

Systoechus laevifrons (Loew, 1855) new to Finland and the Western Palearctic region (Diptera, Bombyliidae)

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Pohjoismäki, J. & Kahanpää, J. 2022. *Systoechus laevifrons* (Loew, 1855) new to Finland and the Western Palearctic region (Diptera, Bombyliidae). *Norwegian Journal of Entomology* 69, 51–61.

Systoechus laevifrons (Loew, 1855) (Diptera, Bombyliidae) is recorded from Finland. Having previously been known only from Eastern Siberia and the Russian Far East, the species is new to the Western Palearctic region.

All verifiable previous records of *Systoechus gradatus* (Wiedemann in Meigen, 1820) from Finland proved to be misidentifications of *Systoechus laevifrons*. *S. gradatus* is here deleted from the national checklist of Finnish species. *Systoechus laevifrons* inherits the national red list status (CR) previously given to *S. gradatus*. Based on museum material, the historical range of *Systoechus laevifrons* in Finland covers most of the southern and middle parts of the country, but records are very sparse and scattered, with only five known localities. In the 21st century *Systoechus laevifrons* has only been found at two localities in Finland (Säkylä and Taipalsaari). Both are army artillery practice grounds on sandy soils. In 2021, at least twenty adults were seen nectaring primarily on *Solidago virgaurea* at the Säkylä site.

In addition to the species record, we provide a partial DNA barcode analysis of the northern Holarctic *Systoechus* species as well as an updated key to the identification of the European species, and discuss the biology and distribution of *Systoechus laevifrons*.

Key words: Diptera, Bombyliidae, *Systoechus*, Europe, identification key, bee flies, country records.

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Introduction

Systoechus Loew, 1855 is a genus of broadly built ‘hairy’ bombyliids (Diptera, Bombyliidae, Bombyliinae, Bombyliini) with a long proboscis, at first glance rather similar to the familiar *Bombylius* species. They are most numerous on deserts and steppes in warm and arid climates; only a few species are found in the boreal to nemoral forest zones (Evenhuis & Greathead 2015). Some 116 species are currently recognised in *Systoechus* (Evenhuis & Greathead 2015).

The diversity is strongly concentrated in the Afrotropical region (90 species), followed by the Palearctic (20 species), Nearctic (5) and Oriental (5) regions. Of the twenty formally recognised Palearctic species, eleven are present in the Near East and nine in Europe. Seven species are known from the Eastern Palearctic subregion, but none of them is endemic to this subregion (Evenhuis & Greathead 2015).

Two *Systoechus* species have been reported from the Nordic countries. *Systoechus ctenopterus* (Mikan, 1796) (syn. *S. sulphureus* (Mikan, 1796))

(Greathead *et al.* 2021) occurs in open sandy biotopes in southern and central part of Finland, Sweden, and Norway. The presence of a second *Systoechus* species in Northern Europe was first noted by J.E. Aro (1900). Aro's record of *Systoechus leucophaeus* (Wiedemann in Meigen, 1820) was based on a male specimen caught in 1897 from Finland, North Savonia, Tuovilanlahti. This specimen is now in the collections of the Finnish Museum of Natural History (MZH). *Systoechus leucophaeus* was later synonymised with *Systoechus gradatus* (Wiedemann in Meigen, 1820) and the species has been reported from Finland repeatedly under the latter name (Frey, Tiensuu & Storå 1941, Hackman 1980, Kahanpää & Winqvist 2005, Kahanpää *et al.* 2014).

Recent re-examination of voucher specimens and fresh material collected in 2021 revealed that previous records of *Systoechus gradatus* (Wiedemann in Meigen, 1820) were incorrectly identified. The second *Systoechus* present in Finland is in fact *Systoechus laevifrons* (Loew, 1855). This species was previously known from the Russia Far East and Eastern Siberia (Republic of Sakha, Magadan and Amur Oblasts, Khabarovsk Krai) (Nartshuk & Bagachanova 2012) and Mongolia (Govi-Altai, Central and Uvs Aimak) (Zaitzev 1974). The species is now officially reported for the first time from the Western Palearctic region and replaces *Systoechus gradatus* on the Finnish checklist (Kahanpää *et al.* 2014). In addition to the species record, we provide DNA barcode analysis of the northern Holarctic *Systoechus* species as well as an updated key to the identification of the European species and discuss the biology and distribution of the newly discovered *S. laevifrons*.

Material and Methods

In the specimen data below, Uniform Resource Identifiers (URIs) beginning with <http://id.luomus.fi/> or <http://tun.fi/> are CETAF Stable Identifiers for voucher specimens. The corresponding collection specimens have a label with the identifier. The coordinates are given in decimal degrees (Grid: Lat/Lon hddd.dddd°N/E; datum WGS84), unless

otherwise stated.

Specimen data

Systoechus autumnalis (Pallas, 1818): 3 ex – 2 ex **Iran**, F. Brandt leg., specimen identifiers <http://id.luomus.fi/GV.86593>, <http://id.luomus.fi/GV.86831> (MZH). 1♂ **Kazakhstan**, Uralsk, year ca. 1907, M. Bartel leg. <http://id.luomus.fi/GV.86830> (MZH).

Systoechus candidulus Loew, 1863: Examined from reference photographs and *Col* barcode only. Public data is available in the Barcode of Life Database (BOLD, www.boldsystems.org) for the following sequence IDs: BBDCP015-10, BBDCP371-10, BBDCP375-10, BFLY069-07, TTDFW090-08, TTDFW091-08, TTDFW252-08, TTDFW253-08, TTDFW254-08, TTDFW264-08, TTDFW280-08, TTDFW294-08, TTDFW365-08 and TTDFW453-08.

Systoechus ctenopterus (Mikan, 1796): 10♂♂3♀♀ – 1♂: **Croatia**, Senj, 14.VI.1889, collector unknown [from Staudinger & Bang-Haas], <http://id.luomus.fi/HT.34220> (MZH). 1♂: **Estonia**, Saarenmaa, Tehumardi, July 24.VII.2017, O. Biström leg., <http://id.luomus.fi/HT.2488> (MZH). 1♂: **Finland**, Sa: Hirvensalmi, Sammakkolampi, 61.659°N, 26.982°E, 2.VII.2010, A. Haarto leg. *Col* barcoded, BOLD sample ID MZH_HP.2199 (MZH). **Finland**, 1♀: Kb: Liperi, Kuorinka, 62.629°N, 29.412°E, 3.VII.2021. J. Pohjoismäki leg. (coll. J. Pohjoismäki). **Finland**, 1♂2♀♀: Kb: Liperi, Hovattavaara, 62.621°N, 29.472°E, 14.VII.2019. 2♂♂: Same locality and collector, 16.VI.2021 (coll. J. Pohjoismäki). **Finland**, 2♂♂2f Kb: Kontiolahti, Lentokenttä, 62.655°N, 29.634°E, 25.VI.2014. J. Pohjoismäki leg. 2♂♂2f: Same locality and collector, 7.VII.2021 (coll. J. Pohjoismäki).

Systoechus gradatus (Wiedemann): 3♂♂2♀♀ – 2♂♂1f: **France**, Provence-Alpes-Côte d'Azur, Flassans-sur-Issole, Rouvede, 43.355°N, 6.255°E, 10.VII.2011. J. Pohjoismäki leg. (coll. J. Pohjoismäki). *Col* barcode from one male, BOLD sample ID JP-A2021-002. 1♀: **Greece**,

Crete, Chania, Mt Psari, 35.3744°N, 24.037°E, 6.VI.2019. (coll. J. Pohjoismäki). 1♂: **Hungary**, Keczel, Thalhammer leg., <http://id.luomus.fi/GV.86821> (MZH).

Systoechus laevifrons (Loew, 1855): 8♂♂6♀♀ – 1♂: **Finland**, Sb: Maaninka, Tuovilanlaks, year 1897, J.E. Aro leg., <http://id.luomus.fi/GV.16708> (MZH). 1♂: **Finland**, U: Hanko, Tulludden, 7.VII.1927, R. Frey leg., <http://id.luomus.fi/GV.16709> (MZH). 1♀: **Finland**, U: Hanko, Tvärminne, year 1923, A. Wegelius leg., <http://id.luomus.fi/GV.16711> (MZH). 1♂: **Finland**, ES: Valkeala, Vuohijärvi, between years 1900–1920, E.W. Suomalainen leg., <http://id.luomus.fi/GV.16717> (MZH). 1♂: **Finland**, St: Säskylä, 15.VI.1992. J. Kullberg leg., <http://id.luomus.fi/GV.86055> (MZH). 3♀♀: **Finland**, St: Säskylä, Säskylänharju, SE slope, wgs84 61.019°N, 22.538°E, 21.VI.2021, J. Kahanpää leg, <http://tun.fi/GAVK.8913>, <http://tun.fi/GAVK.8914>, <http://tun.fi/GAVK.8915>(coll. J. Kahanpää). 2♂♂: **Finland**, St: Säskylä, Säskylänharju, between the 2 main ridges, wgs84 61.025°N, 22.533°E, 22.VI.2021, J. Kahanpää leg, <http://tun.fi/GAVK.8937>, <http://tun.fi/GAVK.8938> (coll. J. Kahanpää). 2♂♂: **Finland**, St: Säskylä, Säskylänharju, 61.011°N, 22.549°E, 21.VI.2021. J. Pohjoismäki leg. *Col* barcode from one male, BOLD sample ID JP-A2021-003. (coll. J. Pohjoismäki). 1♀: **Russia**, Magadanskaya Oblast, Upper Kolyma river, Sipirdik 61.99°N, 148.64°E, 5.VII.1990. Marko Nieminen, Mikko Kuussaari & Jaakko Kullberg leg. *Col* barcoded, BOLD sample ID JP-A2021-004, identifier <http://id.luomus.fi/HT.34147> (MZH). 1♀: **Russia**, Sakha Republic, Yakutsk, 1.VII.1901, leg. B. Poppius, <http://id.luomus.fi/HT.34146> (MZH).

Systoechus longirostis (Becker): 1♂1♀ – 1♂: **France**, Provence-Alpes-Côte d'Azur, Flassans-sur-Issole, Rouvede, 43.355°N, 6.255°E, 12.VII.2011. J. Pohjoismäki leg. (coll. J. Pohjoismäki). 1♀: **Europe**, ex coll. Frauenfeld, <http://id.luomus.fi/GV.86820> (MZH).

Systoechus solitus (Walker, 1849): Examined from reference photographs and *Col* barcode only.

Public data is available in BOLD for the following sequence IDs: BBDIT393-11, BBDIT394-11, BBDIT395-11, BBDIT396-11, BBDIT397-11, BBDIT398-11, BBDIT399-11, BBDIT400-11 and BFLY076-07.

Systoechus vulgaris Loew, 1864: Examined from reference photographs and *Col* barcode only. Public data is available in BOLD for the following sequence IDs: BFLY073-07, BFLY074-07 and BFLY075-07.

Systoechus sp. An unidentified *Systoechus* from the Nearctic region with an unique Barcode Index Number (BIN) in BOLD. Examined from reference photographs and *Col* barcode only. Public data available in BOLD for the following sequence IDs: BBDCP372-10, BBDCP374-10, BBDCP376-10 and BBDIT392-11. There are other unidentified *Systoechus* specimens in BOLD, but they share BINs with *S. candidulus* or *S. solitus*.

The following *Bombylius* specimens were included into the *Col* analysis as a comparison: *Bombylius discolor* Mikan, 1796: 1♀: **Greece**, South Aegean, Kos, Mastihari, 36.8486°N, 27.0919°E, 6.V.2012. J. Pohjoismäki leg. BOLD sample ID JP01087. (coll. J. Pohjoismäki).

Bombylius major (Linnaeus, 1758): 1♂: **Finland**, Ab: Mynämäki, Perkko, 60.615°N, 21.929°E, 22.IV. 2012. A. Haarto. Leg. BOLD sample ID MZH_HP.2208 (MZH).

Bombylius minor (Linnaeus, 1758): 1♀: **Finland** N: Hanko, Vedagrundet, 59.827°N, 23.127°E, 7.VII.2005, J. Kahanpää leg. BOLD sample ID jka-05-04297 (MZH).

DNA extraction, PCR and sequencing

DNA was extracted using the NucleoSpin™ Tissue kit (Macherey-Nagel™, Düren, Germany) following the manufacturer's instructions. The 5'-terminal part of *Col* was amplified using the routine barcoding primers for flies, LepF1

and LepR1 (Hebert *et al.* 2004). As the Russian *Systoechus laevifrons* specimen was more than 30 years old, the initial attempt to amplify the full barcode region was unsuccessful. Instead, the *Col* sequence was amplified and sequenced in smaller fragments using the following primers: Syst269F 5'-CCCCATCTCTTACTCTTCT-3', Syst317R 5'-CTCCGCTTTCGACTATTGAA-3', Syst466F 5'-ACGATCAGTTGGAATTACAT-3', Syst643R 5'-TAGAATAGGGTCACCTCCTC-3'

Separate PCR reactions were carried out with primer pairs LepF1+Syst317R, Syst269F+Syst643R and 466F+LepR1. The PCR program was essentially as the one described in Folmer *et al.* (2004) and the products were purified using the Illustra™ GFX PCR DNA and Gel Band Purification Kit (Merck, Kenilworth, NJ, USA). Sequencing was performed in both directions for each fragment using the same primers as for their amplification (Mix2Seq service, Eurofins Genomics, Cologne, Germany). The obtained sequences are overlapping and the full sequence was assembled excluding the primer regions. A maximum likelihood tree of *Col* genealogies for *Systoechus* species was then constructed using MrBayes v3.2 (Ronquist *et al.* 2012) with the GTR-gamma model, assessing node support through 1,000,000 MCMC generations with 500 sample and 5000 generation diagnostic frequencies. The resulting tree was illustrated and edited using FigTree v1.4.4. (<http://tree.bio.ed.ac.uk/software/figtree/>). Except for *S. laevifrons*, where comparison between Finnish and Russian Far East specimens were informative, only one specimen per species was included into the final tree.

The DNA barcode sequences were uploaded into the Barcode Of Life Database (BOLD) under the Finnish Diptera: ORTHORAPHA-project. BOLD sample IDs are given for each barcoded specimen.

Results

Identification of *Systoechus laevifrons* from Finland

During a visit to Säköjärvi (61.011°N,

22.549°E), south-western Finland on 21.VI.2021, the authors of this paper were looking for the species that was, at the time, thought to be *Systoechus gradatus*. In the recent years the species have been observed rarely and only in single individuals in Finland. However, in 2021 dozens of individuals were observed and some were collected by hand netting for reference purposes. When examining the specimens, author JP noted that they differed markedly from the *S. gradatus* material he had collected in France and Greece. The Finnish specimens are notably larger (9–11 mm) than the southern European ones (< 8 mm) and they had a black frons covered predominantly with long black bristles (Figure 1A–F). The male specimens were not identifiable with the old Palearctic key (Engel 1937), but the females were easily determined as *Systoechus laevifrons* (Loew) due to the characteristic frontal calluses (Figure 1D), not present in any other Palearctic *Systoechus* species. The male of *S. laevifrons* was unknown at the time of writing of the Engel (1937), but it is included in the identification keys to the Bombyliidae of Russian Far East (Zaitzev 2004).

As the Finnish records are far outside the previously known distribution range of *S. laevifrons*, the Finnish specimens were compared with *S. laevifrons* collected from the Russian Far East. No notable morphological differences between the specimens were observed. Furthermore, we were successful in obtaining full *Col* DNA barcode sequences from both Finnish and Russian specimens. The DNA barcode sequences of the *S. laevifrons* specimens were almost identical and also distinct from the sequences of all other *Systoechus* species available in the Barcode of Life Database (BOLD) (Figure 2). It is noteworthy that the northern Nearctic species of *Systoechus* are more closely related to *Systoechus laevifrons* than any European species included in the analysis. Curiously, all the *Col* barcodes available in BOLD for *S. candidulus* and *S. vulgaris* are very similar and share the same BIN. The two species are apparently distinguished from the colour of the facial setulae (Hall & Evenhuis 1981); the species pair might deserve a more detailed analysis.

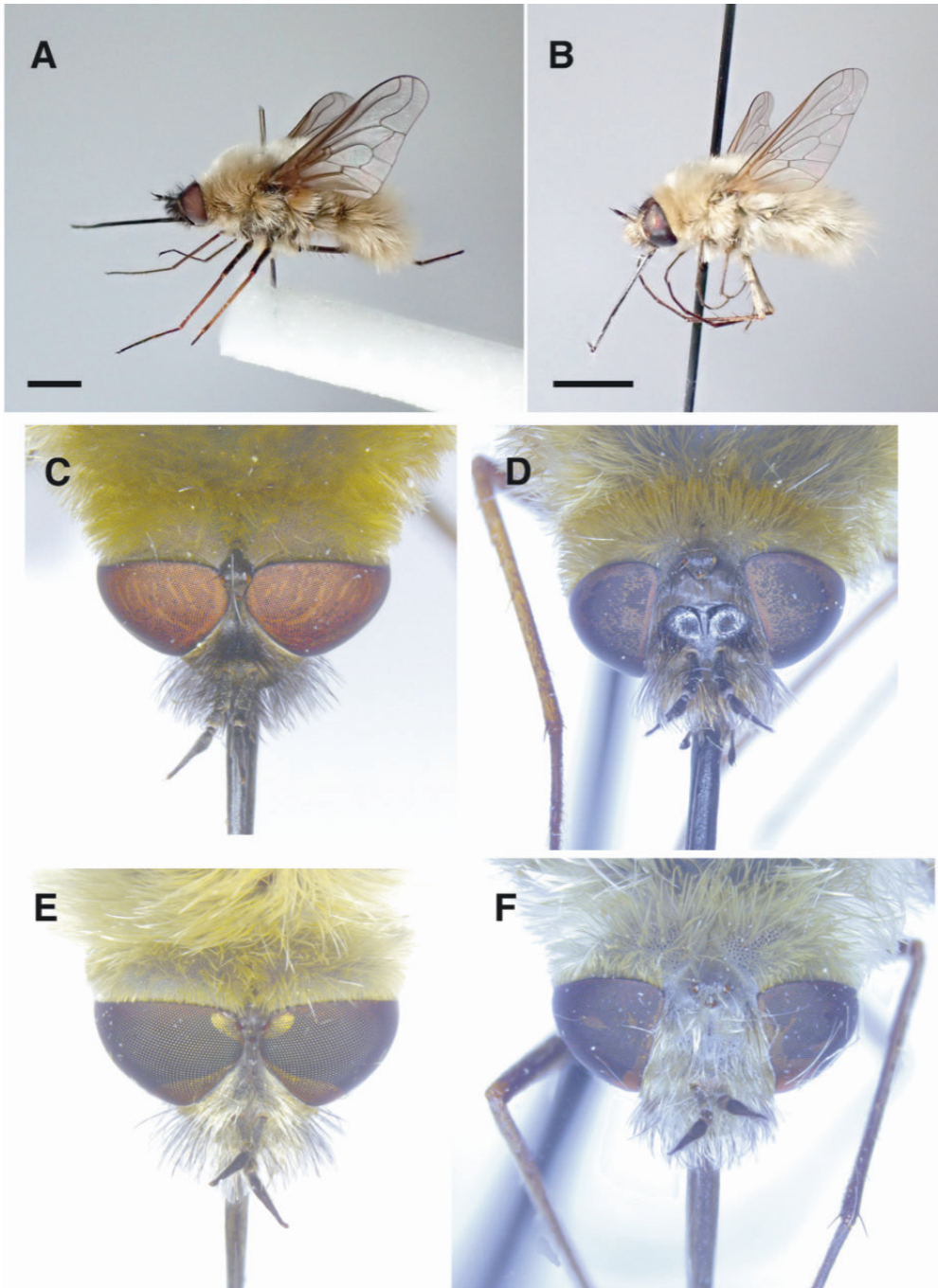


FIGURE 1. *Systoechus* spp. (A) Habitus of male *Systoechus laevifrons* (Loew, 1855). Finland, Säkylänharju, 20.VI.2021. J. Pohjoismäki leg. BOLD sample ID JP-A2021-003 (B) Male *S. gradatus* (Wiedemann in Meigen, 1820). France, Flassans-sur-Issolle, 10.VII.2011. J. Pohjoismäki leg. BOLD sample ID JP-A2021-002. (C) *S. laevifrons* male (same specimen as in A) and (D) female (Finland, Säkylänharju, 20.VI.2021. I. Kakko leg) head in dorsal view. (E) *S. gradatus* male and (F) female head (both France, Flassans-sur-Issolle, 10.VII.2011. J. Pohjoismäki leg.)

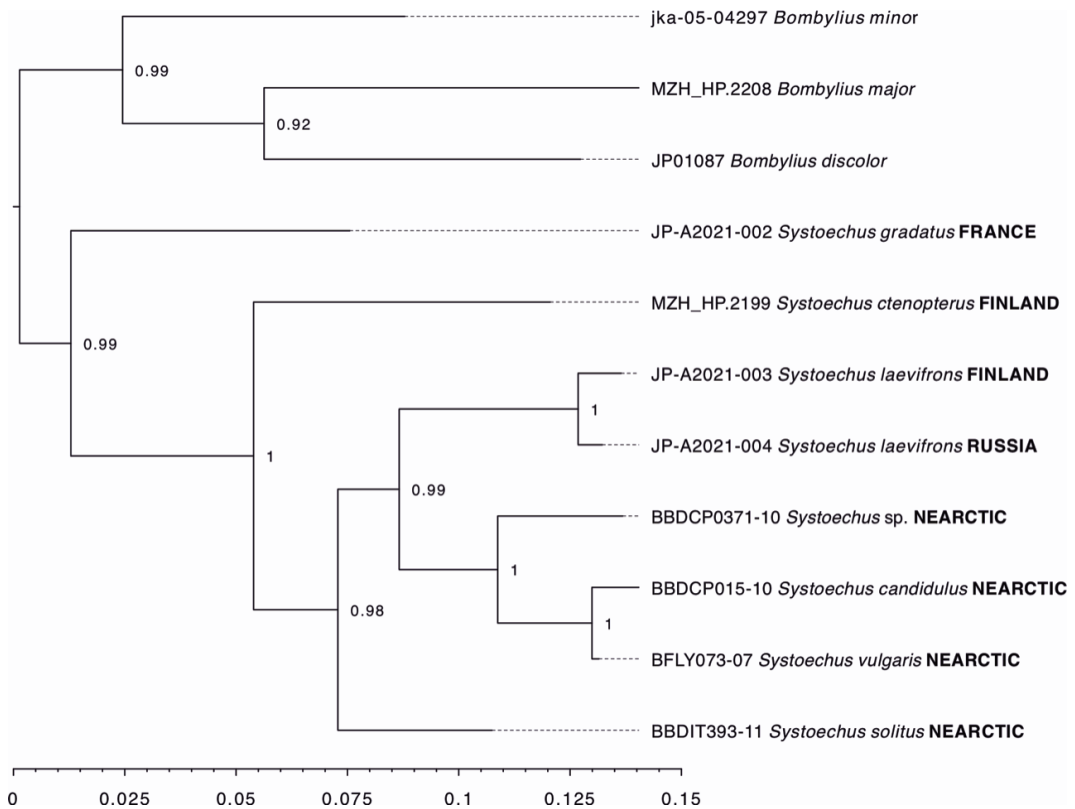


FIGURE 2. *Col* 1 sequence maximum-likelihood phylogenetic tree of *Systoechus* and *Bombylius* species. BOLD sample ID number is given for each specimen.

Discussion

European *Systoechus*. Eight—or nine, see below—species of *Systoechus* are currently known from Europe (Evenhuis & Greathead 2015, Greathead *et al.* 2021). Only one species is widespread across the continent: *Systoechus ctenopterus* has been recorded from most European countries with the most notable exceptions being the British Isles, Norway and Iceland.

The following species are widespread in Southern Europe, ranging from the western or middle Mediterranean to Southeastern Russia, but apparently absent north of the central European mountain ranges: *Systoechus autumnalis* (Pallas, 1818), *S. gradatus* (Wiedemann in Meigen, 1820), *S. longirostris* Becker, 1916, and *S. microcephalus* (Loew, 1855) (Greathead *et al.* 2021). The Swedish species record database Artportalen does currently

contain a single record of *Systoechus gradatus* from Järavallen Naturreservat, Kävlinge, Skåne, in southern Sweden (<https://www.artportalen.se/Sighting/70092016>). As the date given (2.VIII.2010) would be very late for *Systoechus laevifrons* and we know of no confirmed records of *Systoechus gradatus* from Northern or Central Europe, we consider this occurrence record dubious. *Systoechus gomezmenori* Andreu Rubio, 1959 is recorded from countries across southern Europe, but also from Germany and Austria (Evenhuis & Greathead 2015). The central European records may need verification. *S. pumilio* Becker, 1915 is currently only known from Spain, Italy and Tunisia (Evenhuis & Greathead 2015, Greathead *et al.* 2021). *Systoechus laevifrons* is added to the European fauna in this paper based on specimens from Finland.

The ninth nominal European species is

An updated key to the European species of *Systoechus*. This provisional key is based on the keys and species descriptions in Engel (1937), Zaitzev (2004) and Andréu Rubio (1959).

1a. Anterior basal wing cell longer than the posterior basal cell; crossvein r-m thus closer to the center of the anterior margin of the discal cell.	2
1b. Crossvein r-m situated at the proximal third of the discal cell.	3
2a. Only yellow setulae on the head and abdomen. Epistome prominent, protruding further than the first two antennal segments. Mesonotum dorsally with black longitudinal stripes. [no specimens examined]	<i>S. gomezmenori</i> Andréu Rubio, 1959
2b. Not as above.	<i>Bombylius</i> spp.
3a. Head densely covered by long pale yellow setulae from frons to the mouth margin. Setulae on the head ± equally long on all sides, giving it a furry rounded appearance.	<i>Anastoechus</i> spp.
3b. Frons and mouth margin clearly visible under the setulae. Peristomal setulae clearly shorter than the facial setulae.	4
4a. Long black marginal setae on the tergites.	<i>S. ctenopterus</i> (Mikan, 1796)
4b. No black marginal setae on the tergites.	5
5a. Alar section of the costa with pale hairs and pale, whitish to yellowish brown setae.	6
5b. Alar section of the costa with pale hairs and black setae.	7
6a. Ground color of the body grey, posterior part of the scutellum reddish. Legs entirely orange in females, basal third of the femorae darkened in males. Generally, a larger species, body length 6.0-10.5 mm.	<i>S. autumnalis</i> (Pallas, 1818)
6b. Ground color of the body grey-brown, including the scutellum. Legs orange in both sexes. Wing base opaque yellow. Generally, a pale yellow small species, body length 5.0-6.0 mm [no specimens examined]	<i>S. pumilio</i> Becker, 1915
7a. Frons in males shiny black with thin yellowish microtomentum (Figure 1C). Female frons with two shiny calluses (Figure 1D). Frons dominated by black hairs.	<i>S. laevifrons</i> (Loew, 1855)
7b. Male frons matt (Figure 1E), female frons without calluses (Figure 1F). Frons dominated by pale hairs.	8
8a. Proboscis almost 0.75 × of the body length (Figure 3A). Scutellum reddish brown in ground color, paler than rest of the thorax. Legs yellow, except for the dark tarsi.	<i>S. longirostris</i> Becker, 1916
8b. Proboscis shorter (Figure 3B). No color difference between the scutellum and rest of the thorax. At least the femorae darkened.	9
9a. Males. Eyes narrowly separated (Figure 1E)	10
9b. Females. Eyes broadly separated (Figure 1F)	11
10a. Face and scape (basal antenna segment) with mixed black and yellow setulae. Femora darkened brown.	<i>S. gradatus</i> (Wiedeman in Meigen, 1820)
10b. Face with yellow setulae surrounded by black genal hairs. Scape extensively covered with black setulae. Femora black with reddish brown apex. [no specimens examined]	<i>S. microcephalus</i> (Loew, 1855)
11a. Femora darkened brown.	<i>S. gradatus</i> (Wiedeman in Meigen, 1820)
11b. Femora black with reddish brown apex. [Description in Engel (1937) is insufficient and measures for antenna dimensions and frons width are probably misleading. No specimens examined.]	<i>S. microcephalus</i> (Loew, 1855)

Systoechus quasiminimus Evenhuis & Greathead, 1999 (a replacement name for *Bombylius minimus* Fabricius, 1795). This species, described from

‘Germania’ and not reported since, has been omitted from pretty much all subsequent literature. It is likely a synonym of some other species, but



FIGURE 3. *Systoechus* spp. Relative length of rostrum to body. (A) *Systoechus longirostris* Becker, 1916, female specimen <http://id.luomus.fi/GV.86820>. (B) *Systoechus gradatus* (Wiedemann in Meigen, 1820), male specimen <http://id.luomus.fi/GV.86821>.

this remains to be verified.

Biology of *Systoechus laevifrons*. Little is known about the ecology of *Systoechus laevifrons*. The Finnish records are all from xerothermic

sites. The locality of the first Finnish record (as *S. leucophaeus*) was described as “sandbranter”, i.e., steep sand banks (Aro 1900). The 21st century records from Finland are from esker ridge areas.



FIGURE 4. Habitat of *Systoechus laevifrons* (Loew, 1855). Finland, Säskylä, 21.VI.2021. Photos: J. Kahanpää.

The locality in Taipalsaari is a wide, south-facing roadside verge merging into an army artillery practice field.

The Säskylä locality consists of two esker ridges with long axes oriented NW to SE, and a valley between them (Figure 4). This site is also used for army artillery practice. *Systoechus laevifrons* adults were seen on open ground on the SW slopes and between the ridges. Ground vegetation at the site is dominated by *Calluna vulgaris* and *Arctostaphylos uva-ursi*, with patches of *Thymus serpyllum* and *Pilosella* species.

Both sexes of *S. laevifrons* were repeatedly seen nectaring on goldenrod (*Solidago virgaurea*) during a 2021 visit to the Säskylä site (for dates and localities, see records in Results). At least 25 specimens were seen feeding on *Solidago* (Figure 5), with single records of nectaring on *Pilosella* and *Vaccinium vitis-idaea*. Flies nectaring on *Solidago* could be spotted from a distance of 5 meters or more and they could be easily approached for closer observation.

Russian localities are described as “the

bedrock slopes at the southern expositions of large rivers as well as in areas of relict cold steppes with cryoxerophytic vegetation” (Nartshuk & Bagachanova 2012). Besides Finland, *S. laevifrons* is so far only known from Russian North-Eastern Siberia to Magadan, Amur Region, Khabarovsk Territory and Mongolia.

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FIGURE 5. *Systoechus laevifrons* (Loew, 1855) nectaring on a goldenrod (*Solidago virgaurea* L.). Finland, Säskylä, 21.VI.2021. Photos: J. Kahanpää.

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Received: 3 March 2022

Accepted: 28 April 2022