberg EF (1984) Grape cane gallmaker Ampeloglypter sesostris (LeConte). Grape IPM. Insect Identification Sheet No. 2. New York State IPM Program. Cornell University fact sheet. https://ecommons.cornell.edu/bitstream/handle/1813/43098/grape-canegallmaker-FS-NYSIPM.pdf
- Riley EG, Clark SM, Flowers RW, Gilbert AJ (2002) Chrysomelidae Latreille, 1802. In: Arnett RH, Thomas MC, Skelley PE, Frank JH (Eds) American Beetles (Vol. 2). Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, 617–691.
- Rougerie R, Lopez-Vaamonde C, Barnouin T, Delnatte J, Moulin N, Noblecourt T, Nusillard B, Parmain G, Soldati F, Bouget C (2015) PASSIFOR: A reference library of DNA barcodes for French saproxylic beetles (Insecta, Coleoptera). Biodiversity Data Journal 3: e4078. https://doi.org/10.3897/BDJ.3.e4078
- Ruta R, Jałoszynski P, Sienkiewicz P, Konwerski S (2011) Erotylidae (Insecta, Coleoptera) of Poland – problematic taxa, updated keys and new records. ZooKeys 134: 1–13. https:// doi.org/10.3897/zookeys.134.1673
- Rutanen I (2015) Orthoperus Stephens -suvun kovakuoriaisten esiintymisestä Suomessa (Coleoptera: Corylophidae) [On the occurence of the species of Orthoperus Stephens in Finland (Coleoptera, Corylophidae)]. Sahlbergia 21: 40–48.
- Rutanen I, Martikainen P (2014) *Longitarsus pratensis* (Panzer) -ryhmän lajit Suomessa [*Longitarsus pratensis* (Panzer) species group in Finland]. Sahlbergia 20: 28–35. https://www.luomus.fi/sites/default/files/sahlbergia/2014/Sahlbergia_2014_1-Rutanen_Martikainen.pdf
- Saunders MC, Tobin PC (2000) Grape Cane Gallmaker (Coleoptera: Curculionidae) and its impact on cultivated grapes. Journal of Economic Entomology 93: 795–799. https://doi. org/10.1603/0022-0493-93.3.795
- Scheibner RA (1963) A taxonomic study of the genus *Ceutorhynchus* (Coleoptera, Curculionidae). PhD Thesis, Michigan State University, Department of Entomology, 156 pp.
- Schülke M (2012a) Oxytelinae. In: Assing V, Schülke M (Eds) Die Käfer Mitteleuropas, Band 4 (2. Auflage). Spektrum Akademischer Verlag, Heidelberg, 283–284.
- Schülke M (2012b) Tachyporinae. In: Assing V, Schülke M (Eds) Die Käfer Mitteleuropas, Band 4 (2. Auflage). Spektrum Akademischer Verlag, Heidelberg, 130–199.
- Schülke M, Smetana A (2015) Staphylinidae. In: Löbl I, Löbl D (Eds) Catalogue of Palaearctic Coleoptera (Vol. 2). Brill, Leiden, 901–1134. https://doi.org/10.1163/9789004296855
- Silfverberg H (2010) Enumeratio renovata Coleopterorum Fennoscandiae, Daniae et Baltiae. Sahlbergia 16: 1–144.
- Steiner WEJ, Singh BP (1987) Redescription of an ergot beetle, Acylomus pugetanus Casey, with immature stages and biology (Coleoptera: Phalacridae). Proceedings of the Entomological Society of Washington 89: 744–758.

- Steinke D, Breton V, Berzitis E, Hebert PDN (2017) The School Malaise Trap Program: Coupling educational outreach with scientific discovery. PLoS Biology 15: e2001829. https:// doi.org/10.1371/journal.pbio.2001829
- Stengaard Hansen L, Åkerlund M, Grøntoft T, Ryhl-Svendsen M, Schmidt AL, Bergh JE, Vagn Jensen KM (2012) Future pest status of an insect pest in museums, *Attagenus smirnovi*: Distribution and food consumption in relation to climate change. Journal of Cultural Heritage 13: 22–27. https://doi.org/10.1016/j.culher.2011.05.005
- Stephan KH (1989) The Bothrideridae and Colydiidae of America North of Mexico (Coleoptera: Clavicornia and Heteromera). Occasional Papers of the Florida State Collection of Arthropods 6: 1–65.
- Švec Z (2002) Revision of the African species of the genus *Tinodemus* Guillebeau (Coleoptera, Phalacridae). Results of the entomological expeditions of the Museum of Natural History, Berlin to Africa. 76th contribution. Zoosystematics and Evolution 78: 217–256. https:// doi.org/10.1002/mmnz.20020780204
- Švec Z (2007) Phalacridae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera (Vol. 4). Apollo Books, Stenstrup, 506–513.
- Van Tassell ER (2001) Hydrophilidae Latreille, 1802. In: Arnett RH, Thomas MC (Eds) American Beetles (Vol. 1). Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. CRC Press, Boca Raton, 187–208. https://doi.org/10.1201/9781482274325
- Thompson RT (1958) Coleoptera Phalacridae. Handbooks for the identification of British insects (Vol. V), part 5(b). Royal Entomological Society, London, 17 pp. http://www.roy-ensoc.co.uk/sites/default/files/Vol05_Part05b.pdf
- Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive horse-chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). Molecular Ecology 18: 3458–3470. https://doi. org/10.1111/j.1365-294X.2009.04290.x
- Vappula NA (1965) Pests of cultivated plants in Finland. Acta Entomologica Fennica 19: 1–239.
- Vogt H (1967a) Mycetophagidae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 7. Goecke & Evers, Krefeld, 191–196.
- Vogt H (1967b) Phalacridae. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 7. Goecke & Evers, Krefeld, 158–166.
- Warchalowski A (1996) Übersicht der Westpaläarktischen Arten der Gattung Longitarsus Berthold, 1827 (Coleoptera: Chrysomelidae: Halticinae). Genus (Supplement). Wroclaw, 266 pp.
- Webster RP, Davies AE, Klimaszewski J, Bourdon C (2016) Further contributions to the staphylinid fauna of New Brunswick, Canada, and the USA, with descriptions of two new *Proteinus* species (Coleoptera, Staphylinidae). ZooKeys 573: 31–83. https://doi. org/10.3897/zookeys.573.7830
- Webster RP, Klimaszewski J, Pelletier G, Savard K (2009) New Staphylinidae (Coleoptera) records with new collection data from New Brunswick, Canada. I. Aleocharinae. ZooKeys 22: 171–248. https://doi.org/10.3897/zookeys.22.152

- Wheeler AG, Hoebeke ER (2009) Adventive (Non-Native) Insects: Importance to Science and Society. In: Foottit RG, Adler PH (Eds) Insect Biodiversity: Science and Society. Wiley-Blackwell, Oxford, 475–521. https://doi.org/10.1002/9781444308211.ch21
- White RE (1982) A Catalog of the Coleoptera of America North of Mexico. Family: Anobiidae. Agriculture Handbook Number 529–70. United States Department of Agriculture, Agricultural Research Service, Washington, 59 pp.
- White RE (1996) A revision of the genus *Chaetocnema* of America north of Mexico (Coleoptera: Chrysomelidae). Contributions of the American Entomological Institute 29: 1–158.
- Williams SA (1969) The British species of the genus Amischa (Thomson) (Col., Staphylinidae), including A. soror Kraatz, an addition to the list. Entomologist's Monthly Magazine 113: 1–250.
- Wittmer W (1970) Zur Kenntnis der Gattung *Malthodes* Kies. (Col., Cantharidae). Entomologische Arbeiten aus dem Museum G. Frey 21: 13–107.
- Wittmer W (1979) Malthinini. In: Freude H, Harde KW, Lohse GA (Eds) Die Käfer Mitteleuropas, Band 6. Goecke & Evers, Krefeld, 40–51.

Supplementary material I

Table S1. Detailed collection data, GenBank accession numbers, and institutional storage information of the studied specimens

Authors: Mikko Pentinsaari, Robert Anderson, Lech Borowiec, Patrice Bouchard, Adam Brunke, Hume Douglas, Andrew B.T. Smith, Paul D. N. Hebert Data type: species data

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/zookeys.894.37862.suppl1

RESEARCH ARTICLE



New distributional records for sixteen Mordellidae species from the Western Palearctic (Insecta, Coleoptera, Mordellidae)

Dávid Selnekovič¹, Enrico Ruzzier²

l Department of Zoology, Faculty of Natural Sciences, Comenius University in Bratislava Ilkovičova 6, SK-84215, Bratislava, Slovakia **2** World Biodiversity Association Onlus, c/o Museo Civico di Storia Naturale, Lungadige Porta Vittoria 9, Verona, Italy

Corresponding author: Dávid Selnekovič (david.selnekovic@uniba.sk)

Academic editor: W. Steiner Received 30 August 2019 Accepted 11 October 2019 Published 4 December 2	2019
http://zoobank.org/90BFBE36-8158-45D9-9421-2CE7A03F1452	

Citation: Selnekovič D, Ruzzier E (2019) New distributional records for sixteen Mordellidae species from the Western Palearctic (Insecta, Coleoptera, Mordellidae). ZooKeys 894: 151–170. https://doi.org/10.3897/zookeys.894.39584

Abstract

A list of 22 new distributional records is presented for 16 Mordellidae species from the Western Palearctic: *Variimorda caprai* (Franciscolo, 1951) (Montenegro); *V. mendax* Méquignon, 1946 (Montenegro); *Mordellistena falsoparvula* Ermisch, 1956 (Bosnia and Herzegovina, Montenegro); *M. olympica* Ermisch, 1965 (Cyprus, Montenegro); *M. kraatzi* Emery, 1876 (Morocco); *M. longicornis* Mulsant, 1856 (Morocco); *M. dives* Emery, 1876 (Kazakhstan); *M. krujanensis* Ermisch, 1963 (Montenegro); *M. tarsata* Mulsant, 1856 (Cyprus, North Macedonia); *M. michalki* Ermisch, 1956 (Kyrgyzstan); *M. thuringiaca* Ermisch, 1963 (Bulgaria, Montenegro, Slovakia, Spain); *M. koelleri* Ermisch, 1956 (Italy, Montenegro); *Mordellistenula longipalpis* Ermisch, 1965 (Montenegro); *Mordellochroa milleri* (Emery, 1876) (Italy); *Dellamora palposa* Normand, 1916 (Italy). Information about the distributional range is summarised for each species, and notes on habitat and host plants are also provided.

Keywords

Bionomy, Bosnia and Herzegovina, Bulgaria, Cyprus, distribution, faunistics, host plants, Italy, Kazakhstan, Kyrgyzstan, Montenegro, *Mordellistena*, *Mordellochroa*, Morocco, North Macedonia, Slovakia, Spain

Introduction

Mordellidae Latreille, 1802 is a rather diverse but poorly known and sporadically studied family of beetles. It comprises more than 2300 described species distributed nearly worldwide except for the polar and subpolar zones. Mordellid beetles inhabit various ecosystems including tropical rainforests, temperate deciduous forests, grasslands and ruderal ecosystems. The majority of species are pollinivorous in adult stages, feeding on a wide variety of plant species. Exceptions are the members of the genus *Glipa* Leconte, 1859, reported to feed on fern spores (Takakuwa 2000), or the South American *Boatia albertae* Franciscolo, 1985 which was found to have the foregut filled with fungal spores (Lawrence and Ślipiński 2010). Larvae of some mordellid beetles are wood borers (e.g., *Mordella* Linnaeus, 1758, some *Mordellistena* Costa, 1854), the others develop in sporocarps of Polyporaceae fungi (e.g., *Curtimorda* Méquignon, 1946, *Mordella marginata* Melsheimer, 1845), or in stems of various herbaceous plants (e.g., *Mordellistena* Costa, 1854, *Mordellistenula* Shchegoleva-Barovskaya, 1930). In some cases, mordellid larvae seem to have predaceous habits against other insect larvae (Tooker and Hanks 2004) or can be inquilines of termite colonies (Hill 1922).

The majority of distribution records available on Palearctic Mordellidae are usually included in publications focused primarily on the taxonomy (e.g., Ermisch 1963b, 1965, 1977; Horák 1985; Plaza 1985). Several authors have summarised the distributional information on regional level (e.g., Ermisch 1956, 1963a, b, c, 1969b, 1977; Köstlin and Vogt 1971; Batten 1976b; Franciscolo 1995; Odnosum 2003, 2010; Zemoglyadchuk 2007; Ruzzier 2013; Ruzzier et al. 2017). Comprehensive catalogues were published, for instance, by Heyden et al. (1906), Csiki (1915), and Horák (2008). Despite the great effort of these authors, the knowledge of the distribution of many Palearctic species can be still considered poor, and several species remain to be known only from the localities stated in the original description.

Herein we provide new distributional and bionomical data obtained during the recent collecting activities of both authors (2010–2018) and by the re-examination of the material deposited in museums or private collections listed below. We also summarise the previously published distributional data and provide the lists of countries from which the species have been previously reported.

Materials and methods

The present study is based on the material sampled by the authors or accessed from the museums and private collections listed below. Specimens were collected individually from flowers or by sweeping the vegetation. Larvae of *Mordellistena* species were reared from stems of herbaceous plants collected in April, cut to the smaller pieces (ca. 20 cm), transferred to the laboratory, and stored in plastic containers with air access. Adult specimens were killed in ethyl acetate. Dry specimens were relaxed in water with a small amount of acetic acid, then dissected and glued on cards. Dissected genitals were glued with the respective specimen using dimethyl hydantoin formaldehyde (DMHF) or stored in micro-vials containing glycerol and pinned under the specimen. Habitus images were taken by Cannon 5D mark IV attached to Zeiss Axio-Zoom V-16 stereomicroscope with diffuse LED lighting, stacked in Zerene Stacker 1.04 and subsequently edited in Adobe Photoshop CC.

Identifications were carried out using original species descriptions, identification keys (e.g., Ermisch 1956, 1963b, 1969a, 1977) or by comparison with the type material. Each specimen was labelled with identification data containing full species name, name of the identifier and year when the identification was made. Examined specimens are deposited in the following collections:

DSPC	Dávid Selnekovič private collection, Bratislava, Slovakia
EEPC	Eduard Ezer private collection, Zlín, Czech Republic
ERPC	Enrico Ruzzier private collection, Mirano, Italy
HNHM	Hungarian Natural History Museum, Budapest, Hungary
SNMB	Museum of Natural History, Slovak National Museum, Bratislava, Slovakia
SNSD	Senckenberg Naturhistorische Sammlungen, Dresden, Germany

In the section "New records", we provide the data on examined material concerning only those countries from which the species are reported for the first time. The "Distribution" section contains the list of countries from which the species have been previously reported, followed by the citation of its first appearance in the published sources. In the "Remarks" section, we provide information about habitat preferences, host plants and collecting circumstances (if available).

Results

In the list below, we present 22 new country-level records of 16 Mordellidae species. The list is based on 201 examined specimens from thirty localities in the Western Palearctic. We also provide information about distribution and bionomy for each species.

Variimorda (Galeimorda) caprai (Franciscolo, 1951)

Fig. 1A

Mordella (s. str.) *caprai* Franciscolo, 1951: 7–9 [type locality: Shkodër, Albania]. *Variimorda caprai*: Ermisch 1969b: 846, 849. *Variimorda (Galeimorda) caprai*: Horák 1985: 15.

New records. MONTENEGRO • 43 $\Diamond \Diamond$, 13 $\heartsuit \Diamond$; Bar env., Volujica hill; 42°04'29.0"N, 19°06'11.8"E; 20 June 2011; D. Selnekovič leg.; slopes with dry grassland vegetation; on the flowers of *Helichrysum*; D. Selnekovič det.; DSPC • 15 $\Diamond \Diamond$, 12 $\heartsuit \heartsuit$; Bar env., Ribnjak Monastery; 42°07'56"N, 19°07'33"E, 22 June 2011; D.



Figure I. A Variimorda (Galeimorda) caprai (Franciscolo, 1951), male B Mordellistena (s. str.) dives Emery, 1876, male.

Selnekovič leg.; slopes with dry grassland vegetation; on the flowers of *Helichrysum*; D. Selnekovič det.; DSPC.

Distribution. Albania (Franciscolo 1951), Montenegro (new country record).

Remarks. Variimorda caprai was described based on three male specimens from Shkodër, Albania and since then no other record has been published. In 2011, the first author collected 83 specimens in the environment of Bar in Montenegro on the slopes with xerothermophilous grassland vegetation (Fig. 2). Specimens were found feeding on the flowers of *Helichrysum*. The immature stages and their host plants remain unknown.



Figure 2. Mediterranean xeric grasslands with flowering *Helichrysum* on Volujica hill in Montenegro, 42°04'29.0"N, 19°06'11.8"E. *Variimorda caprai* (Franciscolo, 1951), *Mordellistena olympica* Ermisch, 1965 and *Mordellistenula longipalpis* Ermisch, 1965 recorded from this locality are new to Montenegro.

Variimorda (s. str.) mendax Méquignon, 1946

- *Mordella (Variimorda) mendax* Méquignon, 1946: 63, 71–72 [type locality: Laigneville, France].
- Mordella (Variimorda) mendax var. devillei Méquignon, 1946: 71–72 [type locality: Bordeaux, France].
- *Mordella (Variimorda) mendax* var. *chobauti* Méquignon, 1946: 71–72 [type locality: La Bonde, France].

Variimorda (s. str.) mendax: Ermisch 1956: 277.

New records. MONTENEGRO • 1 3; Bar; 42°06'36"N, 19°05'20"E; 19 June 2011; D. Selnekovič leg.; ruderal vegetation in urban environment; on the flowers of *Daucus carota*; D. Selnekovič det.; DSPC.

Distribution. Albania (Ermisch 1969b), Algeria (Méquignon 1946), Austria (Méquignon 1946), Azerbaijan (Ermisch 1956), Bosnia and Herzegovina (Ermisch 1956), Bulgaria (Ermisch 1969b), Croatia (Ermisch 1956), Czech Republic (Méquignon 1946), France (Méquignon 1946), Georgia (Horák 2008), Germany (Ermisch 1956), Greece (Ermisch 1969), Hungary (Ermisch 1956), Italy (Ermisch 1956; Ruzier 2013), Montenegro (**new country record**), Poland (Borowiec 1996), Russia (Er-

misch 1956), Slovakia (Horák 2008), Spain (Batten 1976b), Switzerland (Méquignon 1946), Ukraine (Odnosum 2010).

Remarks. Variimorda mendax inhabits various grassland and ruderal habitats. Adults are usually found feeding on the flowers of *Daucus carota*. Larvae and host plants remain unknown.

Dellamora palposa Normand, 1916

Dellamora palposa Normand, 1916: 285–286 [type locality: Téboursouk, Tunisia].

New records. ITALY • 1 ♂; S. Angelo Muxaro, Sicilia; 23 Mar. 2017; L. Colacurcio leg.; E. Ruzzier det.; ERPC.

Distribution. Cyprus (Horák 2008), Greece (Ermisch 1963c), Iran (Samin et al. 2016), Italy (**new country record**), Lebanon (Ermisch 1941), Mongolia (Samin et al. 2016), Morocco (Horák 2008), Portugal (Ermisch 1963c), Spain (Ermisch 1941), Tunisia (Normand 1916) Turkey (Horák 2008), Turkmenistan (Odnosum 1984).

Remarks. Adults of *D. palposa* were reported to be found on the flowers of lotus (*Nelumbo*) (Normand 1916) and *Euphorbia* (Odnosum 1984). Larval stages and their bionomy remain unknown.

Mordellistena (s. str.) dives Emery, 1876

Fig. 1B

Mordellistena (s. str.) dives Emery, 1876: 95 [type locality: Sarepta, Russia].

New records. KAZAKHSTAN • 2 ♂♂; Aktjubinsk reg., Temir riv.; 27 May 1999; D. Selnekovič det.; DSPC.

Distribution. Armenia (Horák 2008), Georgia (Horák 2008), Hungary (Kaszab 1979), Kazakhstan (**new country record**), Romania (Schilsky 1895), Russia (Emery 1876). Schilsky (1895) reported *M. dives* from "Süd-Ungarn: Mehadia" which is situated in present-day Romania.

Remarks. Information about bionomy and host plants remain unknown.

Mordellistena (s. str.) falsoparvula Ermisch, 1956

Mordellistena (s. str.) falsoparvula Ermisch, 1956: 281 [type locality: Mecklenburg, Germany].

New records. BOSNIA AND HERZEGOVINA • 1 \bigcirc ; Bosnia; E. Bokor leg.; D. Selnekovič det.; HNHM • 2 \bigcirc \bigcirc ; Sarajevo; Apfelbeck leg.; D. Selnekovič det.; HNHM.

MONTENEGRO • 1 ♂; Durdevica Tara Bridge env.; 43°08'49.4"N, 19°17'52.1"E, 3. June 2010; D. Selnekovič leg.; meadow; D. Selnekovič det.; DSPC.

Distribution. Austria (Ermisch 1956), Belarus (Zemoglyadchuk 2007), Bosnia and Herzegovina (**new country record**), Bulgaria (Ermisch 1969a), Czech Republic (Ermisch 1956), Deutschland (Ermisch 1956), Estonia (Silfverberg 2004), France (Ermisch 1977), Georgia (Horák 2008), Hungary (Ermisch 1969a; Kaszab 1979), Italy (Ermisch 1969a; Ruzzier 2013), Kazakhstan (Odnosum 2010), Montenegro (**new country record**), Netherlands (Batten 1976a), Poland (Ermisch 1956; Borowiec 1996), Portugal (Horák 2008), Slovakia (Majzlan and Vidlička 2016), Switzerland (Borowiec 1996), Ukraine (Odnosum 2006), former Yugoslavia (Serbia and Montenegro) (Horák 2008).

Remarks. This species inhabits xerothermophilous and mesophilous grasslands and ruderal vegetation where the adults feed on flowers of herbaceous plants, e.g., *Chrysanthemum, Cirsium, Achillea* (Borowiec 1996). The larva was described by Odnosum (1983, 2010) and reported to develop in stems of *Artemisia absinthium* and *A. vulgaris.* The first author reared adults from stem of Apiaceae plant infested by larvae in southern Slovakia.

Mordellistena (s. str.) koelleri Ermisch, 1956

Mordellistena (s. str.) *koelleri* Ermisch, 1956: 289 [type locality: Hale, Lettiner Höhen, Germany].

New records. ITALY • 1 ♂; Magredi di Cordenons, Pordenone, Friuli-Venezia Giulia; 46°01'50"N, 12°43'33"E; 02 June 2018; E. Ruzzier leg.; E. Ruzzier det.; ERPC • 1 ♂; Treviso, Veneto; 45°50'04"N, 11°44'47"E; 17 June 2018; E. Ruzzier leg.; E. Ruzzier det.; ERPC. MONTENEGRO • 2 ♂♂; Prokletije Mountains, Grebaje valley; 42°31'53"N, 19°47'36"E; 2 Aug. 2016; D. Selnekovič leg.; D. Selnekovič det.; DSPC.

Distribution. Austria (Ermisch 1963b), Bosnia and Herzegovina (Ermisch 1963b), Bulgaria (Ermisch 1969b), Czech Republic (Ermisch 1963b), Denmark (Ermisch 1969a), France (Köstlin and Vogt 1971), Germany (Ermisch 1956), Hungary (Ermisch 1963b), Italy (**new country record**), North Macedonia (Ermisch 1969b), Poland (Borowiec 1996), Montenegro (**new country record**), Slovakia (Horák 1979), Spain (Horák 2008), Sweden (Kangas and Rutanen 1984), Switzerland (Köstlin and Vogt 1971), Ukraine (Odnosum 1993, 2010), former Yugoslavia (Horák 2008; without further information).

Remarks. Mordellistena koelleri inhabits various grassland habitats from lowlands to highlands reaching up to 1700 m a.s.l. (Köstlin and Vogt 1971) The adults feed on flowers of herbaceous plants. It was observed by the authors on the subpannonian steppes and calcareous grasslands in Slovakia on flowers of *Tithymalus*, on a pastured montane meadow in Montenegro on *Daucus carota*, and a sandy steppe in Italy on flowers of *Daucus carota*. The larvae and host plants remain unknown. Specimens examined for the present study were compared with the type series deposited in SNSD.

Mordellistena (s. str.) kraatzi kraatzi Emery, 1876

Mordellistena (s. str.) *kraatzi kraatzi* Emery, 1876: 91–92 [type locality: Sarepta, Russia].

New records. MOROCCO • 2 ex.; 30 km NE Fez, Tissa env., Qued Leben riv.; 34°15'02"N, 4°45'54"W; 9 May 2015; E. Ezer leg.; D. Selnekovič det.; EEPC

Distribution. Albania (Ermisch 1956), Azerbaijan (Horák 2008), Armenia (Horák 2008), Belarus (Zemoglyadchuk 2007), Bosnia and Herzegovina (Ermisch 1956), Bulgaria (Ermisch 1969b), Croatia (Ermisch 1956), Cyprus (Baudi di Selve 1877; Ermisch 1956), Czech Republic (Horák 1989), Georgia (Horák 2008), Germany (Ermisch 1956), Greece (Ermisch 1969b), Hungary (Schilsky 1895), Iran (Horák 2008), Iraq (Abdul-Rassoul 2010), Italy (Baudi di Selve 1877; Ruzzier 2013), Kazakhstan (Odnosum 2003), Kyrgyzstan (Horák 2008), North Macedonia (Ermisch 1969b), Morocco (**new country record**), Poland (Borowiec 1996), Portugal (Ermisch 1963c), Romania (Roubal 1936; Ermisch 1956), Russia (Emery 1876), Slovakia (Roubal 1936), Spain (Ermisch 1956), Switzerland (Baudi di Selve 1877), Syria (Ruzzier et al. 2017), Tajikistan (Odnosum 2003), Turkey (Ermisch 1956), Turkmenistan (Odnosum 2003), Ukraine (Odnosum 1993).

Remarks. This species has a wide distributional range in Europe, North Africa and the western parts of Asia. It inhabits xerothermophilous grassland habitats where adults feed on flowers of various herbaceous plants (e.g., *Daucus carota, Tithymalus*). The larvae described by Odnosum (2010) feed on the stems of Asteraceae plants (e.g., *Arctium, Centaurea salonitana*).

Mordellistena (s. str.) krujanensis Ermisch, 1963

Mordellistena (s. str.) krujanensis Ermisch, 1963b: 14, 17 [type locality: Kruja, Albania].

New records. MONTENEGRO • 1 \Diamond , 1 \bigcirc ; Bar city; 42°06'N, 19°06'E; 19 June 2011; D. Selnekovič leg.; on flowers of *Daucus carota* in ruderal vegetation; D. Selnekovič det.; DSPC.

Distribution. Ermisch (Ermisch 1963b) in the original description reported *M. krujanensis* from Albania and Bosnia and Herzegovina. *M. krujanensis* is recorded here for the first time from Montenegro.

Remarks. The first author observed the adults on flowers of *Daucus carota* in ruderal vegetation along a roadside in Montenegro. The record represents a first report after the original description. The immature stages and host plants remain unknown.

Mordellistena (s. str.) longicornis Mulsant, 1856

Mordellistena (s. str.) longicornis Mulsant, 1856: 373-374 [type locality: France].

New record. MOROCCO • 1 ♂; Col du Zad, Moyen Atlas Mts; 2100 m a.s.l.; 20 May 2015; E. Ruzzier det.; ERPC.

Distribution. Armenia (Odnosum 2010), France (Mulsant 1856), Greece (Horák 2008), Morocco (**new country record**), Spain (Ermisch 1956; Plaza 1983), Ukraine (Odnosum 2005). Ermisch (1956) mentioned the occurrence of *M. longicornis* in North Africa without further information about the locality.

Remarks. Adults have been reported feeding on flowers of *Thapsia villosa* in Spain (Plaza 1983). The immature stages are unknown.

Mordellistena (s. str.) michalki Ermisch, 1956

Mordellistena (s. str.) *michalki* Ermisch, 1956: 288 [type locality: Pernitz, Steirmark, Germany].

New records. KYRGYZSTAN • 1 ♂; N Kirgizsky mountain range, Kara-Balta river; 1800 m a.s.l.; 28 June 1997; D. Selnekovič det.; DSPC.

Distribution. Austria (Ermisch 1956), Bosnia and Herzegovina (Ermisch 1962), Croatia (Ermisch 1962), Czech Republic (Borowiec 1996), Germany (Ermisch 1962), Italy (Franciscolo 1995; Ruzzier 2013), Kazakhstan (Odnosum 1992), Kyrgyzstan (**new country record**), Russia (Odnosum 2010), Slovakia (Ermisch 1963b), Turkmenistan (Odnosum 2003).

Remarks. This species inhabits steppes and xeric grasslands where adults feed on flowers of Apiaceae and Euphorbiaceae (e.g., *Seseli, Tithymalus*). The larvae and host plants remain unknown. Specimens examined for the present study were compared with the type series deposited in SNSD.

Mordellistena (s. str.) olympica Ermisch, 1965

Mordellistena (s. str.) *olympica* Ermisch, 1965: 265, 268–269 [type locality: Morea, Olymp env., Greece].

New records. CYPRUS • 6 \Im , 2 \Im ; Skoulli village env.; 34°58'17"N, 32°27'02"E; 24 Apr. 2018; D. Selnekovič leg.; in ruderal vegetation along the road; D. Selnekovič det.; DSPC • 2 \Im , 2 \Im ; Skoulli village env.; 34°58'05"N, 32°26'46"E; 24 Apr. 2018; D. Selnekovič leg.; ruderal vegetation along the field margin, on the flowers of

Daucus carota; D. Selnekovič det.; DSPC. MONTENEGRO • 2 \Im , 1 \Im ; Bar city, Stari Bar; 42°05'31"N, 19°07'58"E, 19 June 2011; D. Selnekovič leg.; D. Selnekovič det.; DSPC • 3 \Im , 1 \Im ; Bar city, Volujica hill; 42°04'16"N, 19°06'10"E; 20 June 2011; dry grasslands along the sea coast; D. Selnekovič det.; DSPC • 26 \Im , 17 \Im Virpazar env.; 42°14'40"N, 19°05'36"E; 30 m a.s.l.; 21 June 2011; D. Selnekovič leg.; D. Selnekovič det.; DSPC.

Distribution. Bulgaria (Ermisch 1965), Cyprus (**new country record**), Greece (Ermisch 1965), North Macedonia (Ermisch 1965), Montenegro (**new country record**), Turkey (Horák 2008) and former Yugoslavia (Horák 2008; without further information).

Remarks. The first author collected adults in Mediterranean xeric grasslands and ruderal vegetation along roadsides and field margins in Bulgaria, Montenegro (Fig. 2) and Cyprus (Fig. 3). The specimens were feeding on flowers of *Daucus carota*. The immature stages and host plants remain unknown. Specimens examined for the present study were compared with the type specimens deposited in SNSD.

Mordellistena (s. str.) thuringiaca Ermisch, 1963

Mordellistena (s. str.) *thuringiaca* Ermisch, 1963b: 23–24 [type locality: Kyffhäusers bei Frankenhausen, Germany].

New records. BULGARIA • 1 ♂; Kresna, Struma banka; 24 May–4 June 1976; K. Majer leg.; D. Selnekovič det.; SNMB • 1 3; Lilvanovo village env.; 41°37'23"N, 23°19'41"E; 26 June 2015; D. Selnekovič leg.; D. Selnekovič det.; DSPC. MONTE-NEGRO • 1 &; Virpazar env.; 42°14'40"N, 19°05'36"E; 30 m a.s.l.; 21 June 2011; D. Selnekovič leg.; D. Selnekovič det.; DSPC. SLOVAKIA • 2 ざう; Chľaba village env.; 47°49'52.6"N, 18°49'55.3"E; 8 June 2011; D. Selnekovič leg.; meadow, on flowers of *Tithymalus*; D. Selnekovič det.; DSPC • $3 \sqrt[3]{3}$; Kamenín village, Kamenínske slanisko; 47°52'43.2"N, 18°38'46.5"E; 10 June 2011; D. Selnekovič leg.; halophile grassland, on flowers of *Galium vernum*; D. Selnekovič det.; DSPC • 1 3; Podhoroď village, Papratný vrch; 48°49'07"N, 22°18'24"E; 15 July 2011; D. Selnekovič leg.; meadow, on flowers of *Daucus carota*; D. Selnekovič det.; DSPC • 1 3; Silická Brezová village env.; 48°31'30"N, 20°29'07"E; 3 July 2014; D. Selnekovič leg.; dry grassland; D. Selnekovič det.; DSPC • 1 \eth ; Tvrdošovce village env.; 48°06'01"N, 18°01'59"E; 26 July 2016; D. Selnekovič leg.; halophile grassland; on the flowers of Daucus carota; D. Selnekovič det.; DSPC • 1 👌; Banský Studenec village env.; 48°26'14"N, 18°59'38"E; 25 June 2017; D. Selnekovič leg.; meadow; D. Selnekovič det.; DSPC. SPAIN • 3 🖉 [specimens identified by Ermisch as an undescribed species *M. balearica*]; Son Españolet; 26 May-9 June 1958; R. López leg.; D. Selnekovič det.; SNSD.

Distribution. Austria (Köstlin and Vogt 1971), Belarus (Zemoglyadchuk 2007), Bulgaria (**new country record**), France (Ermisch 1963b), Germany (Ermisch 1963b), Hungary (Ermisch 1963b), Italy (Ruzzier 2013), Kazakhstan (Odnosum 1992a), Mon-



Figure 3. Ruderal vegetation near Skoulli village in Cyprus, 34°58'05"N, 32°26'46"E. *Mordellistena olympica* Ermisch, 1965 and *M. tarsata* Mulsant, 1856 recorded from this locality are new to Cyprus.



Figure 4. Xeric grassland near Lilyanovo village in Pirin Mountains in Bulgaria, 41°37'23"N, 23°19'41"E. *Mordellistena thuringiaca* Ermisch, 1963 recorded from this locality is new to Bulgaria.

tenegro (**new country record**), Poland (Borowiec 1996), Russia (Odnosum 1992b), Slovakia (**new country record**), Spain (**new country record**), Switzerland (Köstlin and Vogt 1971), Turkmenistan (Odnosum 2003), Ukraine (Odnosum 2010). Records from the Russian Far East (Odnosum 1992b) need to be revised.

Remarks. It is an infrequently found species inhabiting various grassland habitats. The first author observed adults on xerothermophilous (Fig. 4) and mesophilous grasslands on flowers of herbaceous plants (e.g., *Daucus carota, Tithymalus, Galium*). The immature stages and host plants remain unknown. Specimens examined for the present study were compared with the type series deposited in SNSD.

Mordellistena (s. str.) tarsata Mulsant, 1856

Mordellistena (s. str.) tarsata Mulsant, 1856: 381 [type locality: Lyon env., France].

New records. CYPRUS • 2 33; Skoulli village env.; 34°58'17"N, 32°27'02"E; 24 Apr. 2018; D. Selnekovič leg.; in ruderal vegetation along the road; D. Selnekovič det.; DSPC. NORTH MACEDONIA • 1 2; Nichpur village env.; 41°43'15"N, 20°40'06"E; 930 m a.s.l.; 19 Aug. 2018; D. Selnekovič leg.; river valley; on the flowers of *Daucus carota*; D. Selnekovič det.; DSPC.

Distribution. Albania (Ermisch 1956), Algeria (Csiki 1915), Austria (Ermisch 1956), Bosnia and Herzegovina (Ermisch 1956), Bulgaria (Ermisch 1956), Croatia (Schilsky 1895; Ermisch 1956), Cyprus (**new country record**), Czech Republic (Ermisch 1956), France (Mulsant 1856), Georgia (Ermisch 1956), Germany (Csiki 1915; Ermisch 1956), Greece (Ermisch 1969b), Hungary (Ermisch 1956) Italy (Emery 1876; Baudi di Selve 1878; Ruzzier 2013), Kazakhstan (Odnosum 1992a), Kyrgyzstan (Odnosum 2003), North Macedonia (**new country record**), Mongolia (Odnosum 1992b), Romania (Ermisch 1956; as Hungary: Mehadia), Russia (Odnosum 1992b), Slovakia (Horák 1989), Spain (Ermisch 1956; Plaza 1983), Switzerland (Ermisch 1963b), Turkey (Ermisch 1956), Turkmenistan (Odnosum 2003), Ukraine (Odnosum 1993, 2010), former Yugoslavia (Serbia and Montenegro; Horák 2008; without further information).

Remarks. Mordellistena tarsata has a wide distributional range across the Palearctic realm. It inhabits dry grasslands and ruderal vegetation (Fig. 3) where adults feed on flowers of various herbaceous plants, e.g., Daucus carota, Rubus fruticosus, Achillea millefolium, Filipendula ulmaria (Ermisch 1963b), Heracleum spondylium (Ermisch 1963b), Thapsia villosa (Plaza 1983), Ruta montana (Plaza 1983). Although M. tarsata is widely distributed, it is not a common species, and usually, only a few individuals are found in a particular locality. The immature stages and their host plants remain unknown.

Mordellistenochroa fallaciosa (Ermisch, 1969)

Mordellistena (s. str.) *fallaciosa* Ermisch, 1969c: 110–111 [type locality: "Grado bei Triest", Italy].

Mordellistenochroa fallaciosa: Horák (1990: 141).

New records. ITALY • 1 ♂; Cesenatico (dry canal), Forlì-Cesena Emilia-Romagna; 9 June 2012; L. Colacurcio leg., E. Ruzzier det.; ERPC.

Distribution. Hungary (Merkl and Németh 2008), Italy (Ermisch 1969c), Switzerland (Horák 2008).

Remarks. Up to present, *M. fallaciosa* is known only from several localities in Italy, Hungary and Switzerland (Ermisch 1969c; Merkl and Németh 2008; Horák 2008). Although this species was originally described from Italy by Ermisch (1969c), we provide here another record of this rare species, increasing the information about its distribution in the country. The immature stages and their host plants remain unknown.

Mordellistenula longipalpis Ermisch, 1965

Fig. 5A

Mordellistenula longipalpis Ermisch, 1965: 256–259 [type locality: Belgrader wald, Turkey].

New records. MONTENEGRO • 8 $\Im \Im$, 5 $\Im \Im$; Bar city env., Volujica hill; 42°04'16"N, 19°6'10"E; 20 June 2011; D. Selnekovič leg.; dry grassland along the seashore, on the flowers of *Helichrysum*; D. Selnekovič det.; DSPC.

Distribution. Armenia (Horák 2008), Azerbaijan (Horák 2008), Bulgaria (Ermisch 1969b), Greece (Ermisch 1969b), Kazakhstan (Odnosum 2003), North Macedonia (Horák 2008), Montenegro (**new country record**), Turkey (Ermisch 1965), Ukraine (Odnosum 2010), former Yugoslavia (Horák 2008, without specification).

Remarks. This species is known from the Balkans and western Asia. It inhabits dry grasslands where adults feed on flowers of herbaceous plants. The first author observed adults on Mediterranean xeric grassland along the seashore on flowers of *Helichrysum* in Montenegro (Fig. 2), and in ruderal vegetation along roadsides on flowers of *Daucus carota* in Bulgaria. The immature stages and their host plants remain unknown.

Mordellochroa milleri (Emery, 1876)

Fig. 5B

Mordellistena (Mordellochroa) milleri Emery, 1876: 80, 83 [type locality: Mehadia, Romania]. Mordellistena (Tolida) milleri: Reitter (1911: 376). Tolida milleri: Ermisch (1941: 717). Mordellochroa milleri: Ermisch (1950: 78–79).

New records. ITALY • 1 \bigcirc ; Lago I Piani, Rincine, Londa, Firenze, Toscana; 43°52'55"N, 11°35'47"E; C. Massarone leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, Castel D'Aiano, Spe Mountain, Bologna; 5 July 2014; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 25–29 May 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 2 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 1–10 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 1–10 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 1–20 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; I. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; I. Colacurcio leg.; E. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 11–20 July 2016; L. Colacurcio leg.; I. Ruzzier det.; ERPC • 1 \bigcirc ; Emilia-Romagna, M. S. Pietro – S. Martino, Bologna; 18 May 2017; L. Colacurcio leg.; E. Ruzzier det.; ERPC.

Distribution. Austria (Reitter 1911), Azerbaijan (Odnosum 1996), Czech Republic (Horák 2008), France (Sainte-Claire Deville 1936), Hungary (Horák 2008), Italy (new country record), Poland (Kubisz 2000), Romania (Emery 1876), Slovakia (Roubal 1936), Slovenia (Horák 2008), Spain (Viñolas et al. 2009), Switzerland (Sanchez et al. 2015), Ukraine (Reitter 1911; Odnosum 1996).

Remarks. *Mordellochroa milleri* usually occurs in beech, oak or floodplain forests, and on its margins, but it was also reported from coniferous forest with spruces and pines in Bialowieza National Park, Poland (Kubisz 2000). Adults were found feeding



Figure 5. A Mordellistenula longipalpis Ermisch, 1965, male B Mordellochroa milleri (Emery, 1876), male.

on flowers of Apiaceae (e.g., *Libanotis montana*) and Brassicaceae (*Cardaria draba*) plants. Larvae feed in dead wood.

Discussion

The Palearctic fauna of Mordellidae consists of approximately 700 described species (Horák 2008; Odnosum 2009; Takakuwa 2010; Horák et al. 2012; Ruzzier and Kovalev 2016; Tsuru 2017; Selnekovič and Kodada 2019). The most recent comprehensive cata-

logue of Palearctic Mordellidae was provided by Horák (2008). Since then several new country-level records were published in the catalogues focused on smaller geographical areas (Abdul-Rassoul 2010; Serrahima 2011; Horák et al. 2012; Ruzzier 2013; Ruzzier et al. 2017) or as single-species records (Horák and Háva 2008; Ferenca and Tamutis 2009; Odnosum 2009; Viñolas et al. 2009; Diéguez Fernández 2010; Sanchez et al. 2015; Viñolas et al. 2016; Selnekovič and Kodada 2019). Although the distribution of Mordellidae species has been studied mostly in the western Palearctic, the recent fieldwork combined with efforts to re-examine the material deposited in major European collections have revealed 22 new country-level records for 16 species. Such results suggest that our knowledge of the distribution of Mordellidae species can be still considered poor and that continuous sampling effort will lead to further new and interesting records.

Furthermore, huge gaps exist in our knowledge of the bionomy of these beetles. Information about habitat preferences and host plants is scarce. Most of the larval descriptions and host plant records were provided by V. K. Odnosum (e.g., Odnosum 1983, 1985, 2010; Odnosum and Litvin 2009). Despite his and other authors' great effort, the number of species for which larval stages are described is relatively low. The general lack of information makes it extremely difficult to identify the larvae based solely on their morphology. The use of DNA barcoding should simplify the species identifications in the future and reveal new information about host-plant relationships and habitat preferences.

Each published record represents a small step to better understanding the distribution and bionomy of mordellid beetles, and their role in the ecosystems. Such information is becoming still more critical, especially in the current age of global environmental changes and loss of natural habitats.

Acknowledgements

We are grateful to Olaf Jäger (SNSD), Ottó Merkl (HNHM), Vladimír Janský (SNMB), and Eduard Ezer for providing us with the specimens from the museums and private collections. Financial support was provided partially by the Slovak Research and Development Agency, Project No.: APVV-15-0147 and by Comenius University in Bratislava, grant no. UK/101/2019.

References

- Abdul-Rassoul MS (2010) Tumbling flower beetles (Coleoptera, Mordellidae) of Iraq. Bulletin of the Iraq Natural History Museum 11(2): 1–5.
- Batten R (1976a) De Nederlandse soorten van de keverfamilie Mordellidae. Zoölogische Bijdragen 19: 3–37.
- Batten R (1976b) Mordellidae (Coleoptera) from the South of France and the Pyrenees. Entomologische Berichten 36: 164–171.

- Baudi di Selve F (1878) Coleotteri eteromeri esistenti nelle collezioni del R. Museo zoologico di Torino ed in altre italiane. Eteromeri delle famiglie susseguenti a quella dei tenebrioniti nei limiti della fauna europaea e circummediterranea. Atti della Reale Accademia delle Scienze di Torino 13: 765–866, 1027–1183.
- Borowiec L (1996) Mordellidae, Miastkowate (Insecta: Coleoptera). Fauna Polski, Vol. 18. Muzeum i Instytut Zoologii, Warszawa, 190 pp.
- Csiki E (1915) Pars 63: Mordellidae. In: Junk W, Schenkling S (Eds) Coleopterorum Catalogus. W. Junk, Berlin, 1–51.
- Diéguez Fernández JM (2010) Primera cita de *Curtimorda maculosa* (Neazen 1794) para la Península Ibérica (Coleoptera: Mordellidae). Arquivos Entomolóxicos 4: 15–16.
- Emery MC (1876) Essai monographique sur les Mordellides de l'Europe et des contrées limitrophes. L'Abeille: Journal d'Entomologie 14: 1–128.
- Ermisch K (1941) Tribus Mordellistenini (Col. Mordell.). Mitteilungen der Münchener Entomologischen Gesellschaft 31: 710–726.
- Ermisch K (1956) Mordellidae. In: Horion A (Ed.) Faunistik der mitteleuropäischen Käfer. Band 5: Heteromera. Entomologische Arbeiten aus dem Museum G. Frey Tutzing bei München, München, 269–328.
- Ermisch K (1962) 17. *Mordellistena breddini* n. sp. aus dem Siebengebirge und der Eifel. Decheniana 10: 183–186.
- Ermisch K (1963a) Die Mordelliden der Insel Cypern (Coleoptera, Heteromera, Mordellidae). Notulae Entomologicae 43: 49–67.
- Ermisch K (1963b) Neue Mordelliden (Heteromera, Mordellidae) aus Deutschland und Nachträge zur Faunistik der Mitteleuropaischen Mordelliden. Entomologische Blätter 59: 1–36.
- Ermisch K (1963c) Beitrag zur Mordelliden-Fauna Portugals (Coleopt. Heteromera, Mordellidae). Notulae Entomologicae 42: 14–21.
- Ermisch K (1965) Neue Mordelliden von der Balkanhalbinsel (Coleoptera, Mordellidae). Reichenbachia 5(30): 251–272.
- Ermisch K (1966) Neue westpaläarktische *Mordellistena*-Arten (Coleoptera-Heteromera-Mordellidae). Entomologische Blätter 62 (1): 30–39.
- Ermisch K (1969a) 79. Familie: Mordellidae. In: Freude H, Harde KW, Lohse GA (Eds) Die K\u00e4fer Mitteleuropas. Band 8, Teredilia, Heteromera, Lamellicornia. Goecke & Evers, Krefeld; G. Fischer, Jena, Stuttgart, 160–196.
- Ermisch K (1969b) Ergebnisse der Albanien-Expedition 1961 des Deutschen Entomologischen Institutes, 76. Beitrag, Coleoptera: Mordellidae. Beiträge zur Entomologie 19(7/8): 845–859.
- Ermisch K (1969c) Neue Mordelliden aus Europa, Nordafrika und dem Nahen Osten. Entomologische Blätter 65(2): 104–115.
- Ermisch K (1977) Die Mordellistena-Arten Ungarns und benachbarter Gebiete sowie Beschreibung einer neuen Hoshihananomia-Art aus Siebenbürgen. Folia Entomologica Hungarica (New Series) 30: 151–177.
- Ferenca R, Tamutis V (2009) Data on seventeen beetle (Coleoptera) species new for Lithuanian fauna. New and Rare for Lithuania Insect Species 21: 32–39.

- Franciscolo ME (1951) Una nuova Mordella dell'Albania. Bollettino della Società Entomologica Italiana 81: 7–9.
- Franciscolo ME (1995) Famm. Mordellidae. In: Angelini F, Audisio P, Bologna MA, de Biase A, Franciscolo ME, Nardi G, Ratti E, Zampetti MF, Coleoptera Polyphaga XII (Heteromera escl. Lagriidae, Alleculidae, Tenebrionidae). In: Minelli A, Ruffo S, La Posta A (Eds) Checklist delle specie della fauna italiana, fasc. 58. Ed. Calderini, Bologna, 11–13.
- Heyden L, Reitter E, Weise J (1906) Mordellidae. In: Catalogus coleopterorum Europae, Caucasi et Armeniae Rossicae. Editio secunda. Friedländer & Sohn, Berlin, Paskau, Caen, 453–458.
- Hill GF (1922) A new species of *Mordellistena* (Coleoptera, fam. Mordellidae) parasitic on termites. Proceedings of the Linnean Society of New South Wales 47: 346–347.
- Horák J (1979) Faunistic records from Czechoslovakia. Mordellidae. Acta Entomologica Bohemoslovaca 66: 346.
- Horák J (1985) Ergebnisse der tschechoslowakisch-iranischen entomologischen Expeditionen nach Iran 1970, 1973 und 1977, Coleoptera: Mordellidae 1 (Stenaliini, Mordellini). Entomologische Abhandlungen 49(1): 1–25.
- Horák J (1989) Faunistic records from Czechoslovakia. Coleoptera, Mordellidae. Acta Entomologica Bohemoslovaca 86: 477–478.
- Horák J (1990) Typenrevision einiger wenig bekanntner Arten aus der Gattung *Mordellistena* Costa (Insecta, Coleoptera: Mordellidae). Entomologische Abhandlungen 53(9): 125–142.
- Horák J (2008) Family Mordellidae Latreille, 1802. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera. Vol. 5. Tenebrionoidea. Apollo Books, Stenstrup, 87–105.
- Horák J, Farkač J, Nakládal O (2012) Mordellidae (Coleoptera) from Socotra Island. Acta Entomologica Musei Nationalis Pragae 52 (Suppl. 2): 253–268.
- Horák J, Háva J (2008) Faunistic records from the Czech Republic 259. Klapalekiana 44: 236.
- Kangas E, Rutanen I (1984) Four *Mordellistena* species (Coleopetra: Mordellidae) new to Sweden. Entomologisk Tidskrift 105: 99–101.
- Kaszab Z (1979) Felemás lábfejízes bogarak II. Heteromera II. In: Magyarország állatvilága (Fauna Hungariae), IX, 2. Akadémiai Kiadó, Budapest, 105 pp.
- Köstlin R, Vogt H (1971) Beitrag zur Mordellidenfauna. Mitteilungen des Entomologischen Vereins Stuttgart 6: 35–74.
- Kubisz D (2000) Mordellochroa milleri Emery (Mordellidae), Anaspis bohemica Schilsky (Scraptiidae) and Corticeus bicoloroides (Roubal) (Tenebrionidae) – Tenebrionidea (Coleoptera) new to the Polish fauna. Wiadomości Entomologiczne 19 (1): 9–14.
- Lawrence JF, Ślipiński A (2010) Mordellidae Latreille, 1802. In: Leschen RAB, Beutel RG, Lawrence JF (Eds) Handbook of Zoology, Coleoptera, Beetles, Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim), Volume 2. Walter de Gruyter, Berlin-New York, 533–537. https://doi.org/10.1515/9783110911213.533
- Majzlan O, Vidlička L (2016) Specific diversity of beetles (Coleoptera) near cowsheds. Entomofauna Carpathica 28(1): 1–13.
- Méquignon A (1946) Contribution à l'étude des mordellides paléarctiques. Revue Française d'Entomologie 13: 52–76.
- Merkl O, Németh T (2008) Notes on and further new species of the beetles in the Hungarian fauna (Coleoptera). Folia Entomologica Hungarica 69: 165–172.

- Mulsant E (1856) Histoire des coléoptères de France. Barbipalpes, longipèdes, latipennes. Annales de la Société Linnéenne de Lyon (New Series) 3: 193–544.
- Normand H (1916) Nouveaux coléoptères de la faune tunisienne. Bulletin de la Société Entomologique de France 1916: 283–287.
- Odnosum VK (1983) Morfologiya litschinki zhuka-gorbatki *Mordellistena falsoparvula*. Vestnik Zoologii 1983(5): 82–84.
- Odnosum VK (1984) Novyj dlya fauny SSSR rod *Dellamora* Normand (Coleoptera, Mordellidae) iz Turkmenii. Vestnik Zoologii 1984: 22.
- Odnosum VK (1985) K diagnostike litschinok Zhukov-gorbatok (Coleoptera, Mordellidae) fauny Ukrainy. Vestnik Zoologii 1985(2): 24–28.
- Odnosum VK (1992a) Zhuki-gorbatki (Coleoptera, Mordellidae) fauny Kazakhstana. Vestnik Zoologii 1992(6): 32–39.
- Odnosum VK (1992b) Sem. Mordellidae gorbatki ili shiponoski. In: Ler PA (Ed.) Opredelitel nasekomych Dalnego Vostoka SSSR v shestykh tomakh. Tom III. Zhestokrylye, ili zhuki. Chast 2. Nauka, Saint Petersburg, 517–526.
- Odnosum VK (1993) Subfamily Mordellinae mordellid beetles (Coleoptera, Mordellidae) of the Ukrainian fauna. Communication 2. Vestnik Zoologii 1993(6): 20–28.
- Odnosum VK (1996) Mordellid-beetles of the genus *Mordellochroa* (Coleoptera, Mordellidae) of the East Palaearctics. Vestnik Zoologii 1996(6): 47–52.
- Odnosum VK (2003) Mordellid Beetles (Coleoptera, Mordellidae) in the Fauna of Kazakhstan and Middle Asia. Communication 2. Vestnik Zoologii 37(4): 33–49.
- Odnosum VK (2005) Tumbling flower beetles (Coleoptera: Mordellidae) of the central and eastern Europe fauna. Communication 2. Subfamily Mordellinae. Tribe Mordellistenini. The Kharkov Entomological Society Gazette 11(1–2): 93–112.
- Odnosum VK (2006) Mordellid beetles of the *Mordellistena parvula* group (Coleoptera, Mordellidae) in the fauna of Ukraine. Vestnik Zoologii 40(4): 311–319.
- Odnosum VK (2009) Review of Mordellid Beetles of the *Mordellistena confinis* group (Coleoptera, Mordellidae). Vestnik Zoologii 43(1): 3–14. https://doi.org/10.2478/v10058-009-0023-9
- Odnosum VK (2010) Vypusk 9, Zhuki-Gorbatki (Coleoptera, Mordellidae). Fauna Ukrainy, tom 19, Zhestokrylye. Naukova Dumka, Kiev, 263 pp.
- Odnosum VK, Litvin O (2009) Description of *Mordellistena parvuliformis* larva (Coleoptera, Mordellidae). Vestnik Zoologii 43(6): 18–20. https://doi.org/10.2478/v10058-009-0023-9
- Plaza E (1983) Mordellidae (Col.) de la provincial de Madrid. Actas del I Congreso Iberico de Entomologia 1983: 567–577.
- Plaza E (1985) Las especies españolas de *Mordellistena* Costa del grupo *episternalis* (Col., Mordellidae). Eos: Revista Española de Entomología 61: 275–292.
- Reitter E (1911) Fauna Germanica. Die Käfer des Deutschen Reiches. Nach der analytischen Methode bearbeitet. Band 3. K. G. Lutz, Stuttgart, 436 pp.
- Roubal J (1936) Katalog Coleopter (brouků) Slovenska a Podkarpatské Rusi na základě bionomickém a zoogeografickém a spolu systematický doplněk Ganglbauerových "Die Käfer Mitteleuropas" a Reitterovy "Fauna germanica". Vol. II. Slovanský ústav v nakladatelství Orbis, Bratislava, 434 pp.

- Ruzzier E (2013) Taxonomic and faunistic notes on Italian Mordellidae (Coleoptera Tenebrionoidea) with redescription of *Falsopseudotomoxia argyropleura* (Franciscolo, 1942) n. comb. Bollettino della Società Entomologica Italiana 145(3): 103–115. https://doi.org/10.4081/ BollettinoSEI.2013.103.
- Ruzzier E, Kovalev AV (2016) First record of *Calycina* Blair, 1922 (Coleoptera, Mordellidae) in the Russian Far East with description of a new species. Zootaxa 4103(1): 075–078. http:// doi.org/10.11646/zootaxa.4103.1.9
- Ruzzier E, Ghahari H, Horák J (2017) A checklist of the Iranian Mordellidae (Coleoptera: Tenebrionidea). Zootaxa 4320(1): 146–158. https://doi.org/10.11646/zootaxa.4320.1.8
- Sainte-Claire Deville J (1936) Catalogue raisonné des Coléoptères de France. (Complete et publie par Mequignon A.). L'Abeille: Journal d'Entomologie 36 (2): 161–264.
- Samin N, Háva J, Kubisz D (2016) A contribution to the knowledge of some families of Coleoptera (Insecta) from Iran. Arquivos Entomolóxicos 15: 29–38.
- Sanchez A, Chittaro Y, Monnerat Ch. (2015) Coléoptères nouveaux ou redécouverts pour la Suisse ou l'une de ses régions biogéographiques. Entomo Helvetica 8: 119–132.
- Schilsky J (1895) Die K\u00e4fer Europa\u00e3s. Nach der Natur Beschrieben von Dr. H. C. K\u00fcster und Dr. G. Kraatz Fortgesetzt von J. Schilsky, Vol 31. Bauer und Raspe (Emil K\u00fcster), N\u00fcrnberg 1–100. [viii + no. taxa]
- Selnekovič D, Kodada J (2019) Taxonomic revision of *Mordellistena hirtipes* species complex with new distribution records (Insecta, Coleoptera, Mordellidae). ZooKeys 854: 89–118. https://doi.org/10.3897/zookeys.854.32299
- Serrahima I (2011) Catálogo provisional de los Mordellidae (Coleoptera) de Cataluña (España). Boletín de la Sociedad Entomológica Aragonesa 48: 375–381.
- Silfverberg H (2004) Enumeratio nova Coleopterorum Fennoscandiae, Daniae et Baltiae. Sahlbergia 9: 1–111.
- Takakuwa M (2000) A taxonomic study of the mordellid subgenus *Stenoglipa* (Coleoptera, Mordellidae). Bulletin of the Kanagawa Prefectural Museum (Natural Science) 29: 53–105.
- Takakuwa M (2010) Two unexpected new species of the genus *Variimorda* (Coleoptera, Mordellidae) from the Ogasawara Islands. Elytra, Tokyo 38(2): 193–200.
- Tooker JF, Hanks LM (2004) Trophic position of the endophytic beetle, *Mordellistena aethiops* Smith (Coleoptera: Mordellidae). Environmental Entomology 33(2): 291–296. https:// doi.org/10.1603/0046-225X-33.2.291
- Tsuru TK (2017) A new species of the genus *Mordellina* (Coleoptera, Mordellidae, Mordellistenini) from Okinawa Island, southwestern Japan. Elytra, New Series 7(2): 305–311.
- Viñolas A, Muñoz J, Soler J (2009) Noves o interresants citacions de coleòpters per a Catalunya (Parc Natural del Montseny) i per a la peninsula Ibèrica (Coleoptera) (3a nota). Orsis 24: 159–167.
- Viñolas A, Muñoz-Batet J, Soler J (2016) Noves o interessants localitzacions d'espècies de coleòpters per a la península Ibèrica i illes Canàries (Coleoptera). Butlletí de la Institució Catalana d'Història Natural 80: 101–112.
- Zemoglyadchuk AV (2007) Species composition and biotopical distribution of the mordellid beetles (Coleoptera, Mordellidae) of the Belarus fauna. Bulletin of Moscow Society of Naturalists, Biological series 112(2): 14–17.