RESEARCH ARTICLE



# New species and new records of earthworms of the genus *Drawida* from Kerala part of the Western Ghats biodiversity hotspot, India (Oligochaeta, Moniligastridae)

S. Prasanth Narayanan<sup>1</sup>, S. Sathrumithra<sup>1</sup>, G. Christopher<sup>1</sup>, J.M. Julka<sup>2</sup>

I Advanced Centre of Environmental Studies and Sustainable Development, Mahatma Gandhi University, Priyadarsini Hills, Kottayam – 686560, Kerala, India 2 School of Biological and Environmental Sciences, Faculty of Basic Sciences, Shoolini University, Solan – 173212, Himachal Pradesh, India

Corresponding author: S. Prasanth Narayanan (narayanankc@gmail.com)

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#### Abstract

Two new species of *Drawida* Michaelsen, 1900, namely *Drawida polydiverticulata* Narayanan & Julka, **sp. n.** and *Drawida thomasi* Narayanan & Julka, **sp. n.**, are described from material collected from the Indian state of Kerala, which lies in the Western Ghats biodiversity hotspot. *Drawida elegans* Rao, 1921, *Drawida kanarensis* Stephenson, 1917, *Drawida modesta* Rao, 1921, *Drawida somavarpatana* Rao, 1921, and *Drawida thurstoni* Gates, 1945 are recorded for the first time from the state.

#### Keywords

Annelida, Clitellata, description, distribution, habitat, soil fauna, taxonomy

#### Introduction

Kerala is a narrow coastal equatorial tract of India (between  $8^{\circ}17'-12^{\circ}47'N$  and  $74^{\circ}52'-77^{\circ}24'E$ ). The steep sloping land of Kerala along the southwest corner of the Indian Peninsula has its own unique identity (Nair 2011). The dominating surface

feature of the state is the Western Ghats, which is one of the eight 'hottest hotspots' of biodiversity in the world (Myers et al. 2000, Mittermeier et al. 2011). In a broad generalized approach, Kerala can be divided into three distinct physiographic regions, namely the coastal lowlands (< 75 m a.s.l.), midlands (75–500 m a.s.l.), and high ranges (500–2000 m a.s.l.) (Iype et al. 1991). The area experiences two rainy seasons, viz., the southwest monsoon (June to September) and northeast monsoon (October to November). Annual rainfall ranges from 1,520 to 4,075 mm, but it may be as high as 6,000 mm in certain pockets and as low as 600 mm in rain shadow areas (KSCSTE 2007). The general climate is mostly tropical but tends to be temperate in high mountainous areas (average temperature 19°C–37°C; minimum 0°C in high ranges). Major forest types are tropical evergreen and semi evergreen, tropical moist and dry deciduous, mountain 'sholas', grasslands and low land scrub jungles (Islam and Rahmani 2004).

A great variety of vegetation coupled with high rainfall and moderate temperature has created a cradle for earthworm diversity in Kerala, which harbours about 21% of country's known earthworm species (Narayanan et al. 2016). It is noteworthy that Kerala also possesses about 40% of earthworm species found in the Western Ghats that constitute India's mega earthworm diversity area with 200 species (Julka and Paliwal 2005, Julka et al. 2009, Narayanan et al. 2016) of the 505 species from the Indian region (Blakemore 2007).

Several species in Kerala are known only from the original description, and most of them were recorded more than 80–90 years ago (Narayanan et al. 2016). Hence, we conducted extensive survey of earthworms in diverse habitats in the coastal areas, midlands and various types of forests in the hilly regions of the state. This has revealed the presence of two new species and five new records of the genus *Drawida* Michaelsen, 1900. The details of the two new species *Drawida polydiverticulata* sp. n. and *Drawida thomasi* sp. n. and the newly recorded *Drawida elegans* Rao, 1921, *Drawida kanarensis* Stephenson, 1917, *Drawida modesta* Rao, 1921, *Drawida somavarpatana* Rao, 1921, and *Drawida thurstoni* Gates, 1945 are dealt with in this paper.

#### Materials and methods

Earthworms were obtained from soil by digging and hand sorting methods, and also searching organic microhabitats such as fallen tree trunks and leaf litter. Specimens were fixed in 5% formalin and subsequently transferred to ethanol. All anatomical observations were made by dissection under a stereomicroscope (Nikon SMZ800N), and illustrations were made by the attached drawing tube. Holotype and paratype specimens of the new species have been deposited at Zoological Survey of India, Western Ghats Regional Centre (ZSI-WGRC), Kozhikode (Calicut), Kerala, India. Other specimens are housed in Advanced Centre of Environmental Studies and Sustainable Development (ACESSD), Mahatma Gandhi University, Kottayam, Kerala, India.

#### Systematic studies

#### Genus Drawida Michaelsen, 1900

Type species. Drawida barwelli Michaelsen, 1900

#### *Drawida polydiverticulata* Narayanan & Julka, sp. n. http://zoobank.org/90E6A8F1-6BBD-4598-A93B-777BAF638391

**Type material.** *Holotype*. Clitellate (Reg. no. ZSI/WGRC/IR/INV-8835), Meenthottychola (10°10'21.4"N; 77°02'2.3"E) in Eravikulam National Park, Idukki District, Kerala State, India, 2010 m a.s.l., stream side in shola forest, 22 November 2016, S.P. Narayanan, S. Sathrumithra and G. Christopher coll.

*Paratype.* 6 clitellate (Reg. no. ZSI/WGRC/IR/INV-8836); same collection data as for holotype.

**Other material.** Two aclitellate (ACESSD/EW/721), Pullaradichola (10°11'33.4"N; 77°12'9.7"E) in Anamudi Shola National Park, Idukki District, Kerala State, India, 2113 m a.s.l., from the side of a water logged area within grassland, where recently the exotic wattle plantations has been clear felled, 25 May 2013, S.P. Narayanan, T. Augustine, A. Sasi and S. Sathrumithra coll.; 3 aclitellate (ACESSD/EW/722), Mattuchola (10°14'28.7"N; 77°14'12.9"E) in Chinnar Wildlife Sanctuary, Idukki District, Kerala State, India, 1954 m a.s.l., stream side in a grassland, 24 November 2013, T. Augustine, D. Kuriakose, S. Sathrumithra and S.P. Narayanan coll.; 4 aclitellate (ACESSD/EW/723), Pettymudy forest camp shed area (10°10'26.7"N; 77°01'25.6"E) in Eravikulam National Park, Idukki District, Kerala State, India, 1966 m a.s.l., stream side within shola forest, 21 November 2016, S.P. Narayanan, S. Sathrumithra and G. Christopher coll.

**Diagnosis.** Length 50–73 mm, diameter 4–5 mm, segments 120–136. Colour bluish. Male pores in 10/11, at centres of oval porophores, at about mid bc. Spermathecal pores in 7/8 at c lines. Genital markings absent. Gizzards number 3–5 in 12–17. Coiled vas deferens mass about one fourth to half of testis sac; vas passing directly into prostate dorsally at about its middle. Prostates glandular ovate and erect, prostatic capsule club-shaped. Spermathecal atria erect in segment 7, each with 4–6 ental lobes. Nephridiopores aligned with d.

**Description**. Colour bluish (bluish pigmentation in circular muscle layer); body circular in cross section. Dimension: Holotype – 73 mm by 4 mm at segment 9, 120 segments; paratypes – 50–72 mm by 4–5 mm at segment 9, 125–136 segments. Setae lumbricine, closely paired, present from segment 2; setal formula aa = 8–15.2 ab = 1.05-1.95 bc = 13.33-19 cd = 0.28-0.45 dd at segment 8, aa = 11.5-12.67 ab = 0.92-1.08 bc = 9.2-9.5 cd = 0.26-0.31 dd at segment 20. Clitellum annular, at segments 10-13 (4 segments), intersegmental furrows distinct, colour reddish. Spermathecal pores paired, small transverse slits, with tumescent lips, at intersegmental furrow 7/8, aligned with setae c; males pores paired, minute, at intersegmental furrow 10/11,



Figure 1. Drawida polydiverticulata sp. n. A Holotype - ventral view B Paratype – ventral view C Prostate – ventral view (gland uplifted) D Prostatic capsule – dorsal view E Spermathecal atria - dorsal view
F Spermathecal atria - ventral view. Abbreviations: Atr. – Atrium; Atr.D. – Atrial duct; Pr.C. – Prostatic capsule; Prs. – Prostate; Pr.D. – Prostatic duct; Sep. – Septum; Sp.D. – Spermathecal duct; Sp.P. – Spermathecal pore; Vd – Vas deferens.

each pore at centre of oval porophore at about mid bc (Fig. 1A, B). Genital markings absent. Nephridiopores present from segment 3, aligned with setae d.

Septa 5/6/7/8/9 slightly muscular. Gizzards 4 in segments 12–15 (holotype), smallest in segment 12 increasing in size progressively; number variable in other specimens, 3 in segments 12–14 or 13–15 (Meenthottychola specimens), 3 in segments 13–15 or 4 in segments 12–15 (Pettymudy specimens), 4 in segments 13–16 (Pullaradichola specimens), 5 in segments 13–17 (Mattuchola specimens); intestine begins in segment 22±1. Last pair of hearts in segment 9; commissures of extra oesophageal vessels present on posterior face of septa 8/9 and 9/10. Testis sacs paired, mostly in segment

10, extending to segment 11; vas deferens long, coiled in a number of hairpin loops aggregated to form a mass about one fourth to half the size of testis sac, passing directly into prostate dorsally at about its middle. Prostates paired, glandular, ovate, erect (may be bent on itself anteriorly or posteriorly) (Fig. 1C); prostatic capsule smooth, club shaped (Fig. 1D); prostatic duct short, slender, narrowed before entering parietes. Spermathecae paired in segment 8; atrium erect in segment 7 and with 4–6 ental lobes arranged in two groups (Fig. 1E, F), spermathecal duct discharges at junction of common ducts of two groups. Ovarian chamber complete, ovisacs short, extending to segment 12–13. Nephridia holoic, avesiculate; functional at segment 10.

**Etymology.** The specific epithet '*polydiverticulata*' is after multi-lobed condition of spermathecal atrium.

**Type locality.** Meenthottychola (10°10'21.4"N; 77°02'2.3"E) in Eravikulam National Park, Idukki District, Kerala State, India, 2010 m a.s.l., 23 km away from Munnar town, stream side in shola forest. Common vegetation of this region is dominated by *Syzygium arnottianum*, *Ilex denticulata*, *Michaelia nilagirica*, *Elaeocarpus recurvatus*, and *Microtropis ramiflora*.

**Ingesta.** Coagulum comprising of mineralized soil, rootlets, tiny pieces of bark and leaves.

**Distribution.** India: Kerala: District Idukki: Meenthottychola and Pettymudy in Eravikulam National Park, Pullaradichola in Anamudi Shola National Park and Mattuchola in Chinnar Wildlife Sanctuary (Fig. 2).

Habitat. Shola forest in vicinity of streams; near to stagnant pools or streams in grass lands.

**Remarks.** *Drawida polydiverticulata* sp. n. is distinguishable from all the known species of the genus in having spermathecal atrium with more than two lobes. In one specimen from Pettymudy, spermatheca on right side with one branch of atrium along with lobes extends to segment 8.

#### *Drawida thomasi* Narayanan & Julka, sp. n.

http://zoobank.org/319B601A-CEDE-4AD6-89AA-56056C42FC44

**Type material.** *Holotype*. Clitellate (Reg. no. ZSI/WGRC/IR/INV-8837), Kozhippara waterfalls (11°21'14.5"N; 76°6'29.2"E) near Kakkadampoyil, Malappuram District, Kerala State, India, 541 m a.s.l., by the side of tuber cultivated field earlier used for coffee plantation, 29 October 2014, S.P. Narayanan and S. Sathrumithra coll.

*Paratype*. One clitellate and one aclitellate (Reg. no. ZSI/WGRC/IR/INV-8838), same collection data as holotype.

**Diagnosis.** Length 55–66 mm, diameter 4.5 mm, segments 66–105. Colour bluish. Male pores in 10/11, large transverse slits, slightly lateral to b lines. Spermathecal pores in 7/8 at c lines. Genital markings absent. Gizzards number 3 in 15–17. Coiled vas deferens mass as large as testis sac; vas discharging directly into prostate dorsally at about its middle. Prostates glandular tubular, slightly bent, prostatic capsule tubular, bent entally. Spermath-



Figure 2. Distribution of newly described and reported Drawida species from Kerala.

ecal atria bilobed, one lobe in segment 7 and the other in segment 8; atrial lobes tubular, very long, 9–10 mm in length, coiled into compact masses. Nephridiopores aligned with d.

**Description.** Colour bluish; body circular, slightly flattened dorsoventrally. Dimension: Holotype 66 mm by 4.5 mm at segment 9, 105 segments; paratypes 55–57.5 mm

Holotype		Setae on	left side		Setae on right side				
Segment	d	с	b	a	a	b	с	d	
2	х	x	х	х	х	x	х		
3	х	x	x	x	x	x	х	$\checkmark$	
4	х	x	х	x	$\checkmark$		х		
5		x	х	V	x		$\checkmark$		
6		√	х	V	х	х	$\checkmark$		
7		x	х	V	V		х	х	
8		√	x	V	V	х			
9		$\checkmark$	$\checkmark$	x	х		x		
10		√	$\checkmark$	V	V				
Paratype 1		Setae on	left side		Setae on right side				
Segment	d	с	b	a	a	b	с	d	
2		x	x	x	x	х			
3		√	x	V	$\checkmark$	х		Х	
4		√	$\checkmark$	$\checkmark$	x	х			
5		√	$\checkmark$	V	V		х		
6		√	$\checkmark$	$\checkmark$	$\checkmark$				
7		√	$\checkmark$	V	x	x			
8		√	$\checkmark$	V	V				
9		√	x	V	V				
10		x	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	х	х	
Paratype 2		setae on tl	ne left side		setae on the right side				
Segment	d	с	Ь	a	а	Ь	с	d	
2	$\checkmark$	x	x	x	x	х	х	х	
3	$\checkmark$	x	x	$\checkmark$	x	$\checkmark$	х	$\checkmark$	
4	$\checkmark$	x	$\checkmark$	x	х	х		$\checkmark$	
5	х	x	x	x	$\checkmark$	х	х	х	
6	х	x	$\checkmark$	$\checkmark$	$\checkmark$	х	х	х	
7	х	$\checkmark$	x	$\checkmark$	х	$\checkmark$	х	$\checkmark$	
8		x	$\checkmark$	$\checkmark$	x				
9			x	x	x				
10		$\checkmark$	x	x	$\checkmark$				

**Table I.** Presence  $(\sqrt{y})$  or absence (x) of setae on some anterior segments of the type materials.

by 4.5 mm at segment 9, 66–96 segments. Setae lumbricine; some setae on anterior segments may be absent (Table 1); setae ab enlarged on segment 8 and posterioriad segments (Fig. 3A); setal formula aa = 5-7.5 ab = 1.11-3 bc = 5.71-7.5 cd = 0.17-0.31 dd at segment 8, aa = 6.25-14.5 ab = 0.71-1.11 bc = 8.33-14.5 cd = 0.24-0.29 dd at segment 20.

Clitellum annular, at segments 10-13 (= 4 segments), indicated by reddish colour and slight swelling, intersegmental furrows distinct. Spermathecal pores paired, small transverse slits at setae at intersegmental furrow 7/8, aligned with setae c; male pores paired, large transverse slits at intersegmental furrow 10/11, slightly lateral to setae



**Figure 3.** *Drawida thomasi* sp. n. **A** Holotype - ventral view **B** Prostate and testis sac **C** Prostatic capsule **D** Spermathecal atria - partially uncoiled. Abbreviations: Atr. – Atrium; Div. in seg. – diverticula in segment; Pr.C. – Prostatic capsule; Prs. – Prostate; Pr.D. – Prostatic duct; Sp.D. – Spermathecal duct; Sp.P. – Spermathecal pore; TS – Testis sac; Vd – Vas deferens.

b lines. Genital markings absent. Nephridiopores, present from segment 3, aligned with setae d.

Septa 5/6/7/8/9 slightly muscular. Gizzards 3 in segments 15–17 (holotype and paratypes); intestine begins in segment 24. Last pair of hearts in segment 9; commissures of extra oesophageal vessel present on posterior face of septum 8/9, not recognizable on posterior face of 9/10. Testis sacs paired, in segments 9 and 10, extending to segment 15 on left side and to segment 17 on right side; vas deferens long, coiled

in hairpin loops, aggregated into a mass as large as testis sac, discharging directly at about middle of dorsal face of prostate. Prostates paired, glandular, tubular, slightly bent at ental end (Fig. 3B); prostatic capsule shining, smooth, tubular, slightly bent entally (Fig. 3C); prostatic duct about half as long as gland, thick, slightly narrowed before entering parietes. Spermathecae paired, in segment 8; atrium bilobed, one lobe in segment 7 and the other in segment 8, each lobe tubular, very long and coiled into a compact mass occupying entire body cavity of respective segment, 9–10 mm long (when uncoiled); spermathecal duct short with a few coils entering at junction of two atrial lobes (Fig. 3D). Ovarian chamber incomplete; ovisacs paired extending back to segment 16. Nephridia holoic, avesiculate; functional at segment 10.

**Etymology**. Named after Prof. (Dr.) A.P. Thomas, who initiated taxonomic studies on the earthworms of Kerala state at Advanced Centre of Environmental Studies and Sustainable Development, Mahatma Gandhi University.

**Type locality.** Kozhippara waterfalls (11°21'14.5"N; 76°6'29.2"E) near Kakkadampoyil, 27 km away from Nilambur town, Malappuram District, Kerala State, India, 541 m a.s.l., by the side of tuber-ultivated field earlier used for coffee plantation.

**Distribution.** Known only from the type locality (Fig. 2).

Ingesta. Mostly silt, with tiny pieces of mica and organic material.

**Biology.** Autotomy is very common. Infested with nematodes in the region of reproductive system.

**Habitat.** Bushes with grassy under growth, loamy soil, rich in organic matter, by the side of tuber cultivated field earlier used for coffee plantation.

**Remarks.** Drawida thomasi sp. n. belongs to a group of species of Drawida with glandular prostates and bilobed spermathecal atria. It can be easily distinguished from other members of the group, D. robusta robusta (Bourne, 1887), D. robusta ophidioides (Bourne, 1894), D. ghatensis Michaelsen, 1910, and D. somavarpatana Rao, 1921 by the characteristics as given in Table 2.

#### Newly recorded species of Drawida from Kerala state

#### Drawida elegans Rao, 1921

Drawida elegans Rao, 1921. Ann. Mag. Nat. Hist. (ser. 9), 8: 519. Drawida elegans, Stephenson 1923. Fauna Br. India, Oligochaeta: 137.

**Material examined.** 7 aclitellate (ACESSD/EW/404), Paithalmala (12°10'1.7"N; 75°33'31.1"E), Kannur district, Kerala, India, 1076 m a.s.l., higher altitude evergreen forest, 30 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.

**Diagnosis.** Length 130 mm, diameter 5 mm, 206 segments. Setae aa = 20 ab = 1.2 bc = 20 cd on segment 7, aa = 27 ab = 1.7 bc = 27 cd on mid body segments. Male pores paired, small, at 10/11, slightly lateral to setae b lines, at centres of slightly raised oval papillae. Spermathecal pores paired, at 7/8, at setae c lines. Gizzards 5, in segments 12–16.

Character	D. robusta robusta (Bourne, 1887)	D. robusta ophidioides (Bourne, 1894)	<i>D. ghatensis</i> Michaelsen, 1910	D. somavarpatana Rao, 1921	D. thomasi sp. n.
Length (mm)	136–200	310	80-160	85 (81–133 <sup>§</sup> )	55-66
Diameter (mm)	6	7	2–6	4 (5–6 <sup>§</sup> )	4.5
Segments	150-160	200	145-150	124 (104–154 <sup>§</sup> )	66–105
Male pores	Nearer to c setal lines	Nearer to c setal lines	About midway between b and c setal lines	Nearer to b setal lines	Nearer to b setal lines
Spermathecal atrium	Distinctly bilobed; lobes erect, tubular; one lobe in segment 7 and the other in segment 8, anterior lobe larger	Distinctly bilobed; lobes teat like, one lobe in segment 7 and the other in segment 8, anterior lobe smaller	Slightly bilobed: lobes slight protuberances, confined to segment 7	Distinctly bilobed; lobes cylindrical, one lobe in segment 7 and the other in segment 8; both lobes of almost equal length	Distinctly bilobed; lobes tubular, one lobe in segment 7 and the other in segment 8: each lobe very long, coiled into a compact mass, occupying the entire body cavity of segment
Testis sacs	Confined to segments 9 &10	Confined to segments 9 &10	Extend to segments 13–14	Extend to segment 14	Extend to segments 15–17
Prostates	Hemispherical, sessile	Hemispherical, sessile	Thickly pear-shaped?	Bifid; lobes erect, finger like	Tubular, erect, slightly bent entally
Opening of Vas into prostate	Ental end of prostate <sup>5</sup>	۰.	۸.	Ectal end of prostate <sup>#</sup>	About middle of prostate
Number of gizzards (segment location)	4 (12,13–16)	3 (14–16)	4 (16–19)	3 (16–18)	3 (15–17)
S.Raced on the t	dt ni minche a Accheminte	is forme 5 of Monification in di	4.6 Ranham 1803 in Roi	(1804) Monification	ious is a surround of Duranida valueta

Sbased on the present study; § As shown in the figure 5 of Moniligaster indicus Benham, 1893 in Bourne (1894), Moniligaster indicus is a synonym of Drawida robusta robusta (Michaelsen 1900); # As observed by one of the author (JMJ) during his studies on the types (syntypes) of Drawida somawarpatana (Reg. no. W416/1) in 'National Zoological Collection' at Zoological Survey of India, Kolkata.

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Table 2. Comparison of *Drawida thomasi* sp. n. with related species.

Prostates glandular, sessile, elongated; vas deferens long, coiled into a mass of hairpin loops, discharging directly at ental end of prostate. Spermathecae paired, in segment 8; atrium large, shortly pear-shaped, narrower ectal end; spermathecal duct discharging at ental end of atrium.

**Distribution.** India: Kerala: District Kannur: Paithalmala (new record) (Fig. 2); Karnataka: District Kodagu (Coorg): Bhagamandla, Coorg Hills (Rao 1921).

**Remarks.** Range of the length, diameter, and number of segments in the Kerala specimens are 83–117 mm, 5–6 mm, and 161–171 respectively. Three gizzards in the present specimens in segments 12–14. Mass of vas deferens loops is shorter than testis sac.

#### Drawida kanarensis Stephenson, 1917

*Drawida kanarensis* Stephenson, 1917. Rec. Indian Mus., 13: 364. *Drawida kanarensis*, Stephenson 1923. Fauna Br. India, Oligochaeta: 143.

Material examined. 2 clitellate, 2 aclitellate (ACESSD/EW/170), Ranipuram (12°25'18.2"N; 75°21'14.4"E), Kasaragod district, Kerala, India, 935 m a.s.l, evergreen forest, 19 October 2012, S.P. Narayanan, S. Sathrumithra and M. Ramesan coll.; 1 aclitellate (ACESSD/EW/174), Periyathaduka - Padre (12°37'26.6"N; 75°7'58.4"E), Kasaragod district, India, 89 m a.s.l., Arecanut plantation, 18 October 2012, S. Sathrumithra, S.P. Narayanan and M. Ramesan coll.; 1 clitellate (ACESSD/EW/175), Adakasthala - Perla (12°40'9.6"N; 75°6'54.3"E), Kasaragod district, Kerala, India, 77 m a.s.l., cultivated area near to river, 18 October 2012, S.P. Narayanan, S. Sathrumithra and M. Ramesan coll.; 3 clitellate, 2 aclitellate (ACESSD/EW/176), Pandigaya - Perla (12°40'27"N; 75°07'27.8"E), Kasaragod district, Kerala, India, 102 m a.s.l., rubber plantation, 18 October 2012, S.P. Narayanan, S. Sathrumithra and M. Ramesan coll.; 4 clitellate, 4 aclitellate (ACESSD/EW/177), Kottencheri (12°20'57.6"N; 75°24'45.9"E), Kasaragod district., India, 801 m a.s.l., evergreen forest, 20 October 2012, S.P. Narayanan, T. Augustine, S. Sathrumithra and M. Ramesan coll.; 3 clitellate, 3 aclitellate (ACESSD/EW/178), Plachikkara (12°20'6.2"N; 75°17'19.8"E), Kasaragod district, Kerala, India, 56 m a.s.l., degraded forest, 20 October 2012, T. Augustine, S.P. Narayanan and M. Ramesan coll.; 1 clitellate (ACESSD/EW/179), Veeramalakunnu hillock (12°13'49.8"N; 75°9'15.8"E), Kasaragod district, Kerala, India, 13 m a.s.l., dense scrub land with exotic Acacia auriculiformis trees, 21 October 2012, S.P. Narayanan, M. Ramesan, T. Augustine and S. Sathrumithra coll.; 5 clitellate (ACESSD/EW/180), Melerippukavu Sree Veerabhadrakavu, Klayikkod (12°14'34.2"N; 75°9'55.2"E), Kasaragod district, Kerala, India, 19 m a.s.l., sacred grove, 21 October 2012, T. Augustine, M. Ramesan, S.P. Narayanan and S. Sathrumithra coll.; 11 clitellate, 12 aclitellate (ACESSD/EW/181), Sree Mannampurathukavu, Nileshwar (12°15'31"N; 75°7'58.1"E), Kasaragod district, Kerala, India, 13 m a.s.l., evergreen sacred grove, 20 October 2012, T. Augustine, S.P. Narayanan, S.

Sathrumithra and M. Ramesan coll.; 8 clitellate, 13 aclitellate (ACESSD/EW/182), Kulangattumala Temple, Kadamgod (12°12'16.9"N; 75°8'3.9"E), Kasaragod district, Kerala, India, 7 m a.s.l., evergreen patch with litter, 21 October 2012, S.P. Narayanan, S. Sathrumithra, T. Augustine and M. Ramesan coll.

**Diagnosis.** Length 60–70 mm, diameter 3.5 mm, 150–173 segments. Setae aa = 4.75-5.75 ab = 0.95-1.04 bc = 5.42-5.75 cd = 0.23-0.27 dd at segment 8; aa = 7.33-9 ab = 1-1.04 bc = 7.33-9 cd = 0.25-0.35 dd at segment 20. Male pores paired, at 10/11, slightly lateral to setae b lines. Spermathecal pores paired, at 7/8, at setae c lines. Genital markings paired, lateral to setae ab on segment 11, occasionally extending on to segment 12. Four gizzards in segments 13-16 or 14-17. Prostates glandular, hemi-ovoidal, sessile; vas deferens short, joining prostate at anterior and inner side. Spermathecae paired in segment 8; atrium cushion like ectal widening of spermathecal duct, partly embedded in body wall in segment 8, several times as wide as spermathecal duct.

**Distribution.** India: Kerala: District Kasaragod: Adakasthala, Kadamgod, Klayikkod, Kottencheri, Nileshwar, Pandigaya, Periyathaduka, Plachikkara, Ranipuram and Veeramalakunnu (all new records) (Fig.2); Karnataka: District Uttara Kannada (North Kanara): Talewadi, Castle Rock (Stephenson 1917); District Shivamogga (Shimoga): Batkal, Kogar, Nakkalu (Blanchart and Julka 1997).

**Remarks.** Range of the length, diameter, and number of segments of the Kerala specimens are 38–51 mm, 3 mm, and 166–177 respectively. Gizzards are in segments 14–17.

#### Drawida modesta Rao, 1921

Drawida modesta Rao, 1921. Ann. Mag. Nat. Hist. (ser. 9), 8: 525. Drawida modesta, Stephenson 1923. Fauna Br. India, Oligochaeta: 145.

Material examined. 14 clitellate, 4 aclitellate (ACESSD/EW/160), Chandanathodu - Kannavam range (11°51'3.2"N; 75°48'12"E), Kannur district, Kerala, India, 784 m a.s.l., evergreen forest, 01 December 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 3 clitellate (ACESSD/EW/166), Chandanathodu - Periya Range (11°50'44.6"N; 75°48'27.4"E), Wayanad district, Kerala, India, 778 m a.s.l., evergreen forest, 01 December 2012, T. Augustine, S. Sathrumithra and S.P. Narayanan coll.; 1 clitellate, 6 aclitellate (ACESSD/EW/399), Perumalkunnu (11°53'50.1"N; 75°54'16.3"E), Kannur district, Kerala, India, 1076 m a.s.l., grassland and evergreen forest, 02 December 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 14 clitellate (ACESSD/EW/401), Kunnathoorpadi (12°4'55"N; 75°37'39.1"E), Kannur district, Kerala, India, 579 m a.s.l., evergreen forest with reed breaks, 30 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 1 clitellate (ACESSD/ EW/402), Chandanathodu - Kottiyoor range (11°51'4.2"N; 75°47'12"E), Kannur district, Kerala, India, 714 m a.s.l., evergreen forest, 1 December 2012, S.P. Narayanan and T. Augustine coll.; 4 clitellate (ACESSD/EW/403), Nedumpoil (11°50'30.5"N; 75°46'39.1"E), Kannur district, Kerala, India, 365 m a.s.l., semi-evergreen forest, 1 December 2012, S.P. Narayanan, S. Sathrumithra and T. Augustine coll.; 7 clitellate, 2 aclitellate (ACESSD/EW/406), Koovattumoola – Thirunelli (11°54'3.8"N; 76°0'48.4"E), Wayanad district, Kerala, India, 782 m a.s.l., abandoned paddy field, 21 December 2012, A. Sasi, S.P. Narayanan and S. Sathrumithra coll.; 1 clitellate (ACESSD/EW/407), Paithalmala (12°10'1.7"N; 75°33'31.1"E), Kannur district, Kerala, India, 1076 m a.s.l., higher altitude evergreen forest, 30 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 5 clitellate (ACESSD/EW/409), Ambayithodu (11°51'50.8"N; 75°53'37.2"E), Kannur district, Kerala, India, 216 m a.s.l., disturbed mixed forest area, 02 December 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 5. Sathrumithra coll.; 14 clitellate, 8 aclitellate (ACESSD/EW/472), below Kakkadampoyil (11°19'41.9"N; 76°9'54.8"E), Malappuram district, Kerala, India, 98 m a.s.l., semi-evergreen forest near to a stream, 29 October 2014, S.P. Narayanan and S. Sathrumithra coll.; 1 clitellate (ACESSD/EW/473), Naadukaani (11°25'58"N; 76°23' 18.7"E), Malappuram district, Kerala, India, 530 m a.s.l., evergreen forest, 28 October 2014, S.P. Narayanan and S. Sathrumithra coll.

**Diagnosis.** Length 75 mm, diameter 4 mm, 207 segments. Intersegmental furrow 1/2 very faint. Setae aa = 13.3 ab = 0.7 bc = 13.3 cd on segment 7, aa = 15.3 ab = 0.7 bc = 15.3 cd on segment 35. Male pores paired, transverse slits with prominent lips, at 10/11, slightly lateral to setae b lines. Spermathecal pores paired, at 7/8, at or slightly lateral to setae b lines. Genital markings paired, oval shaped on segment 7, just anterior to spermathecal pores. Gizzards 2, in segments 13–14. Prostates paired, glandular, sessile, circular to oval in shape; vas deferens short, discharging at dorsal surface and centre of prostates. Spermathecae paired in segment 8; atrium absent.

**Distribution.** India: Kerala: District Kannur: Ambayithodu, Chandanathodu -Kannavam range, Chandanathodu - Kottiyoor range, Kunnathoorpadi, Nedumpoil, Paithalmala, Perumalkunnu; District Wayanad: Chandanathodu - Kannavam range, Koovattumoola – Thirunelli; District Malappuram: Kakkadampoyil, Naadukaani (all new records) (Fig. 2); Karnataka: District Kodagu (Coorg): Moornad, Coorg Hills (Rao 1921).

**Remarks.** Range of the length, diameter, and number of segments of the Kerala specimens are 60–72 mm, 3–4 mm, and 151–197 respectively. Genital markings are absent in some specimens from Kerala (Table 3).

Site & Reg. no.	With GM	Without GM	Total
Chandanathodu (Periya range); ACESSD/EW/166	1	2	3
Perumalkunnu; ACESSD/EW/399	3	4	7
Kunnathoorpadi; ACESSD/EW/401	4	10	14
Nedumpoil; ACESSD/EW/403	3	1	4
Ambayithodu; ACESSD/EW/409	4	1	5
Paithalmala; ACESSD/EW/407	1	0	1
Koovathumoola; ACESSD/EW/406	8	1	9
Chandanathodu (Kottiyoor range); ACESSD/EW/402	0	1	1
Total	22	20	42

Table 3. Number of Drawida modesta specimens with and without genital markings (GM).

#### Drawida somavarpatana Rao, 1921

Drawida somavarpatana Rao, 1921. Ann. Mag. Nat. Hist. (ser. 9), 8: 497. Drawida somavarpatana, Stephenson 1923. Fauna Br. India, Oligochaeta: 158.

Material examined. 6 clitellate (ACESSD/EW/405), Ranipuram (12°25'5.7"N; 75°21'4.4"E), Kasaragod district, India, 935 m a.s.l., grassland and evergreen forest, 17 December 2013, S.P. Narayanan and S. Sathrumithra coll.; 2 clitellate (ACESSD/ EW/408), Paithalmala (12°10'1.7"N; 75°33'31.1"E), Kannur Dist., India, 1076 m a.s.l., higher altitude evergreen forest, 30 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 1 clitellate, 3 aclitellate (ACESSD/EW/410), Koombanmala (12°20'43.2"N; 75°24'41.4"E), Kasaragod district, Kerala, India, 867 m a.s.l., grassland, 20 October 2012, S.P. Narayanan, S. Sathrumithra, M. Ramesan and T. Augustine coll.; 1 clitellate, 1 aclitellate (ACESSD/EW/411), Kottathalachimala (12°15'53.1"N; 75°25'45"E), Kannur district, Kerala, India, 664 m a.s.l., deciduous forest, 28 November 2012, S. Sathrumithra, T. Augustine and S.P. Narayanan coll.; 2 clitellate (ACESSD/EW/412), Kunnathoorpadi (12°4'55"N; 75°37'39.1"E), Kannur district, Kerala, India, 579 m a.s.l., evergreen forest with reed breaks, 30 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 2 clitellate (ACESSD/EW/413), Sree Deviyottukavu sacred grove - Aalapadamba (12°12'34.1"N; 75°15'9.7"E), Kannur district, Kerala, India, 8 m a.s.l., evergreen sacred grove, 29 November 2012, S.P. Narayanan, T. Augustine and S. Sathrumithra coll.; 9 clitellate, 12 aclitellate (ACESSD/EW/414), Kottencheri (12°20'57.6"N; 75°24'5.9"E), Kasaragod district, Kerala, India, 801 m a.s.l., evergreen forest, 20 October 2012, S.P. Narayanan, T. Augustine, S. Sathrumithra and M. Ramesan coll.; 4 aclitellate (ACESSD/ EW/449), Panathoor (12°27'31.3"N; 75°20'42.9"E), Kasaragod district, Kerala, India, 98 m a.s.l., 24 October 2014, areca nut and coconut plantation, S. Sathrumithra coll.

**Diagnosis.** Length 82–133 mm, diameter 4–6 mm, 111–154 segments. Ventral setae enlarged on pre-clitellar segments; aa = 5 ab = bc = 5 cd on segment 7, aa = 11 ab = 0.7 bc = 11 cd on segment 35. Male pores paired puckered orifices with tumid lips, slightly lateral to setae b lines, at 10/11. Spermathecal pores paired, small, at 7/8, at setae c lines or in bc but closer to c. Gizzards 3–5, in segments 15–20. Prostates glandular, bilobed; vas deferens discharges at junction of prostatic lobes. Spermathecae paired in segment 8; atrium bilobed, elongate and erect; one lobe in segment 7 and the other in segment 8; spermathecal duct discharges at junction of atrial lobes.

**Distribution.** India: Kerala: District Kasaragod: Koombanmala, Kottencheri, Panathoor, Ranipuram; District Kannur: Kottathalachimala, Kunnathoorpadi, Paithalmala, Aalapadamba (all new records from Kerala) (Fig.2); Karnataka: District Kodagu (Coorg): Somavarpatana, spelt as 'Somvarpet' (Stephenson 1923), Coorg Hills (Rao 1921).

**Biology.** Spermathecae and male genitalia are absent in a number of worms from Kerala, indicating parthenogenetic mode of reproduction.

**Remarks.** The diagnosis is based on the present material from Kerala, description as given by Stephenson (1923) and re-examination of type material in Zoological Survey

Site name & registration number	Length (mm)	Width (mm)	Number of segments	Number of gizzards (segments)
	87	5	125	5 (16–20)
Koombanmala; ACESSD/EW/410	83	5	119	5 (16–20)
	83	6	130	NC
	82	5	104	5 (16–20)
Kottathalachimala; ACESSD/EW/411	NM	6	113	NC
	107	6	135	NC
Kunnathoorpadi; ACESSD/EW/412	86	5	134	3 (17–19)
Sree Deviyottukavu – Alapadamba;	NM	5	NC	3 (18–20)
ACESSD/EW/413	NM	5	NC	3 (17–19)
	133	6	154	4 (16–19)
Kottencheri; ACESSD/EW/414	101	5	142	5 (15–19)
	97	5.5	144	4 (16–19)
	91	5.5	131	3 (18–20)
	95	5.5	125	4 (17–20)
	NM	5	NC	4 (16–19)
Ranipuram; ACESSD/EW/405	89	6	111	4 (16–19)
	96	5	NC	4 (15–19)
	NM	NM	NC	5 (15–19)

**Table 4.** Length, width, number of segments, and number of gizzards in selected specimens of *Drawida somavarpatana* from various localities.

NM - not measured, NC - not counted.

of India, Kolkata (Reg. no. W416/1). Worms from Kerala are longer and stouter, and have a greater number of gizzards than worms from Karnataka (Rao 1921). Body dimensions and number of gizzards in Kerala worms are: average length 94.61 mm (range = 82-133 mm; n = 13); average width 5.38 mm (range 5–6 mm; n = 17); average number of segments 128.23 (range 111–154; n = 13), gizzards 3–5, mainly located between segments 15–20 (Table 4).

#### Drawida thurstoni Gates, 1945

Drawida thurstoni Gates, 1945. Jl. R. Asiat. Soc. Bengal, 11: 71.

**Material examined.** 2 clitellate, 4 aclitellate (ACESSD/EW/183), Kanjipara (11°26'16.4"N; 76°7'41.7"E), Kozhikode district, Kerala, India, 2000 m a.s.l., Shola forest, 23 December 2012, T. Augustine, S.P. Narayanan, A. Sasi and S. Sathrumithra coll.

**Diagnosis.** Length 185–220 mm, diameter 7–8 mm, 166–187 segments. Setae aa = 12-13.33 ab = 1.06-1.11 bc = 12-16 cd = 0.21-0.23 dd at segment 8; aa = 13.66-14 ab = 1.13-1.23 bc = 20.5-21 cd = 0.24-0.28 dd at segment 20. Male pores paired, transverse slits at 10/11, about mid bc. Spermathecal pores paired, minute at

7/8, close to setae c lines. Nephridiopores on or close to setae d lines, occasionally dislocated into setae a, b on some segments behind clitellum. Genital markings absent. Gizzards 5, in segments 14–22. Prostates glandular, mushroom-shaped, stalked and erect, laterally compressed, glandular lining restricted to ental end; prostatic capsule vertical, ovoid; vas deferens coiled in to a cluster of hairpin loops; vas discharging into anterior face of prostate at ectal end. Spermathecae paired in segment 8; atrium irregularly ovoid, covered over by a thin layer of muscle, in segment 7 only or slightly extending to segment 8.

**Distribution.** India: Kerala: District Kozhikode: Kanjipara (new record) (Fig. 2); Tamil Nadu: District Nilgiris: Nilgiri Hills (Gates 1945).

**Remarks.** Range of the length, diameter, and number of segments of the Kerala specimens are 171–176 mm, 7.5–8 mm, and 183–185 respectively.

#### Discussion

Earthworms of the primitive family Moniligastridae are believed to have originated somewhere in the region of Malaya Archipelago (Gates 1972, Blakemore et al. 2014); Jamieson (1977) suggests their origin near Myanmar. Its natural range encompass, south, southeast and east Asia, from peninsular India to Japan through Myanmar, China, extreme southern portion of Far East Russia, Korea, the Philippines, Borneo, and Sumatra (Gates 1972). The large range is primarily due to the spread of *Drawida*, the most speciose moniligastrid genus that presumably colonized peninsular India after the collision of Indian plate with Asia during Caenozoic period (Gates 1972, Blakemore et al. 2014). Recent attempts to resolve conflicts within the taxonomy of the genus have used molecular mtDNA barcoding, where possible of primary types (Blakemore et al. 2010, 2014; Blakemore and Kupriyanova 2010).

*Drawida* has undergone extensive radiation in India with 72 species listed by Blakemore (2007) but its greatest concentration (43 species) is found in the Western Ghats (Stephenson 1923, Gates 1945). Within the Western Ghats, the genus has an important centre of speciation in the southernmost state of Kerala, most species being endemic; there are 16 species, ten of which are endemic (Narayanan et al. 2016). The present discovery of two new species and five new records of *Drawida* further contribute to the vast species richness of the genus in the state.

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CHECKLIST



### The Orthoptera of Castro Verde Special Protection Area (Southern Portugal): new data and conservation value

Sílvia Pina<sup>1,2</sup>, Sasha Vasconcelos<sup>1,2</sup>, Luís Reino<sup>1,2</sup>, Joana Santana<sup>1,2</sup>, Pedro Beja<sup>1,2</sup>, Juan S. Sánchez-Oliver<sup>1</sup>, Inês Catry<sup>1,2</sup>, Francisco Moreira<sup>2,3</sup>, Sónia Ferreira<sup>1</sup>

I CIBIO/InBIO-UP, Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto. Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485–601, Vairão, Portugal 2 CEABN/InBIO, Centro de Ecologia Aplicada "Professor Baeta Neves", Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal 3 REN Biodiversity Chair, CIBIO/InBIO-UP, Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485–601 Vairão, Portugal

Corresponding author: Silvia Pina (akenaton\_73@hotmail.com)

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#### Abstract

With the increasing awareness of the need for Orthoptera conservation, greater efforts must be gathered to implement specific monitoring schemes. Despite recent surveys, little is known about Portuguese Orthoptera populations. This study was performed in 2014 and 2015 mainly in Castro Verde Special Protection Area (SPA), southern Portugal, and is the first Orthoptera inventory conducted in the area. A total of 35 Orthoptera species was recorded, with two new species reported for Portugal. We provide species' habitat occurrences within the protected area and use information on the conservation status and the Iberian distribution of each documented species to discuss the importance of Castro Verde SPA for Orthoptera conservation. The data presented here sheds new light on Castro Verde SPA biodiversity and emphasizes the inclusion of this area in the conservation of Orthoptera diversity, particularly in the protection of threatened endemic species.

#### Keywords

Biodiversity, open-habitats, species inventory, distribution extension

#### Introduction

The results of the recent Red List assessment of Europe's grasshoppers, crickets and bush-crickets indicate that the highest species diversity and the greatest concentration of threatened species are found in the Mediterranean region. Moreover, the highest number of Data Deficient species are found in the Mediterranean region and many are also found in the Iberian Peninsula along with endemic species (Hochkirch et al. 2016). The climate and ecological conditions in the Iberian Peninsula promote the presence of an abundant and varied orthopterofauna (Llucià-Pomares 2002). To preserve this biodiversity, it is essential to increase our knowledge on species distributions. Therefore, taxonomic studies and faunistic inventories at a local and regional level should be intensified.

On the Iberian Peninsula, the Orthoptera fauna has been more comprehensively studied in Spain, while there is still a lack of knowledge regarding the Portuguese Orthoptera (Schmidt et al. 2009). To find the first studies on the Orthoptera fauna of Portugal we have to consult the literature of the last quarter of the XIX century. Bolívar (1876) published the first study about this group for Portugal and Spain, although some species had been previously referred to by Baptista (1789), Vandelli (1797), Charpentier (1841–1845) and Fischer (1853). More recently, several Portuguese and foreign researchers have contributed to improve the knowledge of the Portuguese Orthoptera fauna, e.g. Lock (1999); Miranda-Arabolaza and Barranco (2005); Ferreira et al. (2006, 2007, 2008, 2009); Ferreira (2007, 2009); Ferreira and Grosso-Silva (2008a, b, c); Schmidt et al. (2009); Lemos et al. (2016); Monteiro et al. (2016). However, these studies are scattered over time, distinct in focus, and generally lack comprehensive inventories. There are thus numerous unexplored Portuguese regions regarding the knowledge of the orthopterofauna. As a consequence, ten species have been assessed as Data Deficient in continental Portugal (Hochkirch et al. 2016). Moreover, in recent studies, several species were reported for the first time for the country, e. g. Lemos et al. (2016), Monteiro et al. (2016). These evidences suggest that there is still much to learn about this group, and that further in-depth research on Orthoptera of Portugal is necessary.

The Castro Verde Special Protection Area (SPA, PTZPE0046, Natura 2000 network) consists mainly of extensive cereal-steppes, however in recent years the afforested area has increased. The area houses the most significant diversity and abundance of steppe birds in Portugal and, therefore, was designated for steppe bird conservation under the European Union Birds Directive (79/409/EEC). Several bird species listed in Annex I of the Birds Directive are regularly found there, including the lesser kestrel (*Falco naumanni*), the great bustard (*Otis tarda*) and the little bustard (*Tetrax tetrax*). While the biological and conservation importance of birds in Castro Verde SPA has long been recognized, little is known about its value for other groups, namely for arthropods. Many orthopterans, especially grasshoppers, are highly dependent on grassland habitats and are major primary herbivores (Ingrisch and Köhler 1998, Köhler et al. 1987). Furthermore, orthopterans are important components in grassland ecosystems, often accounting for the largest biomass of arthropods (Little et al. 2013). On the other hand, they are an important food resource for a range of species, some of which are of conservation concern. For example, *O. tarda, T. tetrax* and *F. naumanni* consume orthopterans during the breeding and pre-migration periods (Rocha et al. 2005, Jiguet 2002, Catry et al. 2014, Bounas and Sotiropoulosa 2017). Despite its importance, to date no comprehensive inventory on Orthoptera fauna has been performed in Castro Verde SPA. The only available information comes from the work of Schmidt et al. (2009), who conducted surveys between 1992 and 2000 in several regions of Portugal, and recorded six species from Castro Verde.

With this study, we aim to increase the knowledge of the Orthoptera fauna in Portugal, presenting a list of species and the respective habitats of occurrence in a fragmented and human-altered landscape. We gather information on the conservation status and distribution of each documented species, and discuss the importance of the Castro Verde SPA for the conservation of Iberian Orthoptera diversity.

#### Methods

The data presented in this paper are a result of fieldwork performed in a farmland landscape mostly included in the Castro Verde SPA, southern Portugal (Figure 1). The climate is Mediterranean, with hot summers (averaging 24°C [16–32°C] in July), mild winters (9°C [5–14°C] in January) and >75% of annual rainfall (500–600 mm) concentrated in October–March. The area is the most representative steppe area in Portugal, with 85.345 hectares of which around 60.000 hectares are pseudo-steppe (EC 2016). The landscape is flat or gently undulating (100–300 m a.s.l.) and dominated by an agricultural mosaic of cereal, pastures and grazed fallow land (Ribeiro et al. 2016). Tree cover is characterized by plantations of eucalyptus (*Eucalyptus* sp.), oaks (*Quercus rotundifolia* and *Q. suber*) and umbrella pines (*Pinus pinea*). Pine and oak plantations often have a grassy understorey grazed by livestock. The area occupied by forest plantations increased since the 1990's, mostly in the periphery of the Castro Verde SPA, due to Common Agricultural Policy (CAP) subsidies for farmland afforestation (Reino et al. 2010). Nevertheless, specifically within the protected area afforestation is currently prohibited.

To study species diversity and habitat specificity, orthopterans were visually recorded along transects placed in the different habitats. This method was chosen because it has been widely used to sample Orthopteran (Gardiner et al. 2005), and because it provided a simple and standardised approach to sample a large number of sites with different vegetation structure within a relatively short period. Sampling was performed in 61 sites, each composed of one forest plantation and one adjacent fallow field (Table 1). The forest plantations consisted of one of the following types: pine, oak, eucalyptus and mixed pine-oak. Sampling was performed in 32 sampling sites in 2014 and the remaining 29 sites in 2015, in three periods each year (2014: 15 April–15 May, 15 May–4 June, 13 June–1 July; 2015: 16 April–17 May, 18 May–1 June, 15 June–23 June). Surveys were carried out under similar meteorological conditions (sunny weather, with temperature > 17° C and without strong winds), during the periods of highest activity



**Figure 1.** Location of the study area in southern Portugal showing the sites sampled (triangles), the Special Protection Area of Castro Verde, and the six municipalities encompassed.

**Table 1.** Information on the sampling sites prospected in this study: site code, municipality, locality, WGS 84 coordinates, elevation and plantation type. Each coordinate corresponds to the centre of the edge between fallow and plantation.

Sampling	Municipality	Locality	Latitudo	Longitudo	Elevation	Plantation
site	winnerpairty	Locality	Lautude	Longitude	(m a.s.l.)	type
A29	Aljustrel	Aljustrel	37°52.11'N	-8°7.152'W	206	Oak
A33	Aljustrel	Aljustrel	37°52.992'N	-8°8.484'W	140	Pine
A57	Aljustrel	Aljustrel	37°49.818'N	-8°11.49'W	214	Eucalyptus
A63	Aljustrel	Messejana	37°49.23'N	-8°12.336'W	217	Eucalyptus
A64	Aljustrel	Messejana	37°48.276'N	-8°13.086'W	213	Oak
A68	Aljustrel	Aljustrel	37°50.574'N	-8°7.65'W	200	Oak
A74	Aljustrel	Aljustrel	37°51.774'N	-8°5.556'W	169	Eucalyptus
A90	Aljustrel	Messejana	37°50.268'N	-8°12.27'W	229	Eucalyptus
B1	Aljustrel	Aljustrel	37°50.58'N	-8°11.196'W	223	Eucalyptus
B4	Aljustrel	Messejana	37°48.804'N	-8°12.666'W	241	Eucalyptus
P27	Aljustrel	Messejana	37°47.922'N	-8°10.956'W	198	Eucalyptus
P29	Aljustrel	Messejana	37°50.016'N	-8°13.692'W	220	Eucalyptus
P30	Aljustrel	Messejana	37°49.176'N	-8°14.256'W	197	Mixed pine-oak
P31	Aljustrel	Messejana	37°48.156'N	-8°15.09'W	173	Mixed pine-oak
P36	Aljustrel	Aljustrel	37°49.722'N	-8°6.138'W	178	Eucalyptus
P39	Aljustrel	Aljustrel	37°52.614'N	-8°8.466'W	150	Oak
P42	Aljustrel	Messejana	37°49.536'N	-8°16.176'W	169	Eucalyptus

Sampling site	Municipality	Locality	Latitude	Longitude	Elevation (m a.s.l.)	Plantation type
A152	Almodôvar	Aldeia dos Fernandes	37°34.71'N	-8°10.398'W	258	Oak
P10	Beja	Albernoa	37°48.804'N	-7°57.006'W	169	Oak
A85	Castro Verde	Santa Bárbara dos Padrões	37°37.11'N	-7°58.482'W	238	Oak
A98	Castro Verde	São Marcos da Ataboeira	37°37.89'N	-7°53.214'W	202	Pine
B5	Castro Verde	Casével	37°44.748'N	-8°12.846'W	186	Eucalyptus
B6	Castro Verde	São Marcos da Ataboeira	37°43.254'N	-7°53.43'W	216	Eucalyptus
B14	Castro Verde	Castro Verde	37°41.322'N	-8°1.434'W	180	Eucalyptus
P1	Castro Verde	São Marcos da Ataboeira	37°43.224'N	-7°55.878'W	167	Pine
P3	Castro Verde	São Marcos da Ataboeira	37°42.414'N	-7°57.396'W	187	Oak
P8	Castro Verde	Entradas	37°46.746'N	-7°59.658'W	184	Oak
P9	Castro Verde	Entradas	37°48.75'N	-7°58.056'W	176	Eucalyptus
P16	Castro Verde	Santa Bárbara dos Padrões	37°37.932'N	-7°59.166'W	237	Eucalyptus
P17	Castro Verde	Santa Bárbara dos Padrões	37°36.48'N	-7°59.604'W	255	Pine
P18	Castro Verde	Santa Bárbara dos Padrões	37°37.29'N	-7°57.996'W	232	Oak
P19	Castro Verde	Santa Bárbara dos Padrões	37°36.258'N	-7°57.594'W	253	Oak
P20	Castro Verde	São Marcos da Ataboeira	37°38.436'N	-7°52.902'W	194	Mixed pine-oak
P22	Castro Verde	São Marcos da Ataboeira	37°39.708'N	-7°52.488'W	192	Pine
P24	Castro Verde	Castro Verde	37°43.818'N	-8°6.648'W	220	Eucalyptus
P25	Castro Verde	Castro Verde	37°43.962'N	-8°9.432'W	227	Oak
P28	Castro Verde	Castro Verde	37°38.322'N	-8°4.398'W	233	Oak
P33	Castro Verde	Casével	37°44.634'N	-8°12.06'W	190	Oak
A76	Mértola	São João dos Caldeireiros	37°38.148'N	-7°52.062'W	197	Pine
A78	Mértola	São João dos Caldeireiros	37°38.094'N	-7°50.886'W	183	Pine
A79	Mértola	São João dos Caldeireiros	37°40.116'N	-7°48.366'W	142	Pine
A99	Mértola	Alcaria Ruiva	37°39.732'N	-7°50.694'W	170	Pine
B7	Mértola	Alcaria Ruiva	37°43.14'N	-7°48.732'W	168	Eucalyptus
B8-1	Mértola	Alcaria Ruiva	37°43.35'N	-7°48.954'W	184	Eucalyptus
P5	Mértola	Alcaria Ruiva	37°43.794'N	-7°51.384'W	196	Eucalyptus
P6	Mértola	Alcaria Ruiva	37°44.958'N	-7°51.522'W	169	Pine
P11	Mértola	Alcaria Ruiva	37°47.262'N	-7°53.688'W	152	Oak
P12	Mértola	Alcaria Ruiva	37°47.184'N	-7°52.05'W	148	Oak
P13	Mértola	Alcaria Ruiva	37°41.868'N	-7°51.654'W	172	Pine
P15	Mértola	Alcaria Ruiva	37°40.386'N	-7°50.454'W	162	Pine
P23	Mértola	São João dos Caldeireiros	37°39.138'N	-7°51.756'W	173	Pine
P52	Mértola	Alcaria Ruiva	37°42.162'N	-7°52.062'W	175	Pine
B3	Ourique	Panóias	37°46.044'N	-8°17.31'W	153	Pine
B13-2	Ourique	Conceição	37°47.232'N	-8°11.688'W	194	Mixed pine-oak
P32	Ourique	Conceição	37°47.172'N	-8°13.614'W	202	Oak
P46	Ourique	Conceição	37°47.076'N	-8°16.746'W	161	Pine
P47	Ourique	Ourique	37°37.374'N	-8°10.398'W	257	Oak
P48	Ourique	Ourique	37°38.058'N	-8°10.17'W	249	Oak
P49	Ourique	Ourique	37°37.41'N	-8°8.616'W	249	Mixed pine-oak
P50	Ourique	Panóias	37°49.602'N	-8°20.154'W	118	Oak
P51	Ourique	Conceição	37°45.384'N	-8°13.986'W	186	Pine

of most orthopterans (9:00 am to 6:00 pm). Linear transects 50m long were placed in each of the forest plantation, adjacent fallow and the edge between both, and within each site we sampled 1 transect at the habitat edge, 3 transects in fallows and 1-3 transects in plantations, depending on the forest patch size. Orthopterans were recorded along the 50-m transects, within 50cm on either side of the observer, and collected by direct capture a representative sample of adults that appeared to be morphologically distinct. To complement the species inventory, within each sampling site we further collected individuals recorded outside the standardised 50-m transects, which appeared to be morphologically distinct. All individuals collected were later identified to species level in the laboratory, based on: Llucià-Pomares (2002), Defaut (2005a) and Defaut and Aulin (2008) for Aiolopus spp.; Barat (2012) for Bradyporinae; Defaut (2004) and García et al. (2005) for Dociostaurus spp.; Ragge and Reynolds (1984) for Euchorthippus spp.; Llorente and Pinedo (1990) for Odontura spp.; Cordero et al. (2009) for Oecanthus spp.; Defaut (2006) for Oedipoda spp.; Clemente et al. (1990) for Omocestus spp.; Massa (2012) and Llorente and Presa (1997) for Pamphagidae; and Husemann et al. (2013) and Defaut (2005b) for Sphingonothus spp. Scientific nomenclature follows Cigliano et al. (2016) and vouchers of each species are deposited in CIBIO's collection.

For each species the following information is provided: sampling site, collection date, habitat occurrence and number of males (M) and females (F) recorded. Species are coded according to their occurrence in the studied habitats, as follows: FAL – fallow; EDG – edge; OAK - oak plantation; PIN – pine plantation; EUC – eucalyptus plantation; MIX – mixed pine-oak plantation. The current distribution of each documented species in the Iberian Peninsula is also given, along with a remark when our findings indicate an extension of the known species' distribution range. Information about the conservation status of each species is also provided (see Suppl. material 1). Distribution data and conservation status are based on Hochkirch et al. (2016).

To evaluate the conservation value of the different habitat types, we calculated the Grasshopper Conservation Index (GCI) and the standardised Grasshopper Conservation Index (GCIn) proposed by Matenaar et al. (2015) (see Suppl. material 1). As proposed by Matenaar et al. (2015) the index was calculated for each recorded species using three parameters: "endemism", "dispersal capacity" and "rarity". "Endemism" was scored as: "1" - species with a large distribution range not confined to the Mediterranean Basin; "2"- species when endemic to the Mediterranean basin and "3" species endemic to the Iberian Peninsula. For "dispersal capacity", scoring was made according to the following criteria: "1" - fully capable of flight; "2" - wing-dimorphic and "3" - flightless. Rarity was scored based upon the occurrence of a species in the sampling sites: rare ("3") when it occurred at  $\leq 5$  sites, intermediate ("2") at  $\leq 10$  sites and common ("1") at >10 sites.

#### Results

A total of 35 species were recorded during this study: 33 species during transect sampling, and two additional species outside of the transects: *Aiolopus strepens* (Latreille, 1804) and *Pyrgomorpha conica* (Olivier, 1791). Two species are recorded for the first time for Portugal: *Dociostaurus hispanicus* Bolivar, 1898 and *Euryparyphes terrulentus* (Serville, 1838). Furthermore, *Platystolus martinezii* (Bolívar, 1873), first recorded around 100 years ago in Portugal (Aires and Menano 1916), is now recorded for the second time. The most representative orthopteran families are Acrididae, with 21 species belonging to six subfamilies and Tettigonidae with 10 species belonging to three subfamilies. The remaining families, Pamphagidae, Pyrgomorphidae, Gryllidae and Tetrigidae, are each represented by a single species (Figure 2). Furthermore, all six families are represented in tree plantations, while we have only found five families in fallows and four in habitat edges (see Suppl. material 1).

The number of species was broadly similar in fallows (29), edges (24) and tree plantations (27), despite the highest number of transects placed in fallows. Among the forest types, the most speciose were oak plantations (21), whereas only 13 species were found in eucalyptus plantations. The lowest value of Grasshopper Conservation Index (GCIn) was found for eucalyptus plantations ( $0.44\pm0.12$ ) and pine plantations ( $0.44\pm0.12$ ), while the highest was found for fallows ( $0.52\pm0.18$ ) and mixed pine-oak plantations ( $0.48\pm0.18$ ) and oak plantations ( $0.47\pm0.14$ ). The species with highest possible GCI value (1) was *Euryparyphes terrulentus*.

Twenty species were common to fallows, edges and plantations, while other species only occurred in a particular habitat. The species, *Aiolopus strepens*, *Oedaleus decorus* (Germar, 1826), *Platycleis affinis* Fieber, 1853, *Platystolus martinezii* and the Red-Listed species *Dociostaurus hispanicus* and *Platycleis falx* (Fabricius, 1775) were only recorded in fallows. The species *Truxalis nasuta* (Linnaeus, 1758), was only recorded in edges. Three species, *Platycleis intermedia* (Serville, 1838), *Pyrgomorpha conica* and *Tettigonia viridissima* (Linnaeus, 1758) were only recorded in tree plantations (see Suppl. material 1).

In terms of frequency of occurrence, the species Chorthippus (Glyptobothrus) apicalis (Herrich-Schaeffer, 1840), Calliptamus wattenwylianus Pantel, 1896 and Tessellana tessellata (Charpentier, 1825) were collected in the majority of the sampling sites (>80%) (Figure 3b). Overall, there was little variation in the frequencies of occurrence of these species among most of the habitat types, though there were generally lower frequencies in eucalyptus plantations. Within forest plantations, and specifically in eucalyptus plantations, Chorthippus vagans (Eversmann, 1848) occurred most frequently, possibly due to shade, patches of bare ground and sparse vegetation dominated by grasses characteristic of these plantations (Hochkirch et al. 2008). In pine plantations, Sphingonotus (Sphingonotus) lluciapomaresi (Defaut, 2005) was the species occurring most frequently. This is an Iberian endemic that occurs in areas with bare and rocky ground (Llucià-Pomares & Fernández-Ortín 2009), which characterize some of the pine plantations surveyed. In fallows, the species most frequently encountered was Dociostaurus maroccanus (Thunberg, 1815) (Figure 3a). This species typically occurs in dry grasslands, with patches of bare ground and short vegetation (Latchininsky 1998), which are created through livestock grazing. There are references from the 20th century of *Dociostaurus maroccanus* as an agricultural pest, with population outbreaks recorded in Portugal and Spain (Silva 1947,



**Figure 2.** Total number of Orthoptera species per family and per subfamily. The Acrididae and Tettigonidae subfamilies are discriminated in the stacked columns.



**Figure 3.** Frequency of occurrence (%) of each Orthoptera species per habitat type, calculated by dividing the number of occurrences by the number of transects in each habitat type (**a**), and percentage of sampling sites where the species occurred (**b**).

Latchininsky 1998), and elsewhere in Europe (e.g., Nagy 1994). Although in recent decades *Dociostaurus maroccanus* has lost its economic importance, outbreaks may eventually occur again in the future under favourable ecological and agricultural management conditions (Latchininsky 1998, Aragón et al. 2013).

#### Data resources

The data underpinning the analysis reported in this paper are deposited at GBIF, the Global Biodiversity Information Facility, http://ipt.gbif.pt/ipt/archive.do?r=orthopt\_castroverde (doi:10.15468/byd0kt, http://www.gbif.org/dataset/65f32597-48a7-4877-ae13-e4256b51fb6b).

#### Material examined

Family Tettigoniidae Krauss, 1902 Subfamily Tettigoniinae Kirby, 1906

Decticus albifrons (Fabricius, 1775) IUCN category: Least Concern
 Material examined. A29: 15/05/2015, OAK (1 M). A79: 26/05/2015, FAL (1 F).
 P20: 24/05/2014, MIX (1 M).

Iberian distribution. Widespread and very common all over the Peninsula.

## Platycleis affinis Fieber, 1853 IUCN category: Least Concern Material examined. A68: 20/06/2015, FAL (1 F). B5: 16/06/2015, FAL (1 F). P1: 25/06/2014, FAL (1 F). P46: 16/06/2015, FAL (1 F).

Iberian distribution. Present all over the Peninsula, except in the Pyrenees.

*Platycleis falx* (Fabricius, 1775) IUCN category: Vulnerable B2ab(ii,iii,iv,v) Material examined. B8-1: 21/06/2015, FAL (1 F).

**Iberian distribution.** Occurs mostly in the south-eastern part of the Iberian Peninsula and, specifically, it is known to occur in the central region of Portugal (Hochkirch et al. 2016). Our record expands this species' distribution range to southern Portugal.

*Platycleis intermedia* (Serville, 1838) IUCN category: Least Concern Material examined. A85: 21/06/2015, OAK (1 F). P52: 31/05/2014, PIN (1 F). Iberian distribution. This species occurs throughout continental Spain, except in the

Northern region with a more Atlantic climate influence and most of the Pyrenees. Prior to this research, the species was only accounted for in the central region of Portugal. However, our study suggests that this species may have a larger distribution range in southern Portugal.

#### Platycleis sabulosa Azam, 1901 IUCN category: Least Concern

- Material examined. P15: 18/06/2014, EDG (1 F). P22: 25/06/2014, PIN (1 F).
  P23: 18/06/2015, FAL (1 F). P48: 24/06/2014, OAK (1 F). P51: 24/06/2014, PIN (1 F).
  P52: 25/06/2014, FAL (1 F).
- **Iberian distribution.** In Spain, it is widespread in the south and centre, but is apparently scarce in the northern regions. In Portugal, the species occurs from the centre to the south.

#### Tessellana tessellata (Charpentier, 1825) IUCN category: Least Concern

Material examined. A29: 22/06/2015, FAL (2 F), OAK (1F). A33: 20/06/2015, FAL (1 F, 1M), PIN (1 F), A57: 20/06/2015, EDG (1 F), FAL (1F), A64: 22/06/2015, FAL (1 F, 2 M). A68: 20/06/2015 FAL (3 F), OAK (2 M). A76: 27/05/2015, FAL (3 M); 19/06/2015, EDG (1 M), FAL (2 F, 1 M). A78: 21/06/2015, FAL (1 F). A79: 23/06/2015, FAL (2 M), PIN (1 F). A85: 21/06/2015, FAL (2 F), EDG (1 F), OAK (1 F). A90: 24/06/2014, FAL (4 M), EDG (1 M). A98: 19/06/2015, FAL (2 F), EDG (1 M), PIN (1 M). A99: 19/06/2015, EDG (1 F), FAL (2 F). A152: 15/06/2015, EDG (1 M), FAL (1 F, 1 M), OAK (1 F, 2 M). B1: 16/06/2015, FAL (1 F). B5: 16/06/2015, FAL (2 F, 1 M). B6: 18/06/2015, FAL (1 F, 2 M). B7: 18/06/2015, FAL (2 F, 1 M). B8-1: 21/06/2015, FAL (1 F, 2 M). B13-2: 22/06/2015, FAL (1 F, 1 M), EDG (1 M), MIX (1 M). B14: 01/06/2015, FAL (1 F, 2 M); 23/06/2015, FAL (1 F, 1 M). P1: 03/06/2014, FAL (1 F, 3 M), EDG (2 M); 25/06/2014, FAL (2 F, 1 M), EDG (1 M). P3: 18/06/2015, FAL (3 F), EDG (1 F), OAK (1 F, 2 M). P5: 18/06/2014, FAL (1 F, 5 M). P6: 15/06/2014, FAL (1 F, 1 M), EDG (1 M), PIN (2 F, 2 M). **P8:** 16/06/2014, FAL (3 F, 5 M), EDG (3 F). **P9:** 20/06/2014, FAL (1 F, 5 M), EUC (1 F). **P11:** 20/06/2014, FAL (2 F, 4 M), EDG (1 F, 1 M), OAK (1 F, 1 M). P12: 20/06/2014, FAL (2 F, 2 M), EDG (1 M). P13: 16/06/2014, FAL (1 F, 3 M), EDG (2 M). P15: 18/06/2014, FAL (1 F, 1 M), EDG (1 F, 1 M), PIN (2 F). P17: 15/06/2014, FAL (2 F, 4 M), EDG (1 M). P18: 14/06/2014, FAL (4 F, 2 M), EDG (1 F, 2 M), OAK (4 F, 1 M). P20: 18/06/2014, FAL (3 F), EDG (1 F), MIX (1 F, 2 M). P22: 04/06/2014, FAL (2 F, 1 M), EDG (1 F), PIN (1 F, 1 M); 25/06/2014, FAL (1 F, 1 M), PIN (2 F). P23: 18/06/2015, FAL (1 M). P24: 14/06/2014, FAL (2 M). P27: 16/06/2015, FAL (2 F, 2 M). P28: 17/06/2014, FAL (6 F, 1 M), EDG (1 M), OAK (3 F, 1 M). P29: 19/06/2014, FAL (2 F). P30: 15/06/2015, FAL (1 F, 2 M), EDG (1 F), MIX (1 F). P31: 19/06/2014, FAL (1 M), MIX (2 F, 1 M). P32: 19/06/2014, FAL (3 F, 4 M), OAK (2 F, 2 M). P36: 24/06/2014, FAL (2 F). P39: 15/06/2015, FAL (2 F), EDG (1 F), OAK (1 M). P46: 16/06/2015, FAL (1 F, 1 M), EDG (1 M). P47: 16/06/2014 (3 F, 1 M), EDG (1 M), OAK (3 M). P48: 24/06/2014, FAL (2 F, 2 M), EDG, (1 M). P49: 01/07/2014, FAL (2 F, 1 M), EDG (1 F, 1 M), MIX (2 F, 1 M). P51: 24/06/2014, FAL (1 F, 5 M), EDG (1 F). P52: 25/06/2014, FAL (4 F), EDG (1 F, 1 M), PIN (1 F).

Iberian distribution. Widespread and very common all over the Peninsula.

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*Tettigonia viridissima* (Linnaeus, 1758) IUCN category: Least Concern Material examined. A85: 12/05/2015, OAK (1 M). Iberian distribution. Widespread and very common all over the Peninsula.

#### Subfamily Phaneropterinae Kirby, 1904

*Odontura* (*Odontura*) *glabricauda* (Charpentier, 1825) IUCN category: Least Concern Material examined. A63: 26/05/2015, FAL (1 M); B7: 22/04/2015, FAL (1 F); P18: 17/04/2014, OAK (1 F); P20: 26/04/2014, MIX (1 M); P39: 16/04/2015, EDG (1 M).

**Iberian distribution.** This is an Iberian endemic species and is restricted to the south-western quadrant of the Peninsula, where it is widespread and common.

#### Tylopsis lilifolia (Fabricius, 1793) IUCN category: Least Concern

- Material examined. A29: 22/06/2015, EDG (1 M), FAL (3 M), OAK (1 M); A33: 20/06/2015, EDG (2 M), FAL (3 F), PIN (1 M); B7: 18/06/2015, FAL (1 F, 1 M); B8-1: 21/06/2015, EDG (1 M); P5: 18/06/2014, FAL (1 F, 1 M); P6: 15/06/2014, PIN (2 M).
- **Iberian distribution.** In Spain it occurs mostly in the southern Mediterranean regions; in Portugal it is mainly known from the central region. It was Seabra (1937, 1939) who cited this species from a locality called Évora, representing the southernmost record in Portugal. Thus, our findings expand this species' distribution range to a southernmost locality in Portugal, which suggest a larger distribution range.

#### Subfamily Bradyporinae Burmeister, 1838

*Platystolus martinezii* (Bolívar, 1873) IUCN category: Least Concern Material examined. A29: 31/05/2015, FAL (1 F, 1 M).

**Iberian distribution.** This is an Iberian endemic species mainly distributed in the centre of the Peninsula (Barat 2012). Until now, the only record of this species in Portugal was provided by Aires and Menano (1916) in Portalegre, a central locality near the border with Spain. Therefore, our new record considerably expands its endemic distribution range to southern Portugal.

#### Family Gryllidae Saussure, 1893 Subfamily Oecanthinae Kirby, 1906

## *Oecanthus pellucens* (Scopoli, 1763) IUCN category: Least Concern Material examined. B1: 16/06/2015, FAL (1 F); P3: 18/06/2015, OAK (1 F); P17: 15/06/2014, FAL (1 F); P29: 19/06/2014, EDG (1 F, 1 M); P30: 15/06/2015,

FAL (1 F); **P31**: 19/06/2014, FAL (1 F); **P51**: 24/06/2014, EDG (1 F); **P52**: 25/06/2014, FAL (1 F).

Iberian distribution. Widespread and very common all over the Peninsula.

#### Family Tetrigidae Rambur, 1838 Subfamily Tetriginae Rambur, 1838

Paratettix meridionalis (Rambur, 1838) IUCN category: Least Concern
Material examined. B14: 01/06/2015, EUC (2 F, 1 M); 23/06/2015, EUC (3 F, 2 M); P31: 19/06/2014, MIX (1 F, 2 M); P52: 25/06/2014, FAL (1 F).
Iberian distribution. Widespread and very common all over the Peninsula.

#### Family Pamphagidae Burmeister, 1840 Subfamily Pamphaginae Burmeister, 1840

*Euryparyphes terrulentus* (Serville, 1838) IUCN category: Least Concern

- Material examined. P3: 25/05/2015, EDG (1 M); P13: 22/05/2014, FAL (1 F, 1 M); P15: 02/05/2014, FAL (1 M); P20: 24/05/2014, MIX (1 F).
- **Iberian distribution.** This species is new to Portugal. *E. terrulentus* was previously considered being endemic to Spain, where it is common in the south. This is the first record of *E. terrulentus* and the first confirmed record of *Euryparyphes* genus for Portugal, expanding its endemic Iberian distribution to southern Portugal.

Family Pyrgomorphidae Brunner, 1893 Subfamily Pyrgomorphinae Brunner von Wattenwyl, 1874

*Pyrgomorpha conica* (Olivier, 1791) IUCN category: Least Concern Material examined. A76: 05/05/2015, PIN (1 F).

**Iberian distribution.** Present in most of the Peninsula, but seems to be absent in a few regions of high altitude in the North.

Family Acrididae Werner, 1936 Subfamily Acridinae Uvarov, 1926

#### Truxalis nasuta (Linnaeus, 1758) IUCN category: Least Concern

Material examined. A33: 17/05/2015, EDG (1 M), 28/05/2015 (1 M); P36: 30/05/2014, EDG (1 F).

**Iberian distribution.** Widely distributed throughout the whole of Portugal, except for a few localities in the North. In Spain it has a meridional distribution, occurring in

the north-eastern part of the country and in the southern half, although it seems to be absent in the centre.

#### Subfamily Calliptaminae Harz, 1975

#### Calliptamus barbarus (Costa, 1836) IUCN category: Least Concern

Material examined. A29: 22/06/2015, OAK (3 F); A33: 20/06/2015, EDG (1 F), FAL (1 F, 2 M); A64: 22/06/2015, FAL (1 M); A76: 19/06/2015, EDG (1 F), FAL (1 F), PIN (1 M); A78: 21/06/2015, FAL (1 F); A85: 21/06/2015, FAL (3 F, 2 M), OAK (1 M); A90: 24/06/2014, FAL (1 F); A98: 19/06/2015, PIN (1 F, 2 M); A99: 19/06/2015, FAL (1 F); A152: 15/06/2015, FAL (1 F, 1 M); **B7**: 18/06/2015, EDG (2 M); **B8-1**: 21/06/2015, FAL (3 F, 1 M), EUC (1 M); B13-2: 22/06/2015, EDG (1 F), MIX (1 F); B14: 23/06/2015, FAL (1 F); P5: 18/06/2014, FAL (1 F); P6: 15/06/2014, PIN (3 M); P11: 20/06/2014, OAK (4 F, 4 M); P13: 16/06/2014, EDG (1 F); P15: 18/06/2014, PIN (2 M); P18: 14/06/2014, EDG (1 M), OAK (1 M); P20: 18/06/2014, EDG (1 M), MIX (1 F, 1 M); P22: 04/06/2014, EDG (1 M), 25/06/2014, FAL (2 M); P23: 18/06/2015, FAL (1 M); P27: 16/06/2015, FAL (1 F); P28: 17/06/2014, EDG (1 M), FAL (1 F); P29: 19/06/2014, FAL (1 M); P30: 15/06/2015, MIX (1 F); P31: 19/06/2014, FAL (3 M); P32: 19/06/2014, OAK (2 M); P39: 15/06/2015, OAK (1 F); P46: 16/06/2015, PIN (1 M); P48: 24/06/2014, EDG (1 F, 2 M), FAL (1 M), OAK (1 F, 1 M); P49: 01/07/2014, EDG (1 F), MIX (2 F, 1 M); P52: 25/06/2014, FAL (1 F, 4 M).

Iberian distribution. Widespread and very common all over the Peninsula.

#### Calliptamus wattenwylianus Pantel, 1896 IUCN category: Least Concern

Material examined. A29: 31/05/2015, EDG (1 M), FAL (1 F, 1 M), 22/06/2015, EDG (1 F), FAL (2 F, 1 M), OAK (2 F); A33: 28/05/2015, FAL (2 F, 1 M), 20/06/2015, FAL (4 M); A57: 20/06/2015, EDG (2 M), FAL (2 F, 1 M); A64: 01/06/2015, FAL (2 F, 3 M), 22/06/2015, FAL (1 F, 2 M), OAK (1 F); A68: 20/06/2015, FAL (2 M), OAK (1 M); A76: 27/05/2015, FAL (3 F, 6 M), EDG (1 M), PIN (2 M), 19/06/2015, FAL (2 M), EDG (1 M), PIN (1 M); A78: 30/05/2015, FAL (3 F, 3 M), PIN (1 F), 21/06/2015, FAL (1 F, 1 M), EDG (1 M), PIN (1 F); A79: 25/05/2015, EDG (1 M), 26/05/2015, FAL (3 F, 5 M), 23/06/2015, FAL (1 F, 2 M); A85: 30/05/2015, FAL (2 F, 3 M), EDG (1 F), OAK (1 F, 1 M), 21/06/2015, FAL (1 F, 2 M), EDG (1 M), OAK (1 M); A90: 24/06/2014, FAL (1 F), EDG (1 F); A98: 27/05/2015, FAL (4 F, 4 M), EDG (1 F, 1 M), PIN (3 M), 19/06/2015, FAL (2 M), EDG (1 M), PIN (1 M); A99: 25/05/2015, FAL (2 M), 19/06/2015, FAL (3 M), EDG (1 M); A152: 15/06/2015, FAL (1 F, 6 M), OAK, (1 F, 3 M); B1: 16/06/2015, FAL (4 F, 1 M), EDG (1 M); B5: 16/06/2015, FAL (4 M); B6: 22/05/2015, FAL (1 F, 2 M), 18/06/2015, FAL (1 F, 2 M), EDG (1 M), EUC (1 F); **B7**: 18/06/2015, EUC (2 M); **B8-1**: 16/05/2015, FAL (1 F),

30/05/2015, FAL (1 F, 4 M), 21/06/2015, FAL (2 F, 1 M); B13-2: 31/05/2015, FAL (5 M), EDG (2 M), 22/06/2015, FAL (1 F, 2 M), EDG (1 M), MIX (1 M); B14: 01/06/2015, FAL (2 F, 2 M), 23/06/2015, FAL (1 F, 1 M), EDG (1 M), EUC (1 M); P1: 03/06/2014, FAL (3 F), 25/06/2014, FAL (3 F, 1 M); P3: 25/05/2015, FAL (3 F, 6 M), OAK (1 F, 2 M), 18/06/2015, FAL (1 F, 4 M), EDG (1 M), OAK (2 F, 2 M); P5: 18/06/2014, FAL (4 F, 4 M); P6: 15/06/2014, FAL (6 F, 5 M); P8: 16/06/2014, FAL (1 F, 4 M), EDG (2 M), OAK (1 M); P9: 20/06/2014, FAL (2 F, 2 M); P11: 29/05/2014, FAL (4 F), EDG (1 M), OAK, (1 F, 2 M), 20/06/2014, FAL (2 M), EDG (1 M), OAK (2 F, 3 M); P12: 29/05/2014, FAL (1 F), 20/06/2014, FAL (2 F, 5 M), OAK (1 F); P13: 21/05/2014, PIN (1 F. 1 M), 22/05/2014, PIN (2 F. 1 M), 16/06/2014, FAL (1 F. 7 M), EDG (1 F. 3 M); P15: 25/05/2014, PIN (2 M), 26/05/2014, FAL (3 M), 18/06/2014, FAL (4 F, 3 M), EDG (1 M), PIN (1 F); P17: 15/06/2014, FAL (5 F, 4 M), EDG (1 M); P18: 14/06/2014, FAL (1 F, 8 M), OAK (5 F, 5 M); P19: 31/05/2014, FAL (2 F, 3 M), EDG (1 F, 1 M), OAK (1 F, 1 M); P20: 24/05/2014, MIX (1 F), 18/06/2014, FAL (4 F, 5 M), EDG (1 F, 1 M), MIX (2 F, 1 M); P22: 04/06/2014, FAL (6 F, 2 M), EDG (1 F), 25/06/2014, FAL (3 F, 7 M), EDG (1 M), PIN (2 M); P23: 22/05/2015, FAL (1 F, 3 M), 18/06/2015, FAL (1 F, 2 M), EDG (1 M); P24: 14/06/2014, FAL (1 M); P27: 16/06/2015, FAL (1 F, 1 M); P28: 17/06/2014, FAL (4 F, 4 M), EDG (1 M), OAK (2 F, 1 M); P29: 19/06/2014, FAL (2 F, 1 M); P30: 15/06/2015, FAL (2 F, 4 M); P31: 19/06/2014, FAL (5 F, 4 M), EDG (1 M), MIX (1 F); P32: 19/06/2014, FAL (6 F, 3 M), EDG (2 F), OAK (4 F, 4 M); P36: 30/05/2014, FAL (1 F), 24/06/2014, FAL (3 F, 4 M); P39: 15/06/2015, FAL (2 F), EDG (1 M), OAK (1 M); P46: 16/06/2015, FAL (1 F, 2 M); P47: 16/06/2014, FAL (5 F, 2 M), OAK (8 F, 4 M); P48: 24/06/2014, FAL (3 F, 1 M); P49: 01/07/2014, FAL (5 F, 3 M); P50: 01/06/2014, FAL (1 F); P51: 24/06/2014, FAL ( 3 F, 3 M); P52: 31/05/2014, FAL (3 F, 3 M), 25/06/2014, FAL (4 F, 7 M), EDG (1 F, 2 M), PIN (4 M).

**Iberian distribution.** Very abundant in the meridional half of the Peninsula but more scattered in the northern half, in the areas with more Atlantic influence.

#### Subfamily Pezotettiginae Uvarov, 1927

Pezotettix giornae (Rossi, 1794) IUCN category: Least Concern

Material examined. A29: 22/06/2015, OAK (2 F); A33: 20/06/2015, FAL (3 F), EDG (1 F); A57: 20/06/2015, FAL (1 F); A64: 22/06/2015, FAL (1 F), EDG (1 F), OAK (1 F); A68: 20/06/2015, FAL (3 F), EDG (1 F), OAK (2 F); A76: 19/06/2015, PIN (1 F); A78: 30/05/2015, FAL (1 F), EDG (1 F), PIN (1 F); A79: 23/06/2015, PIN (1 F); A85: 30/05/2015, OAK (1 F), 21/06/2015, FAL (2 F), OAK (1 F); A90: 24/06/2014, FAL (1 F, 3 M); A98: 19/06/2015, PIN (1 F); A99: 19/06/2015, PIN (1 F); A152: 15/06/2015, FAL (4 F, 1 M), OAK (4 F); B1: 16/06/2015, FAL (1 F, 1 M); B5: 16/06/2015, FAL (2 F), EUC (1 M); B6:

18/06/2015, EDG (1 F); B7: 18/06/2015, EDG (1 F); B8-1: 30/05/2015, FAL (1 F, 1 M), 21/06/2015, FAL (1 F), EDG (1 F); B13-2: 22/06/2015, FAL (3 F), MIX (1 F); B14: 23/06/2015, FAL (1 F), EDG (1 M); P1: 25/06/2014, EDG (1 F); P3: 18/06/2015, FAL (1 M), OAK (1 F, 1 M); P5: 18/06/2014, FAL (1 F, 1 M), EUC (2 F, 1 M); P6: 15/06/2014, FAL (1 F), EDG (2 F), PIN (1 M); P8: 16/06/2014, FAL (1 F, 1 M); P11: 20/06/2014, FAL (1 F), EDG (1 F), OAK (1 F, 2 M); P12: 20/06/2014, FAL (3 F, 1 M), OAK (1 F, 1 M); P15: 18/06/2014, PIN (4 F); P17: 15/06/2014, FAL (1 F, 1 M); P18: 14/06/2014, FAL (4 F, 2 M), OAK (1 M); P20: 18/06/2014, EDG (2 F, 1 M), MIX (1 F); P22: 04/06/2014, FAL (1 F), PIN (1 F, 1 M), 25/06/2014, PIN (1 F); P27: 16/06/2015, EDG (1 F), EUC (1 F); P28: 17/06/2014, FAL (4 F), OAK (1 F); P29: 19/06/2014, FAL (1 F); P30: 15/06/2015, FAL (3 F), MIX (1 F); P31: 19/06/2014, FAL (2 F), MIX (2 F, 1 M); P32: 19/06/2014, FAL (2 F), EDG (1 F), OAK (7 F, 3 M); P36: 24/06/2014, FAL (1 F), EUC (1 M); P39: 15/06/2015, FAL (3 F), EDG (1 F), OAK (2 F); P46: 16/06/2015, FAL (2 F); P47: 22/04/2014, FAL (1 F), 16/06/2014, FAL (3 F), EDG (2 F); P48: 24/06/2014, EDG (1 F, 1 M); P49: 01/07/2014, FAL (2 F), MIX (1 F); P51: 24/06/2014, FAL (1 F), EDG (1 F).

**Iberian distribution.** This species is common and widely distributed throughout all of the Peninsula, particularly in the south.

#### Subfamily Cyrtacanthacridinae Harz, 1975

*Anacridium aegyptium* (Linnaeus, 1764) IUCN category: Least Concern Material examined. B1: 22/04/2015, EDG (1 F); B5: 20/04/2015, EUC (1 M). Iberian distribution. Widespread and very common all over the Peninsula.

#### Subfamily Gomphocerinae Fieber, 1853

## *Chorthippus (Glyptobothrus) apicalis (Herrich-Schaeffer, 1840)* IUCN category: Least Concern

Material examined. A29: 15/05/2015, FAL (3 F, 5 M), EDG (5 M), OAK (4 F, 4 M), 31/05/2015, FAL (1 F, 4 M), EDG (2 M), OAK (1 F, 2 M); A33: 17/05/2015, FAL (2 F, 5 M), EDG (1 F), PIN (3 M), 28/05/2015, FAL (2 M), EDG (1 M), PIN (1 M); A57: 05/05/2015, FAL (2 F, 3 M), 26/05/2015, FAL (2 M); A63: 14/05/2015, FAL (2 F, 5 M), EDG (1 M), 26/05/2015, FAL (1 F); A64: 14/05/2015, FAL (2 M), OAK (2 M); A68: 15/05/2015, EDG (2 M), OAK (2 F, 1 M), 28/05/2015, OAK (1 M); A76: 05/05/2015, FAL (2 F, 1 M), EDG (1 F, 2 M), PIN (1 F, 1 M); A78: 13/05/2015, FAL (2 F, 1 M), EDG (1 F, 4 M), PIN (1 F, 2 M); A79: 02/05/2015, FAL (3 F, 5 M), EDG (1 F, 1 M), PIN (2 F, 3 M); A85: 12/05/2015, FAL (1 F, 3 M), EDG (1 F, 5 M), OAK (1 F, 2 M); A90: 04/06/2014, FAL (1 M); A98: 13/05/2015, FAL (1 F, 2 M), EDG (1 F, 4 M), PIN (1 F, 2 M); A98: 13/05/2015, FAL (1 F, 2 M), EDG (1 F, 4 M); A99: 02/05/2015, FAL (1 F, 2 M), EDG (1 M);

A152: 18/05/2015, FAL (2 M), EDG (1 M), OAK (2 M); B1: 24/05/2015, EDG (3 F); **B4**: 21/04/2015, FAL (1 M), EDG (1 M); **B5**: 20/04/2015, FAL (1 F, 1 M), 21/05/2015, FAL (1 F, 1 M), EDG (1 M); B6: 01/05/2015, FAL (2 F, 4 M), EDG (1 F), 22/05/2015, FAL (1 M); **B7**: 01/05/2015, FAL (2 F, 7 M), EDG (1 M); **B8-1**: 16/05/2015, FAL (1 F, 2 M); B13-2: 31/05/2015, EDG (1 F); B14: 01/06/2015, EDG (1 M); P3: 03/05/2015, FAL (2 F, 1 M), EDG (3 F, 1 M), OAK (12 F, 10 M), 25/05/2015, FAL (1 F, 1 M), OAK (2 F, 1 M); **P5**: 24/04/2014, FAL (1 F, 1 M); P6: 23/04/2014, FAL (1 M), PIN (1 F), 20/05/2014, PIN (1 F); P8: 22/04/2014, FAL (7 F, 7 M), 19/05/2014, FAL (2 F, 4 M), EDG (1 F, 3 M), OAK (1 F, 2 M); P9: 30/04/2014, FAL (1 F, 4 M), 23/05/2014, FAL (2 F, 1 M); P10: 30/04/2014, FAL (2 F, 6 M), EDG (1 F), OAK (2 F, 10 M), 17/05/2014, FAL (3 F, 4 M), EDG (2 M), OAK (1 F, 1 M); P11: 29/04/2014, FAL (5 F, 13 M), EDG (5 F, 5 M), OAK (2 F, 4 M), 29/05/2014, FAL (2 F), EDG (1 F); P12: 29/04/2014, FAL (3 F, 4 M), 29/05/2014, FAL (1 F, 1 M); P13: 25/04/2014, FAL (4 F, 1 M), EDG (1 F, 1 M), PIN (2 F, 4 M), 22/05/2014, FAL (2 F); P15: 02/05/2014, FAL (2 M), EDG (3 M), PIN (2 F, 3 M), 25/05/2014, PIN (1 F, 1 M); P16: 18/04/2014, FAL (1 M); P17: 19/04/2014, FAL (1 M), EDG (1 F), 16/05/2014, FAL (1 F, 1 M); P18: 17/04/2014, FAL (1 F, 2 M), EDG (2 F, 1 M), OAK (4 F, 3 M), 16/05/2014, FAL (3 M), EDG (1 F, 1 M), OAK (2 F, 5 M); P19: 09/05/2014, FAL (10 M), EDG (1 F, 2 M), OAK (9 M), 31/05/2014, OAK (1 M); P20: 25/04/2014, FAL (3 F, 6 M), EDG (1 F, 1 M), MIX (1 F), 26/04/2014, MIX (4 M), 24/05/2014, EDG (1 M); P22: 13/05/2014, FAL (1 F, 1 M), PIN (3 F, 6 M); P23: 18/04/2015, FAL (1 F, 4 M), EDG (1 M), 22/05/2015, FAL (2 F), EDG (2 F, 2 M); P24: 15/05/2014, FAL (1 F, 4 M); P25: 16/04/2015, FAL (1 F), OAK (1 M); P28: 22/05/2014, FAL (3 F, 1 M), EDG (1 M), OAK (1 M); P29: 27/05/2014, FAL (1 M); P30: 18/04/2015, MIX (1 F), EDG (1 M), 19/04/2015, FAL (2 F, 1 M), 21/05/2015, EDG (1 M); P31: 28/04/2014, MIX (1 M), 26/05/2014, EDG (2 M); P32: 01/05/2014, FAL (7 F, 6 M), EDG (1 M), OAK (10 F, 11 M), 27/05/2014, OAK (5 F, 3 M), 19/06/2014, OAK (1 M); P33: 26/04/2014, FAL (1 M), 17/05/2014, FAL (2 M), OAK (1 M); P39: 16/04/2015, FAL (2 M), OAK (2 M), 18/05/2015, FAL (2 F, 1 M), OAK (3 F, 2 M); P42: 14/05/2014, FAL (2 M); P46: 19/04/2015, FAL (2 M), EDG (1 F), PIN (1 M), 21/05/2015, FAL (2 F, 2 M); P47: 21/04/2014, OAK (1 F, 1 M), 19/05/2014, FAL (1 F, 1 M), OAK (2 F, 6 M); P48: 07/05/2014, FAL (1 M), EDG (3 F, 4 M), 08/05/2014, OAK (1 F, 1 M); **P49**: 08/05/2014, FAL (2 F, 1 M), EDG (1 F, 5 M), MIX (1 F, 6 M), 02/06/2014, EDG (1 F), MIX (3 F, 2 M); **P50**: 14/05/2014, EDG (1 M), OAK (1 F, 2 M); **P51**: 27/04/2014, FAL (1 F, 2 M), EDG (1 F); P52: 09/05/2014, FAL (1 F, 2 M), EDG (1 F, 1 M), PIN (4 M), 31/05/2014, FAL (1 F, 1 M).

**Iberian distribution.** Distributed in nearly all regions of the Peninsula, with the exception of the extreme north-west.

#### Chorthippus vagans (Eversmann, 1848) IUCN category: Least Concern

Material examined. A57: 20/06/2015, EDG (2 M); A63: 14/05/2015, EUC (1 M), 26/05/2015, EUC (1 F); A68: 20/06/2015, OAK (1 F); A74: 03/06/2014, EUC (1 F, 2 M); **A90**: 24/06/2014, EUC (2 M); **B1**: 24/05/2015, EDG (1 M), 16/06/2015, EUC (3 F, 2 M); **B3**: 17/05/2015, PIN (1 M); **B5**: 21/05/2015, EUC (2 F), 16/06/2015, EUC (2 M); **B7**: 18/06/2015, EUC (2 F); **P5**: 23/05/2014, EUC (2 F, 1 M); **P6**: 15/06/2014, PIN (1 F, 1 M); **P9**: 22/05/2014, EUC (1 M), 20/06/2014 (1 F, 3 M); **P27**: 24/05/2015, EDG (1 F, 1 M), EUC (1 M), 16/06/2015, EDG (1 F, 1 M), EUC (1 F, 2 M); **P29**: 26/05/2014, EUC (1 F, 1 M), 19/06/2014, EDG (1 M), EUC (1 F, 2 M); **P30**: 15/06/2015, MIX (3 F); **P31**: 19/06/2014, MIX (1 F); **P36**: 30/05/2014, EUC (1 F, 1 M), 24/06/2014, EDG (1 F, 4 M), EUC (2 F, 1 M); **P39**: 15/06/2015, EUC (2 F, 1 M); **P42**: 14/05/2014, EUC (1 F); **P51**: 30/05/2014, PIN (1 F).

Iberian distribution. Widespread and very common all over the Peninsula.

#### Dociostaurus genei (Ocskay, 1833) IUCN category: Least Concern

- Material examined. A78: 21/06/2015, FAL (2 F, 1 M); A79: 23/06/2015, EDG (1 F, 1 M), FAL (3 M); A98: 19/06/2015, EDG (4 F, 1 M), FAL (8 F, 3 M); A99: 19/06/2015, FAL (4 F, 2 M); A152: 15/06/2015, FAL (1 M); B8-1: 21/06/2015, FAL (1 M); B14: 23/06/2015, FAL (1 F); P13: 16/06/2014, PIN (2 F); P15: 18/06/2014, FAL (6 F, 3 M); P17: 15/06/2014, PIN (1 F, 1 M); P23: 18/06/2015, FAL (1 F), PIN (2 F, 1 M); P28: 17/06/2014, EDG (1 M).
- **Iberian distribution.** Present throughout most of the Peninsula with exception of the extreme north-west.

*Dociostaurus hispanicus* Bolivar, 1898 IUCN category: Near Threatened Material examined. P28: 17/06/2014, FAL (1 F).

**Iberian distribution.** First record for Portugal. This is an Iberian endemic species, has in Spain has a more western distribution and can be found from north to south (García et al. 2005). Our record is the southernmost for the Iberian Peninsula, and suggests a wider distribution.

#### Dociostaurus jagoi Soltani, 1978 IUCN category: Least Concern

Material examined. A29: 22/06/2015, FAL (1 F), EDG (1 M), OAK (1 F); A33: 20/06/2015, FAL (3 F, 1 M); A64: 22/06/2015, FAL (2 F, 1 M), EDG (1 M); A68: 20/06/2015, FAL (1 F, 1 M), EDG (1 M); A76: 19/06/2015, FAL (4 F, 5 M), EDG (2 F), PIN (2 F); A78: 21/06/2015, FAL (2 F, 4 M), EDG (1 F, 2 M), PIN (2 F, 3 M); A79: 23/06/2015, FAL (5 F, 5 M), EDG (1 F, 1 M), PIN (1 F, 1 M); A85: 21/06/2015, FAL (5 F, 2 M), EDG (1 M); A98: 19/06/2015, FAL (3 F, 2 M), EDG (1 M), PIN (2 F, 2 M); A99: 19/06/2015, FAL (6 F, 3 M), EDG (1 F, 1 M); A152: 15/06/2015, FAL (3 M), OAK (1 M); B6: 18/06/2015, FAL (7 F, 16 M), EUC (1 F); B7: 18/06/2015, FAL (1 F), EUC (1 F); B8-1: 21/06/2015, FAL (3 F, 1 M), EUC (1 M); B13-2: 22/06/2015, FAL (2 F, 3 M), MIX (1 M); B14: 23/06/2015, FAL (2 F, 3 M); P1: 25/06/2014, FAL (5 F, 3 M); P3: 18/06/2015, FAL (3 M), EUG (1 M); P6: 15/06/2014, PIN (2 F, 2 M); FAL (3 M), EDG (1 F, 1 M), EUC (1 M); P6: 15/06/2014, PIN (2 F, 2 M);

**P9**: 20/06/2014, FAL (1 M); **P11**: 20/06/2014, FAL (4 F, 4 M), EDG (1 F, 1 M), OAK (7 F, 2 M); **P12**: 20/06/2014, FAL (4 F, 2 M), OAK (4 F, 5 M); **P13**: 16/06/2014, FAL (6 F, 1 M), EDG (1 M), PIN (1 M); **P15**: 18/06/2014, FAL (4 F), EDG (1 F, 1 M), PIN (2 F); **P18**: 14/06/2014, OAK (1 F, 2 M); **P20**: 18/06/2014, FAL (2 M), EDG (1 M), MIX (1 F, 2 M); **P22**: 25/06/2014, FAL (2 F, 4 M), PIN (2 M); **P23**: 18/06/2015, FAL (3 F, 5 M), EDG (1 F, 2 M), PIN (2 M); **P27**: 16/06/2015, EUC (3 M); **P28**: 17/06/2014, FAL (1 F, 1 M), OAK (1 F); **P31**: 19/06/2014, FAL (1 F), MIX (2 F, 1 M); **P32**: 19/06/2014, OAK (1 M); **P36**: 24/06/2014, FAL (1 F, 2 M), EDG (1 M); **P36**: 24/06/2014, FAL (1 F, 7 M); **P46**: 16/06/2015, FAL (1 M), PIN (1 F); **P48**: 24/06/2014, FAL (1 F, 4 M), OAK (2 F, 3 M); **P49**: 01/07/2014, FAL (2 M), EDG (1 M), MIX (1 F, 2 M); **P51**: 24/06/2014, FAL (4 F, 3 M); **P52**: 25/06/2014, FAL (1 M).

- **Iberian distribution.** The area of occurrence extends throughout the Peninsula, with the exception of the northern strip faced to the Atlantic Ocean.
- Dociostaurus maroccanus (Thunberg, 1815) IUCN category: Least Concern
- Material examined. A33: 17/05/2015, FAL (1 M), 20/06/2015, FAL (1 M); A76: 27/05/2015, FAL (3 F, 4 M), PIN (1M), 19/06/2015, FAL (1 M), EDG (1 F); A78: 13/05/2015, FAL (2 F, 5 M), EDG (1 M), 30/05/2015, FAL (2 F, 2 M); A79: 26/05/2015, FAL (2 F, 3 M); A85: 30/05/2015, FAL (3 F, 1 M); A98: 13/05/2015, FAL (2 F, 1 M), 27/05/2015, FAL (3 F), EDG (1 F), PIN (1 F); A99: 25/05/2015, FAL (3 M), 19/06/2015, FAL (1 F, 2 M), A152: 15/06/2015, FAL (1 F); B5: 21/05/2015, FAL (1 F, 1 M), 16/06/2015, FAL (2 F, 1 M); B6: 22/05/2015, FAL (4 F, 1 M); B13-2: 31/05/2015, FAL (1 F, 1 M); B14: 01/06/2015, FAL (3 F, 1 M); P3: 25/05/2015, FAL (3 F, 4 M), 18/06/2015, FAL (2 M); P15: 26/05/2014, FAL (3 F, 3 M); P17: 16/05/2014, FAL (1 M), 15/06/2014, FAL (1 F); P19: 31/05/2014, FAL (2 F, 2 M); P22: 13/05/2014, FAL (3 F), 04/06/2014, FAL (1 F, 1 M); P23: 22/05/2015, FAL (3 F, 1 M), 18/06/2015, FAL (2 F, 1 M); P24: 14/06/2014, FAL (1 M); P27: 16/06/2015, FAL (1 M); P28: 22/05/2014, FAL (1 F), 17/06/2014, FAL (1 M); P29: 26/05/2014, FAL (1 F, 2 M), 19/06/2014, FAL (2 M); P30: 21/05/2015, FAL (1 F), 15/06/2015, FAL (1 M); P39: 18/05/2015, FAL (1 F), 15/06/2015, FAL (2 M); P47: 19/05/2014, FAL (1 M), 16/06/2014, FAL (2 F, 2 M); P49: 02/06/2014, FAL (1 F), 01/07/2014, FAL (1 F); P50: 01/06/2014, FAL (1 F, 2 M); **P52**: 31/05/2014, FAL (1 F).
- **Iberian distribution.** Widely distributed in the Mediterranean area of the Peninsula up to north-eastern Portugal. Seems to be absent in the northern strip faced to the Atlantic Ocean of Spain.

#### Euchorthippus elegantulus Zeuner, 1940 IUCN category: Least Concern

Material examined. A33: 28/05/2015, FAL (1 F, 2 M), EDG (1 F), 20/06/2015, FAL (3 F, 1 M), EDG (1 F), PIN (2 M); A57: 20/06/2015, FAL (2 M); A64: 01/06/2015, FAL (1 M), 22/06/2015, FAL (2 F, 3 M), EDG (1 F, 2 M), OAK
(1 M); A68: 20/06/2015, FAL (1 F, 5 M), EDG (1 M), OAK (2 M); A85: 21/06/2015, EDG (1 M); A90: 04/06/2014, FAL (2 M), 24/06/2014, FAL (2 F, 2 M); A99: 25/05/2015, FAL (1 M), EDG (1 F), 19/06/2015, FAL (3 F, 1 M); A152: 15/06/2015, FAL (5 F, 2 M), EDG (1 F, 4 M), OAK (1 F, 1 M); B5: 16/06/2015, FAL (1 F, 1 M); B6: 18/06/2015, FAL (1 F); B8-1: 30/05/2015, FAL (1 F); B13-2: 31/05/2015, FAL (1 F, 2 M), 22/06/2015, FAL (1 F, 3 M), EDG (1 F, 1 M); B14: 01/06/2015, EDG (1 M), 23/06/2015, FAL (1 M), EDG (2 M); P3: 18/06/2015, FAL (1 M); P6: 15/06/2014, EDG (1 M); P9: 20/06/2014, FAL (3 F, 2 M); P11: 29/05/2014, FAL (1 M), OAK (1 M); P12: 29/05/2014, FAL (1 M), 20/06/2014, FAL (1 F, 2 M); P18: 14/06/2014, EDG (1 M), OAK (4 F. 1 M); **P20**: 18/06/2014, EDG (1 F. 1 M), MIX (1 M); **P23**: 18/06/2015, FAL (3 M); P27: 16/06/2015, FAL (3 F, 4 M); P28: 17/06/2014, EDG (1 F, 1 M); P29: 19/06/2014, FAL (2 F, 1 M), EDG (1 M); P30: 15/06/2015, FAL (1 F, 2 M), EDG (1 F), MIX (1 F); P31: 19/06/2014, FAL (1 M), EDG (1 M), MIX (2 F, 3 M); P32: 19/06/2014, FAL (2 F, 3 M); P36: 30/05/2014, FAL (1 M), 24/06/2014, FAL (1 M); P39: 18/05/2015, EDG (1 M), 15/06/2015, EDG (2 F), OAK (3 F, 2 M); P46: 21/05/2015, PIN (1 M), 16/06/2015, FAL (3 F, 4 M), EDG (2 F, 3 M), PIN (3 M); P47: 16/06/2014, OAK (1 F, 2 M); P48: 24/06/2014, OAK (1 F); P51: 24/06/2014, FAL (2 F, 3 M); P52: 25/06/2014, FAL (1 F, 1 M), EDG (1 F, 1 M).

**Iberian distribution.** Present in almost in all of the Peninsula, being absent in the northern third.

# Omocestus panteli (Bolivar, 1887) IUCN category: Least Concern

- Material examined. A33: 17/05/2015, FAL (2 F), PIN (1 F), 28/05/2015, EDG (1 F); A64: 14/05/2015, OAK (3 F, 4 M), 01/06/2015, OAK (3 M), 22/06/2015, OAK (1 M); A90: 04/06/2014, FAL (1 M); A99: 02/05/2015, EDG (2 M), PIN (1 M); A152: 18/05/2015, EDG (1 M); B13-2: 31/05/2015, FAL (2 M); B14: 01/06/2015, EDG (1 F, 1 M), EUC (1 M); P25: 16/04/2015, EDG (1 M); P30: 18/04/2015, MIX (1 F), 19/05/2015, FAL (1 F, 1 M); P31: 25/05/2014, MIX (1 M), 19/06/2014, MIX (1 F, 3 M); P39: 16/04/2015, OAK (2 F), 18/05/2015, OAK (6 F, 3 M); P46: 19/04/2015, PIN (1 F), 21/05/2015, FAL (1 M); P50: 01/06/2014, OAK (1 M); P52: 09/05/2014, FAL (1 M), 31/05/2014, FAL (2 F, 1 M).
- **Iberian distribution.** This is an Iberian endemic species and occurs in most of the Iberian territory, with the exception of a few localities in the North, particularly in the Pyrenees.

# Subfamily Oedipodinae

Acrotylus patruelis (Herrich-Schaffer, 1838) IUCN category: Least Concern
Material examined. A29: 31/05/2015, EDG (1 F, 1 M), 22/06/2015, EDG (1 F, 1 M); A33: 28/05/2015, EDG (1 F, 2 M), PIN (1 M); A79: 25/05/2015, PIN (1 F),

26/05/2015, FAL (1 F); **A90**: 04/06/2014, EDG (1 F); **A99**: 25/05/2015, FAL (1 F); **A152**: 15/06/2015, EDG (1 F); **B1**: 24/05/2015, EDG (1 F), 16/06/2015, EDG (1 M); **B7**: 22/05/2015, EDG (2 F); **B8-1**: 16/05/2015, FAL (1 M); **B13-2**: 31/05/2015, FAL (1 M), 22/06/2015, FAL (1 F); **B14**: 01/06/2015, EUC (1 F); **P1**: 03/06/2014, FAL (2 F); **P3**: 25/05/2015, FAL (1 F); **P13**: 22/05/2014, PIN (1 F); **P19**: 31/05/2014, OAK (1 F), **P22**: 04/06/2014, PIN (1 F); **P23**: 22/05/2015, EDG (1 F); **P29**: 19/06/2014, FAL (1 F); **P30**: 21/05/2015, MIX (1 F); **P31**: 19/06/2014, MIX (1 F, 1 M); **P39**: 18/05/2015, EDG (1 F), OAK (2 F, 3 M), 15/06/2015, OAK (1 F); **P42**: 14/05/2014, EDG (1 M); **P50**: 01/06/2014, EDG (1 F, 1 M).

**Iberian distribution.** Distributed mostly in the meridional half and centre of Spain. In Portugal, it is apparently absent in the northern half of the country and in some localities of the littoral west of the South.

# Aiolopus puissanti Defaut, 2005 IUCN category: Least Concern

- Material examined. A29: 31/05/2015, EDG (1 F, 1 M); A33: 17/05/2015, FAL (2 F), EDG (2 M), 28/05/2015, EDG (1 M); A57: 20/06/2015, FAL (1 F, 1 M); A64: 01/06/2015, EDG (1 F); A68: 28/05/2015, FAL (2 F, 1 M); A74: 03/06/2014, FAL (1 F, 1 M), EDG (1 M); B13-2: 31/05/2015, FAL (2 F, 1 M), 22/06/2015, FAL (1 F); B14: 23/06/2015, EUC (1 F); P1: 03/06/2014, EDG (4 F, 2 M); P10: 17/05/2014, OAK (1 M); P13: 22/05/2014, FAL (1 M); P23: 22/05/2015, FAL (2 F, 2 M), EDG (1 M); P29: 26/05/2014, EDG (1 F, 1 M); P30: 19/05/2015, MIX (1 F), 21/05/2015, FAL (1 M), 15/06/2015, EDG (1 F); P31: 25/05/2014, MIX (1 M), 19/06/2014, MIX (1 F, 1 M); P32: 27/05/2014, EDG (1 F, 1 M); P36: 30/05/2014, EDG (1 M); P39: 16/04/2015, EDG (1 F), 18/05/2015, OAK (4 F); P46: 21/05/2015, FAL (3 F, 2 M), 16/06/2015, FAL (1 F); P50: 01/06/2014, EDG (1 F), OAK (2 F, 1 M); P52: 31/05/2014, FAL (1 F, 1 M), 25/06/2014, FAL (1 F).
- **Iberian distribution.** Present in almost all of the Peninsula with exception of the northern third.

*Aiolopus strepens* (Latreille, 1804) IUCN category: Least Concern Material examined. A74: 03/06/2014, FAL (1 F); B13-2: 17/07/2015, FAL (1 F). Iberian distribution. Widespread and very common all over the Peninsula.

Locusta migratoria (Fabricius, 1781) IUCN category: Least Concern
Material examined. A33: 28/05/2015, EDG (1 M); P3: 25/05/2015, FAL (1 F), 18/06/2015, FAL (1 M); P46: 16/06/2015, FAL (1 F).
Iberian distribution. Widespread and very common all over the Peninsula.

*Oedaleus decorus* (Germar, 1826) IUCN category: Least Concern Material examined. B13-2: 22/06/2015, FAL (1 M); P31: 19/06/2014, FAL (1 M). Iberian distribution. Widespread and very common all over the Peninsula.

# Oedipoda caerulescens (Linnaeus, 1758) IUCN category: Least Concern

Material examined. A29: 31/05/2015, OAK (1 F), 22/06/2015, OAK (1 M); A33: 28/05/2015, FAL (2 F, 3 M), EDG (2 F), PIN (1 M), 20/06/2015, FAL (3 F), EDG (1 F), PIN (1 M); A57: 20/06/2015, EUC (1 M); A63: 26/05/2015, EDG (3 M); A68: 20/06/2015, OAK (1 F); A76: 27/05/2015, PIN (1 M), 19/06/2015, PIN (1 F); A78: 13/05/2015, PIN (1 M), 30/05/2015, FAL (1 F), PIN (1 F), 21/06/2015, PIN (1 F, 2 M); A79: 25/05/2015, PIN (1 M), 26/05/2015, FAL (1 M), 23/06/2015, PIN (1 M); A85: 30/05/2015, OAK (2 F); A90: 24/06/2014, EDG (1 M); A98: 27/05/2015, PIN (1 M); A99: 25/05/2015, EDG (1 F), PIN (1 F), 19/06/2015, EDG (1 M), FAL (2 F); A152: 15/06/2015, FAL (1 F); B1: 16/06/2015, EDG (1 F), EUC (2 F, 2 M); B5: 16/06/2015, EUC (3 M); B6: 18/06/2015, EDG (1 M), EUC (1 F, 4 M); B13-2: 22/06/2015, MIX (1 M); B14: 01/06/2015, EUC (1 M), 23/06/2015, EUC (1 M); P3: 18/06/2015, EDG (1 M); P5: 18/06/2014, EDG (2 M); P6: 15/06/2014, PIN (1 F); P9: 20/06/2014, EUC (2 M); P13: 16/06/2014, PIN (1 F); P17: 15/06/2014, FAL (1 F), PIN (1 M); P18: 14/06/2014, OAK (4 F, 1 M); P20: 18/06/2014, MIX (1 F); P22: 04/06/2014, PIN (1 F, 1 M), 25/06/2014 (1 F, 1 M); P24: 13/06/2014, EDG (2 F); P27: 16/06/2015, EDG (1 F), EUC (1 F, 1 M); P29: 19/06/2014, EDG (1 F), EUC (1 M); P30: 15/06/2015, MIX (1 F, 2 M); P32: 19/06/2014, OAK (1 F, 1 M); P39: 18/05/2015, EDG (1 M), 15/06/2015, FAL (2 F, 2 M), OAK (7 F, 6 M); P47: 16/06/2014, FAL (1 F); P48: 02/06/2014, OAK (2 F, 1 M), 24/06/2014, OAK (2 F, 3 M); P49: 01/07/2014, MIX (1 F, 1 M).

Iberian distribution. Widespread and very common all over the Peninsula.

# Oedipoda charpentieri Fieber, 1853 IUCN category: Least Concern

- Material examined. A76: 27/05/2015, FAL (1 M), 19/06/2015, FAL (2 F, 1 M); A78: 30/05/2015, FAL (6 F); A79: 26/05/2015, FAL (4 M); A85: 21/06/2015, OAK (1 F); A90: 04/06/2014, EDG (1 M); A98: 27/05/2015, FAL (2 F, 3 M), 19/06/2015, FAL (3 F, 1 M); A99: 19/06/2015, FAL (3 F); B6: 18/06/2015, FAL (2 F, 3 M); B14: 01/06/2015, FAL (1 M); P1: 25/06/2014, FAL (1 F); P6: 15/06/2014, FAL (2 F, 2 M); P11: 29/05/2014, FAL (1 F), OAK (1 F, 1 M); P15: 18/06/2014, FAL (1 M); P17: 15/06/2014, FAL (1 F); P19: 31/05/2014, FAL (2 F); P20: 18/06/2014, EDG (1 F); P22: 25/06/2014, FAL (1 M); P23: 22/05/2015, FAL (1 F), 18/06/2015, FAL (2 M); P32: 19/06/2014, FAL (1 M); P47: 16/06/2014, FAL (1 F); P48: 02/06/2014, EDG (1 M), 24/06/2014, FAL (1 M).
- **Iberian distribution.** This species is widespread throughout the Mediterranean region of the Peninsula but is apparently absent in most of the extreme north-west, in the northern Atlantic littoral and in the Pyrenees.

# Sphingonotus (Sphingonotus) lluciapomaresi (Defaut, 2005) IUCN category: Least Concern

Material examined. A76: 19/06/2015, PIN (1 M); A78: 21/06/2015, EDG (1 M), PIN (2 F); A79: 23/06/2015, PIN (1 M); A98: 19/06/2015, FAL (1 M), PIN

(1 M); **A99**: 19/06/2015, FAL (1 M); **P12**: 20/06/2014, OAK (1 M); **P13**: 16/06/2014, PIN (1 M); **P22**: 25/06/2014, PIN (1 F, 1 M); **P23**: 18/06/2015, EDG (2 F, 2 M), PIN (1 F).

**Iberian distribution.** This species is endemic to the Iberian Peninsula and has a wide and central distribution in the Peninsula, occurring also in the south of Spain. Our record is the south-westernmost, extending the species known distribution range.

# Discussion

The results of the present study expand the list of Orthoptera species known for Portugal, and the species richness recorded augment the relevance of Castro Verde SPA in terms of biodiversity. The 35 species recorded are distributed among six of the 11 families known to occur in Portugal. From the species recorded, two are Red-Listed as threatened or near-threatened at the European level, and five are Iberian endemics. The diversity of species observed was probably driven by landscape heterogeneity, as we found species exclusive of both fallow land and forest plantations. Overall, our results point out the importance of Castro Verde SPA for the conservation of Orthoptera, and help identify some threats that may affect this value in the near future.

While the present study highlights the value of Castro Verde SPA in terms of Orthoptera diversity, it is likely that other species are present in the area. A more comprehensive species list can be obtained by using other methods, given the distinct phenologic and ecologic characteristics of certain groups and their ability for crypsis. For instance, beating should be used to collect tree and shrub-dwelling species, which are often difficult to detect. The use of bioacoustic exploration can also be advantageous to obtain information on less conspicuous orthopterans such as crickets and bush-crickets (e.g. *Gryllotalpa* spp.). In fact, despite the occurrence of *Gryllotalpa* spp. in Castro Verde SPA, which is referred in the work of Catry et al. (2012) as a prey of the Lesser Kestrel, the species was not detected in this study. Moreover, carrying out surveys during a broader day time frame should also increase the number of species detected, as some orthopterans are generally more active during the crepuscular and nocturnal periods of the day (e.g. crickets and bush-crickets). Broadening the surveys to other months of the year would also increases the probability of recording different species. The mature forms of some species can be found in autumn and early spring, like Thyreonotus bidens (Bolívar, 1887), whose adults typically occur in autumn (September-November). This species is likely to occur in Castro Verde SPA, as it is usually found in forests with undergrowth (Llucià-Pomares & Fernández-Ortín 2009).

The number of orthopteran species recorded in the Castro Verde SPA appeared to be high, and is similar to results of a few other studies carried out in the South of Portugal: 37 species in Setúbal municipality (Cordeiro 1914); 40 species in Monchique (Ebner 1941) and 37 species in Parque Natural da Ria Formosa (Lock 1999). However, the richness recorded in Castro Verde was much lower than that observed in the Sabor watershed (NE Portugal), where 64 species were found, albeit over a period of about 10 years and in a much larger area encompassing a wider variety of habitats (Miranda-Arabolaza et al. 2005). Clearly, further studies using standardised techniques are required to assess how the species richness varies across regions and habitats in Portugal, and what are the current ecological and anthropogenic drivers of such variation, as little information is available.

Out of the 35 species recorded, two are considered threatened or near-threatened under the IUCN criteria (Platycleis falx and Dociostaurus hispanicus) and five are Iberian endemics: Dociostaurus hispanicus, Euryparyphes terrulentus, Omocestus panteli, Platystolus martinezii and Sphingonotus lluciapomaresi. The presence of these elements underpins the natural value of Castro Verde SPA, as endemic and threatened species are often used in marking biodiversity hotspots and prioritizing areas for conservation (Myers 2000). Some of our records complement the current knowledge on species geographic distribution in southern Europe. Five species occurring in southern Spain expanded their known distribution to southern Portugal, namely: Euryparyphes terrulentus, Platycleis falx, Platycleis intermedia, Sphingonotus lluciapomaresi and Tylopsis lilifolia. The two endemic species, Platystolus martinezii and Dociostaurus hispanicus, previously recorded mostly in the centre of the Iberian Peninsula, extend their known distribution to the south-westernmost location in Europe. These new data referring to species diversity and distribution reflect the scarcity of studies on the orthopterofauna in Portugal, and indicate that some species could have a wider distribution in the Iberian Peninsula than is currently known.

Our results have also shown great variation among habitats in terms of species richness and conservation value. The maximum Grasshopper Conservation Index (GCIn; 0.52) and the maximum number of species (29) were found in fallows, whereas the maximum GCIn (0.49) in plantations was found in mixed pine-oak forests. The importance of fallows is also highlighted by the presence of uncommon species, which includes the two species of conservation concern recorded in our study, Dociostaurus hispanicus and Platycleis falx. In contrast to fallows, mixed pine-oak plantations had a relatively low species richness (16), with the high GCIn observed therein being a consequence of the high number of endemic, rare and flightless species. For instance, within forest plantations the species with the highest GCIn, Euryparyphes terrulentus, was only found in mixed pine-oak. The lowest value of both GCIn (0.44) and species richness (13) was observed in eucalyptus plantations. This was probably because eucalyptus plantations were composed by old trees, with a more closed canopy than other forest types. Moreover, the understorey often had overgrown and dense bushes and few grassy areas, and these conditions are largely unfavourable for open-area species that dominated the Orthoptera assemblages in our study area. These results are in line with other studies showing low abundance of macro-arthropods in Eucalyptus plantations in the Mediterranean region (Zahn et al. 2009). Overall, our results suggest that landscape heterogeneity was one of the drivers of orthopteran diversity observed in the Castro Verde SPA, as it provided opportunities for the persistence of species with different habitat affinities. Forest plantations played a role in this habitat mosaic, as they held species such as Pyrgomorpha conica and Platycleis intermedia that were absent elsewhere. However, as afforestation is considered one of the major threats to Orthoptera associated with open-land habitats, it is fundamental to preserve large unfragmented open habitats with forest patches kept to a minimum (Hochkirch et al. 2016, Bieringer et al. 2013).

The diversity of Orthoptera in the Castro Verde SPA, and particularly that of endemic species and species of conservation concern, may be at risk from ongoing changes in agricultural land uses. The two major land use changes that could threaten Orthoptera are: (i) changes in the rotational farming system, with a shift from the production of dry cereals and extensive sheep grazing on fallows and pastures, to the specialized production of sheep and cattle; and (ii) the expansion of permanent crops, particularly olive groves, though these occur mostly in the periphery of Castro Verde SPA due to legal restrictions within the area (Ribeiro et al. 2014, 2016). Afforestation of open farmland was a problem in the 1990s due to European subsidies under the regulation 2080/92 (Reino et al. 2010), but this is no longer affecting the region to a significant extent. It is uncertain how the ongoing changes will affect Orthoptera in the region, but it is likely that the intensification of land uses and the loss and fragmentation of important habitats such as fallows will greatly affect species richness and the abundance of some endemic species (Bieringer & Zulka 2003, Rook et al. 2004). Therefore, further studies would be necessary to understand the impacts of land use changes in orthopterans, which are needed for improving the management of the Castro Verde SPA.

Overall, our study provided new information on the diversity and ecology of Orthoptera in southern Portugal, providing clues for the conservation management of this group in the Castro Verde SPA and elsewhere in the country. First, a stronger basis is needed to ascertain the conservation status of Orthoptera in Portugal, which should be based on a Red List assessment carried out at the country level. Although the European Red List already provides some important information to assess what species are the most threatened (Hochkirch et al. 2016), there may be strong variation in conservation status at different spatial scales, thus requiring more detailed, regional assessments. This would be important to raise awareness about the value of the Portuguese Orthoptera, and also to identify the actions most needed to conserve this diverse group of insects. Second, the management of the Castro Verde SPA should take consideration of other taxonomic groups besides birds, which until now have been the main focus of attention (e.g. Reino et al. 2010, Santana et al. 2014, and references therein). As we have shown in this study, Orthoptera are a relevant part of biodiversity in the Castro Verde SPA, and so they should also be targeted when formulating new regulations on land use changes or designing agri-environmental subsidy schemes (Ribeiro et al. 2014). Third, surveys are needed on the Orthoptera fauna of other areas included in the Natura 2000 network, as this may be essential to assess the relevance and understand the threats affecting the conservation of this this and other arthropod groups, both in Portugal and elsewhere (Hochkirch et al. 2016). This is critical to undertake management actions that benefit the entire biodiversity, rather than only a few charismatic vertebrate species (e.g., Santana et al. 2014). Finally, we suggest that more

attention should be given to the conservation of Orthoptera and other arthropods when designing the environmental components of the Common Agricultural Policy (CAP). As shown in the Castro Verde SPA, a large number of endemic and threatened species may be associated to low-intensity farmland systems (Weking et al. 2016), and thus these need to be maintained to assure the conservation of European biodiversity. Efforts are thus needed in the future to combine the conservation and agricultural policies, with the broader goal of preserving the rich diversity of species associated with open farmland landscapes such as those of the Castro Verde SPA.

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#### Supplementary material I

# Table S1. Species frequency of occurrence per habitat

Authors: Sílvia Pina, Sasha Vasconcelos, Luís Reino, Joana Santana, Pedro Beja, Juan S. Sánchez-Oliver, Inês Catry, Francisco Moreira, Sónia Ferreira

Data type: species data

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CHECKLIST



# An annotated and illustrated checklist of Microgastrinae wasps (Hymenoptera, Braconidae) from the Canadian Arctic Archipelago and Greenland

Jose Fernández-Triana<sup>1</sup>, Joel Buffam<sup>1</sup>, Melanie Beaudin<sup>1</sup>, Hannah Davis<sup>2</sup>, Ana Fernández-Galliano<sup>3</sup>, Emily Griffin<sup>3</sup>, Shang-Yao Lin<sup>4</sup>, Megan K. McAulay<sup>4</sup>, Robin Richter<sup>1</sup>, Freddy Rodriguez<sup>3</sup>, Gergely Várkonyi<sup>5</sup>

Canadian National Collection of Insects, 960 Carling Ave, Ottawa, K1A 0C6, Canada 2 Institut für Biologie, Freie Universität Berlin, Königin-Luise-Str. 1-3, 14195 Berlin, Germany 3 Ottawa, Ontario, Canada
 Department of Biology, University of Ottawa, 30 Marie Curie, Ottawa, K1N 6N5, Canada 5 Finnish Environment Institute (SYKE), Natural Environment Centre, Lentiirantie 342 B, FI-88900 Kuhmo, Finland

Corresponding author: Jose Fernández-Triana (jose.fernandez@agr.gc.ca)

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#### Abstract

The Microgastrinae (Hymenoptera: Braconidae) from ten islands of the Canadian Arctic Archipelago (CAA) and Greenland were studied based on 2,183 specimens deposited in collections. We report a total of 33 species in six genera, more than doubling the totals previously known. Most of the species (75.7%) have a distribution restricted to the Nearctic, with nine of those (27.3%) confirmed to be High Arctic endemics and another 10 species considered very likely to be High Arctic endemics as well – accounting for all of those, more than half of all species found are endemic to the region. The most diverse genera were *Cotesia* (10 species), *Glyptapanteles* (9 species), and *Microplitis* (7 species), representing 78.8% of the overall species diversity in the region. The six most frequently collected species comprised 84.7% of all examined specimens. The flight period for Microgastrinae in the High Arctic encompasses only two months, with activity peaking during the first half of July, when almost 40% of all available specimens were collected, and then plummeting in the first half to the end of August. Microgastrinae wasps from the High Arctic are currently known to parasitize eight species within four families of Lepidoptera: three species of

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Noctuidae, two each of Lymantridae and Nymphalidae, and one species of Pterophoridae. However, that information is very preliminary, as only six of the 33 species of microgastrines currently have associated host data. An annotated checklist, including photographs for 24 of the 33 species, is provided, as well as a key to all Microgastrinae genera present in the region.

#### **Keywords**

High Arctic, Microgastrinae, checklist, Citizen Science

# Introduction

The High Arctic land areas in North America comprise the Canadian Arctic Archipelago (CAA), with 36,500+ islands covering 1.42 million km<sup>2</sup>, and parts of Greenland, the world's largest island with a total area of 2.17 million km<sup>2</sup> (Danks 1981, Aiken et al. 2007, Böcher et al. 2015). High Arctic areas experience a very long and cold winter, with average temperatures of -25 to -35°C in the coldest months; while the summers are very short, with the average temperature during the warmest month (July) being less than 10°C (Aiken et al. 2007, Böcher et al. 2015).

By any of the geographically, climatically or botanically based definitions, the entire CAA and most of Greenland are unambiguously Arctic, lacking open forest or forest-tundra areas (Danks 1981, Aiken et al. 2007); only some inland areas along the fjords of Southwest and South Greenland have low birch forests and copse growth at protected sites (Böcher et al. 2015). The vascular plant diversity reaches 350 species in the CAA and almost 500 in Greenland (Danks 1981).

The insect fauna of the High Arctic areas in North America is rather poor in diversity. Approximately 360 species were reported by Danks (1981), about half of them being Diptera. A recent treatment of the Greenland 'entomofauna' (Böcher et al. 2015) significantly increased the total for that island to around 1,200 reported species, but that figure included non-insect groups such as Collembola, Arachnida and Chilopoda (the insect diversity recorded in that work was around 800 species, with the actual figure not clear as a relatively large number of species were recorded as 'likely' but not 'confirmed' for Greenland).

Parasitoid wasps (Hymenoptera), one of the most conspicuous and diverse animal groups on Earth (LaSalle and Gauld 1991, 1993, Quicke 1997), comprise the second most diverse group of insects in the High Arctic after Diptera. At least 80 species were reported by Danks (1981: 199), but that total has already increased significantly, as there are now almost 200 species of parasitoid wasps known from Greenland alone (Böcher et al. 2015), and other works have been published on the CAA (e.g., Timms et al. 2013). There is no question that more studies on the High Arctic fauna will further increase that figure.

With 2,710 described species worldwide and several thousand more undescribed (Rodriguez et al. 2013, Yu et al. 2016), the subfamily Microgastrinae (Braconidae) is the single most important group of parasitoid wasps attacking caterpillars (Lepi-

doptera) (Whitfield 1997). Two genera and six unnamed species of Microgastrinae were recorded from the High Arctic areas by Danks (1981: 200, 514–515), but recent studies have increased those figures. A total of 13 species within three genera have been reported from Greenland (van Achterberg 2006, 2015), and Fernández-Triana et al. (2009) and Fernández-Triana (2010) estimated 20 to 25 species to be present in Canada at the 70–80°N latitudinal range (which includes the CAA but also other areas from mainland North America), although he did not provide any specific details on the identity of those species.

Here we update the information on the Microgastrinae fauna of the CAA and Greenland, including an annotated and illustrated checklist of species, as well as a key to all Microgastrinae genera present in the region. Additionally, this paper presents the first results of a Citizen Science project initiated by the Canadian National Collection of Insects (CNC), as part of the Ottawa 2016 Bug Day (http://www.entsocont.ca/bug-day-ottawa-2016.html), as specimen databasing and pictures were mostly done by volunteers.

# Methods

For this paper we follow the traditional definition of the CAA that is detailed in other sources (e.g., Danks 1981, Aiken et al. 2007). From east to west, the CAA extends from the eastern tip of Baffin Island (61°15'W) to the southwest corner of Banks Island (125°49'W), a distance of about 3,000 km. In a north-south direction, it extends from Cape Columbia on the north coast of Ellesmere Island (83°39'N) to Akpatok Island (60°12'N), which is also a distance of about 3,000 km. Greenland lies between latitudes 59° and 83°N, and longitudes 11° and 74°W.

We studied all specimens deposited in the CNC, as well as 25 specimens from the Biodiversity Institute of Ontario collection. We also incorporated information from specimens mentioned in previous papers (van Achterberg 2006, 2015, Várkonyi and Roslin 2013), which are deposited in collections in Denmark, Finland and Hungary. In total 2,183 specimens are included in this paper from Greenland and the following 10 islands of the CAA: Axel Heiberg, Baffin, Banks, Bylot, Devon, Dorset, Ellesmere, Melville, Southampton and Victoria. Localities studied are shown in Figure 1, and in Suppl. material 1. The map was generated using R (the code used to provide the map is provided in Suppl. material 1).

For consistency, localities from mainland North America were excluded, despite the fact that some of them are at higher latitudes than some of the CAA islands covered in this paper (e.g., Boothia and Melville Peninsulas).

Specimens were identified and assigned to species following the most recent taxonomic information available for the region (Fernández-Triana 2010, Fernández-Triana et al. 2011, van Achterberg 2006, 2015). Some specimens could only be identified to genus and were given an alphanumeric species identifier, e.g., '*Cotesia* sp. 1': in all such cases, unique morphological characteristics and/or DNA barcodes clearly identified



Figure 1. Greenland and Canadian Arctic Archipelago localities included in the present study.

them as distinct species. In order to allow these provisional species to be recognized and studied further in the future, we also provide DNA Barcodes Index Numbers (BINs) (Ratnasingham and Hebert 2013) for them in the annotated species checklist.

Pictures of 24 species are provided to illustrate the diversity of microgastrine wasps in the High Arctic. Photos were taken with a Keyence VHX-1000 Digital Microscope, using a lens with a range of  $10-130 \times$ . Multiple images were taken of a structure through the focal plane and then combined to produce a single in-focus image using the software associated with the Keyence System. Plates were prepared using Microsoft PowerPoint 2010.

A key to all genera of Microgastrinae present in CAA and Greenland is provided. Morphological terms follow Mason (1981), Huber and Sharkey (1993), Whitfield (1997), Karlsson and Ronquist (2012), and Fernandez-Triana et al. (2014).

A species checklist was generated using the CNC database (http://www.cnc-ottawa.ca/taxonomy/TaxonMain.php). The list is organized alphabetically by genus and species within a given genus. For every taxon we detail general distribution (outside of the High Arctic), specimens examined, and notes on species where relevant. For zoogeographic regions we use the following acronyms: NEA-Nearctic, OTL-Oriental, and PAL-Palearctic. The acronym BOLD refers to Barcode of Life Data Systems (http:// v4.boldsystems.org/index.php).

A Citizen Science project to database parasitoid wasp specimens deposited in the CNC started during the Ottawa 2016 Bug Day (http://www.entsocont.ca/bug-day-ottawa-2016.html). As part of that project, volunteers photographed specimen labels and later transcribed them into the CNC database. Some of the species photographs used in this paper were also taken by participants in that project.

# **Results and discussion**

At least 33 species within six genera of Microgastrinae were found in the High Arctic (Table 1), more than double the totals previously published (around 12 species and three genera, Oliver 1963, Danks 1981, van Achterberg 2006, 2015, Várkonyi and Roslin 2013, Böcher et al. 2015, Wirta et al. 2016). We also found a few additional species, but were unable to include them in the present paper as the available specimens were in poor condition or could not be studied (we list their voucher codes at the end of the checklist). Investigation of more material from other islands and/or additional specimens from other collections will likely increase the total diversity of this group of parasitoid wasps for the region.

The diversity of Microgastrinae in the High Arctic, as revealed in this paper, can be considered extraordinary. It had previously been estimated that very few species of Hymenoptera were present in that region, but our results show that the number of species is much higher than previously anticipated. For example, Danks (1981: 200, 514–515) estimated that only six species of Microgastrinae occur in the High Arctic. Just from the northern tip of Ellesmere Island, in the localities of Alert (82.5°N) and Hazen Camp (81.8°N) we report here for the first time a total of five species within four different genera of Microgastrinae: *Cotesia eliniae* Papp, 1989, *C. hallii* (Packard, 1877), *Dolichogenidea sicaria* (Marshall, 1885), *Glyptapanteles* sp. 5 and *Microplitis coactus* (Lundbeck, 1896).

Even in the more studied areas, the increase in the number of species and genera of Microgastrinae is still significant. Achterberg (2006) recorded 14 species within three genera for Greenland, but later revised that total down to 12 species (van Achterberg 2015); while Várkonyi and Roslin (2013) added one genus (*Dolichogenidea*) but did not specify the species. Here we add five species and record one additional genus to the fauna of Greenland, which represents the highest diversity of all islands studied with 17 species in five genera (Table 1). Those figures are no doubt the result of Greenland being the largest island, and also the one most intensively sampled (more than half of all specimens considered for this paper) and studied for the longest period of time, as well as having the most diverse vegetation, including subarctic elements (Danks 1981, Böcher et al. 2015).

There were no previous records of Microgastrinae species published for the CAA. Oliver (1963) and Danks (1981) mentioned "*Apanteles* spp." and "*Microplitis* spp." as two genera present in the CAA without further details (but the genus *Apanteles* has not actually been found so far in the High Arctic, see below). In addition, Fernández-Triana (2010) mentioned that the genus *Glyptapanteles* in Canada reached the tip of Ellesmere Island (+82°N), but did not elaborate this further. Here we record 26 species of Microgastrinae for ten islands of the CAA (Table 1), with Banks (11 species), Baffin (10), Ellesmere (9) and Victoria (7) islands harbouring the highest diversity. These totals are also likely correlated to the collecting effort done, which is far from being uniform between the studied islands.

Most of the species (25, representing 75.7% of the total) had a distribution restricted to the Nearctic, while seven species (21.2%) had a Holarctic distribution

ble 1. High Arctic species of Microgastrinae (Hymenoptera, Braconidae), their distribution per island and associated host information (when known). Legend:
ndicates a new species record for a specific island. ** - Indicates a new host record for the wasp species. (1) - Based on published information only, the species
ld be considered a High Arctic endemic; however, unpublished data in the BOLD database reveals that the species is also found on mainland North America
h of the High Arctic (and thus it is not counted as an endemic in the final row 'TOTAL'). (?)- Probable High Arctic endemic species. X(?)- Indicates a dubious
ies record. 9(10)- Nine species are currently reported to be High Arctic endemics, with another 10 species considered as potential endemics.

	High Arctic Endemic	Green land	Axel Heinberg	Baffin	Banks	Bylot	Devon	Dorset	Ellesmere	Melville	Southampton	Victoria	Host information	
<i>Cotesia crassifemonata</i> van Achterberg, 2006	x	×											Unknown	
<i>Cotesia eliniae</i> Papp, 1989	x	x	X*		<b>X</b> *		<b>X</b> *		X*	X*		X*	Unknown	
<i>Cotesia fascifemorata</i> van Achterberg, 2006	X	x											Unknown	
<i>Cotesia hallii</i> (Packard, 1877)	(1)	x	X*	$\mathbf{X}^*$	$\mathbf{X}^*$	$\mathbf{X}^*$	<b>X</b> *		X*	X*	$\mathbf{X}^*$	$\mathbf{X}^*$	Lymantridae: <i>Gynaephona</i> groenlandica **	
<i>Cotesia yakutatensis</i> (Ashmead, 1902)		x		<b>X</b> *									Noctuidae (in areas south of the High Arctic)	
Cotesia sp. 1	X										<b>X</b> *		Lymantridae: Gynaephora sp.**	
Cotesia sp. 2	(1)					$\mathbf{X}^*$							Unknown	
Cotesia sp. 3	X				X*								Unknown	
Cotesia sp. 4	x				<b>X</b> *								Unknown	
Cotesia sp. 5	X	X*			X*				<b>X</b> *				Unknown	
													Pterophoridae: Stenoptilia islandica (potential host record	
Dolichogenidea sicaria (Marshall, 1885)		*X	<b>X</b> *	$\mathbf{X}^*$					*				Varkonyi and Roslin 2013)). Eleven families and 33 species	
													known as hosts in areas south of the High Arctic	
Dolichogenidea sp. 1	(3)			$\mathbf{X}^*$	$\mathbf{X}^*$								Unknown	
Dolichogenidea sp. 2	(ئ				X*								Unknown	

Host information	Unknown	Three families (mainly Arctiidae) and 10 species in areas south of the High Arctic	Numerous families and species of Lepidoptera in areas south of the High Arctic (some of those records are dubious)	Numerous families and species of Lepidoptera in areas south of the High Arctic (some of those records are dubious)	Unknown	Unknown	Unknown	Unknown	Noctuidae: Polia richardsoni **	Unknown	Unknown	Unknown	Unknown	Noctuidae: <i>Noctua</i> sp.	Noctuidae: Sympistis nigrita. Two other species (Noctuidae and Erebidae) are also recorded in areas south of the High Arctic	Unknown
Victoria	X*		X*					$\mathbf{X}^*$				$\mathbf{X}^*$				
Southampton																
Melville												$\mathbf{X}^*$				
Ellesmere			X*						$\mathbf{X}^*$	<b>X</b> *				$\mathbf{X}^*$	X*	
Dorset		X*														
Devon												$\mathbf{X}^*$		$\mathbf{X}^*$		
Bylot					X*											X*
Banks					X*		X*						$\mathbf{X}^*$			
Baffin		$\mathbf{X}^*$	X*		X*	$\mathbf{X}^*$		$\mathbf{X}^*$				$\mathbf{X}^*$				
Axel Heinberg			X*													
Green land			X	X		X*			$\mathbf{X}^*$		$\mathbf{X}^*$			X	x	
High Arctic Endemic	(2)				(2)	(1)	(2)	(3)	Х	(¿)	(٤)	(3)				(1)
	Dolichogenidea sp. 3	<i>Glyptapanteles</i> compressiventris (Muesebeck, 1921)	Glyptapanteles fulvipes (Haliday, 1834)	<i>Glyptapanteles pallipes</i> (Reinhard, 1880)	Glyptapanteles sp. 1	Glyptapanteles sp. 2	Glyptapanteles sp. 3	Glyptapanteles sp. 4	Glyptapanteles sp. 5	Glyptapanteles sp. 6	Illidops sp. 1	Illidops sp. 2	Microgaster sp.	<i>Microplitis coactus</i> (Lundbeck, 1896)	Microplitis lugubris (Ruthe, 1860)	Microplitis sp. nr. lugubris

Host information	Unknown	stuidae: several species (in south of the High Arctic)	tuidae: <i>Tholera cespitis</i> (in south of the High Arctic)	Unknown	
/ictoria		Noc areas	Noc	<b>X</b> *	7
Southampton					2
Melville					3
Ellesmere					6
Dorset					1
Devon					4
Bylot					4
Banks				X*	11
Baffin					10
Axel Heinberg					4
Green land	x	X	X(?)		17
High Arctic Endemic	X			(2)	9 (10)
	<i>Microplitis lugubroides</i> van Achterberg, 2006	<i>Microplitis mandibularis</i> (Thomson, 1895)	<i>Microplitis sofron</i> Nixon, 1970	Microplitis sp. nr. sofron	TOTAL

(Nearctic and Palaearctic), and only one species had a wider distribution (Nearctic, Palaearctic and Oriental). Nine species (27.3%) are confirmed in this paper to be High Arctic endemics. Another 10 species are very likely to be High Arctic endemics as well – if accounting for all of those, then more than half of all species found in Greenland and the CAA are endemic to the region.

The most diverse genera were *Cotesia* (10 species), *Glyptapanteles* (9 species), and *Microplitis* (7 species). Those three genera accounted for 78.8% of the overall species diversity in the region. *Apanteles*, currently the most diverse and widespread genus of Microgastrinae with over 1,000 species worldwide (Yu et al. 2016), was notably absent from the High Arctic samples we could examine. However, that genus is present in mainland North America (in localities of similar latitude and habitats than the CAA), so it is likely that the genus will eventually be found in the High Arctic when more studies are done and additional samples from the region are analyzed.

The most frequently collected species were *Microplitis lugubris* (Ruthe, 1860) (716 specimens), *Cotesia hallii* (575 specimens), *Glyptapanteles fulvipes* (Haliday, 1834) (243 specimens), *Cotesia eliniae* (129 specimens) *Microplitis coactus* (117 specimens), and *Dolichogenidea* sp. 1 (105 specimens). Those six species altogether accounted for 87.4% of all High Arctic specimens examined by us.

In contrast to Greenland, where research activity has been rather high recently (e.g., van Achterberg 2006, 2015, Várkonyi and Roslin 2013, Roslin et al. 2013, Wirta et al. 2014, Wirta et al. 2016), most of the specimens from the CAA were collected during early to mid 20<sup>th</sup> century (Table 2). That is likely a reflection of the funding opportunities for Arctic research at the time, e.g., the Northern Insect Survey (Freman 1952, Freeman and Twinn 1955, Buddle et al. 2008, Fernández-Triana et al. 2009).

Based on the studied specimens, the flight period for Microgastrinae in the High Arctic encompasses only two months, from the second half of June to the second half of August. There were less than 20 specimens with collecting dates of late May/early June or early September, but all came from the southernmost localities in the studied region. Activity peaks during the first half of July, when almost 40% of all available specimens were collected. The number of specimens drops slightly during the second half of July and then plummets in the first half to end of August, marking the end of the flying season for Microgastrinae in the region (Figure 2). This is by far the shortest flying season we have observed for microgastrine wasps worldwide, although it is otherwise expected due to the high latitude and very low temperatures in the High Arctic.

The majority (82%) of the High Arctic species of Microgastrinae have no host data available. Only six of the 33 species analyzed in this paper have some Lepidoptera recorded as hosts, with three of those species being new records reported here: *Cotesia hallii* parasitizing *Gynaephora groenlandica* (Lymantridae), *Cotesia* sp. 1 as a parasitoid of *Gynaephora* sp. (Lymantridae), and *Glyptapanteles* sp. 5 parasitizing *Polia richardsoni* (Noctuidae).

There are two additional host records for unnamed species of Microgastrinae in the High Arctic. Várkonyi and Roslin (2013) reported "*Dolichogenidea* sp." as a parasitoid of *Stenoptilia islandica* (Pterophoridae) in Greenland. *Dolichogenidea sicaria* is the only

**Table 2.** Microgastrinae specimens collected in the Canadian Arctic Archipelago during successive time periods between 1930–2014. Data from present paper.



**Figure 2.** Flight period of Microgastrinae in the High Arctic. Number of specimens (as shown on Y axis) based on data from present paper. I First half of a month II Second half of a month.

species of that genus known from Greenland and the specimens from Várkonyi & Roslin (2013) have DNA barcodes that clearly match (see comments under that species in the Checklist below and also the Supplementary Info file in Wirta et al. (2016)), thus we consider here that the "*Dolichogenidea* sp." specimens mentioned by Várkonyi & Roslin (2013) and Wirta et al. (2016) belong to *D. sicaria*.

Várkonyi and Roslin (2013) also reported "*Cotesia* spp." as important parasitoids of *Boloria chariclea* and *B. polaris* (Nymphalidae) in Greenland. According to those authors, the identity of their "*Cotesia* spp." specimens is more difficult to establish, but it is likely to be in the *C. eliniae | C. hallii* species complex. Unfortunately at this point we cannot conclude with certainty about the species identity of those *Cotesia* specimens.

When including all the information available, the Microgastrinae from the High Arctic are currently known to attack eight species within four families of Lepidoptera: three species of Noctuidae, two each of Lymantridae and Nymphalidae, and one species of Pterophoridae (Table 1).

# Key to genera of Microgastrinae found in the Canadian Arctic Archipelago and Greenland

1	Fore wing with areolet (second submarginal cell entirely closed by veins)2 Fore wing wihout areolet (second submarginal cell not entirely closed by
2(1)	Posterior margin of anteromesoscutum with sharply defined carina right before scuto-scutellar sulcus; scutellar disc with band of rugosity centrally on posterior margin; mediotergite 1 relatively long and narrow (length centrally $2.0 \times$ or more its width at posterior margin), not widening towards posterior margin in High Arctic species; mediotergite 2 mostly smooth and poorly defined laterally; meta- coxa relatively small, not surpassing posterior margin of mediotergite 2; metati-
_	Posterior margin of anteromesoscutum without carina right before scuto- scutellar sulcus; scutellar disc without band of rugosity centrally on poste- rior margin; mediotergite 1 relatively broad (length centrally 1.0 × or less its width at posterior margin), strongly widening towards posterior margin; me- diotergite 2 heavily sculptured and rectangular-shaped; metacoxa relatively large, surpassing posterior margin of mediotergite 2; metatibial spurs more than half length of first segment of metatarsus
3(2)	Ovipositor sheaths relatively short, its length less than half metatibia length, usually much shorter
_	Ovipositor sheaths relatively long, its length close to or longer than metatibia
4(3)	Propodeum heavily sculptured, with median carina and usually partial to complete transverse carinae (which might be obscured by strong sculpture on entire propodeum); mediotergite 1 heavily sculptured and relatively broad (length centrally 1.0 × or less its width at posterior margin), strongly widening towards posterior margin; mediotergite 2 heavily sculptured and rectangular-shaped
_	Propodeum slightly sculptured or entirely smooth, median carina rarely com- plete (usually only defined partially on posterior half, sometimes entirely absent), transverse carinae always absent; mediotergite 1 mostly to entirely smooth, relatively long and narrow (length centrally 2.0 × or more its width at posterior margin), narrowing towards posterior margin; mediotergite 2 mostly to entirely smooth, subtriangular to trapezoidal in shape
5(3)	Scutellar disc with band of rugosity centrally on posterior margin; propo- deum heavily sculptured but without defined areola; fore wing with vein R1 shorter than pterostigma length; head in frontal view with eyes converging ventrally
_	Scutellar disc without band of rugosity centrally on the posterior margin; propodeum slightly sculptured to smooth, with partial to completely defined areola; fore wing with vein R1 longer than pterostigma length; head in frontal view with eyes not converging ventrally

#### **Checklist of species**

#### Cotesia crassifemorata van Achterberg, 2006

Distribution. NEA. High Arctic endemic.

**Notes.** Only known from the original description; from Greenland (van Achterberg 2006).

#### Cotesia eliniae Papp, 1989

Fig. 3

**Distribution.** NEA. High Arctic endemic (the species was described from Scoresby Sund, which is at the northern boundary of Low Arctic zone).

**Notes.** Previously only known from Greenland, here also recorded from the CAA islands of Axel Heiberg, Banks, Devon, Ellesmere, Melville, and Victoria. The DNA barcodes of a few specimens cluster with some sequences of *C. hallii* and it is not clear if these two are indeed different species. The keys provided by van Achterberg (2006, 2015), based on Greenland material, do not always work for CAA specimens –nor for other Greenlandic specimens (e.g., Várkonyi and Roslin (2013)). The only reliable character that seems to delineate species is the sculpture on mediotergite 3, which ranges from almost to fully sculptured in *C. eliniae*, whereas is almost to fully smooth in *C. hallii*. No host record is known for *C. eliniae*. One series of specimens from Ellesmere, collected by J.R. Smith on July 1980, were reared from an unspecified caterpillar (the labels have no information on the identity of the host, but just a code number: '217'). The available DNA sequences for this species correspond in BOLD to BIN BOLD:ACE6464.

# Cotesia fascifemorata van Achterberg, 2006

**Distribution.** NEA. High Arctic endemic.

**Notes.** Only known from the original description; from Greenland (van Achterberg 2006).

#### Cotesia hallii (Packard, 1877)

Fig. 4

**Distribution.** NEA. High Arctic and some additional, unpublished records in BOLD from northern Canada (mainland).

**Notes.** A total of 575 specimens from Greenland and nine islands in the CAA: Axel Heiberg, Baffin, Banks, Bylot, Devon, Ellesmere, Melville, Southampton, and

Victoria. Host: Gynaephora groenlandica (Wocke, 1874) (Lymantridae), records based on two wasp specimens (with voucher codes MIC 000317, MIC 000320) from Eureka, Ellesmere Island, and a series of 24 specimens (voucher codes CNC492946-CNC492969) from Devon Island. They represent the first known record of a Braconidae parasitizing G. groenlandica. The available DNA sequences for this species correspond in BOLD to BIN BOLD:AAA5700.

#### Cotesia yakutatensis (Ashmead, 1902)

Fig. 7

# Distribution. NEA.

Notes. This species is rather widely distributed in the Nearctic. It had previously been recorded from Greenland by Papp (1989), and here we also recorded it from the CAA for the first time, based on two specimens collected in Baffin and Bylot Islands (voucher codes CNC497416, CNCH0395). It is clearly a southern species, scarcely reaching its northernmost range in the High Arctic. The majority of the specimens identified in BOLD as C. yakutatensis correspond to BIN BOLD:ABZ4485, but other specimens, including the one from Bylot Island, actually belong to BIN BOLD:AAA5701. Solving the limits of C. yakutatensis will require examination of specimens from across the species range, which is beyond the scope of the present paper.

# Cotesia sp. 1

Distribution. NEA. High Arctic endemic.

Notes. A series from Southampton Island (five specimens mounted but more than 40 additional specimens in alcohol, kept with the host remains and wasp cocoons mass). The species is morphologically similar to C. hallii and C. eliniae, but is distinctive because of the very strong and deep sculpture on mediotergites 1, 2 and at least anterior 0.2-0.3 of mediotergite 3 (in contrast, C. eliniae has most of mediotergites 1-3 sculptured, but the sculpture is much finer and mat). One of the specimens (voucher code CAM0668) has a partial barcode (421 base pairs) which is unique among all Cotesia specimens in BOLD, and rather different from those of C. hallii and C. eliniae. Host: Gynaephora sp. (Lymantridae).

# Cotesia sp. 2 Fig. 5

Distribution. NEA. High Arctic and some additional, unpublished records in BOLD from northern Canada (mainland).

**Notes.** One female specimen from Bylot Island (voucher code CAM 0574). It has a large hypopygium, which extends beyond the end of the tergites. We have seen additional specimens from this species in Naujaat (known until 2015 as Repulse Bay), a locality in mainland Nunavut, Canada.

# Cotesia sp. 3

Fig. 6

#### Distribution. NEA. High Arctic endemic.

**Notes.** One female specimen from Banks Island (voucher code GOU 0520). It has a unique DNA barcode and morphology. The available DNA sequences for this species correspond in BOLD to BIN BOLD:AAI6054.

# Cotesia sp. 4

Distribution. NEA. High Arctic endemic.

**Notes.** One male specimen from Banks Island (voucher code GOU 0524). It has a unique DNA barcode and morphology. The available DNA sequences for this species correspond in BOLD to BIN BOLD:ACE3031.

#### Cotesia sp. 5

Distribution. NEA. High Arctic endemic.

**Notes.** A total of 16 specimens from Banks and Ellesmere Islands, as well as Greenland. This species has been referred to as *Cotesia* jft09 in other papers (e.g. Fernández-Triana et al. 2011, 2016), and it corresponds in BOLD to BIN BOLD:AAA6099. The species seems to be related to a complex of species, from both Europe and North America but for the time being is left as an undescribed species, until more studies of the Holarctic fauna are carried out.

#### Dolichogenidea sicaria (Marshall, 1885)

Fig. 8

#### Distribution. NEA, PAL.

**Notes.** This species is widely distributed in the Holarctic region, and it has also been introduced into New Zealand (Yu et al. 2016). Here we record the species for the first time in the High Arctic: Greenland, as well as Axel Heiberg, Baffin and Ellesmere Islands. Várkonyi and Roslin (2013) and Wirta et al. (2016) recorded it as '*Dolichogenidea* sp.' from Greenland. The sequence of that specimen in BOLD (sequence code:

GRAFW237-11) matches several sequences of Dolichogenidea sicaria (from Canada, Norway, Sweden and USA specimens), clearly indicating that the Greenland specimen is conspecific with them. Hosts: In the High Arctic, Várkonyi and Roslin (2013) mentioned as probably host Stenoptilia islandica (Staudinger, 1857) (Pterophoridae), a record we accept here as very likely based on their explanation [Várkonyi and Roslin (2013) wrote: "On 17 July 2011, a microgastrine cocoon attached to the remains of a microlepidoptera larva was found under a tuft of Saxifraga cespitosa Linnaeus (Saxifragaceae) >700m in the bare basalt cap area of Aucellabjerg. By 24 August 2011, a female Dolichogenidea species hatched from this sample. As S. cespitosa is the host plant of Stenoptilia islandica (Staudinger) (Lepidoptera: Pterophoridae) (Table 3), as several specimens of this microlepidopteran species were seen and collected (exclusively) at high elevations on Aucellabjerg, and as *Dolichogenidea* species (like all microgastrine wasps; for the Zackenberg species see Table 1) are koinobiont endoparasitoids of Lepidoptera larvae (Shaw and Huddleston 1991), S. islandica seems a potential host of this species. Clearly, direct rearing records are needed to verify this hypothesis."]. In more southern localities, outside of the High Arctic, many other species of Lepidoptera have been cited as hosts of D. sicaria (e.g., Yu et al. 2016), with some of those records being questionable.

# Dolichogenidea sp. 1

Fig. 9

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** A total of 105 specimens from Banks and Baffin Islands. Differences in DNA barcodes, and morphology (sculpture of propodeum, mediotergites 1 and 2, length of fore wing vein R1), separate this species from the next one. The available DNA sequences for this species correspond in BOLD to BIN BOLD:AAE6509.

# **Dolichogenidea** sp. 2 Fig. 10

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** A total of 21 specimens from Banks Island, see above for differences with previous species. Only a mini barcode (144 base pairs) is available from this species (from specimen with voucher code MIC 000290), which is not enough to clearly characterize the species from a DNA barcoding perspective.

# Dolichogenidea sp. 3

Fig. 11

Distribution. NEA. Probably a High Arctic endemic.

**Notes.** Three male specimens from Victoria Island. Although male specimens are usually less informative in terms of the taxonomy of Microgastrinae wasps, the studied specimens are very distinctive due to their very smooth propodeum and different shape and sculpture of mediotergites 1 and 2, as compared to the previous three species of *Dolichogenidea*. Thus, we consider them as a separate species. No DNA sequences are available for this species.

# Glyptapanteles compressiventris (Muesebeck, 1921)

Fig. 12

# Distribution. NEA, PAL.

**Notes.** A total of 14 specimens from Baffin and Dorset Islands. Only Clyde River (Clyde Inlet) can be considered northern (70° 29' N); the other localities are from southern Baffin Island and Dorset Island (62–64° N). There are many specimens in the CNC from more southern Canadian localities, suggesting that this species is likely more common in southern Nearctic areas and that the CAA is the northernmost limit of the species' range. Available barcodes suggest that the name *compressiventris* may include at least two cryptic species, but that is beyond the scope of this paper and thus for now all Canadian specimens are left under that name. The available DNA sequences for this species correspond in BOLD to BIN BOLD:ACE5800.

# *Glyptapanteles fulvipes* (Haliday, 1834) Fig. 13

### Distribution. NEA, PAL.

**Notes.** A total of 179 specimens in total from Greenland and Axel Heiberg, Baffin, Ellesmere and Victoria Islands. The majority of the specimens identified in BOLD as *G. fulvipes* correspond to BIN BOLD:ACE7221 (but see next species for comments of a potential species complex).

#### Glyptapanteles pallipes (Reinhard, 1880)

#### Distribution. NEA, OTL, PAL.

**Notes.** This species is widely distributed in North America, Europe and Asia, usually from more southern areas, but also recorded from Greenland by Papp (1989). No other specimen has been found in the region since, neither by van Achterberg (2006) nor by us. Specimens deposited in the CNC (from southern localities) have been sampled for DNA barcoding and their sequences are similar to those of *G. fulvipes*. It seems likely that specimens previously identified and named as *G. pallipes* or *G. fulvipes* actually comprise a complex of morphologically cryptic species (e.g., see next species below). Solving that complex is beyond the scope of this paper.

# *Glyptapanteles* sp. 1 Fig. 14

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** This species is morphologically related to *G. fulvipes* and *G. pallipes*. Slight differences in morphology and partial DNA barcodes (but only mini barcodes of 144 base pairs are available from High Arctic specimens) suggest this is a different species. However, it cannot be described until a comprehensive study of the *fulvipes/pallipes* complex is done. Most of the 46 studied specimens are from Banks Island, with two specimens from Bylot and Baffin Islands.

# Glyptapanteles sp. 2

Fig. 15

**Distribution.** NEA. High Arctic and some additional, unpublished records in BOLD from northern Canada (mainland).

**Notes.** Most specimens from Baffin Island (Clyde Inlet), but one specimen from Peary Land (Greenland). They are characterized by almost completely smooth mediotergites 1 and 2. No DNA sequences are available. We have seen other specimens from localities in mainland Canada. Additional study of the whole Holarctic fauna of *Glyptapanteles* will be needed before the identity of this species can be established.

# Glyptapanteles sp. 3

Fig. 16

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** One female from Banks Island. Much more sculptured mediotergites 1 and 2 than in any other High Arctic species of *Glyptapanteles*. We are also including here three specimens from Banks Island (Aulavik National Park) that we were not be able to examine, but the available picture in BOLD is similar enough to the female specimen to place them here, at least provisionally. The available DNA sequences for this species correspond in BOLD to BIN BOLD:ACR4201.

#### Glyptapanteles sp. 4

Figs 17, 18

Distribution. NEA. Probably a High Arctic endemic.

**Notes.** Four female and 23 male specimens, mostly collected in Victoria Island, with some from Baffin Island (Clyde River). The external genitalia of male specimens suggest that this species might better be placed within *Sathon* (which would represent the northernmost record for that genus); however, the ovipositor and ovipositor sheaths in females indicate it is better placed within *Glyptapanteles*. DNA barcodes could only be obtained from three male specimens, but the sequences were too short (104-144 base pairs) and thus DNA barcoding could not conclusively place the species within any of the two potential genera. Based on the length of the female ovipositor we are provisionally placing this species within *Glyptapanteles*, although this may change with future studies.

#### Glyptapanteles sp. 5

Fig. 19

#### Distribution. NEA. High Arctic endemic.

Notes. Collected in Alert (during three different time periods: 1951, 2001 and 2008) and Hazen Camp (1963), both on Ellesmere Island. There are also two specimens from Greenland, one collected in 1966, and the other between 2009–2011 (no clear date established, see Várkonyi and Roslin 2013). Additionally, in the CNC collection there is a pin with host remnants and the wasp cocoons, clearly indicating that the parasitoid is a gregarious species. There are five full DNA barcodes from the 2008 samples, as well as three mini barcodes (134-144 base pairs) from specimens collected in 1951 which perfectly match the full barcode sequences. Glyptapanteles sp. 5 has 11 base pairs of difference (1.7 %) with the rest of the *fulvipes* (or near *fulvipes*) barcoded specimens that are available in BOLD from all over the Holarctic, and the new species cluster is clearly distinct. Host: Polia richardsoni (Curtis, 1834) (Noctuidae), this is the second record of a Microgastrinae parasitoid for that Lepidoptera species (recently Microplitis lugubris had been reported from Greenland by Wirta et al. (2014)). Because of the unique barcode and lepidopteran host, we consider this to be a new Glyptapanteles species, to be described in a separate paper. The available DNA sequences for this species correspond in BOLD to BIN BOLD: ABY9539.

# *Glyptapanteles* sp. 6 Fig. 20

Distribution. NEA. Probably a High Arctic endemic.

**Notes.** Two female and two male specimens from Ellesmere Island. The wing venation is strikingly different from all other *Glyptapanteles* occurring in the High Arctic.

# Illidops sp. 1

Fig. 21

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** Greenland, Peary Land. One female specimen (voucher code MIC000287), with a mini barcode of 144 base pairs. DNA barcoding and slight morphological differences separate this species from the following one.

# Illidops sp. 2

Fig. 22

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** One female and 16 male specimens from Baffin, Devon, Melville and Victoria Islands. The two available mini barcodes (126–144 base pairs) separate this species from the Greenlandic species of *Illidops*.

# Microgaster sp. 1

Fig. 23

### Distribution. NEA.

**Notes.** One male specimen from Banks Island (voucher code MIC000311). The poor condition of the specimen prevents further identification. Its associate sequence (a mini barcode of 144 base pairs) is not sufficient for an unambiguous placement of the species within other *Microgaster* sequences in BOLD.

# Microplitis coactus (Lundbeck, 1896)

Figs 24-27

# Distribution. NEA, PAL.

**Notes.** A total of 35 specimens from Devon and Ellesmere Islands, as well as Greenland. The Canadian specimens match the available descriptions provided by Papp (1984) and van Achterberg (2006), but the metafemur is not as thick as mentioned for the Greenlandic and Icelandic specimens. However, all the other morphological characters mentioned by those authors agree with the specimens from the CAA, so for the time being, we are considering them all to be conspecific. One female specimen from Devon Island and one male specimen from Ellesmere Island (voucher codes MIC 000313 & MIC 000315) have mini barcodes (114–144 base pairs), although they differ rather substantially (by seven base pairs) and it is not sufficient to unambiguously place these specimens within other sequences of *Microplitis* in BOLD. Hosts: *Noctua* sp. (Noctuidae).

#### Microplitis lugubris (Ruthe, 1860)

Fig. 28

#### Distribution. NEA, PAL.

**Notes.** The only Nearctic record until now was from Greenland (van Achterberg 2006, Várkonyi and Roslin 2013). Here it is recorded for the first time from Canada (Ellesmere Island) as well as an additional locality record for Greenland (Peary Land, based on one specimen deposited in the CNC). We are also aware of specimens from a southern Canadian locality: Churchill, Manitoba (at around 59° N), which had been named as "*Microplitis* jft01" in previous papers (Fernández-Triana 2010, Fernández-Triana et al. 2011). The records from Churchill expand considerably the southernmost distribution of the species within the Nearctic. Based on the number of specimens (716), *Microplitis lugubris* is probably the most commonly found species of Microgastrinae in Greenland (although most of the specimens came from rearing caterpillars, see Várkonyi and Roslin 2013). The available DNA sequences for this species correspond in BOLD to BIN BOLD:ABY9068.

#### Microplitis sp. near lugubris

Fig. 29

**Distribution.** NEA. High Arctic and some additional, unpublished records in BOLD from northern Canada (mainland).

**Notes.** Five males from Bylot Island; we have also seen numerous specimens from Churchill, Manitoba, Canada (which have in BOLD the interim name "*Microplitis* jft04"). This species is morphologically similar to *M. lugubris*, but we consider it a different species based on the significant difference in the DNA barcodes (59 base pairs, representing 8.9% of differences in the DNA barcoding region). The available DNA sequences for this species correspond in BOLD to BIN BOLD:AAB1314.

#### Microplitis lugubroides van Achterberg, 2006

**Distribution.** NEA. High Arctic endemic.

Notes. Only known from the original description, from Greenland.

#### Microplitis mandibularis (Thomson, 1895)

### Distribution. NEA, PAL.

**Notes.** The only record for the High Arctic is from Greenland (van Achterberg 2006).

# Microplitis sofron Nixon, 1970

#### Distribution. NEA, PAL.

**Notes.** Recorded from Greenland, but considered a dubious record by van Achterberg (2006).

# *Micro plitis* sp. nr. *sofron* Fig. 30

**Distribution.** NEA. Probably a High Arctic endemic.

**Notes.** A total of 12 specimens from Banks and Victoria Islands. This species will run to *M. sofron* in the keys provided by Nixon (1970), Papp (1984), and van Achterberg (2006). However, its metatibia is not bright yellow, and the shape of mediotergite 1 does not resemble the illustration of Papp (1984: figure 83). The color of metatibia and shape of mediotergite 1 are actually closer to *M. lugubroides*, but from that species it differs in the length of the last flagellomere, the main feature that van Achterberg used to separate *M. sofron* from *M. lugubroides*. The Canadian specimens probably represent a new species, but without examining the types of *sofron* and *lugubroides* we cannot be certain. No DNA sequences are available for this species.

#### Aditional species

A few specimens, currently identified to genus level only, are likely to represent additional species records for the High Arctic. They are listed below, pending further study to assess their status.

- *Cotesia* specimens from Greenland. Specimens with voucher codes ZMUC00023383, ZMUC00023385, ZMUC00023386, BIOUG15488-A02, 24361-A10, 24361-A12, 24361-B09, 24361-E07, 24388-C11, 24391-G12, 24412-H08, 24478-E01, 24523-C12, ZA2009-100, ZA2010-103, ZA2010-104, ZMUC00023387, ZMUC00023382, ZMUC00023381.
- *Glyptapanteles* specimens from Baffin, Banks and Bylot Islands. Specimens with voucher codes BIOUG16577-D03, BIOUG16811-D10, CNCH0578, CNCH0579, CNCH0580, MIC000306, MIC000333.



Figure 3. *Cotesia eliniae*. A Habitus, lateral B Fore wing C Metasoma, dorsal D Head, frontal-dorsal E Head and mesosoma, dorsal.



Figure 4. *Cotesia hallii*. A Habitus, lateral B Fore wing C Head and mesosoma, dorsal D Head, frontal E Metasoma, dorsal.



Figure 5. *Cotesia* sp. 2. **A** Habitus, lateral **B** Metasoma, dorsal **C** Head, frontal-dorsal **D** Fore wing **E** Head and mesosoma, dorsal.


Figure 6. *Cotesia* sp. 3. **A** Habitus, lateral **B** Fore wing **C** Mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



Figure 7. *Cotesia yakutatensis*. A Habitus, lateral B Fore wing C Head and mesosoma, dorsal D Head, frontal E Propodeum F Metasoma, dorsal.



Figure 8. *Dolichogenidea sicaria*. A Habitus, lateral B Fore wing C Head and mesosoma (partially), dorsal D Head, frontal E Metasoma (partially) and ovipositor, dorsal.



**Figure 9.** *Dolichogenidea* sp. 1. **A** Habitus, lateral **B** Fore wing and hind wing **C** Head and mesosoma, dorsal **D** Head, frontal-dorsal **E** Metasoma, dorsal.



Figure 10. *Dolichogenidea* sp. 2. **A** Habitus, lateral **B** Metasoma, dorsal **C** Head, frontal **D** Fore wing **E** Head and mesosoma (partially), dorsal.



**Figure 11.** *Dolichogenidea* sp. 3. **A** Habitus lateral **B** Metasoma, dorsal **C** Head, frontal-lateral **D** Fore wing **E** Head (partially) and mesosoma (partially), dorsal.



Figure 12. *Glyptapanteles compressiventris*. A Habitus, lateral B Fore wing C Head and mesosoma (partially), dorsal D Head, frontal E Metasoma, dorsal.



Figure 13. *Glyptapanteles fulvipes*. A Habitus, lateral **B** Fore wing and hind wing **C** Head and mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



Figure 14. *Glyptapanteles* sp. 1. **A** Habitus, lateral **B** Fore wing **C** Mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



**Figure 15.** *Glyptapanteles* sp. 2. **A** Habitus, lateral **B** Head and mesosoma, dorsal **C** Head, fontal **D** Fore wing **E** Metasoma, dorsal.



Figure 16. *Glyptapanteles* sp. 3. **A** Habitus, lateral **B** Mesosoma, dorsal **C** Head, frontal **D** Fore wing **E** Metasoma, dorsal.



Figure 17. *Glyptapanteles* sp. 4. A Habitus, lateral B Fore wing C Metasoma, dorsal D Head, frontal E Head and mesosoma, dorsal.



Figure 18. *Glyptapanteles* sp. 4. **A** Habitus, lateral **B** Metasoma, dorsal **C** Head, frontal **D** Fore wing **E** Head and mesosoma (partially), dorsal.



**Figure 19.** *Glyptapanteles* sp. 5. **A** Habitus, lateral **B** Fore wing and hind wing (partially) **C** Head and mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



**Figure 20.** *Glyptapanteles* sp. 6. **A** Habitus, lateral **B** Head and mesosoma, dorsal **C** Head, lateral **D** Fore wing and hind wing **E** Metasoma, dorsal.



**Figure 21.** *Illidops* sp. 1. **A** Habitus, lateral **B** Fore wing and hind wing **C** Head and mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



**Figure 22.** *Illidops* sp. 2. **A** Habitus, lateral **B** Fore wing and hind wing **C** Mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



Figure 23. *Microgaster* sp. 1. **A** Habitus, lateral **B** Mesosoma, dorsal **C** Head, frontal **D** Fore wing **E** Metasoma (partially), dorsal.



Figure 24. *Microplitis coactus*. A Habitus, lateral B Fore wing C Metasoma, dorsal D Head, dorsal E Head and mesosoma, dorsal.



**Figure 25.** *Microplitis coactus.* **A** Habitus, lateral **B** Fore wing **C** Head and mesosoma, dorsal **D** Head, frontal **E** Metasoma, dorsal.



**Figure 26.** *Microplitis coactus*. **A** Habitus, lateral **B** Fore wing **C** Head and mesosoma, dorsal **D** Head, frontal **E** Metasoma and propodeum, dorsal.

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Figure 27. *Microplitis coactus*. A Habitus, lateral B Fore wing C Metasoma, dorsal D Head, frontal E Head and mesosoma, dorsal.



Figure 28. *Microplitis lugubris*. A Habitus, lateral B Fore wing C Mesosoma, dorsal D Head, frontal E Metasoma, dorsal.



**Figure 29.** *Microplitis* sp. near *lugubris*. **A** Habitus, lateral **B** Fore wing and hind wing **C** Metasoma (partially), dorsal **D** Head, frontal **E** Head and mesosoma, dorsal.



Figure 30. *Microplitis* sp. near *sofron*. A Habitus, lateral B Fore wing C Mesosoma, dorsal D Head, frontal E Metasoma, dorsal.

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# Supplementary material I

# Details of all studied specimens of Microgastrinae (Hymenoptera, Braconidae) from the Canadian Arctic Archipelago and Greenland

Authors: Jose Fernández-Triana, Joel Buffam, Melanie Beaudin, Hannah Davis, Ana Fernández-Galliano, Emily Griffin, Shang-Yao Lin, Megan K. McAulay, Megan K. McAulay, Robin Richter, Freddy Rodriguez, Gergely Várkonyi

Data type: speciems data

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- Link: https://doi.org/10.3897/zookeys.691.14491.suppl1

# Supplementary material 2

# R code used to generate the map

Authors: Jose Fernández-Triana, Joel Buffam, Melanie Beaudin, Hannah Davis, Ana Fernández-Galliano, Emily Griffin, Shang-Yao Lin, Megan K. McAulay, Megan K. McAulay, Robin Richter, Freddy Rodriguez, Gergely Várkonyi

Data type: codes

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RESEARCH ARTICLE



# To be or not to be a subspecies: description of Saperda populnea lapponica ssp. n. (Coleoptera, Cerambycidae) developing in downy willow (Salix lapponum L.)

Henrik Wallin<sup>1</sup>, Torstein Kvamme<sup>2</sup>, Johannes Bergsten<sup>1</sup>

Department of Zoology, Swedish Museum of Natural History, P. O. Box 50007, SE-104 05 Stockholm, Sweden
Norwegian Institute of Bioeconomy Research (NIBIO), P. O. Box 115, NO-1431 Ås, Norway

Corresponding author: Henrik Wallin (henrik.wallin@saiglobal.com)

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# Abstract

A new subspecies of the European cerambycid *Saperda populnea* (Linnaeus, 1758) is described: *Saperda populnea lapponica* **ssp. n.** based on specimens from Scandinavia. The male genitalia characters were examined and found to provide support for this separation, as well as differences in morphology, geographical distribution and bionomy. The preferred host tree for the nominate subspecies *S. populnea populnea* is *Populus tremula* L., whereas *S. populnea lapponica* **ssp. n.** is considered to be monophagous on *Salix lapponum* L. DNA sequence data of mitochondrial cytochrome oxidase subunit I (COI) was generated from Scandinavian specimens of *S. populnea populnea* and specimens representing *S. populnea lapponica* **ssp. n.** The two subspecies were not reciprocally monophyletic and genetic distances in COI were small. All synonyms of *S. populnea populnea* have been considered, and species similar to *S. populnea populnea* have been examined, and not found to be related to S. *populnea lapponica* **ssp. n.** A male lectotype has been designated for each of the two following synonyms: *Cerambyx decempunctatus* De Geer, 1775, and *Saperda salicis* Zetterstedt, 1818. The synonymised species from Asia, *S. balsamifera* (Motshulsky, 1860), is elevated to subspecies: *S. populnea balsamifera* **stat. n.** We end with a discussion on the definition of subspecies under the unified species concept.

## Keywords

Palaearctic region, Nearctic region, taxonomy, Cerambycidae, Lamiinae, *Saperda*, new subspecies, new synonyms, genitalia characters, *Salix lapponum*, subspecies definition, unified species concept

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# Introduction

The tribe Saperdini Mulsant, 1839 is extremely rich in species and consists of about 1000 species, mainly in the Oriental region (Bilý and Mehl 1989). The genus *Saperda* Fabricius, 1775, on the other hand, consists only of 42 species in the Holarctic region. In the Palaearctic region, 26 species and two subspecies are known (Aurivillius 1921, Löbl and Smetana 2010). In North America, 16 species and two subspecies were reported (Felt and Joutel 1904, Linsley and Chemsak 1995) but have recently been reduced to 15 species and one subspecies (Bezark 2016). There are no *Saperda* species from Europe also with Holarctic distribution, as currently defined (Bezark 2016). Only eight species are known from Europe (Bense 1995, Löbl and Smetana 2010), of which six species occur in Fennoscandia (Bilý and Mehl 1989, Silfverberg 2010).

Recently, there have been some taxonomic changes within the genus Saperda. Saperda balsamifera (Motschulsky, 1860) from east Palaearctic was listed as a separate species by Löbl and Smetana (2010). Shapovalov (2013) considered S. balsamifera to be synonymous with S. populnea (Linnaeus, 1758). Later, Danilevsky (2016) considered S. balsamifera to be a subspecies of S. populnea. The North American subspecies S. populnea moesta Le Conte, 1850 (Linsley and Chemsak 1995) was considered to be a valid species by Shapovalov (2013). The most recently described species of Saperda is S. gilanense Shapovalov, 2013 from Northern Iran.

Our study focus mainly on the northern populations of *S. populnea*, which have less dense and more greyish pubescence and found to be monophagous on downy willow, *Salix lapponum* L. Reared specimens were compared with the preserved type specimens of the southern populations which are larger and have denser and more orange-brown pubescence. The southern form was described by Linnaeus already in 1758. A large number of similar specimens from Scandinavia and other parts of Europe, often confirmed to have been collected on, or reared from, *Populus tremula* L. are included. *Saperda populnea lapponica* ssp. n., which we describe in this study from populations in the Fennoscandian mountains, has exclusively been reared from *Salix lapponum* (Fig. 1).

Salix lapponum is abundant at higher altitudes in the Scandinavian mountains, where the shrubs may reach a height of 1–2 m on moist areas such as bogs and swamps, but scarce or absent in the southern coastal areas (Hultén 1971, Elven 2005). Conversely, *Populus tremula* is scarce or absent in mountain areas in Scandinavia where *S. lapponum* is most abundant (Hultén and Fries 1986). *S. lapponum* is distributed in northern Europe and eastwards into Siberia, approximately to the Jenisej Valley as well as in northern Scotland (Hultén and Fries 1986). We have no information on *S. populnea lapponica* ssp. n. or *S. populnea populnea* attacking *Salix lapponum* in Scotland, or elsewhere in the UK.

We have not been able to find any attacks on, or specimens reared from, any other *Salix* species in areas where *Saperda populnea lapponica* ssp. n. is common. All the specimens from Scandinavia have been recorded at localities where *Salix lapponum* is abundant (Fig. 1). We therefore consider *S. populnea lapponica* ssp. n. to be monophagous on *Salix lapponum* in Scandinavia. Taxonomic position of *Salix lapponum* is rather isolated



**Figure 1.** Habitat of *Saperda populnea lapponica* ssp. n., Trysil: Ljørdalen, Norway with an accumulation of downy willow (*Salix lapponum* L.) on a boreal and elevated boggy meadow.

from other *Salix* species in the Palaearctic Region. It is placed in the subgenus *Vetrix*, in the section *Villosae*. This section only includes the nearest relative *Salix alaxensis* (Andersson) Coville from North America, apart from *Salix lapponum* (Reidar Elven pers.com.). *Salix lapponum* is known to hybridize with many other species. Both hybrids and triple hybrids as well as diploids/polyploids are known (Jonsell 2000), but we do not know if the hybrids or polyploids are used as host trees. *Salix lapponum* is also well known to be a "mild tasting" food for herbivores, due to a low content of phenolic components (Elven 2005). *Populus tremula* is absent in the spots where we found *Salix lapponum*. However, several *Salix* species occur in these biotopes. *Populus tremula* requires drier soil, and is therefore not found in the same biotopes as *S. lapponum* (Reidar Elven pers. com.).

We have also made a comparison with other *Saperda* species from Europe, Asia (Siberia) and North America, with special emphasis on related species in the subgenus *Compsidia* Mulsant, 1839. The presented taxonomic study is based on examination of morphological characters as well as studies of the genitalia. We also use two different fragments of the mitochondrial gene cytochrome oxidase subunit I (COI) to test for reciprocal monophyly and calculate genetic distances. We adhere to the unified species concept (de Quieroz 2007) and define species as separately evolving metapopulation lineages. There are several lines of evidence that can be used to show that two lineages are separately evolving, such as intrinsic reproductive isolation, ecological niche differ-

entiation, phenotypically divergent and diagnosable and reciprocally monophyletic in genetic markers. However, none of these are part of the species definition (de Quieroz 2007). We define subspecies under the unified species concept as potentially incipient species in allopatry or parapatry that are diagnosable by at least one presumably heritable trait (see further under discussion).

# Methods

## Taxon sampling for DNA

All 17 available sequences for Saperda populnea in Bold and Genbank were downloaded. Apart from one sequence of mitochondrial ribosomal 16s, the remaining 16 were of mitochondrial cytochrome oxidase subunit I (COI). Of these one turned out to be misidentified (KF247304), one was of the 3-prime ("pat-jerry") fragment of COI and 14 were of the 5-prime (LCO-HCO) barcode fragment of COI. Thirteen of these were from Finland and the FINBOL Barcoding project and had been released by Pentinsaari et al. (2014). The last (KM286402) was from a specimen from the French Alps. We combined these 14 sequences with available sequences of the same fragment of COI from other Saperda species to analyse the gene tree topology and intraspecific variation. The downloaded sequences were aligned with Clustal X (Larkin et al. 2007) under default settings. The 13 Saperda populnea specimens from Finland included two specimens from Lappish Finland and were of the smaller less hairy form that fitted our concept of what we will hereafter refer to as *S. populnea lapponica* ssp. n. (see taxonomy part), based on photos. However, the sequences for all the Finnish material were shorter (407 bp) than normal barcode fragments (full 658 bp; minimum barcode standards >500 bp). After examining the alignment, it turned out that they only differed at two positions (including the French specimen). We therefore decided to aim for the longer 3-prime end 825 bp fragment of CO1 for the new material.

New material of both *S. populnea lapponica* ssp. n. and *S. populnea populnea* was collected as larva from the host plants *Populus tremula* and *Salix lapponum* in Sweden and Norway 2009-2013 (Tab. 1). We also collected new material of related species of the genus *Saperda*, both as larvae and adults. In addition, we extracted a number of dry-pinned adult specimens from the collections at the Swedish Museum of Natural History (NHRS), Stockholm, Sweden. These ranged in collection dates from 1948–1994 and included material from the two important donations of Lars Huggert and Stig Lundberg (Tab. 1). All DNA vouchers are kept at NHRS.

#### Molecular laboratory protocols

DNA from imagines was extracted from adults using 1 leg, 2 legs, thoracic muscle tissue, or head and prothorax. When DNA from larvae was extracted, tissue from tergites

Species	Extr. ID	Ext method	CO1 Acc	Stage	from	Country, province, locality	Date	Leg.
Saperda p. lapponica	JB941	Qiagen	MF491465	larva	Salix lapponum	Norway, Hedmark, Ljørdalen	27.06.2013	Torstein Kvamme
Saperda p. lapponica	JB942	Qiagen	MF491467	larva	Salix lapponum	Norway, Hedmark, Engerdal	27.06.2013	Torstein Kvamme
Saperda p. lapponica	JB946	Qiagen	MF491463	larva	Salix lapponum	Norway, Hedmark, Ljørdalen	27.06.2013	Torstein Kvamme
Saperda p. lapponica	JB949	Qiagen	MF491468	larva	Salix lapponum	Sweden, Lule lappmark, Kiruna	24.06.2013	Torstein Kvamme
Saperda p. lapponica	JB950	Qiagen	MF491462	larva	Salix lapponum	Norway, Hedmark, Trysil	27.06.2013	Torstein Kvamme
Saperda p. lapponica	JB016	GeneMole	Failed	adult		Sweden, Torne Lappmark, Silkimuotka	28.VI.1948	N. Höglund
Saperda p. lapponica	JB017	GeneMole	Failed	adult		Sweden, Torne Lappmark, Silkimuotka	28.VI.1948	N. Höglund
Saperda p. lapponica	JB021(JB250)	GeneMole	MF491469	adult		Sweden, Åsele Lappmark, Kittelfjäll	28.VI.1972	T-E Leiler
Saperda p. lapponica	JB022(JB249)	GeneMole	MF491461	adult		Sweden, Torne Lappmark, Soppero	30.VI.1980	Stig Lundberg
Saperda p. lapponica	JB023(JB248)	GeneMole	Failed	adult		Sweden, Torne Lappmark, Soppero	15.VI.1968	Stig Lundberg
Saperda p. lapponica	JB024(JB251)	GeneMole	MF491460	adult		Sweden, Lule Lappmark, Messaure	14.VII.1971	S. Lundberg & T. Müller
Saperda p. populnea	JB945	Qiagen	MF491471	larva	Populus tremula	Sweden, Uppland, Uppsala	07.2013	Henrik Wallin
Saperda p. populnea	JB018(JB247)	GeneMole	MF491471	adult		Sweden, Öland, Räpplinge	03.V.1976	Bert Gustafsson
Saperda p. populnea	JB019(JB246)	GeneMole	MF491466	adult	Salix sp.	Sweden, Småland, Åseda	26.XII.1974	Bert Gustafsson
Saperda p. populnea	JB020(JB245)	GeneMole	MF491470	adult	Salix sp.	Sweden, Uppland, Uppsala	01.V.1984	Stig Lundberg
Saperda p. populnea	JB025(JB252)	GeneMole	MF491459	adult		Sweden, Norrbotten, Kalix	30.VI.1994	S. Lundberg & T. Müller
Saperda p. populnea	JB026	GeneMole	Failed	adult		Sweden, Västerbotten, Umeå	09.V.1969	Lars Huggert
Saperda p. populnea	JB027	GeneMole	Failed	adult		Sweden, Halland, Släp	02.V.1965	Lars Huggert
Saperda p. populnea	JB028	GeneMole	Failed	adult		Sweden, Västergötland, Amundön	31.12.1968	Lars Huggert
Saperda p. populnea	JB029	GeneMole	MF491472	larva	Populus tremula	Sweden, Uppland, Uppsala	05.2009	Henrik Wallin
Saperda scalaris	JB030	GeneMole	MF491473	adult	Quercus robur	Sweden, Uppland, Knutby	05.2009	Henrik Wallin
Saperda similis	JB938(RB122)	Qiagen	MF491458	larva	Salix caprea	Sweden, Uppland, Uppsala	07.2013	Henrik Wallin
Saperda carcharias	JB944	Qiagen	MF491456	larva	Populus tremula	Sweden, Uppland, Knutby	07.2013	Henrik Wallin
Saperda carcharias	JB031	GeneMole	MF491457	adult		Sweden, Södermanland, Haninge	20.IX.2009	Julio Ferrer
Saperda moesta	JB939	Qiagen	Failed	adult	Populus balsamifera	Canada, Ontario, Ottawa	07.07.1961	S.D. Hicks
Saperda tulari	JB943	Qiagen	Failed	adult	Populus fremontii	USA, California, Turlock	24.05.1955	R.R. Snelling
Oberea oculata	JB948	Qiagen	MF491455	larva	Salix caprea	Sweden, Uppland, Knutby	07.2013	Henrik Wallin

Table 1. Metadata for specimens included in the molecular analysis. Column four gives GenBank accession numbers.

or sternites was used. Extraction of DNA was done by using either the Quiagen tissue kit, or a GeneMole robot (Tab. 1), following standard protocols for both apart from using 20ul of DTT (Dithiothreitol). DTT may improve DNA extraction of material with degraded DNA as with the dry-pinned 20-70 years old samples. For fresh alcohol samples we amplified the COI fragment using primers "PatDyt" (TCATTGCAC-TAATCTGCCATATTAG; Isambert et al. 2011) and "Jerry" (CAACATTTATTTT-GATTTTTTGG; Simon et al. 1994). When older material was used we attempted to amplify DNA in two or three overlapping fragments, each about 400-450 bp long using primer pairs Jerry - Hal450rw (GGAAATCATTGAATAAATCCAGCT), Hal200fw (CTGCAACAATAATCATTGCTGTTC) - Hal600rw (AAGCATCTG-GATAATCAGAATAATC) and Hal450fw (AGCTGGATTTATTCAATGATTTCC) - PatDyt. The first and third fragment overlaps at the 450fw/450rw primer-binding site which the second fragment covers. These primer pairs were originally designed by JB to amplify this COI part in two or three fragments from degraded DNA of Haliplidae. But it turns out that it also works for other families of Coleoptera.

Ready-ToGo<sup>™</sup> PCR beads (Amersham Biosciences) were used in all PCR recations and 2-4ul of DNA. The longer fragments were amplified under the following conditions: 95C for 5min followed by 40 cycles of 95C for 30s, 50C for 30s and 72C for 60s and a final extension period of 72C for 8min. The shorter fragments were amplified under the same conditions or with a shorter extension time (72C 50s). In second trials with samples that failed the first time, the annealing temperature was lowered to 47C. PCR reactions were purified with Exonuclease I and FastAP (Fermentas) and sequenced with a BigDye<sup>™</sup> Terminator ver. 1.1 Cycle Sequencing Kit (Applied Biosystems), cleaned with a DyeEx 96 kit (QIAGEN) and ran on an ABI Prism 3100 Genetic Analyzer (Applied Biosystems).

## Molecular analyses

Sequence chromatograms were edited in SEQUENCHER (Gene Codes Corporation). Contigs were created of the forward and reverse reads and of the two or three overlapping fragments for the older material. Sequences were exported in fasta format after primers had been removed and aligned using CLUSTALX 2.0 (Larkin et al. 2007). There were no gaps in the alignment.

We calculated genetic distances under the Kimura 2-parameter model using MES-QUITE (Maddison and Maddison 2017). For both 5-prime and 3-prime datasets we performed a Bayesian clock analysis in BEAST 1.8.4 (Drummond et al. 2012). Ultrametric genetrees were inferred under a HKY+I+G substitution model with a strict clock model for branch lengths and allowed each codon position its own relative substitution rate. A constant size coalescent tree prior was used, as it was the tree topology and branch length within *Saperda populnea* that was of interest, not the relationship to other *Saperda* species. The MCMC analysis was run for one million generations,
sampled every 1000 generations. A maximum clade credibility tree with median node heights and clade support values was computed using TREE ANNOTATOR (part of the Beast package). TRACER 1.6 (Rambaut et al. 2014) was used to control the performance of the runs.

#### Morphological study

Our study includes descriptions of the sclerotised parts of the male terminalia: the aedeagus, endophallus with the sclerites inside the median phallomere and the internal sac, tegmen with parameres and median lobe, and tergite VIII. The internal sac of the males was embedded in glycerol and photographed using a regular light microscope. This method is described in detail by Wallin et al. (2009, 2012, 2013). The studies of the female terminalia included tignum, tergite VIII and the spermathecal capsule. Other parts of the male genitalia and also the female genitalia were dry mounted. The terminology used is based on Lingafelter and Hoebeke (2002), Hubweber and Schmitt (2010), Yamasako and Ohbayashi (2011), Lin et al. (2009), Slipiński and Escalona (2013), Wallin et al. (2014) and Wallin and Kvamme (2015).

We maintain the use of the internal sac (part of the median phallomere), since it has been frequently used in the past (*cf.* Wallin et al. 2013). The sclerites inside the internal sac may vary considerably between species and have been found to be very useful when describing species of *Leiopus* (Wallin et al. 2012), *Monochamus* (Wallin et al. 2013), *Sybra* species (Weigel and Skale 2009) and species of *Nemophas* (Wallin et al. 2014). However, such sclerites are less variable in the genera *Saperda* and *Stenostola* since they mostly consist of three long shafts (without extensions), varying little in size and shape (Sama 2008). Hind wing morphology follows Lingafelter and Hoebeke (2002).

Male genitalia photos were taken using an Olympus SZX 10 UC 30 camera attached to a Zeiss microscope and operated via the software ANALYSIS docum and Olympus Soft Imaging Solutions GmbH Version 5.1 (Build 2677). No stacking was used on these images. Habitus photos were taken using a Canon EOS 5D Mark II DSLR camera with a Canon MP-E 65mm f/2.8 1–5× macro lens and a Canon MT-24EX Macro Twin Lite flash with custom-made light diffusors. The camera was mounted on a motorized Stackshot rail (Cognisys) and operated via the software ZERENE STACKER (Zerene Systems) that was also used for stacking the images. Measurement data of body length (BL) and the ratio (BL/BW) between body length and maximum body width (BW) was first tested for normality with a Shapiro-Wilk normality test in R (R Core Team, 2016). Normality was rejected for at least one species x sex category for both measurements. We therefore used the non-parametric Wilcoxon rank sum test of independent samples (also known as the Mann-Whitney U test, or the Wilcoxon-Mann-Whitney test). In order to evaluate the variation between species, we have also included specimens from North America and Asia.

### Rearing of adult beetles

Stems and branches were cut from shrubs of *Salix lapponum* at localities where the host plant was abundant. Only host material with visible attacks was collected. At one locality near the road, the shrubs had been cut by ditch cleaning machines and infested branches were collected from the ground. The infested stems and branches of *Salix lapponum* were placed in rearing cabinets stored at room temperature. Most of the material was collected from mid-May to the beginning of June, shortly after snowmelt.

### Nomenclature applied

The species nomenclature follows Linsley and Chemsak (1995) and Löbl and Smetana (2010).

Specific information on examined specimens is mentioned under each species in the section "Taxonomy". The dates and other information were copied from the labels. In some cases, additional information provided by collectors has been added.

### Abbreviations

AMNH	American Museum of Natural History, New York, USA
BPBM	Bernice Pauahi Bishop Museum, Honolulu, USA
CAEL	Collection Arne E. Laugsand
CBE	Collection Bengt Ehnström, Nås, Sweden
CCH	Collection Carolus Holzschuh, Villach, Austria
CHW	Collection Henrik Wallin, Uppsala, Sweden
CMD	Collection Michail Danilevsky, Moscow, Russia
COS	Collection Ove Sørlibråten, Mysen, Norway
CPKS	Collection Per Kristian Solevåg, Lier, Norway
CPS	Collection Pesarini & Sabbadini, Milano, Italy
CRP	Collection Roger Petterson, Laxbacken, Sweden
СТК	Collection Torstein Kvamme, Ås, Norway
CUN	Collection Ulf Nylander, Gävle, Sweden
CÅL	Collection Åke Lindelöw, Uppsala, Sweden
GNM	Göteborg Natural History Museum, Gothenburg, Sweden
LINN	Collection of The Linnean Society of London, London, UK
MZH	Helsinki Natural History Museum, Helsinki, Finland
MCZ	Museum of Comparative Zoology Harvard University, Cambridge, Mas-
	sachusetts, USA
MNHN	Muséum National d'Histoire Naturelle, Paris, France
ZMUB	Natural History Collections, Bergen Museum, University of Bergen, Norway

NHMO	Natural History Museum Oslo, University of Oslo, Norway
NHRS	Swedish Museum of Natural History, Stockholm, Sweden
NIBIO	Norwegian Institute of Bioeconomy Research, Ås, Norway
ZMUO	University of Oulu, Finland
UUZM	Museum of Evolution–Zoology, Uppsala University, Uppsala, Sweden
MZLU	Zoological Museum–University of Lund, Sweden
ZMUM	Zoological Museum of Moscow University
ZIN	Zoological Institute RAN, St. Petersburg, Russia
BL	Body length
BW	Body width
HT	Holotype
РТ	Paratype

## Results

### Molecular and statistical analyses

There are 69 published and released 5-prime end fragments of COI in Genbank and Bold of *Saperda*. The ultrametric strict clock tree from Beast recovered all *S. populnea* specimens in one monophyletic clade, apart from one released sequence from genbank (KF247304) (Fig. 2). This specimen, possibly from China, is an obvious misidentification, and must be another eastern Palearctic species of *Saperda*. The true *S. populnea* clade contained two shallow groups, one of which contained the French specimen, the two specimens from Finnish Lapponia (*S. populnea lapponica* ssp. n.) as well as three specimens from other parts of Finland (all with identical sequences apart from one bp difference in KJ964605). The two clades differed at a single position in the 407 bp long alignment. The genetic distance between specimens was 0–0.49%.

Amplification of the 3-prime end fragment of COI was successful for all specimens collected in the 1970s or later, but failed for all specimens from the 1960s or earlier (Tab. 1). A second independent extraction and amplification of five of the old dry-mounted specimens confirmed the sequences and assured that no cross-contamination was involved. The ultrametric strict clock tree from Beast recovered all *S. populnea* specimens in one monophyletic clade (Fig. 3). *S. populnea lapponica* ssp. n. specimens from the mountain regions of Fennoscandia and *S. populnea populnea* specimens from areas outside the mountain region were intermingled and were not reciprocally monophyletic. This included the larval specimens collected from both *Populus tremula*, and from *Salix lapponum*. A released genbank sequence submitted as *Saperda populnea* (HM062986), from Jilin province, China, came out as the most divergent and sister to remaining specimens (genetic distance: 2.09-2.60%). After receiving a photo of this specimen, we concluded that it actually refers to *Saperda bilineatocollis* Pic, 1924. There were also two moderately divergent mitochondrial clades, one of



**Figure 2.** Gene tree from strict clock analysis with Beast of a 5-prime end fragment of mitochondrial cytochrome oxidase subunit I (the animal Barcoding fragment). Numbers at nodes are posterior probability values, only given for nodes >0.5. Scale bar = expected number of substitutions per site.

which consisted of two specimens from Uppsala, Sweden. The genetic distance of the two Uppsala specimens to the remaining Fennoscandian clade was 1.97–2.35%. The genetic distance between *S. populnea populnea* and *S. populnea lapponica* ssp. n. specimens varied between 0 to 2.35%.



**Figure 3.** Gene tree from strict clock analysis with Beast of a 3-prime end fragment of mitochondrial cytochrome oxidase subunit I. Numbers at nodes are posterior probability values, only given for nodes >0.5. Scale bar = expected number of substitutions per site.

The genetic distance between *S. populnea* and any of the other *Saperda* species apart from *S. bilineatocollis*, was larger, between 9.82–19.34%. The smallest interspecific distance was between *S. populnea* and *S. bilineatocollis* (2.09–2.60%) followed by *S. carcharias* and *S. similis* (2.59%). The distance between *S. populnea* and *S. bilineatocollis* (2.09–2.60%) overlaps with the distance within *S. populnea* (0–2.35%). The COI fragment of *S. similis* is the first DNA sequence released of this species.

The body length, among the examined specimens, was significantly smaller in *S. populnea lapponica* ssp. n. than in *S. populnea populnea* both for males (Wilcoxon p = 1.066 e-08) and for females (Wilcoxon p = 5.802 e-07) (Fig. 4). The total ranges overlapped between the examined specimens of the two subspecies (males 8-12mm vs 10.5-13.0 mm; females 9.5-13.0 mm vs 11.0-15.0 mm), but the 25-75% quartiles did not (males 10.0-11.0 mm vs 11.0-12.0 mm; females 10.7-12.5 mm vs 12.9-13.5 mm) (Fig. 4).

The subspecies are not diagnosable based on body length in the sense requiring 75% of individuals of subspecies A to be outside the distribution of 99% of subspecies B (Amadon 1949, Patten and Unitt 2002). The body shape measured as the ratio of body length (BL) / body width (BW) was not significantly different in either sex (Wilcoxon: males p = 0.934; females p = 0.835) (Fig. 5).



Saperda p. populnea

Saperda p. lapponica

**Figure 4.** Body lengths of males and females of *Saperda populnea populnea* (Linnaeus, 1758) and *S. populnea lapponica* ssp. n. Y-axis in mm. \*=significant according to a non-parametric Wilcoxon rank sum test.

### Taxonomy

### Genus Saperda Fabricius, 1775: 184

Type species. Cerambyx carcharias Linnaeus, 1758 Saperda carcharias (Linnaeus, 1758: 394). Cerambyx carcharias Linnaeus, 1758 (original combination)

# Examined specimens.

Saperda carcharias (Linnaeus, 1758: 394)
Sweden: 1 ♂ BL 24.0 mm, Uppland, Tuna Hässelby, 1980-05-05, ex larva from Populus, leg. H. Wallin, CHW; 1 ♂ BL 21.0 mm, Södermanland, Stockholm, 1993-09, leg. H. Wallin, CHW.
Saperda (Saperda) similis Laicharting, 1784: 31



Saperda p. populnea

Saperda p. lapponica

**Figure 5.** Body shape measured as the ratio of total body length to maximum body width of males and females of *Saperda populnea populnea* (Linnaeus, 1758) and *S. populnea lapponica* ssp. n. No significant difference between the subspecies of the same sex according to a non-parametric Wilcoxon rank sum test was found.

**Sweden**: 1 ♂ BL 16.8 mm, Uppland, Knutby, 1995-06-05, *ex larva* from *Salix*, leg. H. Wallin, CHW; 1 ♂ BL 18.0 mm, Småland, Näsby, Bo, 1975-06-16, leg. W. Kronblad, CHW.

Saperda scalaris scalaris (Linnaeus, 1758: 394)

Cerambyx scalaris Linnaeus, 1758: 394 (original combination)

Sweden: 1 & BL 13.8 mm, Uppland, Steninge, 1974-10-26, *ex larva* from *Quercus*, leg. H. Wallin, CHW; 1 & BL 13.2 mm, Uppland, Biskops-Arnö, 1973-05-12, ex larva from *Quercus*, leg. H. Wallin, CHW.

Saperda perforata (Pallas, 1773: 723)

Cerambyx perforata Pallas, 1773: 723 (original combination)

Sweden: 1 👌 BL 13.2 mm, Uppland, Uppsala, Hågadalen, 1981-06-14, leg. H. Wallin, CHW; 1 👌 BL 13.0 mm, Uppland, Länna, 1974-06, leg. H. Wallin, CHW.

Saperda gilanense (Shapovalov, 2013: 139)

Compsidia gilanense Shapovalov, 2013: 139 (original combination)

**Iran: PT**  $\stackrel{\circ}{\supset}$  BL 11.5 mm, Gassan-Kiade prov., Cefidrouda, leg. B. Ilin, 1916-04-23/24, ZIN; **PT**  $\stackrel{\circ}{\ominus}$  BL 13.7 mm, Gassan-Kiade prov., Cefidrouda, leg. B. Ilin, 1916-04-23/24, ZIN.

Saperda quercus quercus Charpentier, 1825: 224

Saperda quercus Charpentier, 1825: 224 (original combination)

**Greece:** 1  $\bigcirc$  BL 14.0 mm, BW 3.5 mm, Peloponnese, Skala, Lakonia, Evrotas riv., 1994-04-24, leg. Dulik & Jeniš, CHW; 1  $\bigcirc$  BL 14.0 mm, Sparti, 1991-05-31, leg. Sobota, CHW.

Saperda bacillicornis Pesarini & Sabbadini, 1996: 116

**China: HT**  $\circlearrowleft$  (BL not mentioned for the **HT** but overall BL is 9.1-10.3 mm), Qinghai, 40 km S Huangyuang, 1990-07-06/08, leg. Nikodym, CPS (photo examination). *Saperda bilineatocollis* Pic, 1924: 19.

**China:** HT  $\bigcirc$  BL 11.0 mm, Shanghai, MNHN (photo examination). **Russia:** 1  $\bigcirc$  BL 12.5mm, Kabarovsk reg. Solnetchnyi, 320m, 50°44'N, 136°39'E, 10-17.7.1991, leg. A. Shadenkov, CMD.

Saperda innotatipennis Pic, 1910:

**Russia: HT**  $\bigcirc$  BL 10.0 mm, Siberia, ex coll. Maurice Pic, MNHN (photo examination). *Saperda messageei* Breuning, 1962: 10

**Laos: HT**  $\bigcirc$ , Vientiane Province, Tha Ngone, 1971-07-03, ex coll. J.A. Rondon, BPBM (photo examination).

Saperda moesta moesta Le Conte, 1850: 234.

**Canada:** 1  $\Diamond$  BL 8.0 mm, Brittania, Hts., Ontario, 1961-07-07, on *Populus balsamifera*, leg. S.D. Hicks, NHRS; 1  $\heartsuit$  BL 11.0 mm, Ross River, Y.T., 1960-06-21, leg. J.E.H. Martin, NHRS; 1  $\heartsuit$  BL 9.0 mm, Quebec, Oka, 2008-06-22, leg. R. Vigneault, CHW. **USA:** HT  $\heartsuit$  (type no. 4213), MCZ (photo examination).

Saperda moesta tulari (Felt & Joutel, 1904: 70)

**USA:** 1  $\Diamond$  BL 10.0 mm, California, Stanislaus Co., Turlock, 1955-05-24, leg. R.R. Snelling, NHRS; 1  $\bigcirc$  BL 10.5 mm, California, Stanislaus Co., Turlock, 1955-05-24, reared from Cottonwood, leg. R.R. Snelling, NHRS; 1  $\bigcirc$  BL 9.5 mm, California, Davis, 1928-03-30, leg. F.H. Wymore, NHRS; 1  $\Diamond$  BL 8.4 mm, Nevada, leg. Morrison, NHRS no. 8147 E94; 1  $\bigcirc$  BL 9.0 mm, Nevada, leg. Morrison, NHRS no. 8148 E94; 1  $\bigcirc$  BL 9.8 mm, Nevada, leg. Morrison, NHRS no. 8149 E94; **HT**  $\bigcirc$ , Tulare County, California, AMNH (photo examination).

Saperda populnea balsamifera (Motschulsky, 1860), stat. n.

Compsidia balsamifera Motschulsky, 1860: 151 (original combination).

**Russia**: 1  $\bigcirc$  BL 9.5 mm, "less pubescent, "black" form", S. Sachalin, Tomari, Spamberg 850 m, 1976-07-26, leg. W. Dolin, CCH; 1  $\bigcirc$  BL 10.5 mm, "less pubescent black form", Minusinsk (Siberia, Krasnojarsk region), leg. K. Ehnberg (id 772), MZH; 1  $\bigcirc$  and 1  $\bigcirc$  (BL 12–13 mm according to Cherepanov, 1991) "pubescent, yellow form", Novosibirsk, 1974-07-17 on *Salix*. leg. A. Tsherepanov (photo examination), CMD; Lectotype of *Compsidia balsamifera* (probably a male, but only the elytra is preserved), ZMUM (photo examination).

#### Saperda populnea populnea (Linnaeus, 1758).

Figs 6a, d, 8a, 9a, 10a-b, e, g-h, k, m, o, 11a, 12c, 13

Cerambyx populneus Linnaeus, 1758: 394 (original combination).

There are three males preserved at LINN available for photo examination. 1  $\circ$  BL 11.1 mm (LINN 8184), labelled "Populneus" on a pinned and old handwritten label and "57" (recent label added later corresponding to the number of the species in the original description by Linnaeus, type locality: "Europa" according to Linnaeus (1758), and habitat: *Populus tremula* according to Linnaeus (1761)); 1  $\circ$  BL 11.0 mm (LINN 8185), no pinned label available; 1  $\circ$  BL 9.2 mm, no pinned label available.

*Cerambyx decempunctatus* De Geer, 1775: 78 (synonymized by Breuning (1966) and Löbl and Smetana (2010)).

Lectotype (here designated), d BL 12.5 mm, Sweden, ex coll. De Geer, NHRS.

- *Leptura betulina* Geoffroy, 1785: 78 (synonymised by Breuning (1966) and Löbl and Smetana (2010)).
- *Saperda salicis* Zetterstedt, 1818: 258 (synonymised by Gyllenhal, 1827, Dejean, 1835; Breuning (1966) and Löbl and Smetana (2010)).

Lectotype (here designated),  $\circlearrowleft$  BL 11.5 mm, Sweden, Skåne, Abusa, Lund (insect pin supplied with a small, square bright yellow label), 1818-08, on *Salix viminalis* L, leg. J.V. Zetterstedt, MZLU.

- Saperda populi Duméril, 1860: 607 (synonymised by Breuning (1966) and Löbl and Smetana (2010)).
- Saperda ab. bickhardti Sattler, 1918: 200 (synonymised by Breuning (1966)).

Saperda f. kavani Roubal, 1933: 133 (synonymised by Breuning (1966)).

Saperda ab. quadripunctata Podaný, 1953: 52 (synonymised by Breuning (1966)).

Examined specimens. Sweden: 1 9 BL 12.5 mm, -1818, Skåne, SE Lund, Räften Abusa etc., (insect pin supplied with a small bright yellow label), ex coll. J.V. Zetterstedt, MZLU; 1 Q BL 14.0 mm, ~1818, Skåne, E Lund, Björntorps säteri (insect pin supplied with small red and yellow labels), ex coll. J.V. Zetterstedt, MZLU; 1 👌 BL 12.0 mm, ex coll. J.V. Zetterstedt, MZLU; 1 🌻 13.0mm, ~1818, Skåne, labelled var. b., ex coll. J. V. Zetterstedt, MZLU; 1 2 BL 13.0 mm, ~1818, Skåne, SE Lund, Räften Abusa etc., (insect pin supplied with a small bright yellow label), ex coll. J.V. Zetterstedt, MZLU; 1 2 BL 13.0 mm, ~1818, ex coll. J. V. Zetterstedt, MZLU; 1 3 BL 11.0 mm, ~1818, Skåne, Kiviks Esperöd, (insect pin supplied with a small blue label), ex coll. J.V. Zetterstedt, MZLU; 1 👌 BL 10.5 mm, ~1818, Skåne, E Lund, Björntorps säteri (insect pin supplied with small red and yellow labels), ex coll. J.V. Zetterstedt, MZLU; 1 ♀ BL 14.0 mm, ~1818, Skåne, E Lund, Björntorps säteri (insect pin supplied with small red and yellow labels), ex coll. J.V. Zetterstedt, MZLU; 1 👌 BL 12.0 mm, ~1818, Skåne, E Lund, Björntorps säteri (insect pin supplied with small red and yellow labels), ex coll. J.V. Zetterstedt, MZLU; 1 ♂ BL 11.5 mm, ~1818, Skåne, labelled Cer. 10-punctata, ex coll. J.V. Zetterstedt, MZLU; 1 ♀ BL 13.5 mm, ~1818, Skåne, SE Lund, Räften Abusa etc., (insect pin supplied with a small bright yellow label), ex coll. J.V. Zetterstedt, MZLU; 1 ♀ BL 12.0 mm, ~1818, Skåne, SE Lund, Räften Abusa etc., (insect pin supplied with a small bright vellow label), ex coll. J.V. Zetterstedt, MZLU; 1 👌 BL 11.5mm, Uppland, Uppsala, Stabby, 1991-04-19, ex larva from Populus, leg. H. Wallin, HW; 1 d BL 12.0 mm, Norrbotten, Blåkölen, 1983-07-03, leg. S. Lundberg, NHRS; 1 👌 BL 13.0 mm, Norrbotten, Kalix, Kosjäry, 1956-12, ex larva from *Populus tremula*, leg. S. Lundberg, NHRS; 1 2 BL 15.0 mm, Norrbotten, Kalix, Kosjärv, 1956-12, ex larva from Populus tremula, leg. S. Lundberg, NHRS; 1 d BL 11.0 mm, Norrbotten, Kalix, 1994-06-30, leg. S. Lundberg, NHRS; 1 d BL 12.0 mm, Småland, Åseda, ex larva from *Salix*, 1974-12-26, leg. B. Gustafsson, NHRS; 1 d BL 12.2 mm, Uppland, Båtfors, 1987-06-15, leg. S. Lundberg, NHRS; 1 🖧 BL 11.5 mm, Halland, Släp, 1965-05-02, leg. L. Huggert, NHRS; 1 🖧 BL 12.0 mm, Västerbotten, Umeå, 1969-05-09, leg. L. Huggert, NHRS; 1 🏻 BL 13.0 mm, Norrbotten, Pajala, 1976-07-13, on Populus tremula, leg., C. Eliasson, GNM; 1 🖞 BL 10.5 mm, Bohuslän, Högås (Sund), 1947-06-16, leg. H. Arvall, NMG; 1 Q BL 12.0 mm, Östergötland, Omberg, 1983-06-02, on *Salix* tree, leg. S. Lundberg, NHRS; 1 [] BL 12.2 mm, Uppland, Uppsala, 1984-05, *ex larva* from *Salix* tree, leg. S. Lundberg, NHRS; 1 Q BL 13.4 mm, Öland, Räpplinge, 1976-05-03, on *Populus* tree, leg. B. Gustafsson, NHRS; 1 ♀ BL 13.5 mm, Västergötland, Amundön, 1968-12-31, ex larva, leg. L. Huggert, NHRS; 1 2 BL 13.5 mm, Södermanland, Nacka, Storängen, 1972-07-27, ex larva from Populus tremula reared 1973-05-22, leg. L. Hole, CHW; 1  $\bigcirc$  BL 13.5 mm, Uppland, Knutby, 1991-05, ex larva from *Salix* tree, leg. H. Wallin, CHW; 1 ♀ BL 13.5 mm, Uppland, Knutby, Kamsgärd, 2001-07-22/29, collected in a window trap, leg. H. Wallin, CHW; 1 Q BL 12.8 mm, Uppland, Bladåker, 1996-07-03, on Populus tremula, leg. H. Wallin, CHW; 1 d BL 12.0 mm, Medelpad, Sillre, leg, S. Adebratt, CUN; 1 👌 BL 11.0 mm, Östergötland, Omberg, Stora Klint, 1983-05-25, leg. S. Adebratt, CUN; 1  $\bigcirc$  BL 13.5 mm, Uppland, Knutby, 2014-11-22, reared from Populus tremula, leg. Å. Lindelöw, CÅL; 1 👌 BL 12.0 mm, Uppland, Knutby, 2014-11-22, reared from *Populus tremula*, leg. Å. Lindelöw, CÅL; 1  $\bigcirc$  BL 13.5 mm and 1 d BL 11.3 mm, Uppland, Knivsta, 2014-10-02 (emerged 2015-02 from Populus tremula), leg. H. Wallin, CHW; 1 🖉 BL 11.5 mm Västerbotten, Skellefteå, 2014-05-15 (emerged 2015-02 from *Populus tremula*), CHW; 1 Q BL 11.0 mm, Dalarna, Los, 1924-05-25, leg. O. Sjöberg, NHRS-COLE 00007445; 1 ♀ BL 12.5 mm, Västergötland, Essunga, leg. Fogelqvist, NHRS-COLE 00007444; 1 ♀ BL 12.0 mm, Västergötland, Skövde, 1926-08-30, leg. Erlandsson, NHRS-COLE 00007431; 1 👌 BL 12.5 mm Skåne, Sandhammaren, Bjäringeborg, 1947-06-28, leg. G. Wängsjö, NHRS-COLE 00007430; 1 ♀ BL 13.8 mm Östergötland, Norrköping, 1925-05-20, leg. G. Wängsjö, NHRS-COLE 00007424; 1 🖑 BL 11.8 mm, Blekinge, Sjöarp, 1939-06-14, leg. B. Gaunitz, NHRS-COLE 00007419; 1 9 BL 11.0 mm, Värmland, Filipstad, 1932-07-22, leg. K. Sidenbladh, NHRS-COLE 00007456; 1 ♀ BL 13.0 mm, Småland, Tranås, 1953-06-09, leg. L.A.H. Lindgren, NHRS-COLE 00007462; 1 👌 BL 11.5 mm, Närke, Örebro, leg. E. Wieslander, NHRS-COLE 00007482; 1 ♀ BL 13,5 mm, Västergötland, Borås, 1938-06-13, leg. S. Åberg, NHRS; 1 ♀ BL 12.0 mm, Dalarna, Tällberg, 1958-03-25, leg. T-E. Leiler, NHRS; 1 👌 BL 11.5 mm, "Oel., Bhn." (Öland ?), ex coll. Boheman), NHRS no. 8131 E94; 1 9 BL 14.5 mm, Stockholm, Sweden, ex coll. Hoffstein 1850-1916, NHRS-COLE 00007441; 1 ♀ BL 12.8 mm, Uppland, Uppsala, 1907, leg. O. Sjöberg, NHRS-COLE 00007442; 1 ♀ BL 13.0 Öland, leg. Ahlrot, NHRS-COLE 00007420; 1 ♀ BL 14.0 mm, Bohuslän, Ödsmål, leg. B.H. Hanson, NHRS-COLE 00007414; 1 2 BL 14.0 mm, Halland, Vessige, leg. Fogelqvist, NHRS-COLE 00007408; 1 👌 BL 11.5 mm, Skåne, Hallands Väderö, 1951-06-22, leg. O. Lundblad, NHRS-COLE 00007402; 1 👌 BL 11.0 mm, Skåne, Hallands Väderö, 1951-06-22, leg. O. Lundblad, NHRS-COLE 00007400; 1 ♀ BL 14.0 mm, Skåne, Hallands Väderö, 1951-06-22, leg. O. Lundblad, NHRS-COLE 00007401; 1 ♀ BL 13.5 mm, Öland, Ålebäck, 1947, Bg, NHRS-COLE 00007506; 1 ♀ BL 12.3 mm, Värmland, Filipstad, 1932, NHRS-COLE 00007457; 1 ♀ BL 14.5 mm, Uppland, Frösunda, 1955-12-04 (emerged from Populus tremula), leg. T-E. Leiler, NHRS; 1 👌 BL 12.0 mm, Västerbotten, Umeå, 1969-05-09, leg. L. Huggert, NHRS. Finland: 1 👌 BL 11.5 mm, Hammaslahti, Joensuu, 1938-06-05, leg. P. Koutkanen, NHRS; 1 🖑 BL 12.0 mm, Finland, ex coll. Schönherr., NHRS no. 8132 E94. **Norway:** 1 PBL 12.2 mm, 23.06.1915 and 1 PBL 10.9 mm 15.06.1915, Ø, Fr. Hald (= Fredrikshald/Halden), leg. H. K. Hanssen (ex coll. Andreas Strand), ZMUB;  $1 \bigcirc$  BL 13.2 mm, 1∂ BL 11.3 mm, 1♀ BL 13.6 mm and 1♀ BL 13.9 mm, Ø, Fr. Hald (= Fredrikshald/ Halden), 1905, leg. Lyche (ex coll. Ing. Tambs-Lyche), ZMUB (e c G1994); 1 Q BL 12.8 mm, Ø, Fr. Stad (= Fredrikstad), 20.05.1895 (ex coll. E. Sandberg) ZMUB (e c G1994); 1 d BL 10.9 mm, Ø, Aaldenborgilen (= Oldenborgila), Fr.stad (= Fredrikstad/Halden), 29.05.1895, leg. A. Wollebæk, ZMUB (e c M2951); 1 🖒 BL 10.5 mm, Ø, Aaldenborgilen (= Oldenborgila), Fr.stad (= Fredrikstad), 1895-05-26, leg. A. Wollebæk, NHMO; 1 d BL 11.0 mm, Ø, Aaldenborgilen (= Oldenborgila), Fr.stad (= Fredrikstad), 1895-05-26, leg. A. Wollebæk, NHMO; 1º BL 12.5 mm, Ø, Romskogen (= Rømskog), Leg. Holmboe according to Andreas Strand, (ex coll. Andreas Strand) ZMUB; 1<sup>Q</sup> BL 12.3 mm, Ø, Romskog (= Rømskog), Leg. Holmboe according to Andreas Strand, (ex coll. Andreas Strand), ZMUB; 1 👌 BL 10.5 mm, AK, Kristiania (= Oslo), leg. Siebeke, NHMO; 1 PBL 13.6 mm, AK, Bygdø (in Oslo), 12. 07.1907, leg. Lyche (ex coll. Ing. Tambs-Lyche) ZMUB (e c G1994); 1 🖒 BL 11.3 mm, EIS 37, AK, Sørum, Sørliløkka, Dammyra, 1991-06-17, leg. O. Sørlibråten, COS; 1 👌 BL 10.5 mm, AK, Oslo, Brannfjell, 2007-06-05, inside gall on Populus tremula, leg. A. E. Laugsand, CAEL; 1 2 BL 12.0 mm, AK, Oslo, Brannfjell, 2007-06-05, inside gall on Populus tremula, leg. A. E. Laugsand, CAEL; 1º BL 13.4 mm, AK, V. Aker, Oslo, 1907, Leg. Lyche (Ex coll. Ing. Tambs-Lyche) ZMUB (e c G 1994); 1♂ BL 11.7 mm, 1♂ BL 12.3 mm and 1♀ BL 12.7 mm, AK, Bækkelag (in Oslo), before 1892, leg. N. G. Moe?, ZMUB (e c G1995); 1♂ BL 11.1 mm and 1♀ BL 12.0 mm, AK, Kristiania (= Oslo), before 1884, Leg. Esmark, ZMUB (e c M2950);  $1^{\circ}$  10.5 mm and  $1^{\circ}_{\circ}$  BL 11.4 mm, AK, Kristiania (= Oslo), leg. Warloe?, (ex coll. Andreas Strand) ZMUB; 1º BL 13.7 mm, AK, Brønnøya, Asker, 15.06.1961, leg. Andreas Strand, (ex coll. Andreas Strand) ZMUB; 19 BL 12.5 mm, AK, Brønnøya, Asker, 16.06.1934, leg. Andreas Strand, (ex coll. Andreas Strand) ZMUB; 1 2 BL 12.5



**Figure 6.** Habitus (dorsal view). **a**  $\bigcirc$  *Saperda populnea populnea* (Linnaeus, 1758), Knutby (Uppland), Sweden, 13.5 mm **b**  $\bigcirc$  *S. populnea lapponica* ssp. n., Ljørdalen, Norway, 12.5 mm **c**  $\bigcirc$  *S. populnea lapponica* ssp. n., Kiruna (Lappland), Sweden, 12,0 mm **d**  $\bigcirc$  *S. populnea populnea*, Uppsala (Uppland), Sweden, 11.5 mm **e**  $\bigcirc$  *S. populnea lapponica* ssp. n., Ljørdalen, Norway, 10.5 mm **f**  $\bigcirc$  *S. populnea lapponica* ssp. n., Kiruna (Lappland), Sweden, 10.0 mm. Scale bar 10 mm.

mm, AK, Drøbak, before 1939, leg. Warloe, ZMUB (e c M2952); 1 d BL 10.3 mm, AK, Drøbak, 03.06.1895, leg. Warloe, (ex coll. Andreas Strand) ZMUB; 1 BL 12.8 mm, AK, Drøbak, 06.08.1895, leg. Warloe, (ex coll. Andreas Strand) ZMUB;  $1 \oplus BL$ 14.1 mm, AK, Drøbak, 01.06.1895, leg. Warloe, ZMUB (e c M2952); 1 👌 BL 11.2 mm, AK, Drøbak, 03.06.1895, leg. Warloe, (ex coll. Andreas Strand) ZMUB; 1 🖒 BL 11.0 mm, AK, Drøbak, 1891-06-25, leg. Warloe, NHMO; 1 👌 BL 11.5 mm, AK, Drøbak, 1891-06-25, leg. Warloe, NHMO;  $1 \bigcirc$  BL 14.3 mm and  $1 \bigcirc$  BL 11.3 mm, VE, Nøterø (= Nøtterøy), 20.VI.1921, Leg. H. Tambs-Lyche, (ex coll. Ing. Tambs-Lyche) ZMUB (e c G1994); 1<sup>Q</sup> BL 12.3 mm, VE, Tjømø (= Tjøme), 08.07.1909, Leg. Lyche, (ex coll. Ing. Tambs-Lyche) ZMUB; 1<sup>Q</sup> BL 11.0 mm, VE, Kjære, Tjøme, 09.06.1965, on osp (=Populus tremula) Leg. A. Fjellberg, ZMUB; 1 👌 BL 11.0 mm, VE, Sandefjord, 1978-07-20, on Populus tremula, leg. A. Vik, (coll. NIBIO) NHMO; 13 BL 11.6 mm, AAY, Risør, 26.05.1918, leg. Warloe, (Ex coll. Andreas Strand) ZMUB; 1<sup>°</sup> BL 13.6 mm, RY, Fotlandsvatn, Eigersund, 29.05.1973, A. Fjeldså, ZMUB. Germany: 1 3 S. populnea var. quadripunctata Podaný BL 11.2 mm, Westfalen, 1966-06-09, leg. K. W. Stockmann (id 1377), MZH; 1 2 BL 12.3 mm, Märzat, 1920-05-27, NHRS no. 8136 E94; 1 ♀ BL 13.5 mm, Boruss. (= Prussia), Mewes, NHRS no. 8137 E94; 1  $\bigcirc$  BL 13.5 mm, Boruss. (= Prussia), Mewes, NHRS no. 8138 E94; 1 🖒 BL 12.0 mm, Boruss. (= Prussia), Mewes, NHRS no. 8141 E94; 1 🖒 BL 11.0 mm, Heidelberg, det. E. F. Gilmour, NHRS no. 8140 E94. Austria: 1 👌 BL 10.5 mm, "Austria", leg. Ferrari, NHRS no. 8133 E94; 1 🖧 BL 11.0 mm, "Austria", leg. Ferrari, NHRS no. 8134 E94; 1 BL 11.3 mm, Umbegung von Wien, leg. ?, (ex coll. Andreas Strand) ZMUB. France: 1 Q BL 13.6 mm, Gallia Meridionalis (=South France), Tarnier, NHRS no. 8139 E94; 1 👌 BL 11.7 mm, La Roquebrussanne (Var), 2008-06, local collector, CHW; 1 2 BL 13.5mm, La Roquebrussanne (Var), 2008-06, local collector, CHW; 1 ♂ BL 10.5 mm, Aramon, Var, 2015-05-12/15, CHW; 1 ♀ BL 11.0 mm, Aramon, Var, 2015-05-12/15, CHW. Switzerland: 1 ♀ BL 13.5 mm, 1 ♀ BL 12.5 mm, 1 👌 BL 11.0 mm and 1 👌 BL 10.1 mm, Münstertal, Santa Maria, 1400 m, 1953-06-19/22, leg. Lindberg, MZH. Czech Republic: 1 ♀ BL 12.5 mm, Zbraslav (Prag), 1990-05, leg. Rejzek, CHW. Czech Republic or Poland: 1 9 BL 13.0 mm, Märztdorf, leg. Weisse, NHRS no. 8135 E94; 1 🖉 BL 11.0 mm, Märztdorf, leg. Weisse, NHRS no. 8135 E94. Kazakhstan: 1 9 BL 11.0 mm, S. Kazachstan, Alma-Ata, 2000-2300 m, 1977-06-20-07-05, leg. V. Dolin, det. M. Danilevsky 2003, CCH. **Indonesia[?]:** 1 ♀ BL 12.5 mm, "Java", ex coll. Schönherr, NHRS no. 8142 E94.

Additional material examined. The following specimens are available through Boldsystems Public Data Portal and MZH for photo examination and include: Finland: 1  $\circ$  COLFA145-10, Northern Ostrobothnia (= Österbotten), Oulu, *ex larva* April 2005, leg. Mikko Pentinsaari, Marko Mutanen, id MP00407, ZMUO; 1  $\circ$ COLFA177-10, SW Finland, Eurajoki (N. Rauma), *ex larva* 1996, *Salix phylicifolia*, leg. Juhani Itaemies, id MP00439, ZMUO; 1  $\updownarrow$  COLFA178-10, Nylandia, Uusimaa, Espoo, *ex larva* 1997, *Populus tremula*, leg. Juhani Itaemies, id MP00440, ZMUO; 1  $\updownarrow$  COLFA179-10, Nylandia, Uusimaa, Espoo, *ex larva* 1996, *Populus tremula*, leg. Juhani Itaemies, id MP00441, ZMUO; 1  $\clubsuit$  COLFA180-10, SW Finland, Satakunta,

b a Calsonifege (ca Stand ) fia. she Museum Paris Coll. M. Pic Museum Paris YPE. Coll. M. Pic

**Figure 7.** Habitus (dorsal view). **a** HT  $\bigcirc$  *S. innotatipennis* Pic, 1910, 10.0 mm (photo: **a** Taghavian, MNHN) **b** HT  $\bigcirc$  *S. bilineatocollis* Pic, 1924, 11.0 mm (photo: **b**. Taghavian, MNHN).

Rauma, ex larva 1982, Populus tremula, leg. Juhani Itaemies, id MP00442, ZMUO; 1 & COLFA182-10, SW Finland, Mynaemaeki, ex larva 1996, Salix caprea, leg. Juhani Itaemies, id MP00444, ZMUO; 1 9 COLFA186-10, SW Finland, Lappi (SE Rauma), ex larva 1992, Salix caprea, leg. Juhani Itaemies, id MP00448, ZMUO; 1 🖒 COLFA188-10, Uusimaa, Nylandia, Kirkkonummi (= SE Lohja), ex larva 2003, leg. Erkki Laasonen, id MP00450, ZMUO; 1 🖧 COLFA189-10, Satakunta, SW Rauma, ex larva 1982, Populus tremula, leg. Juhani Itaemies, id MP00451, ZMUO; 1 <sup>Q</sup> COLFA190-10, Satakunta, Rauma, ex larva 1991, Salix phylicifolia, leg. Juhani Itaemies, id MP00452, ZMUO; 1 🖧 COLFA575-12, Nylandia, Uusimaa, Vartiokylae (= SE Vantaa), 2008-06-27, leg. Sami Haapala, id MP00452, ZMUO; 1 ♀ Porvoo, 31.12.1965 (ex larva), leg. H. Valtari, MZH; 1 ♀ Turku (= Åbo), 2.2.1971 (ex larva), leg. E. Linnaluoto, MZH; 1 Q Ruokolahti, Haloniemi, 22.6.1948, leg. W. Hellén, MZH; 1  $\bigcirc$  Ruokolahti, Rasila, Patjasuo, 22.6.1948, collector unknown, MZH; 1  $\bigcirc$ Kuhmoinen, collection date not available, leg. M. Pohjola, MZH;  $1 \bigcirc$  Kirkkonummi, 4.6.1919, leg. Håkan Lindberg, MZH; 1 ♀ Borgå, Seitlax, 18.6.1920, leg. Thuneberg, MZH; 1  $\bigcirc$  Kouvola, Voikkaa, date not available, leg. Paulamo, MZH; 1  $\bigcirc$  Kangasala (= E. Tampere), collection date not available, leg. Grönblom, MZH; 1 ♀ Hämeenlinna, Vanaja, 31.12.1957 (ex larva), leg. Valkeila, MZH; 1 Q Mikkeli, 30.1.2001 (ex larva), leg. M. Koponen, MZH; 1 Q Kankaanpää, collection date not available, leg. M. Pohjola, MZH; 1 ♀ Kokemäki, Kauvatsa, 2.7.1934, leg. R. Elfving, MZH; 1 ♀ Parikkala, Laurila, 16-27.6.1940, leg. S. Hellén, MZH; 1 ♀ Kouvola, Kuusankoski, 31.12.1986 (ex larva), leg. J. Jantunen, MZH; 1 💍 Lapua, 31.12.1971 (ex larva), leg. R. Järvenpää, MZH; 1 ♂ Keuruu, 31.12.1971 (ex larva), leg. R. Järvenpää, MZH; 1  $\bigcirc$  Jyväskylä, 30.01.1975 (ex larva), leg. J. Jalava, MZH; 1  $\bigcirc$  Pieksämäki, 30.01.1975 (ex larva), leg. J. Jalava, MZH; 1 👌 Kuopio, collection date not available, leg. Kurkiharju, MZH; 1 ♀ Kitee, 31.12.1938 (ex larva), leg. J. Kaisila, MZH; 1 ♀ Juuka, 2.7.1949, leg. Wegelius, MZH;  $1 \, \bigcirc$  Joensuu, collection date not available, J. Carpelan, MZH; 1 ♀ Hangö (= Hankö), Lappvik, 16.6.2009, leg. H. Silfverberg, MZH; 1 ♀ Parainen, Nauvo, 16.6.1960, leg. A. Nordman, MZH; 1 🖉 Loppi, 30.6.1943, leg. A. Saarinen, MZH. Russia: 1 🖉 Republic of Karelia, Viipuri (= Vyborg), 18.6.1920, leg. Thuneberg, MZH; 1 2 Leningrad (= St. Petersburg) Oblast, Kuolemajärvi (Pionerskoye), 10.6.1917, leg. M. Ivaschinzeff, MZH; 1 ♀ Republic of Karelia, Impilahti (= Impilaks), collection date not available, leg. Forsius, MZH.

**Redescription.** A medium-sized and subcylindrical species with body length 9.0– 15.0 mm according to e.g. Freude et al. (1966), Bilý and Mehl (1989), Bense (1995) and Ehnström and Holmer (2007). Measurements from the present study; females: BL 11.0–15.0 mm and males: BL 10.5–13.0 mm. Body 3.1 times longer than wide in females and 3.3 times longer than wide in males (Fig. 6a, d). Integument black, the compressed pubescence is orange-brown, with numerous long, erected dark brown hairs. The orange-brown pubescence relatively dense in males and from dense to very dense in females, resulting in females being more orange-brown, and males grayish to orange-brown (Fig. 6a, d). The orange-brown pubescence is extended laterally in females, especially on pronotum, anterior part of elytra and abdomen (Fig. 8a).



**Figure 8.** Habitus (lateral view). **a** *Saperda populnea populnea* (Linnaus, 1758), Stockholm, Nacka (Södermanland), Sweden (photo: Karsten Sund) **b** *S. populnea lapponica* ssp. n., Kiruna (Lappland), Sweden (photo: Karsten Sund).

Head in females. Frons convex and broader than long (about 4.7 times broader than the width of one eye lobe), eyes with lower eye lobes longer than broad and, as long as, or slightly longer than gena below. Head with frons more or less "squareformed" in many female specimens, genae straight and acutely narrowing towards mouthparts (Fig. 9a), frons densely covered with orange-brown pubescence and numerous dark brown, long and erected hairs. Genae posteriorly with long fringes of orange-brown hairs. The area between antennal segments is shallowly impressed. Head in males. Frons convex and broader than long (about 4.5 times broader than the width of one eye lobe), eyes with lower eye lobes longer than broad and 2-3 times longer than the short gena below. Head with frons rounded, genae straight and acutely narrowing towards mouthparts, frons densely covered with whitish and orange-brown pubescence and numerous dark brown, long and erected hairs. Genae posteriorly with long fringes of orange-brown hairs. The area between antennal segments is shallowly impressed. Mouthparts. Frontoclypeal margin with a fringe of relatively long orangebrown pubescence and long, orange brown, suberect hairs. Clypeus glabrous except at base. Labrum with appressed orange-brown pubescence and numerous long, suberect, orange-brown hairs. Antennae. Relatively slender, about as long as body in males (Fig. 6d), shorter in females (Fig. 6a). The length of antennae varies in males from

antennae extending beyond apices by one antennomere to shorter than elytra by three antennomeres. The length of antennae varies less in females with antennae extending beyond the middle of elytra by 3-5 antennomeres. Antennae from third segment with annulation. Scape slender and coarsely punctured with a combination of large and small shallow punctures and long black hairs, subconical, third segment longer than first and fourth. Annulation on antennal segments grevish and covering about 34 of the anterior part of each antennal segment. Thorax. Pronotum subcylindrical, slightly broader than long, lacking lateral spines. Pronotal disk convex, weak median line often with a glabrous and shining area medially, base shallowly impressed, coarse punctures except medially, densely covered with long erect and brown hairs, two broad lateral orange-brown stripes with a weak median line interrupted medially, prosternum densely pubescent with orange-brown hairs. Elytra. 2.5-2.9 times longer than broad in females and 2.7-3.0 times longer than broad in males. No carinae present. Parallel and weakly narrowing towards apices, apices narrowing and rounded, punctures coarse, deep, contiguous towards humeri and apices and confluent medially (especially in males where confluent punctures form short and weakly raised ridges transversally on each elytron), pubescence dense to very dense. There are normally eight distinct and large, orange-brown spots on elytra (apart from an irregular patch of orange-brown pubescence often occurring towards apices). The eight rounded spots are arranged in pairs with the first and third near the suture; each spot in the third pair often elongated transversally or even divided into two spots each; spots in the fourth pair sometimes slightly elongated longitudinally. One or more pairs of spots may be obsolete or rarely missing (particularly in old worn specimens). The remaining part of elytra is covered with scattered orange-brown pubescence and numerous long brown hairs. Scutellum. "U-shaped" and covered with orange-brown hairs, the hairs are mostly concentrated to the middle of scutellum. Hind wing. About 12.0 mm long in females and about 10.0 mm long in males (Fig. 11a). Covered with a weak smoky tint. Several veins are broken with apical portions not connected to basal portions. MP3 (rudimentary), MP4 and AA vein distinct although broken. Radial cell very strong and complete (Fig. 11a). Legs. Relatively short, densely covered with a fine whitish pubescence including tarsi; tarsal claws lacking a process. Venter. Densely covered with orange-brown pubescence in both sexes, prosternal process narrow and flattened anteriorly. Mesosternum and abdominal ventrites are densely covered with orange-brown pubescence and numerous yellowish and long, erected hairs. Posterior margin of sternite VII mostly rounded but sometimes weakly notched medially. Male terminalia. Aedeagus 2.1-2.5 mm long, weakly curved towards apex and compressed dorso-ventrally (Figs 10a-b, 9e), dorsal surface smooth and shining with apical part strongly to moderately narrowed towards apex (Fig. 10e). Tegmen with parameres: 2.2-2.7 mm long with tegmen mostly twisted dorso-ventrally (Fig. 10k). Parameres acutely narrowing towards apex, with dorsal surface densely covered with punctures and suberected setae. The inner margins mostly well separated and diverging towards apices (Fig. 10h) but sometimes projecting inwards (Fig. 10g). Tergite VIII 0.7-1.0 mm long relatively large and rounded with a posterior margin concave in the middle and densely covered with dense white pubes-



**Figure 9.** Frons. **a**  $\bigcirc$  *Saperda populnea populnea* (Linnaeus, 1758), Knutby (Uppland), Sweden **b**  $\bigcirc$  *S. populnea lapponica* ssp. n., Kiruna (Lappland), Sweden.

cence and numerous long brown hairs (Fig. 100). Sclerite inside internal sac: 1.8–2.2 mm long consisting of three parallel "shaft-like" structures of which the apical end (top) is elongated and posterior end often extended and narrowing towards posterior end (Fig. 10m). The colour of male genitalia is brownish. **Female terminalia.** Tignum almost straight, 6.4–8.5 mm long (width 0.1–0.2 mm at the widest point apically). Tergite VIII posterior margin (width: 1.0 mm) with a few brown hairs. The colour is brown. Spermathecal capsule strongly sclerotised, yellowish, round and supplied with a short shaft, diameter: 0.5 mm.

**Remarks.** Morphological characteristics of *S. populnea populnea* are based on type specimens preserved at LINN (males). The host tree was claimed by Linnaeus (1761) to be *Populus tremula. S. populnea populnea* is a highly variable species, the most common form in Europe having extensive orange-brown pubescence on pronotum and elytra and four distinct pairs of orange-brown spots on elytra. The orange-brown pubescence on elytra (apart from the four pairs of spots) is often reduced especially in females, as a result of variation, but also in old worn specimens. The characters presented herein are therefore mainly based on newly hatched and fully sclerotised specimens reared from *Populus tremula*.

**Distribution.** *S. populnea* is the most widespread and variable species within the genus, with populations occurring in almost the entire Palaearctic region from the British Isles in the west to Far East of Russia and China in the east (Löbl and Smetana 2010). *S. populnea populnea* is common in Fennoscandia, although less frequently found in Norway in the past. It was recorded from Northern Norway (Strand 1946, Bily and Mehl 1989, Ehnström and Holmer 2007). We have not seen any of these specimen(s) from Northern or Western Norway and consequently, we do not know the identity of the subspecies. Distribution patterns over the past 200 years in Sweden show stable populations in the southern provinces, with only a few records in the

Host tree species Reference Aurivillius 1917, Strand 1946, Horion 1974, Schwenke 1974, Bílý and Mehl 1989, Burakowski et al. 1989, Cherepanov 1991, Bense 1995, Slama 1998, Vives 2000, Populus tremulae L. Ehnström and Axelsson 2002, Heliövaara et al. 2004, Böhme 2005, Ehnström and Holmer 2007, Lindhe et al. 2010, Berger 2012, CABI 2012 Demelt 1966, Schwenke 1974, Horion 1974, Burakowski et al. 1989, Cherepanov Populus spp. 1991 Bílý and Mehl 1989, Bense 1995, Slama 1998, Sama 2002, Ehnström and Axelsson 2002, Ehnström and Holmer 2007 P. nigra L. Vives 2000, Berger 2012, CABI 2012 Hua et al. 2009 P. nigra var. thevestina P. nigra var. italica CABI 2012 P. alba L. Vives 2000, Hua et al. 2009, Berger 2012, Cabi 2012 P. canadensis Moench Hua 2002, Hua et al. 2009, CABI 2012 Hua 2002, Hua et al. 2009 P. cahtayana Redh. P. simonii Carr. Hua 2002, Hua et al. 2009, CABI 2012 CABI 2012 P. pseudosimonii Kitag. P. davidiana Dode. Hua 2002, Hua et al. 2009 Hua et al. 2009, CABI 2012 P. tomentosa Carr. P. xiaozhuanica CABI 2012 W.Y.Hsu & Liang P. nigra x P. deltoides Schwenke 1974 (Canadian poplar) Populus x wettsteinii Ehnström and Holmer 2007 (Hybrid aspen) Populus x euramericana CABI 2012 P. tremula x P. Lövttyniemi 1972 tremuloides P. alba x glandulosa Park and Kim 1986, CABI 2012 Demelt 1966, Cherepanov 1991, Strand 1946, Horion 1974, Schwenke 1974, Salix spp. Burakowski et al. 1989, Bense 1995, Vives 2000, Sama 2002, Ehnström and Axelsson 2002, Heliövaara et al. 2004, Ehnström and Holmer 2007, Lindhe et al. 2010, Burakowski et al. 1989, Slama 1998, Heliövaara et al. 2004, Hua et al. 2009, Berger S. caprea L. 2012 Heliövaara et al. 2004 S. phylicifolia L. Hua et al. 2009 S. alba L. S. cinerea L. Burakowski et al. 1989 S. viminalis L. Burakowski et al. 1989, Hua et al. 2009 Allen 1979, CABI 2012 Fraxinus excelsior L. Bischofia javanica CABI 2012 Blume Corylus sp. Sama 1988, Bense 1995 Betula sp. Vives 2000, Sama 2002 Quercus glauca Thunb. Hua 2002, CABI 2012

Table 2. Host tree species of Saperda populnea populnea (Linnaeus, 1758) based on data from literature.

Northern provinces, mainly along the coast (Lindhe et al. 2010). Most records of the examined specimens of *S. populnea populnea* from Fennoscandia are from coastal areas in southern Norway and Finland and numerous inland records from southern Sweden



Figure 10. Aedeagi (a–d dorsal view e–f lateral view), parameres with median lobes (g–j dorsal view k–l lateral view), sclerite inside internal sac (m–n) and tergite VIII in males (o–q). a Saperda populnea populnea (Linnaeus, 1758), Joensuu, Finland b S. populnea populnea, Umeå (Västerbotten), Sweden c S. populnea lapponica ssp. n., Ljørdalen, Norway d Soppero (Lappland), Sweden e S. populnea populnea Joensuu, Finland f S. populnea lapponica ssp. n., Silkimuotka, Finland g Saperda populnea populnea (Linnaeus, 1758), Släp (Halland), Sweden h S. populnea populnea, Sillre (Medelpad), Sweden i S. populnea lapponica ssp. n., Ljørdalen, Norway j S. populnea lapponica ssp. n., Kittelfjäll (Västerbotten), Sweden; k: S. populnea, Uppsala (Uppland) I S. populnea lapponica ssp. n., Enontekiö, Finland m Saperda populnea (Linnaeus, 1758), Uppsala, Sweden n S. populnea lapponica ssp. n., Kiruna, Sweden o Saperda populnea (Linnaeus, 1758), Uppsala, Sweden p S. populnea lapponica ssp. n., Trysil: Ljørdalen, Norway g S. populnea lapponica ssp. n., Kiruna, Sweden.

and Finland. Only a few specimens have been recorded in inland, northern Sweden (Fig. 13).

Biology. Females form a "U-shaped mark" in the bark of Populus tremula, on stems and branches 1-2 cm in diameter, forming a lid under which an egg is deposited. Usually, a single larva is tunnelling in the centre of the branch of living aspens, where the host tree responds by forming a more or less distinct gall (Ehnström and Axelsson 2002, Lindhe et al. 2010). An attack by female larvae often results in larger galls than those initiated by male larvae (Fig. 12c). Normally, only scattered attacks can be found in the same habitat with only one or two galls on the same stem or twig. Damages caused by mass attack of S. populnea populnea have been observed in many European countries (e. g. Schwenke 1974) as well as in Asia (e.g. Cherpanov 1991). In Sweden, Populus plantations have been severely damaged (Ehnström and Axelsson 2002). Today the species has become less abundant in Sweden. Only few and scattered records are known from northern Sweden (Lindhe et al. 2010). The development takes 2 years. The biology and larval morphology of S. populnea has been dealt with by many authors (e.g. Duffy 1953, Demelt 1966, Schwenke 1974, Cherepanov 1991, Švácha 2001, Ehnström and Axelsson 2002). We have included specimens of S. populnea populnea from all Fennoscandian countries and as many northern records as possible (Fig. 13).

Host tree. The preferred host tree is *Populus tremula* as a number of authors have claimed (Tab. 2). A total of 16 other *Populus* species and hybrids are attacked in Europe and Asia (Tab. 2). Many species of the genus *Salix* are also reported to be attacked (Tab. 2). Amongst the specimens included in the present study, the majority was reared from *Populus tremula*, while only a few specimens were reared from *Salix caprea* L. and *S. cinerea* L. *S. populnea populnea* is also known to attack living branches and narrow stems of other trees and shrubs in Europe e.g. *Corylus* spp. (Bense 1995) and *Betula* sp. (Vives 2000, Sama 2002), although *Betula* spp. has not been recorded as a host tree in any of the Nordic countries. We, therefore, question the validity of *Betula* sp. as a host tree. Hua (2002) and CABI (2012) mentioned *Quercus glauca* Thunb. (apart from five species of *Populus*) as a host tree in China. *S. populnea populnea* has also been reared from stems of coppiced hedgerow ash (*Fraxinus excelsior* L.) in the UK (Allen 1979) (Tab. 2).

#### Saperda populnea lapponica ssp. n.

http://zoobank.org/85C74E08-E401-48AA-8463-FF5AFC1D9835 Figs 1, 6b–c, e–f, 8b, 9b, 10c–d, f, i–j, l, n, p–q, 11b–c, 12a–b, 13

**Type material. Holotype:**  $\bigcirc$  NHRS (id NHRS-JLKB0000027179), BL 11.0mm, BW 3.0mm, from Sweden, Lappland, Lule lappmark, 2 km SE Kiruna, elev. 500 m, "Aptasvaara", reared from *Salix lapponum* 2014-07-09 (emerged 2015-02), leg. H. Wallin. **Paratypes: Sweden:** 1  $\bigcirc$  BL 11.0 mm, same data as holotype, NHRS; 1  $\bigcirc$  BL 10.0 mm, same data as holotype, CHW; 1  $\bigcirc$  BL 9.5 mm and 1  $\bigcirc$  BL 11.0 mm, same data as holotype, CHW; 1  $\bigcirc$  BL 10.5 mm, Sweden, Lappland,



**Figure 11.** Hind wings. **a**  $\bigcirc$  *Saperda populnea populnea* (Linnaeus, 1758) reared from *Populus tremula* L., Uppland, Knivsta, Sweden. **A** AP vein **B** AA vein **C** CuA vein **D** AA3+4 vein **E** CuA3+4 vein **F** Mp4 vein **G** Mp3 vein **H** medial spur vein **I** RA vein **J** MP vein **K** radial cell **L** RP-MP vein **b**  $\bigcirc$  *Saperda populnea lapponica* ssp. n. reared from *Salix lapponum* L., Trysil: Ljørdalen Norway **c**  $\bigcirc$  *Saperda populnea lapponica* ssp. n. reared from *Salix lapponum* L., Luleå Lappmark, Gallugas 20 km W. Kiruna, Sweden. Scale bar 10 mm.

Lule lappmark, 20 km NW Kiruna, "Gallugas", reared from Salix lapponum 2015-06-11 (emerged 2015-06-24), leg. H. Wallin, CHW; 1 👌 BL 11.0 mm, 1 👌 BL 10.0 mm, 1 ♂ BL 9.5 mm and 1 ♀ BL 11.7 mm, Jämtland, Ånn (5 km W. Tångböle), Åre, reared from Salix lapponum 2016-09-12/13 (emerged 2017-01), leg. H. Wallin, CHW. 1 🖒 BL 12.0 mm, Lappland, Lule lappmark, Messaure, 1971-07-14/21, window trap, leg. T. Mûller, NHRS; 1 d BL 10.5 mm, Lappland, Lule lappmark, Litnok, 1967-07-21, leg. S. Lundberg, NHRS; 1 👌 BL 11.0 mm, Lappland, Torne lappmark, Sappisatsi, N. Vittangi, 1966-07-04, leg. S. Lundberg, NHRS; 1 🖉 BL 11.0 mm, Lappland, Torne lappmark, Soppero, 1968-06-15, ex larva reared from Salix lapponum, leg. S. Lundberg, NHRS; 1 ♂ BL 10.0 mm and 1 ♀ BL 10.5 mm, Lappland, Torne lappmark, Soppero, 1980-06-30, leg. S. Lundberg, NHRS; 2 ♂♂ BL 10.0 mm and 1 ♀ BL 9.5 mm, Lappland, Torne lappmark, Siltimuotka, Soppero, 1948-06-28, leg. N. Höglund, NHRS; 1 👌 BL 11.5 mm, Lappland, Åsele lappmark, Kittelfjäll, 1972-06-28, leg. T-E. Leiler, NHRS; 1  $\bigcirc$  BL 11.2 mm and 1  $\bigcirc$  BL 10.5 mm, Lappland, Torne lappmark, Kiruna, ex larva from Salix lapponum, leg., E.v. Mentzer, CBE; 1 & BL 11.0 mm, Jämtland, Tångböle, Åre, 1964-07-07 (locality J23 in a survey), leg. Waldén, Enckell & Hagberg, NMG; 1  $\stackrel{?}{\circ}$  BL 10.5 mm and 1  $\stackrel{\circ}{\circ}$  BL 13.0 mm, Lappland, Torne lappmark, Kiruna, Aptasvaara, 1976-07-10, on Salix lapponum, leg., C. Eliasson, GNM; 1  $\stackrel{?}{\circ}$  BL 10.3 mm, 1  $\stackrel{?}{\circ}$  BL 10.5 mm and 1  $\stackrel{\circ}{\ominus}$  BL 12.4 mm, Lappland, Lycksele lappmark, Tärnaby, Juksjaur, 2013-06-30, on Salix lapponum, leg. R. Petterson, CRP; 1 🖒 BL 11.0 mm, Jämtland, Järvsand, 1986-06-19, leg. R. Petterson, CRP; 1 ♀ BL 12.0 mm, labelled "Zetterstedt", ex coll. Gyllenhal, UUZM; 1 👌 BL 10.0 mm, labelled "Zetterstedt", ex coll. Gyllenhal, UUZM; 1 ♀ BL 10.0 mm, 1 ♂ BL 8.0 mm, 1 ♂ BL 10.2 mm, 1 d BL 9.0 mm, Dalarna, Idre, 2014-06-26, reared from Salix lapponum, leg. Å. Lindelöw, CÅL; 1 ♀ BL 12.0 mm, 1 ♀ BL 11.3 mm, 1 ♂ BL 11.0 mm, 2 ♂♂ BL 10.0 mm, 2 33 BL 10.5 mm Lappland, Lule lappmark, 2 km SE Kiruna, elev. 500 m,"Aptasvaara", beaten from Salix lapponum 2014-07-09, leg. H. Wallin, CHW; 1 ♀ BL 12.0 mm, 1 ♀ BL 11.0 mm, 1 ♂ BL 9.5 mm, 1 ♂ BL 10.0 mm, Lappland, Lule lappmark, 2 km SE Kiruna, elev. 500 m, "Aptasvaara", reared from Salix lapponum 2014-07-09 (emerged 2015-02), leg. H. Wallin, CHW; 1 & BL 11.0 mm, Härjedalen, Lövhögen, 1946-07-02, leg. N. Höglund, NHRS-COLE 00007432; 1 🌻 BL 11.0 mm, Torne lappmark, Silkimuotka, 1948-06-28, leg. N. Höglund, NHRS-COLE 00007433; 1 ♀ BL 11.0 mm, Torne lappmark, Silkimuotka, 1948-06-28, leg. N. Höglund, NHRS-COLE 00007438; 1 🖉 BL 10.0 mm, Torne lappmark, Silkimuotka, 1948-06-28, leg. N. Höglund, NHRS-COLE 00007436; 1 🖧 BL 11.0 mm, Lp. in., ex coll. Boheman, NHRS; 1 Q BL 11.2 mm, Lp. in., ex coll. Schönherr, NHRS; 1 ♀ BL 12.0 mm, Jämtland, ex coll. Rudolphi, NHRS; 1 ♂ BL 10.2 mm, Lp. i. S.U., NHRS. Norway: 1 👌 BL 11.4 mm, 1 👌 BL 10.9 mm, 1 👌 BL 9.9 mm, 1 👌 BL 10.1 mm, 1 🌻 BL 12.7 mm, 1 🤤 BL 13.5 mm HEN, Trysil: Ljørdalen, Skjærkjølen (EIS 65) 61°21'44.5"N, 12°40'06.3"E, 2014-VI-31, reared from Salix lapponum, Leg. T. Kvamme CTK; 1 🖧 BL 10.0 mm, BV, Ål: Vatsfjorden, 2006-07-17, leg. O. J. Lønnve, NHMO; 1 Q BL 12.5 mm, HEN, Trysil: Tangåtjønna, 2011-06-25, leg. P.K. Solevåg, CPKS; 1 ♂ BL 10.5 mm, OS, Nordre Land: Synfjellet, 1897-07-20/21, NIBIO; 1 ♀



**Figure 12.** Host tree attacks. **a** extensive attacks of *Saperda populnea lapponica* ssp. n., on the entire stem and branches of *Salix lapponum* L. from Trysil: Ljørdalen, Norway **b** three adjacent attacks, including an exit hole, of *Saperda populnea lapponica* ssp. n., on a stem of *Salix lapponum* L. from Gällivare (Lappland), Sweden **c** single attacks, including exit holes, of *Saperda populnea populnea* (Linnaeus, 1758), on a stems of *Populus tremula* L. (beetles emerged at top: male, bottom: female), from Knivsta (Uppland), Sweden.

BL 11.5 mm, HEN, Trysil: Ljørdalen, 2014-06-25, *Salix lapponum*, leg. Å. Lindelöw, CÅL; 1  $\bigcirc$  BL 11.0 mm, 1  $\bigcirc$  BL 11.0 mm and 1  $\bigcirc$  BL 11.5 mm HEN, Skåret, RT90 6826517/1324435, 2014-06-25, *Salix lapponum*, leg. Å. Lindelöw, CÅL; 2  $\bigcirc \bigcirc$  BL 12.5 mm, 1  $\bigcirc$  BL 12.0 mm, 2  $\bigcirc \bigcirc$  BL 13.0 mm, 1  $\bigcirc$  BL 11.0 mm, 6  $\bigcirc \oslash$  BL 11.0 mm, 1  $\bigcirc$  BL 10.5 mm, 2  $\bigcirc \bigcirc$  BL 10.0 mm, HEN, 5km NE Østby (Ljørdalen), 2014-05-31, reared from *Salix lapponum* (emerged 2014-06-12), leg. H. Wallin, CHW; 2  $\bigcirc \bigcirc$  BL 13.0 mm and 1  $\bigcirc$  BL 11.0 mm, HEN, 5km SE Trysil, 2014-05-31, reared from *Salix lapponum* (emerged 2014-06-08), leg. H. Wallin, CHW; Finland: 2  $\bigcirc \oslash$  BL 10.0 mm, Enontekiö, 1951-08-26, leg. Hellman, MZH; 1  $\bigcirc$  BL 10.3 mm, Enontekiö, 1951-08-26, leg. Hellman, MZH; 1  $\bigcirc$  BL 10.3 mm, Enontekiö, 1951-08-26, leg. Hellman, ex coll. Schönherr, NHRS no. 8146 E94. **Russia:** 1  $\bigcirc$  BL 10.0 mm, BW BL 2.5 mm, Central Russia (Russia Merid.), leg. Zarisin, ex coll. C. Nyberg, MZH: 1  $\bigcirc$  BL 8.7 mm, Central Russia (Russia Merid.), ex coll. Duske, MZH; 1  $\bigcirc$  BL 10.6 mm, Petsamo (Petjenga), leg. Hellén (id 716), MZH.

Additional material examined. The following specimens collected in Finland and available (through Boldsystems Public Data Portal) for photo examination includes: 1 Q COLFA181-10, Lapland, Inari, 1980-07-11, leg. Erkki Laasonen, id MP00443, ZMUO; 1 3 COLFA187-10, Lapland, Inari, 1993-08-26, leg. Juhani Itaemies, id MP00449, ZMUO.

**Description.** A relatively small to medium-sized and subcylindrical subspecies with body length 9.5–13.0 mm in females and 8.0–12.0 mm in males, according to measurements from the present study. Body 3.1 times longer than wide in females and 3.4 times longer than wide in males (Fig. 6b–c, e–f). Integument black, the compressed pubescence is yellowish to whitish (most northern populations) (Figs. 6c, f) to reduced orange-brown pubescence (southern populations) (Fig. 6b, e). Elytra with numerous long erected dark brown hairs. The pubescence in the southern populations is relatively dense in both sexes. The yellowish to whitish pubescence in the northern-most populations (above the Arctic Circle) is strongly reduced resulting in exposed and shining integument in both sexes. The orange-brown pubescence is present but weakly extended laterally in females from southern populations and the yellowish to whitish pubescence in females from northern populations very weak laterally (Fig. 8b).

**Head in females.** Frons convex and broader than long (about 5 times broader than the width of one eye lobe), eyes with lower eye lobes slightly longer than broad and as long as gena below it. Genae posteriorly with long fringes of yellowish or whitish hairs and genae evenly narrowing towards mouthparts resulting in head being more "rounded" (Fig. 9b). Frons weakly covered with yellowish to whitish pubescence, and numerous dark brown, long and erected hairs. The area between antennal segments is shallowly impressed. Frons densely covered with orange-brown pubescence and numerous dark brown, long erect hairs. Genae posteriorly with long fringes of orange-brown hairs. **Head in males:** Frons convex and broader than long (about 4 times broader than the width of one eye lobe), eyes with lower eye lobes longer than broad and about 3 times longer than the short gena below. Head with frons rounded, genae straight and acutely narrowing towards mouthparts, frons weakly covered with whitish or orange-



**Figure 13.** Distribution of records mainly from Fennoscandia. Open circles: *Saperda populnea populnea* (Linnaeus, 1758) and black dots: *S. populnea lapponica* ssp. n.

brown pubescence and numerous dark brown, long and erected hairs. Genae posteriorly with long fringes of orange-brown hairs. The area between antennal segments is shallowly impressed. Mouthparts. Frontoclypeal margin has a fringe of relatively long whitish pubescence and long, brown, suberect hairs. Clypeus glabrous except at base. Labrum with appressed, whitish pubescence and numerous long, suberect, orangebrown setae. Antennae. Short, slender, at the most extending beyond the middle of elytra by 2–3 antennomeres in females (Fig. 6b–c). In males, the antennae reach by 3-4 antennomeres past the middle; thus, antennae are always shorter than body in males (Fig. 6e-f). The segments from third segment are annulate. Annulation on antennal segments greyish and covering about 34 of the anterior part of each antennal segment. The subconical, third segment is longer than first and fourth. Scape slender and coarsely punctured with a combination of large and small, shallow punctures and long black hairs. Thorax. Pronotum subcylindrical, slightly broader than long, lacking lateral spines. Pronotal disk convex, weak median line often with a glabrous and shining area medially, base shallowly impressed, coarse punctures except medially, densely covered with long erect and brown hairs, two broad lateral yellowish stripes with a weak median line interrupted medially. Prosternum densely pubescent with yellowish and whitish hairs. Elytra. 2.6-3.0 times longer than broad in females and 2.7-3.1 times longer than broad in males. No distinct carinae present on elytra. Parallel and weakly narrowing towards apices, apices narrowing and rounded, punctures coarse, deep, contiguous towards humeri and apices and confluent medially (especially in males where

confluent punctures form short and weakly raised ridges transversally on each elytron), pubescence relatively weak to dense. There are generally eight relatively distinct and small to relatively large, yellowish to whitish spots on elytra, arranged in pairs: the first and third near the suture, spots in the third pair often elongated transversally or even divided into two spots each, spots in the fourth pair elongated transversally and placed on the middle of elytra in females (Fig. 6b–c), Females from northern populations have irregular spots of yellowish to whitish pubescence between the third and fourth pair of spots and towards apices. No missing spots were seen in any of the examined specimens, but a few old worn specimens had very small i.e. obsolete spots on the elytra. The remaining part of elytra is covered with scattered yellowish or whitish pubescence and numerous long brown hairs. Scutellum. "U-shaped" and weakly covered with whitish hairs (southern populations) or entire scutellum glabrous (most northern populations). Hind wing. About 11.0 mm long in females and 9.0 mm long in males (Fig. 11b-c). Covered with weak smoky tint. Several veins are broken with apical portions not connected to basal portions. MP3 (rudimentary), MP4 and AA vein broken. Radial cell very strong and complete. Legs. Relatively short, densely covered with fine whitish pubescent including tarsi, tarsal claws lacking a process. Venter. Densely covered with whitish to yellowish pubescence in both sexes, prosternal process narrow and flattened anteriorly. Mesosternum and abdominal ventrites are densely covered with yellowish or whitish pubescence and numerous yellowish and long, erected hairs. Posterior margin of sternite VII rounded and often deeply notched on medially. Male terminalia. Aedeagus 2.0-2.3 mm long, evenly curved towards apex and compressed dorso-ventrally (Fig. 10f), dorsal surface smooth and shining with apical part weakly narrowed towards apex (Fig. 10c-d). Tegmen with parameres 2.1-2.5 mm longer and straight dorsoventrally (Fig. 10l). Parameres acutely narrowing towards apex, with dorsal surface glabrous and shining, or (rarely) with entire surface densely covered with punctures and suberected setae. The inner margins well-separated and diverging towards apices (Figs. 10i-j). Tergite VIII 0.6-1.0 mm long, relatively large and rounded with the posterior margin concave in the middle and densely covered with white pubescence and numerous long brown hairs (Fig. 10p-q). Sclerites inside internal sac 1.7–2.1 mm long consisting of three parallel "shaft-like" structures, of which the apical end (top) is elongated and posterior end blunt and acutely narrowing towards posterior end (Fig. 10n). The colour of male genitalia is yellowish to dark brown. Female terminalia. Tignum almost straight, 6.5-8.2 mm long (width 0.1-0.2 mm at the widest point apically). Tergite VIII posterior margin (width: 1.0 mm) with a few brown hairs. The colour is brown. Spermathecal capsule: strongly sclerotised, yellowish, round and supplied with a short shaft, diameter: 0.5 mm.

**Remarks.** morphological characteristics are mainly based on type specimens, either collected on, or reared from branches of *Salix lapponum*. *S. populnea lapponica* ssp. n. is separated from *S. populnea populnea* by the overall smaller body size, shorter antennae in both sexes, reduced pubescence on thorax and elytra, mainly yellowish to whitish pubescence, reduced or absent pubescence on scutellum and short frons in females which is giving the appearance of a rounded head (Fig. 8b). The characters

presented herein are mainly based on newly hatched and fully sclerotised specimens. Small, dark and less pubescent specimens are easily recognized in collections in Fennoscandia and were in most cases, found to belong to the new subspecies *S. populnea lapponica* ssp. n. There are variations in the body size and colour pattern on elytra between the various populations of *S. populnea lapponica* ssp. n. The slightly larger specimens occurring in the southern populations near Trysil, Norway, have more distinct spots on elytra. The darker and smaller specimens from the northern populations, occurring in the northern Scandinavian mountain range near e. g Kiruna, also have intermediate forms occurring e.g. in Juksjaur near Tärnaby. The darker and slightly smaller specimens have more reduced spots on elytra. No such geographical variation in body size and colour pattern has been found in *S. populnea populnea* in Fennoscandia.

**Etymology.** The name is an adjective used as a substantive in the genitive case derived from the specific name of the host plant *Salix lapponum*.

**Distribution.** The distribution of *S. populnea lapponica* ssp. n. is within the distribution of *Salix lapponum* in Fennoscandia (Hultén 1971). The most southern populations of *S. populnea lapponica* ssp. n. occur near Trysil, Norway, while the most northern populations occur north of the Arctic Circle (Fig. 13). Since *Salix lapponum* is distributed eastwards in Siberia approximately to the Jenisej Valley (Hultén and Fries 1986), it is possible that *S. populnea lapponica* ssp. n. has a much wider distribution in Russia than we are able to show in the present paper.

**Biology.** The attacks are similar to *S. populnea populnea* where females form a "U-shaped lid" in the bark under which an egg is deposited. Stems and branches around 1–2 cm in diameter are used. However, normally no galls are formed by the host tree (Fig. 12a–b). The attacks can be massive and one single stem can contain up to 30 attacks (Fig. 12a). Larvae can live during a number of consecutive years since old exit holes are present together with live larvae. It is, therefore, likely that several generations of beetles can develop within the same stem of *Salix lapponum*. Exit holes are normally slightly larger when made by female beetles compared to male, reflecting the differences in size and shape. The development takes at least 2 years, since both small and full-grown larvae were found in stems of *Salix lapponum* after adults had emerged. The localities are wetter than localities where *S. populnea populnea* are found, since *Populus tremula* do not occur in biotopes where *S. lapponum* occur. As a consequence, *S. populnea populnea* and *S. populnea lapponica* ssp. n. live in well separated habitats.

In addition, parasites including wasps and flies frequently attack *S. populnea populnea* (Schwenke 1974, Pulkinn and Yang 1984, Georgiev 2001). Very few such parasites have been collected from stems attacked by *S. populnea lapponica* ssp. n. which might be due to climatic factors. However, we did recover two parasitoid wasps of the family Ichneumonidae from downy willow hatching wood with *Saperda populnea lapponica* ssp. n. attacks. These were identified as one *Poemenia hectica* (Gravenhorst, 1829) (Poemeniinae) and one Campopleginae, possibly belonging to the genus *Pyracmon* (det. Jacek Hilszczański). Unfortunately, the second specimen was damaged during post transfer and could therefore not be identified with certainty. While Campopleginae includes species known as parasitoids of saproxylic beetles, *Poemenia* is known as a parasitoid of wood-nesting wasp larvae, so that it may not have been (directly) related to the *Saperda populnea lapponica* ssp. n. larvae.

#### Discussion

The new subspecies S. populnea lapponica ssp. n. is relatively similar to S. populnea balsamifera stat. n. According to the original description, S. populnea balsamifera stat. n. is characterised by narrow body and weak pubescence with very small dots on elytra. There is no information on body length in the original description by Motschulsky (1860). Cherepanov (1991) redescribed Compsidia balsamifera by referring to the very pubescent and orange-brown form, 11–13 mm long, found on Salix near Novosibirsk. According to M.L. Danilevsky (pers. comm.), the pubescent and orange-brown form is very rare, whereas the darker and less pubescent form with small dots on elytra is more common. The examined specimens of S. populnea balsamifera stat. n. differ from S. populnea lapponica ssp. n. in the following characters: antennae relatively long in both sexes in S. populnea balsamifera stat. n. (extending beyond the middle of elytra by 4.5 antennomeres in males), antennae relatively short in both sexes in S. populnea lapponica ssp. n. (extending beyond the middle of elytra by 3.5 antennomeres in males); head in female in S. populnea balsamifera stat. n. long (almost "square-formed") and lower eye lobe as long as gena below it, head in female in S. populnea lapponica ssp. n. rounded, and lower eye lobe 2-3 times longer than the short gena below it; scutellum in S. populnea balsamifera stat. n. covered with pubescence, scutellum in S. populnea lapponica ssp. n. glabrous or at most weakly covered with few hairs; the four pair of dots on elytra in S. populnea balsamifera stat. n. very small and rounded, the four pair of dots on elytra in S. populnea lapponica ssp. n. larger and often elongated transversally (third pair of dots); male aedeagus in S. populnea balsamifera stat. n. very short and almost straight, aedeagus in S. populnea lapponica ssp. n. long and evenly curved; parameres in S. populnea balsamifera stat. n. short and weakly narrowing towards apices, parameres in S. populnea lapponica ssp. n. long and acutely narrowing towards apices; tergite VIII in S. populnea balsamifera stat. n. short and weakly supplied with very fine hairs, tergite VIII in S. populnea lapponica ssp. n. long and densely covered with pubescence; sclerite inside internal sac in S. populnea balsamifera stat. n. very short with posterior end separated ("Vformed"), sclerite inside internal sac in S. populnea lapponica ssp. n. long with posterior end blunt. The examined specimens of S. populnea balsamifera stat. n. also differ from S. populnea populnea in several of the above-mentioned characters. Thus, we agree with Danilevsky (2016, word document on website) that it cannot be regarded as a synonym of Saperda populnea and we here formally elevate S. balsamifera to a separate subspecies: S. populnea balsamifera stat. n. It may very well be that it should be recognised as a full species, but more material is needed to examine the variation in characters. The type of S. populnea balsamifera stat. n. (which appears to be a male) represents a "black" form with almost glabrous elytra, apart from the very small but distinct spots on elytra not

seen in *S. populnea lapponica* ssp. n. Whether the pubescent orange brown form and the darker less pubescent form truly are conspecific also needs further investigations. *Saperda populnea balsamifera* stat. n. is only known from Siberia and Far East of Russia, China and Japan (Löbl and Smetana 2010). The type locality is in Mongolia, collected on *Populus balsamifera* L. It appears that all records of *S. populnea balsamifera* stat. n. are outside the range of *Salix lapponum* according to the map presented by Hultén E and Fries M (1986). Our findings indicate that the western subspecies *S. populnea lapponica* ssp. n. is more closely related to *S. populnea populnea* than to the eastern subspecies *S. populnea balsamifera* stat. n. We also follow Löbl and Smetana (2010) and tentatively consider *S. innotatipennis* Pic, 1910 (Fig. 7a) to be synonymous with *S. populnea balsamifera* stat. n., although further studies are required to fully investigate the relationship between *S. populnea balsamifera* stat. n. and *S. innotatipennis*.

We agree with Shapovalov (2013) and (Bezark 2016) that the North American species *S. moesta moesta* Le Conte is a valid species, and that *S. moesta tulari* (Le Conte) is a valid subspecies (Bezark 2016). *S. moesta moesta* and *S. moesta tulari* are easily distinguished from *S. populnea populnea* and *S. populnea lapponica* ssp. n. by the deep contiguous or scattered punctuation and lack of spots on elytra in both sexes. Further studies are required to fully investigate the relationship between *S. moesta moesta* and *S. moesta tulari*. *Saperda populnea populnea* was earlier supposed to occur in North America (Felt and Joutel 1904), but it has been corrected in recent work (Linsley and Chemsak 1995, Bezark 2016).

*Saperda gilanense* was described based on specimens from Northern Iran (Shapovalov 2013). The species differ from *S. populnea populnea* by the very bright yellowish and rounded spots on elytra. We have only examined two paratypes (male/female), and further studies are required, preferably including DNA data, to fully evaluate the taxonomic status of the species.

The remaining species within the subgenus *Compsidia* include *S. bacillicornis* Pesarini & Sabbadini, 1996, *Saperda bilineatocollis* Pic, 1924 and *S. messageei* Breuning, 1962.

*S. bacillicornis* is easily separated from *S. populnea populnea* by the narrow and dorso-ventrally flattened prothorax and the antennal segments uniformly covered with a whitish pubescence from 3<sup>rd</sup> antennomere and not annulated. *S. bilineatocollis* (Fig. 7b) is distinguished from *S. populnea populnea* by the absence of spots on elytra and the distinct and broad longitudinal orange-brown stripe on elytra. The lower eye lobe on the HT female of *S. bilineatocollis* is as long as the gena below it. *S. bilineatocollis* collis occur in Far East of Russia and in China (Löbl and Smetana 2010). DNA of *S. bilineatocollis*, based on the genbank sequence for which we have seen a photo of the voucher specimen, was only slightly different (about 2.09–2.60%) from *S. populnea* (Fig. 3). Thus, further studies are required to fully investigate the relationship between *S. bilineatocollis* and *S. populnea populnea* and whether they do occur sympatrically in Far East Russia and China. Here, we do consider *S. bilineatocollis* to be a valid species. *S. messageei* is very similar to *S. populnea populnea* and the question is if this is a mislabelled specimen or even an introduced specimen to Laos. Similarly, we found an old

specimen of *S. populnea populnea* labelled "Java". None of these four species (*S. gilanense, S. bacillicornis, S. bilineatocollis, S. messageei*) are, however, similar to *S. populnea lapponica* ssp. n.

The male genitalia of all other Palaearctic species of *Saperda* differ from both *S. populnea populnea* and *S. populnea lapponica* ssp. n. Each species has unique male genitalia, although the male genitalia appear to be relatively similar between *S. carcharias* and *S. similis*. These two species also had a relatively small genetic distance (2.59%). The most different and striking sclerites inside the internal sac are found in *S. scalaris*, where they exhibit a broad and "fork-shaped" structure. We found no difference in hind wing morphology between *S. populnea lapponica* ssp. n. and *S. populnea populnea*, although statistical analysis with the use of selected landmarks on hind wings has been applied to differentiate two other cerambycid species: *Leiopus nebulosus* L. and *L. linnei* Wallin et al., 2009 (Rossa et al. 2017).

The other species synonymised by Löbl and Smetana (2010) and aberrations earlier synonymised by Breuning (1966) are all considered to be variations of *S. populnea populnea* with reduced number of spots on elytra of which several have been included as drawings by Villiers (1978). The synonymised species include *Leptura betulina* Geoffroy, 1785, *S.* ab. *bickhardti* Sattler, 1918, *Cerambyx decempunctatus* DeGeer, 1775, *S.* f. *kavani* Roubal, 1933, *S. populi* Duméril, 1860, *S.* ab. *quadripunctata* Podaný, 1953 and *S. salicis* Zetterstedt, 1818. No such reduction in the number of spots on elytra has been found in *S. populnea lapponica* ssp. n.

S. salicis was described from specimens collected on Salix viminalis L. at Abusa near Lund in southern Sweden (Zetterstedt 1818). A lectotype of S. salicis has been designated and it corresponds to the original description. Later, Zetterstedt (1828, 1840) referred to small and dark specimens rarely collected by himself in the Swedish Lappland earliest in 1820 (Lycksele and Umeå Lappmark), but without any species or subspecies description. Gyllenhal (1827) mentioned S. salicis as a southern species and called it "var. b". The two specimens of S. populnea lapponica ssp. n. labelled "Zetterstedt" and preserved in the Leonard Gyllenhal collection at UUZM must have been collected by Johan Wilhelm Zetterstedt in the Swedish Lappland. It is known, from preserved letters between these two entomologists, that Zetterstedt visited Gyllenhal when he returned from his journeys to Lappland. We, therefore, assume that the two northern specimens were given to Gyllenhal on one of these occasions. Roubal (1933) and Ehnström and Holmer (2007) incorrectly assumed that S. salicis was the boreal form of S. populnea populnea. In more recent years Ehnström and Axelsson (2002) wrote (page 312): "The specimens living in the mountains are so clearly different from other specimens that they might be a separate species" [translated from Swedish] and Heliövaara et al. (2004) mentioned: "A darker and more slender morph (possibly a separate species), which lives on Salix lapponum, is more abundant in the northern parts of the country". However, no species or subspecies description was made.

That *Saperda populnea populnea* and *Saperda populnea lapponica* ssp. n. were not reciprocally monophyletic (Figs 2–3) by a neutral marker like COI was not surprising (see Patten 2010, Zink 2004). It is clear that reciprocal monophyly should not be the

null expectation for subspecies (Patten 2010, 2015). Reciprocal monophyly in neutral markers is mainly related to the time since divergence and may take a very long time, dependent on effective population size (Zink 2004; Bergsten et al. 2012). It is also possible that these two subspecies hybridize and still maintain some gene flow at the contact zone. Maintained reproductive compatibility is part of the classical definition of a subspecies outlined by Ernst Mayr with small variations in several of his landmark books: Mayr (1942: 106): "The subspecies, or geographical race, is a geographically localized subdivision of the species, which differs genetically and taxonomically from other subdivisions of the species"; Mayr (1963: 348): "A subspecies is an aggregate of local populations of species, inhabiting a geographic subdivision of the range of the species, and differing taxonomically from other populations of the species"; Mayr (1969: 41): "A subspecies is an aggregate of phenotypically similar populations of a species, inhabiting a geographic subdivision of the range of the species, and differing taxonomically from other populations of the species". Further, as the subspecies definition was subordinate the species under the Biological Species Concept (BSC) paradigm, then "Because they are below the species level different subspecies are reproductively compatible" (O'Brien and Mayr, 1991: 1188).

The trinomial subspecies remain a contentious hierarchical level in zoological taxonomy (Zink 2004). Some authors argue for the abandonment of the concept altogether (Wilson and Brown 1953), but it is formally recognized by the International Commission on Zoological Nomenclature (ICZN 1999), albeit without giving any advice or criteria for its recognition. The concept is variously used in different disciplines, extensively in mammals and birds (Gippoliti and Amori 2007, Mayr 1982), less so in insects (Haigh et al. 2006) in general, but more commonly in some groups like butterflies (Braby et al. 2012, Gillham 1956). The concept is more than a mere academic debate as subspecies are recognized in various red-lists and conservation programs, and hence the recognition as a subspecies or not can have legal and monetary consequences (Haigh et al. 2006, Braby et al. 2012, O'Brien and Mayr 1991, Gippoliti and Amori 2007). There have been a few attempts to put a quantifiable limit on what a subspecies is. The most well known such threshold is the "75% rule" (Amadon 1949, Patten 2010, Patten and Unitt 2002): members of a subspecies should be diagnosable by some character so that at least 75% of individuals in subspecies A should be outside of the distribution of 99% of individuals of subspecies B. Patten and Unitt (2002) formalised this rule in a simple t-test statistics. Another suggestion of a subspecies definition in the age of genetic data was proposed by Patten (2015): "I propose that under the phylogenetic species concept, a (morphologically) diagnosably distinct, geographically circumscribed clade that does not form a distinct (neutral) genetic cluster or is not reciprocally monophyletic (I mention this because its assessment is common practice, not because it is a criterion inherent to the concept) in relation to other such clades be deemed a subspecies and not a species".

*S. populnea populnea* and *S. populnea lapponica* ssp. n. fit this definition perfectly. However, we believe that while authors are proposing various new subspecies definitions (Braby et al. 2012, Patten 2015, Patten and Unitt 2002, O'Brien and Mayr 1991), the same mistake of confusing what subspecies *are* and how they can be recognized (operational criteria) is repeated, as with the century old species concept debate. That



**Figure 14.** Subspecies of *Saperda populnea* (Linnaeus, 1758) fall in the grey zone under the unified species concept. Adapted from de Quieroz (2007) and beetle photos by Karsten Sund.

debate was solved by separating the necessary properties (the definition) from the secondary operational criteria in the Unified Species Concept (USC) (de Quieroz 2007). Species under the USC are separately evolving metapopulation lineages (de Quieroz 2007). That is the only necessary property of species. Subspecies under the USC are basically recognized in the grey-zone, commonly displaying some, but not all, properties that may define separately evolving lineages (Braby et al. 2012) (Fig. 14). There is unanimous agreement in all subspecies definitions that subspecies are 1) geographically defined and 2) diagnosable by at least one presumably heritable character. The meaning of geographically defined may vary, and some restrict the use to allopatric, but not parapatric situations (Braby et al. 2012). Also the meaning of diagnosable may vary, whether focused on difference in mean or degree of overlap (Patten and Unitt 2002), and whether one or multiple concordant characters should be required (O'Brien and Mayr 1991). There is also unanimous agreement that subspecies are potentially, but not necessarily, incipient species (Mallet 2001, Patten 2010, O'Brien and Wilson 1991, Crusz 1986). Species evolving through allopatric speciation basically go through a stage which we would call a subspecies (Mayr 1942). From that does not follow, however, that all subspecies become full species with time (Patten 2010, O'Brien and Mayr 1991). A subspecies may also merge back with say, its sister subspecies through geneflow at secondary contact (Patten 2010), or go extinct. We therefore propose that under the unified species concept, subspecies are defined as potentially incipient species in allopatry or parapatry that are diagnosable by at least one presumably heritable trait. Hence the only necessary properties of subspecies are that they are potentially incipient species under the USC (.i.e. potentially on their way to become separately evolving metapopulation lineages), they are currently diagnosable by at least one trait that is heritable and not environmentally determined, and that they are geographically defined. Reciprocal monophyly or not in neutral markers, quantitative thresholds like the 75% rule, reproductive compatibility or degree of gene flow should not be part of the definition.

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RESEARCH ARTICLE



# Formal recognition of the species of Oreosaurus (Reptilia, Squamata, Gymnophthalmidae) from the Sierra Nevada de Santa Marta, Colombia

Santiago J. Sánchez-Pacheco<sup>1,2</sup>, Pedro M. Sales Nunes<sup>3,4</sup>, Sergio Marques-Souza<sup>3</sup>, Miguel T. Rodrigues<sup>3</sup>, Robert W. Murphy<sup>1,2</sup>

I Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, ON M5S 3B2, Canada 2 Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, ON M5S 2C6, Canada 3 Departamento de Zoologia, Instituto de Biociências, Universidade de São Paulo, São Paulo, CEP 05508-090, SP, Brazil 4 Departamento de Zoologia, Centro de Biociências, Universidade Federal de Pernambuco, Av. Professor Moraes Rego S/n, Cidade Universitária 50670-901, Recife, PE, Brazil

Corresponding author: Santiago J. Sánchez-Pacheco (santiago.sanchezpacheco@mail.utoronto.ca)

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#### Abstract

*Oreosaurus* is one of the two genera extracted from the former *Riama sensu lato*, which was recently recognized as polyphyletic. *Oreosaurus* is a small clade (five named and two undescribed species) of montane gymnophthalmid lizards and exhibits an exceptional distributional pattern. Its nominal and undescribed species are discontinuously distributed on the Cordillera de la Costa of Venezuela, the tepuis from the Chimantá massif in Venezuela, the highlands of the island of Trinidad, and the Sierra Nevada de Santa Marta in Colombia (SNSM). Herein, we describe the species of *Oreosaurus* that is endemic to the SNSM. Historically, this species associates with two names that are currently *nomina nuda*: *Proctoporus serranus* and *P. specularis*. Formal nomenclatural recognition of *Oreosaurus* **sp. n.** renders *specularis* a permanently unavailable name for this taxon. *Oreosaurus serranus* **sp. n.** is the sister of all remaining congeners, and differs primarily from them in having only one pair of genial scales, as well as a unique pattern of scutellation. We provide an identification key to the species of *Oreosaurus*.

#### Resumen

*Oreosaurus* es uno de los dos géneros que fueron extraídos de *Riama sensu lato*, el cual fue reconocido recientemente como polifilético. *Oreosaurus* es un clado pequeño (cinco especies nominales y dos indescritas) de gimnoftálmidos de montaña y presenta un patrón de distribución excepcional. Sus especies nominales e indescritas se distribuyen discontinuamente sobre la Cordillera de la Costa de Venezuela, los tepuyes del macizo de Chimantá en Venezuela, las tierras altas de la isla de Trinidad, y la Sierra Nevada de Santa Marta en Colombia (SNSM). Describimos la especie de *Oreosaurus* que es endémica de la SNSM. Históricamente, esta especie se asocia con dos nombres que son *nomina nuda: Proctoporus serranus y P. specularis*. El reconocimiento formal de *Oreosaurus serranus sp. n.* hace que *specularis* sea un nombre permanentemente indisponible para este taxón. *Oreosaurus serranus sp. n.* es la especie hermana de todos los congéneres restantes, y se diferencia de ellos principalmente por tener un único par de escamas geneiales, así como por presentar un patrón único de escamación. Proveemos una clave de identificación para las especies de *Oreosaurus*.

#### **Keywords**

Microteiid lizard, Oreosaurus serranus, nomenclatural recognition, Proctoporus serranus, Proctoporus specularis, nomina nuda, South America, taxonomy

### Introduction

*Oreosaurus* Peters, 1862 (Reptilia: Gymnophthalmidae) contains five named species of montane lizards that have discontinuous distributions on the Cordillera de la Costa and tepuis from the Chimantá massif in Venezuela, and the Aripo northern range in the Caribbean island of Trinidad (Sánchez-Pacheco et al. 2017). An additional species that is the sister of all remaining congeners and is endemic to the Sierra Nevada de Santa Marta in Colombia (SNSM) remains undescribed. Sánchez-Pacheco et al. (2017) referred to it as "Sierra Nevada".

Over 30 years ago, Ayala and Castro reviewed the Colombian lizard fauna in their unpublished but widely distributed book "Lizards of Colombia". Their work included brief descriptions of several species and they referred to informal specific epithets associated with authors to indicate that formal descriptions were not yet published, but were forthcoming. Among these species, Ayala and Castro included "Proctoporus" "serranus", a gymnophthalmid lizard from the Serranía de San Lorenzo, SNSM, and they provided a reference for the description (Harris, dated to 1984). However, Harris' formal description of this taxon was never published. Although Ayala and Castro included a brief description (based on an undetermined number of specimens), the name "serranus" is a nomen nudum because it does not have a reference, and therefore fails to conform to ICZN (1999) Art. 11. Similarly, Ayala (1986) published a list of Colombian lizards, which included undescribed species referred to names within quotes ("") and associated with authors to indicate imminent formal descriptions. Most of these names were the same ones provided by Ayala and Castro (unpublished data), the exception being "Proctoporus" "specularis", also from San Lorenzo, SNSM. Nevertheless, both the locality and the given reference (Harris, but this time dated to 1986-also never published) were strongly suggestive that "serranus" and "specularis" referred to

the same species. However, in accordance with ICZN (1999) Art. 13, the absence of a description for "*specularis*" (Ayala 1986) renders this name a *nomen nudum*.

While carrying out field work in the SNSM, we had the opportunity to collect a series of specimens that conform to the unpublished description of "serranus". Two terminals labeled "Sierra Nevada" 1 and 2 were included in a recently published phylogenetic analysis of Riama Gray, 1858 sensu lato (Sánchez-Pacheco et al. 2017), which recovered this species as part of the resurrected Oreosaurus. Although "serranus" and "specularis" are currently nomina nuda, and by definition unavailable names (i.e., they fail to conform to ICZN Arts. 11 and 13), both of them have reached the modern literature (Rueda-Almonacid et al. 2012 and de Albuquerque et al. 2012, respectively). A nomen nudum can be made available (or validated) if it is published again in a way that meets the criteria of availability (ICZN 1999). Anadia altaserrania Harris & Ayala, 1987, another endemic gymnophthalmid lizard from the SNSM, is a pertinent example. It was included in Ayala and Castro's unpublished book (with reference to Harris, Ayala and Castro, 1984) and listed by Ayala (1986; this time with reference to Harris and Ayala, 1986), but finally published formally by Harris and Ayala (1987). The situation with Oreosaurus is not unlike that of Anolis in which Poe et al. (2009) provided examples of nomen nudum species of Anolis lizards listed by Ayala (1986). Below we provide a name and a description for the species of Oreosaurus from the SNSM.

# Materials and methods

For comparative purposes, specimens of *Oreosaurus achlyens* (Uzzell, 1958), *O. luctuosus* Peters, 1862, *O. shrevei* (Parker, 1935) and the undescribed *O.* "Venezuela" were examined (Appendix 1). Data for *O. mcdiarmidi* (Kok & Rivas, 2011) and *O. rhodogaster* (Rivas et al., 2005) were taken from the literature (Kok and Rivas 2011 and Rivas et al. 2005, respectively). Measurements (snout-vent length [SVL] and tail length) were taken to 0.1 mm with a digital caliper. Sex was determined by noting the presence of hemipenes in males and/or secondary sex characters, such as the number of femoral pores. To facilitate comparisons with other species of *Oreosaurus*, scutellation and head-scale terminology follows Kizirian (1996). Bilateral variation is reported as left/right. Hemipenes were prepared following the procedures described by Manzani and Abe (1988) as modified by Pesantes (1994) and Zaher (1999). The retractor muscle was severed manually and an everted organ was filled with stained petroleum jelly. Following Uzzell (1973) and Nunes et al. (2012), calcareous hemipenial structures were stained in an alcoholic solution of alizarin red. Terminology follows Dowling and Savage (1960), Savage (1997) and Nunes et al. (2012).

The following collection abbreviations are used herein: AMNH (American Museum of Natural History, New York), EBRG (Museo de la Estación Biológica de Rancho Grande, Maracay, Venezuela), MCZ (Museum of Comparative Zoology, Harvard University, Cambridge, USA), ROM (Royal Ontario Museum, Toronto, Canada), and USNM (National Museum of Natural History, Washington D.C., USA).

### Species description

#### Oreosaurus serranus sp. n.

http://zoobank.org/5BB0FB0B-47E8-4788-BD79-2784FF91F63F Figures 1–3

**Holotype.** ROM 53608 (field number JJS 548; Fig. 1), an adult female collected by S.J.S-P., P.M.S.N., S.M.S, Liliana Saboyá-Acosta, Jhon Jairo Ospina-Sarria, Sandy B. Arroyo, and Mariane Targino Rocha in Colombia, Sierra Nevada de Santa Marta, Departamento de Magdalena, headwaters of the Río Guachacos, Corregimiento de Minca, finca Vista Hermosa, approximately 2156 m, June 2013. This locality is situated at approximately 11°05'N, 74°01'W.

**Paratypes.** ROM 53609 (adult female, Fig. 2), ROM 53610 (subadult male), ROM 53611 (subadult female), ROM 53612–13 (juvenile females), and ROM 53614 (juvenile male), all with same data as holotype.

**Diagnosis.** Oreosaurus serranus sp. n. can be distinguished from all its congeners by the number of genial pairs (1 in O. serranus sp. n. versus 2 in the other species). It also differs from all other species of Oreosaurus, except O. mcdiarmidi, by the number of supraoculars (3 in O. serranus sp. n. and O. mcdiarmidi versus 4 in the other species), and dorsal scale relief (smooth in O. serranus sp. n. and O. mcdiarmidi versus keeled or slightly keeled in the other species). Oreosaurus serranus sp. n. also differs from O. mcdiarmidi by the absence of prefrontal scales (present in O. mcdiarmidi).

Description. Oreosaurus serranus sp. n. possesses the following characteristics: (1) maximum known SVL in males 60 mm (n = 2), in females 70.4 mm (n = 5); (2) frontonasal equal to or longer than frontal; (3) prefrontal scales absent; (4) nasoloreal suture complete [= loreal present]; (5) supraoculars three, all in contact with ciliaries; (6) superciliary series incomplete, formed only by the anteriormost superciliary scale; (7) supralabial-subocular fusion absent; (8) postoculars two; (9) postparietals two; (10) supratympanic temporals two; (11) genials in one pair; (12) dorsal scales rectangular, juxtaposed, smooth; (13) nuchal scales smooth; (14) longitudinal dorsal scale rows 10–11; (15) transverse dorsal scale rows 33–36; (16) ventral scales smooth, in 21–22 transverse scale rows; (17) lateral scale rows (oval, non-granular scales) 4–6; (18) femoral pores per hind limb in males 7-9, in females 2-3 (located proximally); (19) scales between medialmost femoral pores two; (20) subdigital scales on toe I four; (21) anterior cloacal plate scales four or six; (22) posterior cloacal plate scales seven; (23) dorsum dark brown to black with fine brown mottling; distinct dorsolateral stripes absent; lateral ocelli (i.e., white spots surrounded by dark blotches) absent (white or cream spots instead); venter black with conspicuous whitish spots mostly on scale sutures; (24) hemipenial body globose, slightly bilobed, ornamented by 14-15 chevron-shaped flounces on each side.

**Description of holotype.** Adult female (Fig. 1), SVL = 70.4 mm, tail length = 72.4 mm; head scales smooth, glossy; rostral scale wider than long, higher than adjacent supralabials, in contact with frontonasal, nasals, and anteriormost supralabials posteri-



**Figure 1.** Oreosaurus serranus sp. n. (holotype, ROM 53608 [70.4 mm SVL]). Dorsal, lateral and ventral views of the head, and ventral view of the pelvic region.

orly; frontonasal roughly quadrangular, longer than wide, widest posteriorly, equal in length to frontal, in contact with nasals and loreals laterally, and frontal posteriorly; prefrontals absent; frontal longer than wide, anterior suture convex, lateral sutures concave, posterior suture angular with point directed posteriorly, in contact with anteriormost



**Figure 2.** *Oreosaurus serranus* sp. n. (paratype, ROM 53609 [68.6 mm SVL]) in life. Photos: S.M.S (top) and Jhon Jairo Ospina-Sarria (bottom).

supraoculars and superciliaries posterolaterally, and frontoparietals posteriorly; frontoparietals pentagonal, in contact anterolaterally with all supraoculars on the left side and second and third supraoculars on the right side, and posteriorly with parietals and interparietal; interparietal hexagonal, longer than wide, lateral sutures concave, in contact with parietals laterally, postparietals posteriorly; parietals in contact with third supraoculars anterolaterally, dorsalmost temporal and postocular scales laterally, and postparietals posteriorly; postparietals pentagonal, two, in broad contact; supraoculars three, all in contact with ciliaries. Nasoloreal suture complete, nasal quadrangular; loreal quadrangular, not in contact with second supralabial; superciliary series incomplete, formed only by the anteriormost superciliary scale, which barely extends onto dorsal surface of head, and lies between loreal, frontal, first supraocular, and anteriormost ciliaries; palpebral disc of lower eyelid divided into three large, unpigmented scales; frenocular quadrangular, in contact with loreal and nasal anteriorly; circumorbital scales between posteriormost supraocular and frenocular five; postoculars two; temporals smooth, glossy, polygonal; supratympanic temporals two; supralabials seven; infralabials four. Mental wider than long, in contact with anteriormost infralabials and postmental posteriorly; postmental roughly pentagonal, posterior suture angular with point directed posteriorly, in contact with first and second infralabials laterally; genials in one pair, roughly quadrangular, in contact with second and third infralabials; scale rows between genials and collar fold (along midventral line) eight, medialmost scales of posteriormost scale row distinctly enlarged, smooth; posteriormost gular row enfolded posteriorly, concealing one small scale row; lateral neck rounded, smooth.

Dorsal scales rectangular, longer than wide, juxtaposed, smooth, in 35 transverse rows; longitudinal dorsal scale rows at fifth transverse ventral scale row nine, at 10<sup>th</sup> transverse ventral scale row 10, at 15<sup>th</sup> transverse ventral scale row 11; lateral scale rows at fifth transverse ventral scale row 6/5, at 10<sup>th</sup> transverse ventral scale row four, at 15<sup>th</sup> transverse ventral scale row four; lateral scales on body near insertion of forelimb small to granular; ventral scales quadrangular, smooth; complete transverse ventral scale rows 22; longitudinal ventral scale rows at midbody 10; anterior cloacal plate scales six; posterior cloacal plate scales seven, medialmost scale with a horizontal suture; scales on tail rectangular and juxtaposed; midventral subcaudals smooth, wider than adjacent scales, nearly square. Femoral pores per hind limb two, located proximally; scales between medialmost femoral pores two.

**Coloration of holotype.** In life, dorsal ground color dark brown to black with fine brown mottling; dorsal surfaces of head, body and tail with an iridescent bluish shine. White or cream spots laterally from neck to posterior portion of body, becoming less distinct posteriorly. Ventral surfaces of head and body predominantly black, with conspicuous whitish spots mostly on scale sutures; subcaudally black without spots. In preservative (70% ethanol), dorsal ground color brown with fine light brown mottling; dorsal surfaces of head, body and tail without the iridescent bluish shine. Ventral surfaces of head and body predominantly black site spots.

Hemipenial morphology. Right organ of subadult male ROM 53610 (Fig. 3) was partially everted and filled. Basal and lobular regions are partially damaged. Hemipe-



Figure 3. *Oreosaurus serranus* sp. n. Sulcate (left), lateral (center) and asulcate (right) views of the right hemipenis of ROM 53610 (paratype).

nial body is roughly globose, ending in two small and partially everted, barely visible lobes. Partial eversion and some damages precluded the detection of folds, or any other ornamentation, on the lobes.

The sulcus spermaticus, central in position, originates at the base of the organ and proceeds in a straight line towards the lobes. It is bordered by two parallel nude areas, and divided by a fleshy fold. Branches of the sulcus spermaticus are not visible. Two columns of at least 14 chevron-shaped flounces ornament the sides of the organ and the borders of the sulcate and asulcate faces of the hemipenial body. Although these flounces do not present calcified comb-like spicules, it is possible that such absence is due to the age of the specimen. These calcified structures are present in adults of most species of *Oreosaurus* (e.g., Kok and Rivas 2011, Nunes 2011, Rivas et al. 2005). A broad nude area occupies at least 50% of the asulcate face. Some damages at the basis of the organ precluded the detection of the isolated horizontal flounces on the proximal-central region of the asulcate face that are often present in species of Cerco-saurinae (e.g., Kok and Rivas 2011, Rivas et al. 2012, Sánchez-Pacheco et al. 2011).

**Variation.** Paratypes consist of four females (SVL = 41.4–68.6 mm) and two males (SVL = 40.4–60 mm). The paratypes are similar to the holotype with the following noteworthy exceptions. Frontonasal longer than frontal in ROM 53609–12 and 53614; loreal scale in contact with second supralabial in ROM 53612–13; ventralmost postocular fused with posteriormost subocular on the right side in ROM 53610–11 and 53614; palpebral disc of the lower eyelid divided horizontally in ROM 53610–11 and 53609; femoral pores per hind limb in female ROM 53612 three. Femoral



**Figure 4.** Distribution of *Oreosaurus serranus* sp. n. in the northwestern slopes of the Sierra Nevada de Santa Marta, northern Colombia. Pentagon indicates type locality.

pore number is the most evident sexually dimorphic character, with males having 7–9 pores per hind limb (ROM 53610 8/9, ROM 53614 9/7) and females having 2–3.

**Distribution and natural history.** *Oreosaurus serranus* sp. n. is known exclusively from the type locality (Figs 4, 5) and San Lorenzo (Ayala and Castro unpublished data, Ayala 1986), two adjacent cloud forest localities on the northwestern slopes of the Sierra Nevada de Santa Marta (SNSM) at elevations of about 1800–2156 m (Fig. 4). This forest-dwelling lizard is often found under fallen, rotten trunks or logs. Holotype and paratypes were collected manually during the day. The new species was found at the type locality in sympatry with *Anadia pulchella*, another gymnophthalmid endemic to the SNSM.

**Etymology.** The specific epithet *serranus*, which is an adjective derived from the Spanish adjective serrano (meaning from the sierra), refers to the location of the species' type locality in the Sierra Nevada de Santa Marta, and preserves the original etymological intent of Harris, as stated by Ayala and Castro (unpublished data).

**Comments.** Formal nomenclatural recognition of *Oreosaurus serranus* sp. n. renders *specularis* (Ayala 1986) a permanently unavailable name for this taxon. Specimens reported by Ayala and Castro (unpublished data) were not included herein because they are presumably lost (S.J.S-P. personal observation).



**Figure 5.** Type locality (top) and habitat (bottom) of *Oreosaurus serranus* sp. n. in the Sierra Nevada de Santa Marta, Colombia. Photos: Jhon Jairo Ospina-Sarria (top) and S.M.S (bottom).



**Figure 6.** Summary of the phylogeny and geographic distribution of *Oreosaurus* (Sánchez-Pacheco et al. 2017). SNSM = Sierra Nevada de Santa Marta, Colombia; TCM = tepuis from the Chimantá massif, Venezuela; CCC = Cordillera de la Costa Central, Venezuela; IT = island of Trinidad; CCO = Cordillera de la Costa Oriental, Venezuela. *Oreosaurus luctuosus*, from the CCC, and *O. rhodogaster*, from the CCO, were included in this genus due to the presumed close relationships of these species and *O. achlyens* and *O. shrevei*, respectively. Data taken from Sánchez-Pacheco et al. (2017).

*Oreosaurus* is one of the two genera extracted from the former *Riama sensu lato*, which was recently found to be non-monophyletic (Sánchez-Pacheco et al. 2017). The other clade, *Andinosaura* Sánchez-Pacheco et al., 2017, includes 11 Andean species and *Riama sensu stricto* is also an exclusively Andean radiation of 16 named species.

Sánchez-Pacheco et al. (2017) discussed the disjunct geographic distributions of species of *Oreosaurus*, as well as their phylogenetic relationships. Figure 6 summarizes these findings. All species of *Oreosaurus* share the absence of a narrow band of differentiated granular lateral scales (present in species of *Andinosaura* and *Riama*).

#### Key to the species of Oreosaurus

r <i>us serranus</i> sp. n.	One pair of genial scales Oreosau	1
2	Two pairs of genial scales	_
O. mcdiarmidi	Prefrontal scales present	2
	Prefrontal scales absent	_
4	Loreal scale absent	3
5	Loreal scale present	_
O. shrevei	Anterior cloacal plate row composed of a small scale	4
O. "Venezuela"	Anterior cloacal plate row composed of two large scales	_
6	Dorsal body scales hexagonal	5
O. luctuosus	Dorsal body scales rectangular	_
O. rhodogaster	42–44 transverse dorsal scale rows	6
O. achlyens	37–40 transverse dorsal scale rows	_

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# Appendix I

# Comparative material examined

Oreosaurus achlyens: VENEZUELA: Aragua: Rancho Grande (AMNH 137260, 137267–69, 137271–76, 137278–82, 137297).
O. luctuosus: VENEZUELA: Aragua: Rancho Grande (AMNH 137270, 137277, MCZ 100410, USNM 196336), Parque Nacional Henry Pittier, Rancho Grande (USNM 259170).
O. shrevei: TRINIDAD & TOBAGO: Horne Tucuche (MCZ 62506–07); El Teluche [in error, probably Tucuche] (MCZ 100466–68); Mt. Tucuche (MCZ 160065–66).
O. "Venezuela": VENEZUELA: Anzoátegui: Cerro El Guamal, Macizo del Turimiquire, municipio Freites, 2150 m (EBRG 5962).

CHECKLIST



# Checklist of the flower flies of Ecuador (Diptera, Syrphidae)

Diego Marín-Armijos<sup>1</sup>, Noelia Quezada-Ríos<sup>1</sup>, Carolina Soto-Armijos<sup>1</sup>, Ximo Mengual<sup>2</sup>

l Museo de Colecciones Biológicas, Departamento de Ciencias Biológicas, Universidad Técnica Particular de Loja, San Cayetano Alto s/n, C.P. 11 01 608, Loja, Ecuador **2** Zoologisches Forschungsmuseum Alexander Koenig, Leibniz-Institut für Biodiversität der Tiere, Adenauerallee 160, D-53113 Bonn, Germany

Corresponding author: Ximo Mengual (x.mengual@leibniz-zfmk.de)

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#### Abstract

Syrphidae is one of the most speciose families of true flies, with more than 6,100 described species and worldwide distribution. They are important for humans acting as crucial pollinators, biological control agents, decomposers, and bioindicators. One third of its diversity is found in the Neotropical Region, but the taxonomic knowledge for this region is incomplete. Thus, taxonomic revisions and species checklists of Syrphidae in the Neotropics are the highest priority for biodiversity studies. Therefore, we present the first checklist of Syrphidae for Ecuador based on literature records, and provide as well the original reference for the first time species citations for the country. A total of 201 species were recorded for Ecuador, with more than 600 records from 24 provinces and 237 localities. Tungurahua, Pastaza, and Galápagos were the best sampled provinces. Although the reported Ecuadorian syrphid fauna only comprises 11.2 % of the described Neotropical species, Ecuador has the third highest flower fly diversity density after Costa Rica and Suriname. These data indicate the high species diversity for this country in such small geographic area.

#### **Keywords**

faunistics, hoverflies, Neotropical Region, species list, Syrphid fauna

# Introduction

Seventeen countries in the world are considered megadiverse, occupying less than 10% of the Earth's surface and comprising nearly 70% of the global biodiversity (Mittermeier et al. 2005). In this group, Ecuador is listed among the first places in the world ranking based on number of species per area unit for vascular plants, mammals, birds, reptiles and amphibians (Mittermeier and Mittermeier 1997, Brehm et al. 2008), but it is the megadiverse country with the smallest land area (Mittermeier et al. 2005). This makes Ecuador rank at the top, or near so, of the megadiversity list if diversity per unit area is taken into consideration. The geographic position of Ecuador and a series of biotic and abiotic elements have resulted in an extraordinary biological diversity in this nation. For instance, there are ca. 20,000 estimated plants in Ecuador, of which up to 5,000 are most likely endemics. In terms of vertebrate diversity, 1.3% of the global diversity of non-fish vertebrates is endemic to Ecuador (Mittermeier et al. 2005).

Insects are the most successful group of living organisms in our planet in number of species and different natural histories. From all known and described species on Earth, *ca.* 1.5–1.7 millions, between 65 and 75% are insects, and among the insect orders only four orders represent more than 80% of the species: Coleoptera, Lepidoptera, Diptera, and Hymenoptera (Adler and Foottit 2009). Despite being abundant and ubiquitous, insects are understudied in Ecuador and many new species and genera are waiting to be formally described (Dangles et al. 2009, Barragán et al. 2009). Furthermore, there is no estimate on the number of invertebrates for Ecuador, neither a checklist for most of the invertebrate groups present in this country (Salazar and Donoso 2014).

Diptera, which includes mosquitoes and true flies, comprises more than 153,000 described species (about 10–12% of the planet's biodiversity) and has a rate of near 1,000 new species described per year (Pape and Thompson 2013). Diptera is not only rich in number of species, but also in morphology and structure, habitats use and human interactions (Courtney et al. 2009). Most recent studies in this country have focused mostly on Lepidoptera (Piñas and Manzano 1997, Bollino and Onore 2001, Piñas and Manzano 2003a, 2003b, Hilt and Fiedler 2005, Brehm 2005, Fiedler et al. 2007, Bodner et al. 2010), and Coleoptera (Celi et al. 2004, Moret 2005, Carpio et al. 2009, Carvajal et al. 2011, Domínguez et al. 2015, Thormann et al. 2016). Salazar and Donoso (2014) present some numbers for the invertebrate fauna of Ecuador and report 722 dipteran species from the literature, but this number is probably an underestimation, which was biased by the research focus of the previous works in Ecuador. Thus, the actual species number of species of Diptera for the country is far from being known.

Commonly called flower or hoverflies, the family Syrphidae is one of the most diverse in Diptera with more than 6,000 described species (Brown 2009), and the third taxon with most species in the Neotropical Region (Amorim 2009). Their coloration, from orange-brown in a few species to striking yellow and black patterns, causes them to be confused with bees or wasps (Hymenoptera). Adults of the family Syrphidae have the ability to hover and are associated with flowers, which are used as mating sites and food sources (pollen and nectar). Therefore, the imagoes are considered important pollinators of herbs, shrubs, and arboreal plants in natural ecosystems as well as in agricultural areas (Speight and Lucas 1992, Marinoni and Thompson 2003, Pérez-Bañón et al. 2003, Ssymank and Kearns 2009, Inouye et al. 2015). Syrphid species have been used as bioindicators as well to assess biodiversity loss and the efficiency of restoration and conservation policies (Sommaggio 1999, Tscharntke et al. 2005, Ricarte et al. 2011, Sommaggio and Burgio 2014).

Larvae are very variable in structure, habits, and feeding modes, including fungal fruiting bodies, brood in nests of social Hymenoptera, dung, decaying wood and water bodies of several types (Rotheray 1993, Rotheray and Gilbert 1999, 2011). Larvae of some species can mine leaves and stems of numerous plant families, or even feed on pollen, and others are predators of arthropods (aphids, caterpillars, larvae of flies or beetles, adult flies, etc.) or are kleptoparasitic or parasitoids (Rojo et al. 2003, Weng and Rotheray 2008, Reemer and Rotheray 2009, Rotheray et al. 2000, Ureña and Hanson 2010, Zuijen and Nishida 2011, Pérez-Lachaud et al 2014, Jordaens et al. 2015, Fleischmann et al. 2016, Dumbardon-Martial 2016). Due to their feeding mode, some syrphid species play an important role as biological control agents of pests (Greco 1998, Schmidt et al. 2004, Bergh and Short 2008, Bugg et al. 2008, Pineda and Marcos-García 2008, Nelson et al. 2012, Amorós-Jiménez et al. 2014, Eckberg et al. 2015) and as decomposers of organic matter (Lardé 1989, Rotheray et al. 2009, Martínez-Falcón et al. 2012).

Flower flies are distributed worldwide, with the exception of Antarctica and a few remote oceanic islands, and their greatest species diversity is found in the tropics (Vockeroth 1992, Reemer 2013, Reemer and Ståhls 2013b). The classification of Neotropical Syrphidae has been largely reviewed by Vockeroth (1969), Thompson (1972, 1999) and Reemer (2014), but the taxonomy of Syrphidae is far from being complete in the Neotropical Region yet, and many new species remain to be described (Mengual and Thompson 2008, Mengual et al. 2009, Thompson et al. 2010, Mengual 2011, Mengual and Thompson 2011, Reemer 2010, 2014, 2016). Moreover, the almost absence of identification keys for Neotropical species makes difficult the elaboration of regional checklists or the discovery of new species to science (Thompson et al. 2010, Montoya et al. 2012). Previously, species lists based on single surveys (Campos 1960, Linsley and Usinger 1966, Linsey 1977), for specific taxa (genus *Toxomerus* Macquart, 1855 by Gerdes, 1974a), or for limited areas, such as Galapagos Islands (Sinclair 2015, Sinclair et al. 2016), have been published for Ecuador.

Amorim (2009) considers Syrphidae among the still underexplored dipteran families in the Neotropical Region, and Ecuador among the most poorly collected areas in South America. Nevertheless, there have been some efforts during the last years to teach Syrphidae taxonomy to young students via workshops and courses with the great help of F.C. Thompson (USNM, National Museum of Natural History, Smithsonian Institution) as a coordinator (Colombia 2006, Peru 2008, Ecuador 2012), with the purpose to educate new taxonomists that may help to elucidate the thrilling evolutionary history of this group. As a fruit from these workshops, a strong collaboration among the authors was established years ago to study the flower flies of Ecuador. Currently, there is no species list for Ecuadorian flower flies that can help as a starting point, and the existing records are few and scattered thorough the literature. Consequently, a species checklist of the family Syrphidae in Ecuador for further biodiversity studies was the highest priority. In this survey, we present the first species checklist of Syrphidae for Ecuador based on literature records and provide as well the original reference for the first time species citations for the country of Ecuador.

### Materials and methods

Thompson et al. (1976) was used as the primary source to check for species cited previously for Ecuador. Based on that keystone publication and Thompson et al. (2010), we reviewed all the published literature up to date in order to find references to Ecuadorian syrphids. Moreover, bibliographic searches were performed in public and scientific journal databases such as Google Scholar, Scopus, ISI Web of Knowledge, BioOne, Redalyc, Scielo, BioOne, ScienceDirect, and ResearchGate. Our keywords in English and Spanish for the searches were invertebrates, Ecuador, Diptera, Syrphidae, Neotropics, distribution, flower flies and hoverflies. In addition, we studied representative collections of Ecuador, i.e. Museo de Zoología de la Pontificia Universidad Católica del Ecuador (QCAZ) and Museo de la Escuela Politécnica Nacional.

To illustrate the flower fly records in a geographic map we used the coordinates available in the literature. For the localities without geographic coordinates we used Google Earth <sup>®</sup> to obtain them. Figure 1 was created using QGIS software (QGIS Development Team, 2009).



Figure 1. Distribution map of flower fly records in Ecuador.

## Results

A total of 201 species plus four unidentified species and two misidentified taxa, belonging to 51 syrphid genera and subgenera, have been recorded up to date for Ecuador. More than 600 records from 24 provinces and 237 different localities of Ecuador are given in Table 1. Although there are records from all the Ecuadorian provinces, they do not show an even collecting effort for the whole country. Tungurahua (with 80 collecting events), Pastaza (72), and Galápagos (60) are the best sampled provinces, while the flower fly records for Orellana (3), Los Ríos (2), Santa Elena (2), Santo Domingo de Los Tsáchilas (2), and Esmeraldas (1) provinces are almost anecdotal. In terms of geographic Ecuadorian regions, the Sierra of Ecuador and the Galapagos Islands have been more extensively sampled and studied (Table 1 and Figure 1). On the other hand, the Costa Region, North and South Amazonia, and Austral Region of Ecuador have been little explored (Figure 1).

Species	Province	Locality (Altitude masl)	References for Ecuador
Alipumilio femoratus Shannon, 1927	Pastaza	Puyo	Rotheray et al. 2000: 137
Allograpta annulipes (Macquart, 1850)	Pastaza	Santa Inés, Río Pastaza (1200)	Fluke 1942: 16 (as A. geminata)
Allograpta browni Fluke, 1942	Imbabura	Cuicocha (3200)	Fluke 1942: 18
411	Tungurahua	Baños	Fluke 1942: 19
Allograpta exotica	Tungurahua	Juive	Fluke 1942: 19
(wiedemain, 1850)	Ecuador		Fluke 1950a: 146 (as Syrphus exoticus)
Alle matter fals sta Eleler 1042	Tungurahua	Baños (1800)	Fluke 1942: 16
Allograpta falcata Fluke, 1942	Tungurahua	Baños (2200)	Fluke 1942: 16
	Galápagos	Española	Sinclair and Peck 2002; Sinclair et al. 2016: 87
	Galápagos	Fernandina	Sinclair et al. 2016: 87
	Galápagos	Floreana	Coquillett 1901: 374; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002; Sinclair 2015; Sinclair et al. 2016: 87
	Galápagos	Genovesa	Sinclair et al. 2016: 87
	Galápagos	Isabela	Sinclair and Peck 2002; Sinclair 2015; Sinclair et al. 2016: 87
	Galápagos	Marchena	Sinclair 2015
Allograpta neosplendens Sinclair &	Galápagos	Pinta	Sinclair and Peck 2002; Sinclair et al. 2016: 87
Thompson, 2016	Galápagos	San Cristóbal	Curran 1934: 153; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002; Sinclair et al. 2016: 87
	Galápagos	Santa Cruz	Boada 2005: 84; Sinclair 2015; Sinclair et al. 2016: 87
	Galápagos	Santa Fé	Sinclair 2015
	Galápagos	Santiago	Coquillett 1901: 374; Curran 1934: 153; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002; Sinclair et al. 2016: 87
	Galápagos		Thomson 1869: 501 (as Syrphus splendens)

**Table 1.** Checklist of Syrphidae species recorded from Ecuador, with the Ecuadorian province, locality, altitude (when cited in the original reference), and the original reference for Ecuador.

Species	Province	Locality (Altitude masl)	References for Ecuador
Allographics resources 1936	Tungurahua	Baños	Fluke 1942: 20
Auograpia neorropica Curran, 1950	Pastaza	Santa Inés	Fluke 1942: 20
	Tungurahua	Baños	Fluke 1942: 19
Allograpta obliqua (Say, 1823)	Carchi	Tulcán	Campos 1960: 25
	Chimborazo	Riobamba	Campos 1960: 25
	Imbabura	Cuicocha (3200)	Fluke 1942: 19
Allograpta tectiforma Fluke, 1942	Imbabura	Cuicocha (3500)	Fluke 1942: 19
	Ecuador		Fluke 1950a: 146
Allograpta teligera Fluke, 1942	Tungurahua	Baños (1800)	Fluke 1942: 18
	Galápagos		Walker 1849: 588; Linsley 1977: 39
	Galápagos	Floreana	Sinclair and Peck 2002; Sinclair 2015
Argentinomvia agonis	Galápagos	Isabela	Sinclair and Peck 2002; Sinclair et al. 2016: 85
(Walker, 1849)	Galápagos	Pinta	Sinclair and Peck 2002; Sinclair et al. 2016: 85
	Galápagos	San Cristóbal	Sinclair 2015
	Galápagos	Santa Cruz	Boada 2005: 86; Sinclair 2015; Sinclair et al. 2016: 85
Argentinomyia altissima	Imbabura	Cuicocha (3200)	Fluke 1945: 20
(Fluke, 1945)	Ecuador		Fluke 1958: 266
Argentinomyia bolivariensis	Bolívar	Hda. Talahua (3100)	Fluke 1945: 19
(Fluke, 1945)	Ecuador		Fluke 1958: 266
Argentinomyia browni	Bolívar	Hda. Talahua (3100)	Fluke 1945: 19
(Fluke, 1945)	Ecuador		Fluke 1958: 266
Argentinomyia festiva (Fluke, 1945)	Tungurahua	Baños (1800)	Fluke 1945: 10
Argentinomyia longicornis (Walker, 1836)	Pastaza	Puyo (3000)	Fluke 1945: 4
Argentinomyia luculenta	Tungurahua	Baños (2300)	Fluke 1945: 18
(Fluke, 1945)	Tungurahua	Pondoa (2800)	Fluke 1945: 18
Argentinomia object (Eluko 1945)	Chimborazo	Urbina (3650)	Fluke 1945: 11
Angenunomym opaca (Pluke, 1949)	Ecuador		Fluke 1958: 266
Argentinomyia rex (Fluke, 1945)	Bolívar	Hda. Talahua (3100)	Fluke 1945: 22
	Ecuador		Fluke 1958: 266
Argentinomyia tropica (Curran, 1937)	Tungurahua	Baños (2300)	Fluke 1945: 17
Claraplumula latifacies	Bolívar	Hda. Talahua (3100)	Fluke 1942: 4
Shannon, 1927	Ecuador		Fluke 1950a: 146
Copestylum (Copestylum) otongaensis Rotheray & Hancock, 2007	Cotopaxi	Otonga	Rotheray et al. 2007: 290
Copestylum (Copestylum) tapia Rotheray & Hancock, 2007	Cotopaxi	Otonga	Rotheray et al. 2007: 307
Copestylum (Phalacromya) araceorum Ricarte & Rotheray, 2015	Cotopaxi	Otonga	Ricarte et al. 2015: 13
	Azuay	Cuenca (2650)	Fluke 1951b: 15 (as Volucella ecuadorea)
Copestylum (Phalacromya) beatricea	Tungurahua	Baños	Fluke 1951b: 15 (as Volucella ecuadorea)
(Hull, 1950)	Imbabura	Cuicocha (3300)	Fluke 1951b: 15 (as Volucella ecuadorea)
	Ecuador		Hull 1950: 236

Species	Province	Locality (Altitude masl)	References for Ecuador
Copestylum (Phalacromya)	Chimborazo	Huigra	Campos 1960: 27 (as Volucella esuriens)
brunneum (Thunberg, 1789)	Cañar	Azogues	Campos 1960: 27 (as Volucella esuriens)
Copestylum (Phalacromya) bulbosum (Fluke, 1951)	Tungurahua	Minza Chica (3750)	Fluke 1951b: 25
Copestylum (Phalacromya) camposi (Curran, 1939)	Guayas	Isla Puná, Puerto Grande	Curran 1939: 8
Copestylum (Phalacromya)	Guayas	San Rafael	Campos 1960: 27
chaetophorum (Williston, 1887)	Guayas	Bucay	Campos 1960: 27
	Pichincha	Guayllabamba	Rotheray et al. 2009: 714
Copestylum (Phalacromya) currani	Tungurahua	Baños	Fluke 1951b: 13
(Fluke, 1951)	Imbabura	Cuicocha (3300)	Fluke 1951b: 13
	Azuay	Cuenca (2650)	Fluke 1951b: 13
	Guayas	San Eduardo	Campos 1960: 27
Copestylum (Phalacromya)	Guayas	Durán	Campos 1960: 27
<i>fulvicorne</i> (Bigot, 1883)	Guavas	San Rafael	Campos 1960: 27
Copestylum (Phalacromya) hambletoni (Fluke, 1951)	Ecuador		Thompson et al. 1976: 77
Copestylum (Phalacromya) multipunctatum Rotheray & Hancock, 2009	Pichincha	Guayllabamba	Rotheray et al. 2009: 704
Copestylum (Phalacromya) nigripes (Bigot, 1857)	El Oro	Chillacocha	Campos 1960: 29 (as Phalacromyia concolor)
Copestylum (Phalacromya) placivum (Hull, 1943)	Pastaza	Santa Inés	Hull 1943b: 31
Copestylum (Phalacromya) rufoscutellare (Philippi, 1865)	Chimborazo	Mirador	Campos 1960: 29
Copestylum (Phalacromya)	Galápagos	San Cristóbal (730)	Sinclair et al. 2016: 83
scintuans (Hull, 1949)	Galápagos	Santa Cruz	Sinclair 2015 (as C. cf. viridana)
Controlling (Dhalamana) is a	Pichincha	Guayllabamba	Rotheray et al. 2009: 720
Copestylum (Phalacromya) sica	Tungurahua	Baños	Curran 1953: 9
(Curran, 1995)	Azuay	Tarqui	Curran 1953: 9
	Pichincha	Cotocollao	Campos 1960: 27 (as Volucella opalina)
Copestylum (Phalacromya) splendens	Tungurahua	Ambato	Campos 1960: 27 (as Volucella opalina)
(Townsend, 1897)	Loja	Loja	Campos 1960: 27 (as Volucella opalina)
	Chimborazo	Riobamba	Campos 1960: 27 (as Volucella opalina)
Copestylum (Phalacromya) viridigaster (Hull, 1943)	Ecuador		Hull 1943h: 41
Dasysyrphus aff. lotus (Williston, 1887)	Pichincha	Pichincha (3300)	Fluke 1942: 3
Dolichogyna chilensis (Walker, 1836)	Azuay	Narihuiña	Campos 1960: 29
Dolichomna mulleri Fluke 1951	Azuay	Girón	Fluke 1951a: 472
	Imbabura	Cuicocha (3200)	Fluke 1951a: 472
Eosalpingogaster nigriventris (Bigot, 1883)	Guayas	Isla Puná, Puerto Grande (253)	Fluke 1937: 11 (as Salpingogaster liposeta)
	Ecuador		Thompson et al. 1976: 101
Fristalis (Foseristalis) bogotensis	Napo- Pichincha	Antisamilla to Pinatura (3350)	Thompson 1997: 223
Macquart, 1842	Pichincha	Santa Catalina Expt. Station (2780)	Thompson 1997: 223
	Pichincha	Quito (2850)	Thompson 1997: 223

Species	Province	Locality (Altitude masl)	References for Ecuador
	Chimborazo	8 mi NE of Tixan	Thompson 1997: 223
	Chimborazo	Lago Zurucuchu	Thompson 1997: 223
	Tungurahua	Ambato (2700)	Thompson 1997: 223
	Carchi	Troya	Thompson 1997: 223
	Carchi	Tulcan (2800)	Thompson 1997: 223
	Carchi	El Ángel (2700)	Thompson 1997: 223
Eristalis (Eoseristalis) bogotensis	Cañar	El Tambo (2800)	Thompson 1997: 223
Macquart, 1842	Pichincha	Pomasqui (2200)	Thompson 1997: 223
	Pichincha	Valle de Machachi (2900)	Thompson 1997: 223
	Loja	Loja (2500)	Thompson 1997: 223
	Azuay	Tarqui (2800)	Thompson 1997: 223
	Azuay	28 km S of Cuenca (2500–2800)	Thompson 1997: 223
	Azuay	Cuenca (2200)	Thompson 1997: 223
	Azuay	Gualaduisa Road (2150)	Thompson 1999: 339
	Tungurahua	Baños	Thompson 1999: 339
	Bolívar	Chota River, Carchi (2000)	Thompson 1999: 339
Eupeodes (Metasyrphus) rojasi	Imbabura	NW Ibarra, Taguando River (1650–1900)	Thompson 1999: 339
Marneff, 1999	Carchi	El Ángel (2700)	Thompson 1999: 339
	Carchi	10 km SW Tulcán (2900)	Thompson 1999: 339
	Imbabura	3km N Ibarra, Yaguarcocha (1950)	Thompson 1999: 339
	Pichincha	Pichincha, 2km W Cayambe (2300)	Thompson 1999: 339
	Tungurahua	Baños	Fluke 1942: 14
Fazia alta (Curran, 1936)	Tungurahua	Juive	Fluke 1942: 14
	Ecuador		Fluke 1950a: 146
	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1942: 10
	Tungurahua	Pondoa (2800)	Fluke 1942: 10
	Pichincha	Páramo del Cerro, Pasochoa (3300)	Fluke 1942: 10
	Pichincha	Hda. San Rafael, Río San Pedro (2700)	Fluke 1942: 10
Fazia altissima (Fluke, 1942)	Pichincha	Uyumbicho (2650)	Fluke 1942: 10
	Pichincha	Hda. San Rafael (3000)	Fluke 1942: 10
	Imbabura	Cuicocha (3200)	Fluke 1942: 10
	Ecuador		Fluke 1950a: 145
	Pastaza	Puyo (1000)	Fluke 1942: 14
	Pichincha	Uyumbicho (2700)	Fluke 1942: 14
	Imbabura	Cuicocha (3200)	Fluke 1942: 14

Species	Province	Locality (Altitude masl)	References for Ecuador
	Tungurahua	Baños, Runtun trail (2100)	Fluke 1942: 14
	Pichincha	Hda. San Rafael (3000)	Fluke 1942: 14
Environmenticile (Eleler 1942)	Azuay	Cuenca (2500)	Fluke 1942: 14
<i>razua argentipua</i> (riuke, 1942)	Tungurahua	Baños, San Pablo (2200)	Fluke 1942: 14
	Bolívar	Hda. Talahua (3100)	Fluke 1942: 14
	Ecuador		Fluke 1950a: 145
	Tungurahua	Baños (2100)	Fluke 1942: 13
	Azuay	Cuenca (2500)	Fluke 1942: 13
Fazia colombia (Curran, 1925)	Pichincha	Pichincha (2700)	Fluke 1942: 13
1 u.m. (Curran, 1729)	Morona Santiago	Sucúa (900)	Fluke 1942: 13
	Ecuador		Fluke 1950a: 146
<i>Fazia decemmaculata</i> (Shannon, 1927)	Ecuador		Thompson et al. 1976: 34 (as <i>F. bullaephora</i> ); Mengual et al. 2009: 17 (as <i>F. bullaephora</i> )
	Tungurahua	Juive (1900)	Fluke 1942: 13
E ( (C	Tungurahua	Baños (1900)	Fluke 1942: 13
Fazia fasciata (Curran, 1932)	Imbabura	Cuicocha (3200)	Fluke 1942: 13
	Ecuador		Fluke 1950a: 146
Fazia fascifrons (Macquart, 1846)	Bolívar	Hda. Talahua (3100)	Fluke 1942: 12 (as <i>Epistrophe armillata</i> )
J	Ecuador		Fluke 1950a: 145 (as <i>Epistrophe armillatus</i> )
Fazia imitator (Curran, 1925)	Tungurahua	Río Mapoto (1400)	Fluke 1942: 11
Fazia luna (Fluke 1942)	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1942: 8
1 uon un (1 teles, 1 / 12)	Bolívar	Hda. Talahua (3100)	Fluke 1942: 8
	Ecuador		Fluke 1950a: 146
	Morona Santiago	Sucúa	Fluke 1942: 14
<i>Fazia micrura</i> (Osten Sacken, 1877)	Morona Santiago	Macas	Fluke 1942: 14
	Carchi	Tulcán	Campos 1960: 26 (as Sphaerophoria picticauda)
Eagia remiais (Fluke 1942)	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1942: 9
<i>1 usu nings</i> (1 luke, 1 <i>)</i> 12)	Bolívar	Hda. Talahua (3100)	Fluke 1942: 9
	Ecuador		Fluke 1950a: 145
Fazia roburoris (Fluke, 1942)	Bolívar	Hda. Talahua (3100)	Fluke 1942: 11
1 man / 00 m 0 m (1 mile, 1 / 12)	Ecuador		Fluke 1950a: 146
Hypselosyrphus marshalli Reemer, 2013	Napo	Tiputini Diodiversity Station	Reemer 2013: 28
Leucopodella boadicea (Hull, 1943)	El Oro	Piñas (1506)	Hull 1943i: 73
<i>Leucopodella delicatula</i> (Hull, 1943)	Tungurahua	Baños	Hull 1943i: 78

Species	Province	Locality (Altitude masl)	References for Ecuador
Leucopodella gracilis (Williston, 1891)	Ecuador		Thompson et al. 1976: 46 (as <i>L. asthenia</i> )
Leucopodella zenilla (Hull, 1943)	Bolívar	Hda. Talahua (3100)	Hull 1943g: 77
Lycastrirhyncha nitens Bigot, 1859	Ecuador		Montoya et al. 2012: supplementary material page 3; Montoya et al. 2016: 492
Mallota aberrans Shannon, 1927	Napo	7 km S of Baeza (2000)	Thompson and Zumbado 2002: 93
Mallota nigra Shannon, 1927	Pastaza	Santa Inés	Shannon 1927: 17
Mallota rubicunda Curran, 1940	Tungurahua	Volcán Tungurahua (2600)	Curran 1940: 13
Meromacrus laconicus (Walker, 1852)	Guayas	Isla Puná (253)	Blatch et al. 2003: 26
Meromacrus panamensis Curran, 1930	Guayas	San Eduardo	Campos 1960: 29
Meromacrus pratorum (Fabricius, 1775)	Ecuador		Thompson et al. 1976: 113
Meropidia rufa Thompson, 1983	Morona Santiago	Limón Indanza (900)	Hippa and Thompson, 1983: 110
Microdon (Chymophila) fulgens Wiedemann, 1830	Guayas	Guayaquil, San Eduardo	Campos 1960: 24
Microdon (Microdon) violaceus (Macquart, 1842)	Guayas	Durán	Campos 1960: 24
Microdon sp.	Guayas	env. of Guayaquil	Campos 1960: 24
Mixogaster thecla (Hull, 1954)	Ecuador		Thompson et al. 1976: 59
Ocyptamus (Calostigma) elnora (Shannon, 1927)	Ecuador		Thompson et al. 1976: 17
Omit tames (Hama accurate)	Pastaza	Puyo (1250)	Hull 1943a: 50 (as Baccha phobifer)
wulpianus (Lynch Arribalzaga, 1891)	Pichincha	40 km SW Quito, Tandapi (1300– 1500)	Vockeroth 1969: 123 (as <i>Hermesomyia</i> bacchiformis)
Ocyptamus (Hybobathus) flavipennis (Wiedemann, 1830)	Ecuador		Thompson et al. 1976: 18
Ocyptamus (Mimocalla) bonariensis	Tungurahua	Baños	Curran 1941: 284 (as Salpingogaster flukei)
(Curran, 1941)	Tungurahua	Baños, Chaupi	Hull 1943a: 51 (as Baccha phobia)
Ocyptamus (Ocyptamus) aeolus (Hull, 1943)	Pastaza	Machai, Río Pastaza (1300 )	Hull 1943g: 70
Ocyptamus (Ocyptamus) anonus (Hull, 1943)	Pastaza	Puyo (1000)	Hull 1943d: 91
Ocyptamus (Ocyptamus) cultratus (Austen, 1893)	Manabí	Palmar	Hull 1943g: 78 (as Baccha satyra)
Ocyptamus (Ocyptamus) cymbellina (Hull, 1944)	Santo Domingo de los Tsáchilas	Santo Domingo (950)	Hull 1944b: 64
Ocyptamus (Ocyptamus) dimidiatus	Guayas	Guayaquil, San Eduardo	Campos 1960: 24
(Fabricius, 1781)	Guayas	San Eduardo	Campos 1960: 24
Ocyptamus (Ocyptamus) niobe (Hull, 1943)	Manabí	Palmar (200)	Hull 1943i: 74
Ocyptamus (Ocyptamus) princeps (Hull, 1944)	Pastaza	Puyo (1000)	Hull 1944b: 57
Ocyptamus (Ocyptamus) saffrona (Hull, 1943)	Manabí	Palmar	Hull 1943i: 74
Ocyptamus (Ocyptamus) zilla (Hull, 1943)	Pastaza	Риуо	Hull 1943j: 215

Species	Province	Locality (Altitude masl)	References for Ecuador
Ocyptamus (Orphnabaccha) cerberus (Hull, 1943)	Imbabura	Cuicocha	Hull 1943g: 67
Ocyptamus (Orphnabaccha) opacus	Tungurahua	Volcán Tungurahua (2800)	Fluke 1950b: 444
(Fluke, 1950)	Tungurahua	Baños (1900)	Fluke 1950b: 444
	Napo- Orellana	Sumaco [as Río Zumac] (1400)	Fluke 1950b: 444
Ocyptamus (Orphnabaccha) pteronis (Fluke, 1942)	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1942: 5
	Bolívar	Hda. Talahua	Fluke 1942: 5
	Ecuador		Fluke 1950a: 145
	Tungurahua	Volcán Tungurahua, Runtun (2900)	Fluke 1942: 6
Ocyptamus (Orphnabaccha) trabis	Imbabura	Cuicocha (3200)	Fluke 1942: 6
(Fluke, 1942)	Pichincha	Páramo de Pasachoa	Fluke 1942: 6
	Ecuador		Fluke 1950a: 145
Ocyptamus (Orphnabaccha) virga (Fluke, 1942)	Imbabura	Cuicocha (3200)	Fluke 1942: 7
Ocyptamus (Orphnabaccha) volcanus (Fluke, 1942)	Pastaza	Santa Inés, Río Pastaza (1200)	Fluke 1942: 7
Ocyptamus (Pipunculosyrphus) scintillans (Hull, 1943)	Guayas	Morro (1500)	Hull 1943e: 136
Ocyptamus (Styxia) eblis (Hull, 1943)	Bolívar	Hda. Talahua	Hull 1943g: 66
<i>Ocyptamus</i> sp.	Guayas	Guayaquil, San Eduardo	Campos 1960: 24
Ornidia major Curran, 1930	Ecuador		Thompson et al. 1976: 69; Thompson 1991: 255
	Galápagos		Peck 1996
	Galápagos	Isabela	Peck et al. 1998: 228; Causton et al. 2006: 135; Sinclair 2015; Sinclair et al. 2016: 84
	Galápagos	San Cristóbal	Peck et al. 1998: 228; Causton et al. 2006: 135; Sinclair 2015; Sinclair et al. 2016: 84
	Galápagos	Santa Cruz	Sinclair 2015
	Ecuador		Thompson et al. 1976: 69; Thompson 1991: 257
	Guayas	Guayaquil	Campos 1960: 26
	Guayas*	El Salado	Campos 1960: 26
Ornidia obesa (Fabricius, 1775)	Guayas	San Eduardo	Campos 1960: 26
Crimina obesa (Fabricius, 1779)	Guayas	Durán	Campos 1960: 26
	Guayas	Naranjito	Campos 1960: 26
	Guayas	San Rafael	Campos 1960: 26
	Guayas	Barraganetal	Campos 1960: 26
	Guayas	Bucay	Campos 1960: 26
	Guayas	Posorja	Campos 1960: 26
	Guayas	Playas del Morro	Campos 1960: 26
	Guayas	Naranjal	Campos 1960: 26
	Zamora Chinchipe	Valle del Zamora	Campos 1960: 26

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	Loja	Loja	Campos 1960: 26
Ornidia obesa (Fabricius, 1775)	Esmeraldas	Telembí, Río Cavapas	Campos 1960: 27
Palpada aemula (Williston, 1891)	Ecuador		Montoya et al. 2012: supporting information, page 5: Montoya et al. 2016: 498
	Galápagos	Santa Cruz	Sinclair 2015
	Galápagos	Floreana	Sinclair et al. 2016: 81
Palpada albifrons	Galápagos	Isabela	Sinclair et al. 2016: 81
(Wiedemann, 1850)	Galápagos	Marchena	Sinclair et al. 2016: 82
	Guayas	San Eduardo	Campos 1960: 28 (as Eristalis albiceps)
Palpada atrimana (Loew, 1866)	Ecuador		Montoya et al. 2016: 496
	Napo	Tena	Morales and Marinoni 2009: 320
Palpada conica (Fabricius, 1805)	Zamora Chinchipe		Morales and Marinoni 2009: 320
Palpada cosmia (Schiner, 1868)	Ecuador		Thompson et al. 1976: 104
	Ecuador		Thompson et al. 1976: 105
Palpada erratica (Curran, 1930)	Azuay		Morales and Marinoni 2009: 332
	Sucumbíos		Morales and Marinoni 2009: 332
	Ecuador		Thompson et al. 1976: 105
Palpada fasciata (Wiedomenn, 1810)	Guayas	Guayaquil	Campos 1960: 28
(wiedemain, 1819)	Guayas	San Eduardo	Campos 1960: 28
Palpada funerea (Rondani, 1851)	Ecuador	Río Napo	Rondani 1851: 357
Palpada furcata	Pichincha	Quito	Macquart 1855: 110 (as <i>Eristalis quitensis</i> )
Wiedemann, 1819)	Ecuador		Thompson et al. 1976: 106
Palpada geniculata (Fabricius, 1805)	Guayas	Guayaquil	Campos 1960: 28 (as <i>Eristalis obsoletus</i> )
Palpada macula (Sack, 1941)	Ecuador		Thompson et al. 1976: 106
Palpada mexicana	Ecuador		Thompson et al. 1976: 110 (as Palpada
(Macquart, 1847)	Carchi	10 km SW Tulcan	testaceicornis) Thompson 1997: 232 (as Palpada eristaloides)
		(2900)	
Delta da mantinela (Dödan 1902)	Carchi	Troya (2950)	Thompson 1997: 232 (as <i>Palpada eristaloides</i> )
Paipada monticola (Roder, 1892)	Azuay	(3100)	Thompson 1997: 232 (as Palpada eristaloides)
	Napo	0°22'S 78°8'W (3500)	Thompson 1997: 232 (as Palpada eristaloides)
Palpada pusilla (Macquart 1842)	Ecuador		Thompson et al. 1976: 108
	Guayas	Durán	Campos 1960: 28 (as Eristalis tricolor)
Palpada pusio (Wiedemann, 1830)	Ecuador		Thompson et al. 1976: 108
Palpada ruficeps (Macquart, 1842)	Ecuador		Thompson et al. 1976: 108
Palpada rufiventris (Macquart, 1846)	Ecuador		Thompson et al. 1976: 108
	Napo		Morales and Marinoni 2009: 344
	Pastaza		Morales and Marinoni 2009: 344
	Guayas	Guayaquil	Campos 1960: 28
Dalta da contallanic	Guayas*	El Salado	Campos 1960: 28
(Fabricius, 1805)	Guayas	San Eduardo	Campos 1960: 28
(	Guayas	Durán	Campos 1960: 28
	Guayas	Yaguachi	Campos 1960: 28
	Guayas	Naranjito	Campos 1960: 28
	Guayas	San Rafael	Campos 1960: 28

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	Guayas	Bucay	Campos 1960: 28
Palpada scutellaris	Guayas	Posorja	Campos 1960: 28
(Fabricius, 1805)	Guayas	Isla Puná, Puerto Grande	Campos 1960: 28
	Imbabura	S Otavalo (3100– 3300)	Thompson 1999: 345
Palpada suprarufa	Napo	Papallacta (2900)	Thompson 1999: 345
Inompson, 1999	Pichincha	28 miles S Quito	Thompson 1999: 345
	Cañar	Pimo (3200)	Thompson 1999: 345
Palpada urotaenia (Curran, 1930)	Ecuador		Thompson et al. 1976: 110
	Galápagos	Española	Sinclair et al. 2016: 82
	Galápagos	San Cristóbal	Sinclair et al. 2016: 82
Palpada vinetorum	Galápagos	Santa Cruz	Linsley 1977: 39; Sinclair 2015; Sinclair et al. 2016: 82
(Fabricius, 1/99)	Ecuador		Thompson et al. 1976: 110
	Guayas	Guayaquil	Campos 1960: 28
	Guayas	San Eduardo	Campos 1960: 28
Pelecinobaccha adspersa (Fabricius, 1805)	Napo	Jatun Sacha Biol. Res. 6 km E Misahuali (450)	Miranda et al. 2014: 18
	Ecuador		Thompson et al. 1976: 12
<i>Pelecinobaccha andrettae</i> Miranda, 2014	Napo	Jatun Sacha Biol. Res. 6 km E Misahuali (450)	Miranda et al. 2014: 22
	Pastaza	Pompeya, Napo R.	Miranda et al. 2014: 24
Pelecinobaccha avispas Miranda, 2014	Napo	Coca, Napo R. (250)	Miranda et al. 2014: 26
Pelecinobaccha brevipennis (Schiner, 1868)	Napo	Coca, Napo R. (250)	Miranda et al. 2014: 30
Pelecinobaccha clarapex (Wiedemann, 1830)	Pichincha	Río Palenque Station (250)	Miranda et al. 2014: 33
Pelecinobaccha dracula (Hull, 1943)	El Oro	Piñas (1200)	Hull 1943j: 215 (as <i>Baccha nerissa</i> ); Hull 1949: 162 (as <i>Baccha nerissa</i> )
Pelecinobaccha ida (Curran, 1941)	Napo	7 km S Baeza	Miranda et al. 2014: 49
Pelecinobaccha ovipositoria (Hull, 1943)	Napo	Jatun Sacha Biol. Res. 6 km E Misahuali (450)	Miranda et al. 2014: 62
Pelecinohaccha pilipes	Sucumbíos	Limoncocha (250)	Miranda et al. 2014: 67
(Schiner, 1868)	Napo	Coca, Napo R. (250)	Miranda et al. 2014: 67
	Napo	Lago Agrio, 41 km W	Miranda et al. 2014: 78
	Orellana	Yasuni Research Stn. (250)	Miranda et al. 2014: 78
Pelecinohaccha transatlantica	Pastaza	Santa Clara	Miranda et al. 2014: 78
(Schiner, 1868)	Sucumbíos	Limoncocha (250)	Miranda et al. 2014: 78
	Zamora Chinchipe	Cumbaratza (700)	Miranda et al. 2014: 78
	Napo	Puerto Misahuallí (350)	Miranda et al. 2014: 78
	Pastaza	Pompeya, Napo R.	Miranda et al. 2014: 78
Peradon aureus (Hull, 1944)	Napo	Jatun Yacu, Rio Naxo, Watershed (700)	Hull 1944a: 36

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Platycheirus (Carposcalis)	Chimborazo	Ríobamba (2700)	Fluke 1945: 16
chalconotus (Philippi, 1865)	Azuay	Cuenca (2500)	Fluke 1945: 16
	Imbabura	Cuicocha (3200)	Fluke 1945: 16
	Azuay	Cuenca (2500)	Fluke 1945: 16
	Bolívar	Hda. Talahua (3100)	Fluke 1945: 16
	Chimborazo	Ríobamba (2700)	Fluke 1945: 16
Platycheirus (Carposcalis)	Chimborazo	Ríobamba (2800)	Fluke 1945: 16
ecuadoriensis (Fluke, 1945)	Pichincha	Uyumbicho (2650)	Fluke 1945: 16
	Pichincha	Chillo Valley, Hda. Teno (2500)	Fluke 1945: 16
	Ecuador		Fluke 1958: 265
Platycheirus (Carposcalis)	Bolívar	Hda. Talahua (3100)	Fluke 1945: 21
inflatifrons (Fluke, 1945)	Ecuador		Fluke 1958: 265
Platycheirus (Carposcalis) punctulatus (Wulp, 1888)	Ecuador	(2100–3300)	Fluke 1945: 15
Platycheirus (Carposcalis) cf. saltanus (Enderlein, 1938)	Ecuador	(4200)	Fluke 1945: 15
Platycheirus (Carposcalis) scutigera (Fluke, 1945)	Pichincha	Uyumbicho (2700)	Fluke 1945: 20
	Santa Elena	La Rinconada	Campos 1960: 24
	Chimborazo	Alausí	Campos 1960: 24
Platycheirus (Carposcalis) stegnus	Carchi	El Ángel	Campos 1960: 24
(049, 102))	Pichincha	Casitagua	Campos 1960: 24
	Carchi	Tulcán	Campos 1960: 24
	Galápagos	Baltra	Sinclair et al. 2016: 89
	Galápagos	Española	Kassebeer 2000: 83; Sinclair et al. 2016: 89
	Galápagos	Genovesa	Kassebeer 2000: 83; Sinclair et al. 2016: 89
	Galápagos	Floreana	Smith 1877: 84 (as <i>Syrphus albomaculatus</i> ); Coquillett 1901: 374; Linsley and Usinger 1966: 168; Linsley 1977: 39; Kassebeer 2000: 83; Sinclair 2015; Sinclair et al. 2016; 89
	Galápagos	Isabela	Curran 1934: 154; Linsley and Usinger 1966: 168; Linsley 1977: 39; Kassebeer 2000: 83; Sinclair 2015; Sinclair et al. 2016: 89
	Galápagos	Pinta	Sinclair et al. 2016: 89
Pseudodoros (Dioprosopa) clavatus	Galápagos	Marchena	Linsley 1977: 39; Sinclair 2015; Sinclair et al. 2016: 89
(Fabricius, 1794)	Galápagos	San Cristóbal	Curran 1934: 154; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair 2015; Sinclair et al. 2016: 89
	Galápagos	Rábida	Sinclair et al. 2016: 89
	Galápagos	Santiago	Coquillett 1901: 374; Linsley and Usinger 1966: 168; Linsley 1977: 39; Kassebeer 2000: 83
	Galápagos	Santa Fé	Sinclair et al. 2016: 89
	Galápagos	Bartolomé	Kassebeer 2000: 83
	Galápagos	Seymour Norte	Johnson 1924: 88
	Galápagos	Santa Cruz	Linsley 1977: 39; Kassebeer 2000: 83; Sinclair 2015; Sinclair et al. 2016: 89
	Galápagos		Thomson 1869 : 548 (as Baccha facialis)

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Pseudodoros (Dioprosopa) clavatus (Fabricius, 1794)	Azuay	32 km W Santa Isabel (900)	Kassebeer 2000: 85
	Manabí	Manta-Jipijapa rd. (150)	Kassebeer 2000: 85
	Zamora Chinchipe	Zamora (1500)	Kassebeer 2000: 85
	Zamora Chinchipe	Loja, San Pedro (1550)	Kassebeer 2000: 85
Pseudodoros (Dioprosopa) vockerothi (Kassebeer, 2000)	Bolívar	Chota River, Carchi (1800)	Kassebeer 2000: 76
	Imbabura	Ibarra, Yaguarcocha (2300)	Kassebeer 2000: 76
	Loja	S. Pedro-Zaruma rd Loja (850– 1100)	Kassebeer 2000: 76
	Imbabura	Taguando R., NW Ibarra (1650– 1900)	Kassebeer 2000: 76
Quichuana aff. quixotea Hull, 1946	Napo	Limoncocha	Ricarte et al. 2012: 129
	Cotopaxi	Latacunga (330)	Miranda et al. 2014: 91
Relictanum crassum (Walker, 1852)	Los Ríos	Río Palenque (150)	Miranda et al. 2014: 91
	Napo	Puerto Misahuallí (350)	Miranda et al. 2014: 91
	Sucumbíos	Limoncocha (250)	Miranda et al. 2014: 91
Relictanum johnsoni (Curran, 1934)	Napo	Coca, Napo R. (250)	Miranda et al. 2014: 93
<i>Rhingia</i> ( <i>Rhingia</i> ) <i>longirostris</i> Fluke, 1943	Bolívar	Hda. Talahua (3100)	Fluke 1943: 431
<i>Rhingia</i> ( <i>Rhingia</i> ) <i>nigra</i> Macquart, 1846	Ecuador		Montoya et al. 2016: 506
Rhinoprosopa lucifer (Hull, 1943)	El Oro	Piñas (1600)	Hull 1943j: 216
Rhinoprosopa nasuta (Bigot, 1884)	Carchi	R. Chota (2000)	Mengual 2015: 16
Rhopalosyrphus ecuadoriensis Reemer, 2013	Orellana	Yasuni Research Station	Reemer and Ståhls 2013a: 119
Salpingogaster browni Curran, 1941	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Curran 1941: 286
<i>Scaeva melanostoma</i> (Macquart, 1842)	Azuay		Thompson et al. 1976: 9
	Pichincha	2 km W Cayambe (2300)	Kassebeer 1999: 99
	Carchi	El Ángel (2700)	Kassebeer 1999: 99
	Pichincha	Valle de Machachi (2900)	Kassebeer 1999: 99
	Chimborazo	Riobamba	Campos 1960: 29; Kassebeer 1999: 99
	Chimborazo	env. of Riobamba	Kassebeer 1999: 99
Scaeva occidentalis Shannon, 1927	Pichincha	Valle de Machachi (2900)	Kassebeer 1999: 101
Sterphus (Crepidomyia) chloropyga (Schiner, 1868)	Ecuador		Schiner 1868: 366 (type-locality as "Colombien", referring to Colombia, Ecuador, or Venezeula); Montoya et al. 2016: 504

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Sterphus (Crepidomyia) plagiatus (Wiedemann, 1830)	Napo	Napo River, Coca (250)	Thompson 1973: 220
	Napo	Napo River	Thompson 1973: 220
	Pastaza	Napo River, Pompeya	Thompson 1973: 220
Sterphus (Telus) telus Thompson, 1973	Azuay	Tarqui (2800)	Thompson 1973: 198
Stipomorpha guianica	Morona Santiago	Limón Indanza (900)	Reemer 2013: 54
(Curran, 1925)	Ecuador		Thompson et al. 1976: 62
<i>Stipomorpha tenuicauda</i> (Curran, 1925)	Napo	Jatun Sacha Res., 6 km E Misahualli (450)	Reemer 2013: 70
Stipomorpha zophera Reemer, 2013	Napo	Limoncocha	Reemer 2013: 75
Syrphus aff. lacyorum Thompson, 2000	Morona Santiago	Río Blanco	Thompson et al. 2000: 39
Syrphus reedi Shannon, 1927	Zamora Chinchipe	Valle de Zamora	Campos 1960: 25
	Tungurahua	Baños (1500– 2100)	Fluke 1942: 3 (as S. willistoni)
	Tungurahua	Juive (1950)	Fluke 1942: 3 (as S. willistoni)
Syrphus shorae Fluke, 1950	Pichincha	Hda. San Rafael, Río San Pedro (2700)	Fluke 1942: 3 (as <i>S. willistoni</i> )
	Ecuador		Fluke 1950a: 143 (as S. willistoni)
Talahua fervida (Fluke, 1945)	Bolívar	Hda. Talahua (3100)	Fluke 1945: 23
	Ecuador		Fluke 1958: 266
	Ecuador		Thompson et al. 1976: 48; Mengual 2011: 9
	Pastaza	Abitagua Oriente	Gerdes 1974a: 14-15
	Tungurahua	Baños	Gerdes 1974a: 14-15
	Pastaza	Cerro Obitahua	Gerdes 1974a: 14-15
	Ecuador**	Conquista	Gerdes 1974a: 14-15
	Tungurahua	Naguazo	Gerdes 1974a: 14-15
	Napo	Napo Oriente	Gerdes 1974a: 14-15
	Pastaza	Obitahua Oriente	Gerdes 1974a: 14-15
	Morona Santiago	Río Blanco	Gerdes 1974a: 14-15
Toxomerus anthrax (Schiner, 1868)	Morona Santiago	Río Negro	Gerdes 1974a: 14-15
Toxonic nas anumax (Scinici, 1999)	Tungurahua	Runtun	Gerdes 1974a: 14-15
	Chimborazo	Sangay Oriente	Gerdes 1974a: 14-15
	Pastaza	Puerto Santana	Gerdes 1974a: 14-15
	Pastaza	Sarayacu	Gerdes 1974a: 14-15
	Pastaza	Sarayacu Oriente	Gerdes 1974a: 14-15
	Pastaza	El Topo	Gerdes 1974a: 14-15
	Pichincha	Chaupi	Gerdes 1974a: 14-15
	Tungurahua	Ulvilla	Gerdes 1974a: 14-15
	Chimborazo	Chilicay	Mengual 2011: appendix 1
	Chimborazo	Huigra	Mengual 2011: appendix 1
	El Oro	Portovelo	Mengual 2011: appendix 1

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Toxomerus antiopa (Hull, 1951)	Bolívar	Hda. Talahua (3100)	Hull 1951: 5
	Chimborazo	Urbina (3650)	Hull 1951: 5
Toxomerus aquilinus Sack, 1941	Ecuador		Metz and Thompson 2001: 233
Toxomerus arcifer (Loew, 1866)	Ecuador		Thompson et al. 1976: 48
¥	Tungurahua	Baños, Runtun trail	Hull 1943g: 20
	Imbabura	Cuicocha	Hull 1943g: 20
	Pastaza	San Francisco	Hull 1943g: 20
	Tungurahua	Juive	Hull 1943g: 20
	Tungurahua	Baños	Hull 1943g: 20; Gerdes 1974a: 19
	Azuay	Cuenca	Hull 1943g: 20
	Tungurahua	Baños	Gerdes 1974a: 19; Gerdes 1975: 20
	Pichincha	Chaupi	Gerdes 1974a: 20; Gerdes 1975: 20
	Ecuador**	Conquista	Gerdes 1974a: 20; Gerdes 1975: 20
	Pastaza	Obitagua	Gerdes 1974a: 20; Gerdes 1975: 20
	Morona	oonuguu	
<i>Ioxomerus brevifacies</i> (Hull, 1943)	Santiago	Río Blanco	Gerdes 19/4a: 20; Gerdes 19/5: 20
	Morona Santiago	Río Negro	Gerdes 1974a: 20; Gerdes 1975: 20
	Tungurahua	Runtun	Gerdes 1974a: 20; Gerdes 1975: 20
	Chimborazo	Sangay Oriente	Gerdes 1974a: 20; Gerdes 1975: 20
	Pastaza	Saravacu	Gerdes 1974a: 20; Gerdes 1975: 20
	Pastaza	Saravacu Oriente	Gerdes 1974a: 20; Gerdes 1975: 20
	Pastaza	Торо	Gerdes 1974a: 20; Gerdes 1975: 20
	Tungurahua	Ulvilla	Gerdes 1974a: 20: Gerdes 1975: 20
	Pastaza	Abitagua Oriente	Gerdes 1974a: 20; Gerdes 1975: 20
	Tungurahua	Naguazo	Gerdes 1974a: 20: Gerdes 1975: 20
	Pastaza	Puerto Santana	Gerdes 1974a: 20; Gerdes 1975: 20
	Pastaza	Río Margaritas, Río Pastaza (1250)	Hull 1942: 107
Toxomerus claracuneus (Hull, 1942)	Ecuador**	Conquista	Gerdes 1974a: 22
	Pastaza	Puerto Santana	Gerdes 1974a: 22
<i>Toxomerus crockeri</i> (Curran, 1934)	Galápagos	Floreana	Curran 1934: 155; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002; Sinclair 2015; Sinclair et al. 2016: 91
	Galápagos	Isabela	Curran 1934: 155; Linsley and Usinger 1966: 168; Linsley 1977: 39; Peck 1994; Sinclair and Peck 2002; Boada 2005: 80; Sinclair 2015; Sinclair et al. 2016: 91
	Galápagos	Pinta	Sinclair and Peck 2002
	Galápagos	San Cristóbal	Curran 1934: 155; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002;
	Galápagos	Santiago	Sinclair et al. 2016: 91 Coquillett 1901: 374 (as Mesogramma duplicata); Curran 1934: 155; Linsley and Usinger 1966: 168; Linsley 1977: 39; Sinclair and Peck 2002
	Galánagos	Fspañola	Sinclair et al. 2016: 91
	Galápagos	Pinta	Sinclair et al. 2016: 91
	Galápagos	Santa Cruz	Curran 1934: 155; Boada 2005: 85; Sinclair 2015; Sinclair et al. 2016: 91

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<i>Toxomerus dispar</i> (Fabricius, 1794)	Tungurahua	Baños	Hull 1943f: 26 (as <i>Mesogramma basilaris</i> var. bifida); Gerdes 1974a: 17		
	Napo	Napo Oriente	Gerdes 1974a: 17 (as Toxomerus basilaris)		
	Morona Santiago	Río Blanco	Gerdes 1974a: 17 (as <i>Toxomerus basilaris</i> )		
	Ecuador		Mengual 2011: 13		
	Pichincha	Pichincha	Hull 1943f: 18 (as Mesogramma arcturus)		
(Wiedemann, 1830)	Pichincha	Tío Loma	Campos 1960: 25		
(wiedemain, 1050)	Napo	Napo Oriente	Gerdes 1974a: 23		
	Azuay	Cuenca (2500)	Hull 1943g: 20		
	Tungurahua	Baños (2200)	Hull 1943g: 20		
	Pichincha	Pichincha (2500)	Hull 1943g: 20		
	Pichincha	Hda. San Rafael, Río San Pedro	Hull 1943g: 20; Gerdes 1974a: 26		
	Pichincha	Uyumbicho	Hull 1943g: 20; Gerdes 1974a: 26		
	Tungurahua	Baños, Río Pablo (2200)	Hull 1943g: 20		
	Tungurahua	Baños, Runtun	Hull 1943g: 20		
Toursenance and annua (Hull 10/2)	Chimborazo	Ríobamba (2700)	Hull 1943g: 20		
<i>Ioxomerus ecuadoreus</i> (Hull, 1943)	Pichincha	Aloag	Gerdes 1974a: 26; Gerdes 1975: 22		
	Tungurahua	Baños	Gerdes 1975: 22		
	Pastaza	Obitagua	Gerdes 1974a: 26; Gerdes 1975: 22		
	Morona Santiago	Río Blanco	Gerdes 1974a: 26; Gerdes 1975: 22		
	Pichincha	Chaupi	Gerdes 1974a: 26		
	Tungurahua	Ulvilla	Gerdes 1974a: 26		
	Morona Santiago	Río Negro	Gerdes 1974a: 26; Gerdes 1975: 22		
	Tungurahua	Runtun	Gerdes 1974a: 26; Gerdes 1975: 22		
	Pastaza	Cerro Obitahua	Gerdes 1974a: 31		
	Napo	Napo Oriente	Gerdes 1974a: 31		
	Pastaza	Puyo Oriente	Gerdes 1974a: 31		
	Chimborazo	Sangay Oriente	Gerdes 1974a: 31		
	Pastaza	1.5 km S Puyo, Río Pido Grande	Mengual 2011: appendix 1		
	Tungurahua	32 km E Baños (1560)	Mengual 2011: appendix 1		
	Napo	Tena	Mengual 2011: appendix 1		
Toxomerus flaviplurus (Hall, 1927)	Napo	Santa Cecilia	Mengual 2011: appendix 1		
	Napo	60 km W LagoAgRío	Mengual 2011: appendix 1		
	Napo	Limoncocha	Mengual 2011: appendix 1		
	Zamora Chinchipe	Zumbi	Mengual 2011: appendix 1		
	Zamora Chinchipe	Cumbaratza	Mengual 2011: appendix 1		
	Zamora Chinchipe	Yantzaza	Mengual 2011: appendix 1		
<i>Toxomerus floralis</i> (Fabricius, 1789)	Ecuador		Thompson and Thompson 2007: 324		
	Napo	Napo Oriente	Gerdes 1974a: 35		
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	Tungurahua	Baños	Gerdes 1974a: 37; Mengual 2011: appendix 1		
	Ecuador		Thompson et al. 1976: 51; Mengual 2011: 16		
-	Pastaza	Cerro Obitahua	Gerdes 1974a: 37		
	Pastaza	Obitahua Oriente	Gerdes 1974a: 37		
Toxomerus hieroglyphicus	Morona	D/ DI	C 1 1074 27		
(Schiner, 1868)	Santiago	Rio Blanco	Gerdes 19/4a: 3/		
	Tungurahua	Runtun	Gerdes 1974a: 38		
	Chimborazo	Sangay Oriente	Gerdes 1974a: 38		
	Pastaza	Abitagua Oriente	Gerdes 1974a: 38		
	Ecuador**	Conquista	Gerdes 1974a: 38		
	Pastaza	Puyo (1000)	Hull 1951: 12; Hull 1951: 13 (as <i>Mesogramm</i> <i>idalia leda</i> )		
Toxomerus idalius (Hull, 1951)	Pastaza	Río Pastaza, San	Hull 1951: 13 (as Mesogramma idalia leda);		
	I dStdZd	Francisco (1200)	Hull 1951: 18 (as Mesogramma eurydice)		
	Ecuador		Thompson et al. 1976: 50 (as <i>T. elongatus</i> );		
			Metz and Thompson 2001: 235		
	Tunguranua	Baños	Gerdes 19/4a: 29 (as <i>Toxomerus elongatus</i> )		
Toxomerus insignis (Schiner, 1868)	Napo	Napo Oriente	Gerdes 19/4a: 29 (as <i>Toxomerus elongatus</i> )		
Townerus usignis (Seinner, 1000)	Tungurahua	Ulvilla	Gerdes 1974a: 29 (as <i>Toxomerus elongatus</i> )		
	Pastaza	Abitagua	Gerdes 1974a: 29 (as <i>Toxomerus elongatus</i> )		
	Pastaza	Sarayacu	Gerdes 1974a: 29 (as Toxomerus elongatus)		
	Pastaza	Abitagua	Gerdes 1974a: 29 (as Toxomerus elongatus)		
	Napo	Napo Oriente	Gerdes 1974a: 40		
	Pastaza	Obitahua Oriente	Gerdes 1974a: 40		
Toxomerus lacrymosus (Bigot, 1884)	Nariño [Colombia]**	Piedrancha	Gerdes 1974a: 40		
	Chimborazo	Sanqay Oriente	Gerdes 1974a: 40		
	Pastaza	Sarayacu	Gerdes 1974a: 40		
Toxomerus laenas (Walker, 1852)	Ecuador		Thompson et al. 1976: 53 (as <i>T. nitidiventris</i> )		
Toxomerus marginatus (Say, 1823)	Cañar- Chimborazo	Quinua-Loma	Campos 1960: 25		
	Pichincha	Casitagua	Campos 1960: 26		
	Carchi	El Vínculo	Campos 1960: 26		
	Azuay	Borma	Campos 1960: 26		
	Santa Elena	La Rinconada	Campos 1960: 26		
<i>Toxomerus minutus</i> (Wiedemann, 1830)	Cañar- Chimborazo	Quinua-Loma	Campos 1960: 26		
	Santo Domingo de los Tsáchilas	Santo Domingo de los Colorados	Campos 1960: 26		
	Carchi	Tulcán	Campos 1960: 26		
	Loja	Loja	Campos 1960: 26		
	Pichincha	Uyumbicho (2700)	Hull 1951: 8 (as Mesogramma ultima)		
	Tungurahua	Baños (2500)	Hull 1943c: 36 (as Mesogramma sylpha)		
	Tungurahua	Baños (1800)	Hull 1943c: 36 (as Mesogramma sylpha)		
Toxomerus nasutus Sack, 1941	Tungurahua	Baños	Gerdes 1975: 14		
	Pichincha	Chaupi	Gerdes 1974a: 42; Gerdes 1975: 14		
	Ecuador**	Conquista	Gerdes 1974a: 42; Gerdes 1975: 14		
	Tungurahua	Naguazo	Gerdes 1974a: 42; Gerdes 1975: 14		
	Napo	Napo Oriente	Gerdes 1974a: 42; Gerdes 1975: 14		

Species	Province	Locality (Altitude masl)	References for Ecuador	
	Pastaza	Obitagua	Gerdes 1974a: 42; Gerdes 1975: 14	
	Pastaza	Obitahua	Gerdes 1974a: 42; Gerdes 1975: 14	
-	Pastaza	Abitagua Oriente	Gerdes 1974a: 42	
	Pastaza	Cerro Obitahua	Gerdes 1974a: 42	
	Manabí*	San José	Gerdes 1974a: 42	
	Tungurahua	El Topo	Gerdes 1974a: 43	
	Morona Santiago	Río Blanco	Gerdes 1974a: 42; Gerdes 1975: 14	
Toxomerus nasutus Sack, 1941	Morona Santiago	Río Negro	Gerdes 1974a: 42; Gerdes 1975: 14	
	Tungurahua	Runtun	Gerdes 1974a: 42; Gerdes 1975: 14	
	Tungurahua*	El Salado	Gerdes 1974a: 42; Gerdes 1975: 14	
	Chimborazo	Sangay	Gerdes 1974a: 43; Gerdes 1975: 14	
	Pastaza	Puerto Santana	Gerdes 1974a: 43; Gerdes 1975: 14	
	Pastaza	Sarayacu	Gerdes 1974a: 43; Gerdes 1975: 14	
	Pastaza	Sarayacu Oriente	Gerdes 1974a: 43; Gerdes 1975: 14	
	Pichincha*	Yunguilla	Gerdes 1974a: 44; Gerdes 1975: 14	
Toxomerus norma (Hull, 1941)	Ecuador		Thompson et al. 1976: 52 (as <i>T. mulio</i> ); Metz and Thompson 2001: 239 (as <i>T. mulio</i> )	
	Pastaza	Río Margaritas (1250)	Hull 1942: 106	
	Morona Santiago	Sucúa, Río Blanco (950) Hull 1942: 106		
	Pastaza	Puyo	Hull 1942: 106	
Toxomerus nymphalius (Hull 1942)	Pastaza	Río Mapeto Hull 1942: 106		
10x0mitras nymphanas (11un, 1912)	Pastaza	Cerro Obitahua Gerdes 1974a: 46		
	Pastaza	staza Obitahua Oriente Gerdes 1974a: 46		
	Chimborazo	Sangay Oriente	Gerdes 1974a: 46	
	Pastaza	Sasayacu Oriente	Gerdes 1974a: 46	
	Pichincha*	Yunguilla	Gerdes 1974a: 46	
Toxomerus parvulus (Loew, 1866)	Ecuador		Thompson et al. 1976: 55 (as T. slossonae)	
Toxomerus pichinchae Gerdes, 1974	Pichincha	Aloag (2600)	Gerdes 1974b: 280	
	Pastaza	Cerro Obitahua	Gerdes 1974a: 48	
Toxomerus pictus (Macquart, 1842)	Chimborazo	Sangay Oriente	Gerdes 1974a: 48	
	Napo	Napo Oriente	Gerdes 1974a: 49	
Toxomerus picudus Mengual, 2011	Orellana	Estación Tiputini (227)	Mengual 2011: 21	
	Galápagos	Floreana	Sinclair 2015	
	Galápagos	Isabela	Sinclair 2015	
	Galápagos	Santa Cruz	Sinclair et al. 2016: 93	
Toxomerus politus (Sav. 1823)	Galápagos	San Cristóbal	Sinclair 2015	
	Galápagos	Santiago	Sinclair et al. 2016: 93	
	Tungurahua	gurahua Baños Gerdes 1974a: 51		
1 ()	Napo	Napo Oriente	Gerdes 1974a: 51	
	Nariño [Colombia]**	Piedrancha	Gerdes 1974a: 51	
	Pastaza	Sarayacu	Gerdes 1974a: 51	
	Ecuador		Thompson et al. 1976: 53; Metz and Thompson 2001: 241	
Toxomerus porticola (Thomson, 1869)	Ecuador		Thompson et al. 1976: 54	

Species	Province Locality (Altitude masl)		References for Ecuador	
	Morona	Macas, Río Upano	Hull 1951: 10 (as Mesogramma cyrilla)	
-	Ecuador	(1000)	Curran 1930: 5	
	Napo	Napo Oriente	Gerdes 1974a: 53: Gerdes 1975: 16	
	Pastaza	Obitahua	Gerdes 1974a: 53: Gerdes 1975: 16	
	Chimborazo	Sangay	Gerdes 1974a: 53; Gerdes 1975: 16	
Toxomerus productus	Pastaza	Sarayacu	Gerdes 1974a: 53; Gerdes 1975: 16	
(Curran, 1930)	Pastaza	Sarayacu	Gerdes 1974a: 54; Gerdes 1975: 16	
	Tungurahua	Baños	Gerdes 1974a: 54; Gerdes 1975: 16	
	Pastaza	Obitagua	Gerdes 1974a: 54; Gerdes 1975: 16	
	Morona Santiago	Río Negro	Gerdes 1974a: 54; Gerdes 1975: 16	
	Tungurahua	Runtun	Gerdes 1974a: 54; Gerdes 1975: 16	
	Pastaza	Sarayacu Oriente	Gerdes 1974a: 54; Gerdes 1975: 16	
<i>Toxomerus rombicus</i> (Giglio- Tos, 1892)	Azuay	Cuenca	Campos 1960: 25	
	Ecuador		Thompson et al. 1976: 50 (as <i>T. flavus</i> ), 54; Metz and Thompson 2001: 246	
	Tungurahua	Baños	Gerdes 1974a: 33 (as Toxomerus flavus)	
	Ecuador**	Conquista	Gerdes 1974a: 34 (as Toxomerus flavus)	
Toxomerus sathiridicets	Morona Santiago	nna Río Blanco Gerdes 1974a: 34 (as <i>Toxomerus fi</i>		
(Bigot, 1884)	Manabí*	San José	Gerdes 1974a: 34 (as Toxomerus flavus)	
	Nariño [Colombia]**	Piedrancha	Gerdes 1974a: 34 (as <i>Toxomerus flavus</i> )	
	Tungurahua	Runtun	Gerdes 1974a: 34 (as Toxomerus flavus)	
	Pastaza	Pastaza Sarayacu Gerdes 1974a: 34 (as <i>Toxome</i>		
	Los Ríos	Soledad	Gerdes 1974a: 34 (as Toxomerus flavus)	
Toxomerus sp.	Galápagos	Santa Cruz	Boada 2005: 86	
	Guayas	San Eduardo	Campos 1960: 26	
Toxomerus sp.	Guayas	Guayaquil	Campos 1960: 26	
	Guayas	Durán	Campos 1960: 26	
	Morona Santiago	Sucúa, Río Blanco and Río Upano (950)	Hull 1943f: 21 (as Mesogramma steatornis)	
Toxomerus steatogaster (Hull, 1941)	Pastaza	Puyo (1000)	Hull 1943f: 21 (as Mesogramma steatornis)	
	Napo	Napo Oriente	Gerdes 1974a: 55	
	Ecuador		Thompson et al. 1976: 55	
	Tungurahua	Baños	Hull 1943c: 35; Gerdes 1974a: 57	
	Pastaza	Cerro Obitahua	Gerdes 1974a: 57	
Toxomerus sylvaticus (Hull, 1943)	Pastaza	Obitahua Oriente	Gerdes 1974a: 57	
	Morona Santiago	Río Blanco	Gerdes 1974a: 57	
	Chimborazo	Sanqay Oriente	Gerdes 1974a: 57	
	Pichincha	Chaupi	Gerdes 1974a: 57	
Toxomerus tibicen (Wiedemann, 1830)	Guayas	Guayaquil, San Eduardo	Campos 1960: 25	
Toxomerus tubularius (Hull, 1942)	942) Tungurahua Baños (2000) Hull 1942: 104		Hull 1942: 104	

Species	Province Locality (Altitude masl)		References for Ecuador	
<i>Toxomerus virgulatus</i> (Macquart, 1850)	Ecuador		Thompson et al. 1976: 49 (as <i>T. confusus</i> )	
Toxomerus watsoni (Curran, 1930)	Ecuador		Thompson et al. 1976: 56	
Tuberculanostoma antennatum	Bolívar	Talahua (3100)	Fluke 1943: 426	
Fluke, 1943	Ecuador		Fluke 1958: 266	
	Chimborazo	Urbina (3650)	Fluke 1943: 429	
<i>Tuberculanostoma browni</i>	Bolívar	Hda. Talahua (3100)	Fluke 1943: 430	
Fluke, 1743	Bolívar	Cumbre de Tililac (4200)	Fluke 1943: 430	
<i>Tuberculanostoma cilium</i> Fluke, 1943	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1943: 428	
	Bolívar	Hda. Talahua (3100)	Fluke 1943: 428	
<i>Tuberculanostoma pectinis</i> Fluke, 1943	Bolívar	Hda. Talahua (3100)	Fluke 1943: 430	
Ubristes ictericus Reemer, 2013	Sucumbíos	Sach Lodge (270)	Reemer 2013: 80	
	Bolívar	Hda. Talahua (3100)	Fluke 1945: 22	
Xanthandrus (Xanthandrus) palliatus (Fluke, 1945)	Tungurahua	Volcán Tungurahua, Minza Chica (3200)	Fluke 1945: 22	

Some original locality names were difficult to place in the current administrative divisions of Ecuador. The Río Pastaza (= Pastaza river) runs through two Ecuadorian provinces, i.e. Pastaza and Morona Santiago, and we used Pastaza province for this locality. On the other hand, Quinua Loma is a locality situated between two provinces, Cañar and Chimborazo, and we listed both provinces in Table 1.

Most of the uncertainties on geographical localities come from Gerdes (1974a). For instance, Gerdes (1974a) named three localities as different ones, i.e. Obitagua, Obitahua, and Abitagua, although we believe that they might refer to the same area. There is a single locality named Abitagua in Ecuador, but instead of assuming all being the same locality, we left the three names in Table 1. We are not sure if the locality San José (Gerdes 1974a) is the one currently situated in Manabí, and there are two localities named El Salado in Guayas (between 0 and 200 masl) and in Tungurahua (circa 2,000 masl). We listed El Salado in Guayas for the records of Campos (1960), as most of the records in that work were from Guayas, but we used Tungurahua for El Salado of Gerdes (1974a, 1975) for the record of *Toxomerus nasutus* Sack, 1941 because other records for this species are close to or over 2,000 masl. We had a similar problem with Yunguilla, a locality also found in two different provinces (Azuay and Pichincha), and we used Pichincha in

this case because Gerdes had studied material from Pichincha but not from Azuay. All these records are marked with an asterisk (\*) in the Province column of Table 1.

The locality Piedrancha belongs to Colombia (Nariño department), but it was left in Table 1 because Gerdes (1974a) listed it as Ecuador. Finally, we were not able to locate Conquista in Ecuador. These records are marked with two asterisks (\*\*) in the Province column of Table 1.

For the elaboration of Tables 1 and 2, the most recent Syrphidae classification has been used (Mengual et al. 2008, 2009, Thompson 2012, 2013, Reemer and Ståhls 2013a, Miranda et al. 2014, 2016, Mengual 2015). Flower fly species recorded in Ecuador are listed in Table 1 in alphabetical order. Genera with the highest number of species were *Toxomerus* (38), *Ocyptamus* (22) and *Palpada* (21) (Table 2).

Four unidentified species are listed as such (*Microdon* sp., *Ocyptamus* sp. and two *Toxomerus* sp.), and three species are *affinis* to known species, *Dasysyrphus* aff. *lotus*, *Syrphus* aff. *lacyorum* and *Quichuana* aff. *quixotea*. Ricarte et al. (2012) reviewed the taxonomy of the genus *Quichuana* Knab, 1913 and mentioned one *Quichuana* species recorded for Ecuador (Ricarte et al. 2012: 129, Figure 84). The identity of this species was not stated by Ricarte et al. (2012), but personal communication with A. Ricarte revealed that it is *Quichuana* aff. *quixotea* (Hull 1946). Four specimens from Ecuador labelled as *Q. quixotea* are known to be deposited in the USNM collection. However, they show some morphological differences with the holotype that prevented Ricarte et al. (2012) to ascertain their identity (Antonio Ricarte, pers. comm.).

There was some ambiguity with *Peradon oligonax* (Hull, 1944) to either include it or not in the checklist. *Peradon oligonax* was described from Pto. America, Río Putumayo (Hull 1944c). Thompson et al. (1976: 66) indicated the type-locality as part of Ecuador, but Hull (1944c: 36) listed it as Brazil. Putumayo River forms part of Colombia's border with Ecuador, as well as most of the frontier with Peru, and it ends as a tributary of the Amazon River in Brazil, but there it is known as Içá. Rasmussen (2016) gave details of the Cornell University expedition to South America (collectors of the type material) and he provided evidences that the expedition never went to Ecuador and the expedition was near Javary island (Santo Antônio do Içá) in the dates when the type material was collected. Thus, the type-locality is in Brazil and not in Ecuador, as indicated by Thompson et al. (1976).

Another uncertain taxon was *Priomerus gagathinus* Bigot, 1887, originally described from Loja. Thompson et al (1976) declared the type of this taxon as lost and did not recognize the species. Thompson (2015) indicated that the name *Priomerus* was preoccupied and its species currently belong to four different genera. He did not recognize either the species *gagathinus* Bigot. Thus, we did not list this species in Table 1.

In the literature, we found two doubtful species records, probably due to a misidentification. *Sphaerophoria (Sphaerophoria) sulphuripes* (Thomson, 1869) is a Nearctic species found along the west coast of the United States and Canada (Knutson 1973). Thompson et al. (1976: 38) listed one specimen identified as *S. sulphuripes* (with no details about the responsible of this identification) in The Natural History Museum

Genus	Number of species in Ecuador			
Alipumilio Shannon, 1927	1			
Allograpta Osten Sacken, 1875	9			
Argentinomyia Lynch Arribalzaga, 1891	10			
Claraplumula Shannon, 1927	1			
Copestylum Macquart, 1846	19			
Dasysyrphus Enderlein, 1938	1			
Dolichogyna Macquart, 1842	2			
Eosalpingogaster Hull, 1949	1			
Eristalis Latreille, 1804	1			
Eupeodes Osten Sacken, 1877	1			
Fazia Shannon, 1927	12			
Hypselosyrphus Hull, 1937	1			
Leucopodella Hull, 1949	4			
Lycastrirhyncha Bigot, 1859	1			
Mallota Meigen, 1822	3			
Meromacrus Rondani, 1848	3			
Meropidia Hippa & Thompson, 1983	1			
Microdon Meigen, 1803	3			
Mixogaster Macquart, 1842	1			
Ocyptamus Macquart, 1834	22			
Ornidia Lepeletier & Serville, 1828	2			
Palpada Macquart, 1834	21			
Pelecinobaccha Shannon, 1927	10			
Peradon Reemer, 2013	1			
Platycheirus Lepeletier & Serville, 1828	7			
Pseudodoros Becker, 1903	2			
<i>Quichuana</i> Knab, 1913	1			
Relictanum Miranda, 2014	2			
Rhingia Scopoli, 1763	2			
Rhinoprosopa Hull, 1942	2			
Rhopalosyrphus Giglio-Tos, 1891	1			
Salpingogaster Schiner, 1868	1			
Scaeva Fabricius, 1805	2			
Sterphus Philippi, 1865	3			
Stipomorpha Hull, 1945	3			
Syrphus Fabricius, 1775	3			
Talahua Fluke, 1945	1			
<i>Toxomerus</i> Macquart, 1855	38			
Tuberculanostoma Fluke, 1943	4			
Ubristes Walker, 1852	1			
Xanthandrus Verrall, 1901	1			

**Table 2.** Number of genera and species registered in Ecuador.

(BMNH, London, U.K.) from Ecuador with a question mark. This specimen might be mislabeled or it could be an *Allograpta* specimen, most likely a female, somehow similar to *S. sulphiripes*. We believe that *S. sulphuripes* does not occur in Ecuador and it was not included in Table 1. The other taxon that was misidentified is *Eristalis* (*Eoseristalis*) pertinax (Scopoli, 1763), identified by Campos (1960). This species ranges from Fennoscandia south to Iberia and the Mediterranean, and from Ireland through much of Europe into European parts of Russia and Turkey; apparently it is not known beyond the Urals (Speight 2016). We do believe that the record might be an *Eristalis* species, but not *E. pertinax* as it does not occur in the Neotropics. Thus, this record is not listed in Table 1.

Three species are not listed due to the uncertainty of their taxonomic identity. *Syrphus excavatus* (Rondani 1851: 359) and *Syrphus fasciventris* (Rondani 1851: 360), both described from Río Napo, are not included because the type material was not studied and the generic name is probably incorrect. The third species not included is *Xanthandrus* sp. (Curran 1934: 155; from Pinta Island, Galapagos). Sinclair et al. (2016) could not find the material studied by Curran to confirm if the specimen from Galapagos is truly *Xanthandrus* or *Argentinomyia agonis* (Walker 1849).

#### Discussion

Montoya et al. (2012) recorded 128 species of 40 different genera for Ecuador, indicating that Ecuador shares a high number of species with Brazil (29 species), Colombia (50) and Peru (29). The present work raises those numbers considerably, up to 201 identified species of 51 genera and subgenera. Based on previous studies, the Ecuadorian diversity of flower flies is comparable to the one from Peru (195 spp., 75 genera; Montoya et al. 2012), Costa Rica (228 species, 41 genera; Montoya et al. 2012) or Suriname (183 species, 36 genera; Reemer 2016). It is important to emphasize that Ecuador is one of the smallest countries in the Neotropics and South America, but it has one of the highest diversity densities for the Neotropics with ca. 7.2 species per 10.000 km2. This diversity density makes Ecuador the third top country after Costa Rica and Suriname, the two most explored and well-studied faunae in the Neotropics. It must also be pointed out that the present work is based only on records from the literature, and authors are sure that the flower fly diversity in Ecuador is higher.

This study confirms the argument of Montoya et al. (2012) when stating that "The understanding of the distribution and composition of Syrphidae in the Neotropical Region remains far from complete". Since Thompson et al. (1976) there have been mostly taxonomic contributions on the Neotropical flower flies, but little faunistic studies have been published. Thompson (1999) provided a key to the Neotropical genera of Syrphidae, including a glossary of taxonomic terms and the description of a few new species, and Thompson (2006) compiled all the taxonomic knowledge of Neotropical flower flies up to that date, but those cannot be considered faunistic studies. In the *Systema Dipterorum*, Thompson (2013) had some distributional range notes for each species, but the fauna of the Neotropical countries has not been studied more thoroughly yet. The

syrphid fauna of three Neotropical countries have been recently revised: a catalogue for Colombia (Montoya 2016, see also Gutierrez et al. 2005), another online catalogue for Brazil (Morales and Marinoni 2017), and an extensive taxonomic study of the flower flies of Suriname (Reemer 2010, 2014, 2016). In addition, Thompson et al. (2010) gave a very comprehensive synopsis of the Central American Syrphidae.

Thompson et al. (2010) stated that ca. 1,800 flower fly species are described from the Neotropical Region, but other authors argue that this may be only half of the actual number of species (Reemer 2016). Thus, Ecuadorian syrphid fauna comprises roughly 11.2% of the described Neotropical species. Emulating the arguments of Reemer (2016), the syrphid fauna of Ecuador might be two to four times larger, up to 900 species, if we compare the known species of other taxa in this country with the total number of species in the Neotropical Region. Cárdenas et al. (2009) estimated that Ecuador has 16.3% of the Neotropical species of the family Tabanidae (Diptera). Mittermeier et al. (2005) calculated that the bird species present in Ecuador are ca. 47% of the total number of species in the Neotropics. With an estimate of 4,000 species of butterflies (Salazar and Donoso 2014, M. Espeland pers. comm.), Ecuador probably hosts half of the Neotropical diversity of this order. In other words, considering these numbers and the fact that Syrphidae is underexplored in Ecuador (Amorim 2009), we are far from having a good estimate of the total number of flower fly species for Ecuador.

We think that the inventory and study of the Syrphidae fauna are essential not only to describe new species from Ecuador, but also to help in the selection of areas to protect, based on species richness, and to improve the management of conservation areas in this country. Salazar and Donoso (2014) mentioned that the taxonomic complexity, the lack of experts for some groups, the high species richness, and the endemicity of many invertebrates in Ecuador make the study of its invertebrate fauna a major challenge in science. Moreover, Ecuador has two biodiversity hotspot regions: Tropical Andes and Tumbes-Chocó-Magdalena (Myers et al. 2000, Mittermeier et al. 2004). These regions are heavily threatened and need urgent conservation efforts. In such cases, faunistic studies should have priority to understand the biological diversity of those hotspots. Furthermore, the poor knowledge of the relationships between flower flies and their prey, as well as the unknown associations with host plants, make the study of this group essential 1) to improve our understanding about their roles in the ecosystem performance and organic matter decomposition, 2) to evaluate the biological richness of Ecuador in order to establish new management and control protocols over its natural resources, and 3) to revise the quarantine and international trade policies for preventing potential pest species dispersal and creating new banned species list.

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CORRIGENDA



# Corrigenda: Ješovnik A, Schultz TR (2017) Revision of the fungus-farming ant genus Sericomyrmex Mayr (Hymenoptera, Formicidae, Myrmicinae). ZooKeys 670: 1–109. https://doi.org/10.3897/zookeys.670.11839

Ana Ješovnik<sup>1,2</sup>, Ted R. Schultz<sup>1,2</sup>

I Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia, United States of America 2 Maryland Center for Systematic Entomology, Department of Entomology, University of Maryland, College Park, Maryland, United States of America

Corresponding author: Ana Ješovnik (ana.mrav@gmail.com), Ted R. Schultz (schultzt@si.edu)

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In our recent revision (Ješovnik and Schultz 2017) of the ant genus *Sericomyrmex*, we failed to address the taxonomic standing of the subspecies *S. opacus muelleri* Forel, 1912. Even though we examined the type specimen, measured it, and included it in Suppl. material 1: Table S2, we did not include it in our synonymy list because *S. opacus muelleri* was described as a variety (Forel 1912) and not as a subspecies. However, it has subsequently been brought to our attention that, according to International Code of Zoological Nomenclature Articles 45.5 and 45.6 (International Commission on Zoological Nomenclature 1999), if a variety was described before 1961 it should be treated as a subspecies. We therefore here correct the relevant portions of the abstract, taxonomic synopsis for the genus, detailed taxonomic synopsis for the species, and notes section of *S. mayri*, as well as Suppl. material 1: Table S2.

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#### Corrected "Abstract" (p. 1):

The following species and subspecies are synonymized: under *S. opacus* [=*S. aztecus* Forel **syn. n.**, *S. zaca-panus* Wheeler **syn. n.**, and *S. diego* Forel **syn. n.**]; under *S. bondari* [=*S. beniensis* Weber **syn. n.**]; under *S. mayri* [=*S. opacus muelleri* Forel **syn. n.**, =*S. luederwaldti* Santschi **syn. n.**, *S. moreirai* Santschi **syn. n.**, *S. harekulli* Weber **syn. n.**, *S. harekulli arawakensis* Weber **syn. n.**, *S. urichi* Forel **syn. n.**]; under *S. saus-surei* [=*S. burchelli* Forel **syn. n.**, *S. impexus* Wheeler **syn. n.**, *S. urichi maracas* Weber **syn. n.**]; and under *S. parvulus* [=*S. myersi* Weber **syn. n.**].

#### Corrected "Taxonomic synopsis" for the genus (p. 31):

Sericomyrmex mayri Forel, 1912, Colombia to Bolivia and Brazil (w, q, m, l).

- =Sericomyrmex opacus muelleri Forel, 1912, syn. n.
- =Sericomyrmex urichi Forel, 1912, syn. n.
- =Sericomyrmex luederwaldti Santschi, 1925, syn. n.

=Sericomyrmex moreirai Santschi, 1925, syn. n.

=Sericomyrmex harekulli Weber, 1937, syn. n.

=Sericomyrmex harekulli arawakensis Weber, 1937, syn. n.

Corrected detailed taxonomic synopsis for the species (pp. 61-62):

#### Sericomyrmex mayri Forel, 1912

Figures 36, 37, 38 (Worker); Figure 39 (Queen and male); Figure 40 (Larva); Figure 41 (Map)

- Sericomyrmex mayri Forel, 1912: 194. Lectotype worker (here designated): BRAZIL, Rio de Janeiro, Niterói, [-22.8751, -43.2775], ANTC31816, A. Forel, (MHNG: 1w, CASENT0909370). Paralectotypes: same data as lectotype (MHNG: 1w, US-NMENT00445567; 3m, USNMENT00445580).
- *=Sericomyrmex opacus muelleri* Forel, 1912, **syn. n.** Type material examined: BRAZIL, ANTC31817, A. Forel, (MHNG: 1q, CASENT0909371).
- *=Sericomyrmex urichi* Forel, 1912: 193. **syn. n.** Type material examined: TRINIDAD AND TOBAGO, ANTC31818, F. W. Urich (MHNG: 3w, CASENT0909372).
- *=Sericomyrmex luederwaldti* Santschi, 1925: 15. **syn. n.** Type material examined: BRAZIL, Minas Gerais, Pirapora, [-17.355, -44.9447], ANTC35978, ANTC25817, E. Garbe (NHMB: 5w, CASENT0912516) (MSNG: 1w, CASENT0904989).
- *=Sericomyrmex moreirai* Santschi, 1925: 16. **syn. n.** Type material examined: BRAZIL, Rio de Janeiro, [-22.8751, -43.2775], ANTC35979, Moreira (MCZ: 2w, MCZ 1-2 21140) (NHMB: 3w, CASENT0912517; 2w, USNMENT01126231; 2q, USNMENT01126232).

- =Sericomyrmex harekulli Weber, 1937: 398. syn. n. Type material examined: GUY-ANA, East Berbice-Corentyne, Oronoque River, [2.75, -57.4167], NAW598, 27 Jul 1936, N. A. Weber (USNM: 1w, USNMENT00529483) (MCZ: 2w, USN-MENT00924104; 2w, USN- MENT00924105)
- Sericomyrmex harekulli arawakensis Weber, 1937: 399. syn. n. Type material examined: GUYANA, Cuyuni-Mazaruni, Mazaruni River, Forest Settlement, [6.39733, -58.6781], 10 m, NAW 277, 15 Aug 1935, N. A. Weber (MCZ: 2w, MCZ 23051; 2w, 1q, USNMENT00924106)

Corrected "Synonymy" section in the "S. mayri notes" section (pp. 68-69):

The examined syntypes of S. luederwaldti, S. harekulli, and S. harekulli arawakensis conform to typical S. mayri morphology. Their original authors (Forel 1912, Santschi 1925, Weber 1937) focus on slight differences in mesosomal tubercles, head shape, and scape length, all of which are variable within *mayri*. Likewise, the subspecies S. opacus muelleri, described from a single queen specimen by Forel, is a typical mayri queen, both in morphological characters and measurements. The moreirai syntypes have the cephalic emargination less pronounced than in the mayri lectotype, but this difference is encompassed by the range of variation in *mayri* as here defined. In his description of S. moreirai, Santschi (1925) calls it the "neighbor" of mayri, but says it is "much more stocky." He also compares moreirai with urichi and reports small differences in pilosity and mesosomal tubercles, both of which fall within the variation observed in S. mayri. The syntypes of urichi we examined, unlike the *mayri* lectotype, have almost completely smooth mandibles, but, as discussed above, smooth mandibles are encountered in some *mayri* populations, especially those from Trinidad and Tobago, the type locality of urichi. In all other characters and measurements, urichi clearly agrees with S. mayri. In his description Forel (1912) distinguished *mayri* and *urichi* by complete versus incomplete frontal carinae and by the depth of the cephalic emargination, but he does not mention striate vs. smooth mandibles. Again, the cited differences (depth of the emargination, length of the frontal carinae, and degree of mandibular sculpture) fall within the range of observed intraspecific variation in S. mayri as here defined.

Corrected Suppl. material 2: Table S2 (sheet d Type specimens):

Genus	Species	Туре	Pins	Institution	Specimen code	Coll. code	Collector	Country
Sericomyrmex	mayri	<i>opacus muelleri</i> holotype	1pin, 1q	MHNG	CASENT0909371	ANTC31817	A. Forel	Brazil

## Acknowledgements

We would like to thank Barry Bolton for bringing the mistaken omission of *S. opacus muelleri* to our attention.

## Supplementary material I

# Table S2. Full list of measured, imaged, and type specimens; localities for all specimens examined; and full statistics for morphological measurements.

Authors: Ana Ješovnik, Ted R. Schultz

Data type: specimens measurements

Explanation note:

- a) Measured specimens. All workers measured for this study, with all measurements in millimeters.
- **b)** Measured specimens. All queens and males measured for this study, with all measurements in millimeters.
- c) Imaged specimens. Specimen data for all figures.
- d) Type specimens. Specimen data for type specimens examined in this study.
- e) Statistics for all measurements and indices for each species.
- **f**) **Localities list**. A list of localities and other specimen data for all pinned specimens examined.
- **g**) *S. mayri* **populations.** A list of localities and other specimen data for specimens used to create the *S. mayri* population map (Figure 42). This map is based on the subset of *S. mayri* samples for which molecular data (either UCE or COI) were obtained.
- 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.

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CORRIGENDA



# Corrigenda: Revision of the Neotropical green lacewing genus Ungla (Neuroptera, Chrysopidae). ZooKeys 674: I-188. https://doi.org/10.3897/zookeys.674.11435

Catherine A. Tauber<sup>1</sup>, Francisco Sosa<sup>2</sup>, Gilberto S. Albuquerque<sup>3</sup>, Maurice J. Tauber<sup>1,†</sup>

I Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853-2601 and Department of Entomology, University of California, Davis, CA, USA 95616 2 Museo Entomológico "Dr. José Manuel Osorio" (MJMO), Universidad Centroccidental "Lisandro Alvarado", Venezuela 3 Laboratório de Entomologia e Fitopatologia, CCTA, Universidade Estadual do Norte Fluminense, Campos dos Goytacazes, RJ, Brazil 28013-602

Corresponding author: Catherine A. Tauber (cat6@cornell.edu)

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After the publication of our article, we noted that we had neglected to list one of two specimens that we had examined during the description of the new species *Ungla mexicana* Tauber. In addition, in the figure captions, we reported the location of the holotype depository in error. Corrections are as follows:

Page 82, line 6: The paragraph under "Holotype" should read:

"We examined only two female specimens of this species, and we were reluctant to describe it as new on the basis of such limited material. However, the specimens

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<sup>†</sup> Deceased

are very well preserved, and the external features (head and body coloration and markings, wings) are notable. The abdomen of the holotype is cleared, stained, and in a vial attached to the specimen. Because of the species' importance as the northernmost record for the genus, we describe it to facilitate future identifications."

Page 83, Fig. 61 caption, last line: change CAS to FSCA.

Page 84, Fig. 62 caption, last line: change CAS to FSCA.

Page 85, Fig. 63 caption, last line: change CAS to FSCA.

Page 85, last line should read: "Specimens examined (in addition to holotype). Mexico. Veracruz: Cd. Mendoza, 3.xii.1975, C. M. Flint & O. S. Flint, Jr. (1F, paratype, USNM)."