



## Research article

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# Revision of the Swedish species of *Neoxorides* Clément, 1938 (Ichneumonidae: Poemeniinae) with the description of a new species and an illustrated key to species

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**Abstract.** *Neoxorides* Clément, 1938 is a small genus of ichneumonid wasps that develop on wood-boring beetles. We here revise the Western Palaearctic species of the genus, with a special focus on Sweden. A new species, *N. striatus* Johansson sp. nov. is described. *Neoxorides opacus* (Kokujev, 1903) stat. rev. is excluded from the synonymy with *N. nitens* (Gravenhorst, 1829) and reinstated as a valid species. The species is redescribed from European material. *Neoxorides kissi* (Ulbricht, 1911) is confirmed as a junior synonym of *N. opacus*. A neotype for *N. opacus* is designated. New characters to distinguish *N. varipes* (Holmgren, 1860), *N. collaris* (Gravenhorst, 1829) and *N. montanus* Oehlke, 1966 are presented. Almost all of the species treated are supported by DNA-barcoding. An illustrated key to the species occurring in the Western Palaearctic is provided, a prerequisite for making the genus accessible for future ecological and conservation studies.

**Keywords.** Saproxylic, molecular, new species, review, barcoding.

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## Introduction

Our knowledge of species diversity in insects is still embarrassingly incomplete, even in relatively well-known regions such as Europe. A large inventory based on millions of insect specimens from the Swedish Malaise Trap Project (SMPT) recently concluded that the largest gaps in our knowledge are among dipteran decomposers and hymenopteran parasitoids (Ronquist *et al.* 2020), such as Ichneumonidae Latreille, 1802 (also called “Darwin wasps” since recently: Klopstein *et al.* 2019). Even small and easily recognized genera still hold undetected diversity, if examined carefully. We here revise the Western Palaearctic species of *Neoxorides* Clément, 1938, using a combination of morphological and molecular data.

*Neoxorides* belongs to the ichneumonid subfamily Poemeniinae Narayanan & Lal, 1953. It is a small Holarctic genus currently comprising 10 described species worldwide (Yu *et al.* 2016). The species are assumed to be idiobiont ectoparasitoids of various xylophagous Coleoptera Linnaeus, 1758, primarily Cerambycidae Latreille, 1802 and Buprestidae Leach, 1815 (Broad *et al.* 2018). It shall hereby be noted that there are many unreliable host associations in the literature, where specimens of *Neoxorides* have been reared from wood containing multiple species of Coleoptera as well as hole-nesting aculeates (Broad *et al.* 2018). The Western Palaearctic species were revised by Oehlke (1966), who recognized four species: *Neoxorides nitens* (Gravenhorst, 1829), *N. collaris* (Gravenhorst, 1829), *N. varipes* (Holmgren, 1860) and *N. montanus* Oehlke, 1966. The fauna of North America was revised by Townes *et al.* (1960) and the Oriental fauna has partly been treated by Uchida (1928) and Sheng (1998). Kanders (2009), revised the Swedish species of Poemeniinae, including *Neoxorides*, in a Master's degree project at Uppsala University. However, the study only recognized two species, *Neoxorides collaris* and *N. varipes*.

The genus *Neoxorides* in the Western Palaearctic is distinguished from all but one similar genera by the elongate and slender legs and body (Figs 1A, 8B), the relatively long ovipositor in the female and the coarsely sculptured temples, which have a scale-like structure (Fig. 1B). These features are also found in the closely related genus *Podoschistus* Townes, 1957, which has the tergites distinctly and densely punctate, in contrast to the smoother and finely shagreened tergites in *Neoxorides*.

This paper reviews the Swedish species of *Neoxorides*. Six species are recognized and revised taxonomically using morphological and molecular methods.

## Material and methods

### Specimen base and morphological analyses

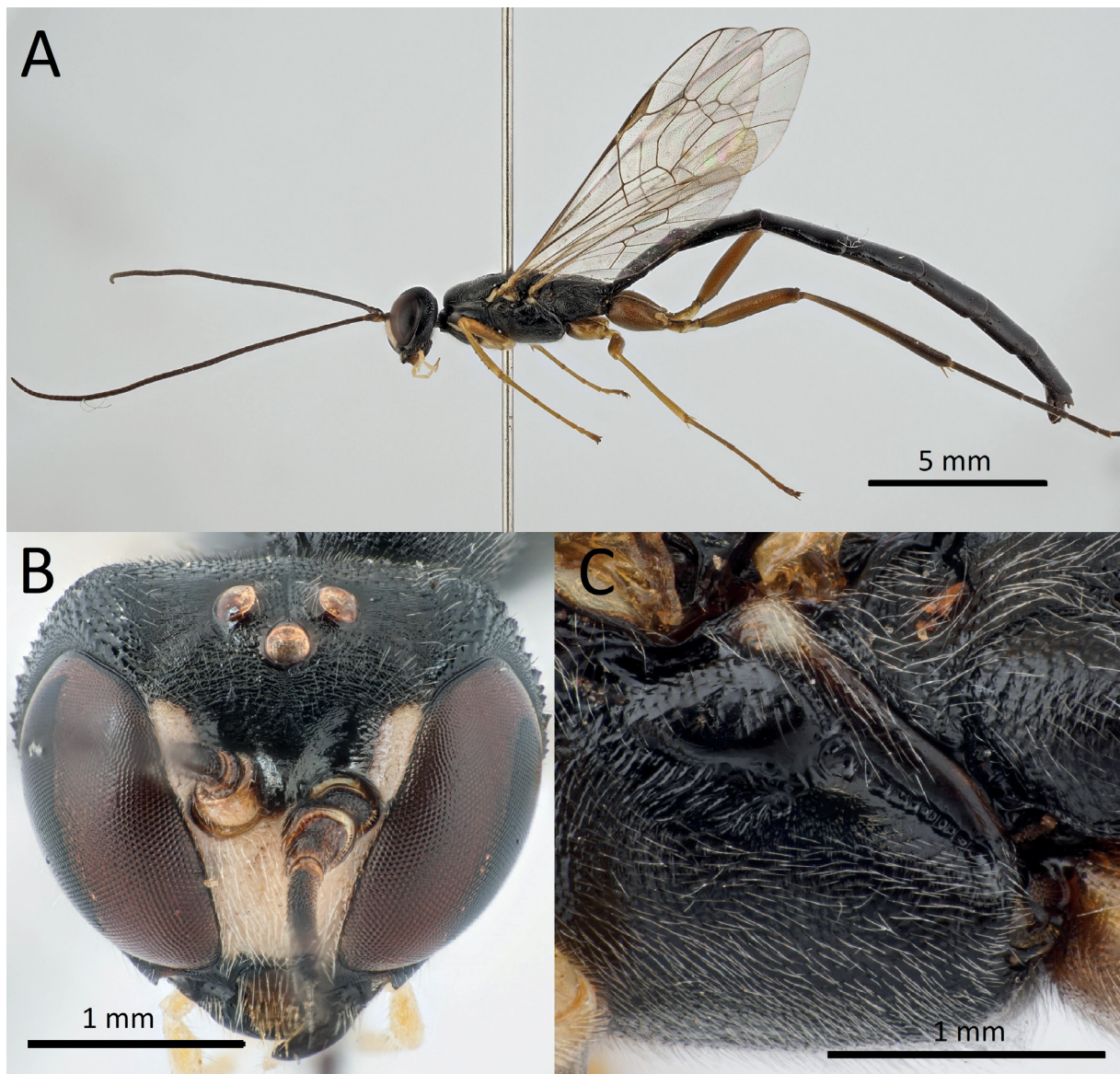
About 150 specimens of *Neoxorides* in private and public collections in Sweden and to some extent other countries, as well as relevant type material, were studied and sorted out by the first author. Some of the studied specimens were then barcoded by the second author to support the conclusions presented by the morphological and taxonomical analysis (see below). The material collected by the Swedish Malaise Trap Project seems to be lost (Dave Karlsson, SMTP, pers. comm.), but has been treated partly by Kanders (2009) and Olexandr Varga (unpublished data; Dave Karlsson, SMTP, pers. comm.). Since none of these authors were aware of the true diversity of the genus in Sweden, these records are not relisted.

Morphological terminology follows Broad *et al.* (2018). Fore wing length is measured as the greatest distance from the apex of the tegula to the wing tip. Unless stated otherwise, close up photos were taken by Alexander Berg with a Canon EOS 6D with a reversed tube lens-Thorlabs ITL200 with either a Schneider Kreuznach Componon 28 mm f4 or a Schneider Kreuznach Componon-S 50 mm f2.8 and then stacked with Zerene Stacker. Geographical regions with abbreviations are depicted in Fig. 2.

### Depositories (corresponding curator/contact)

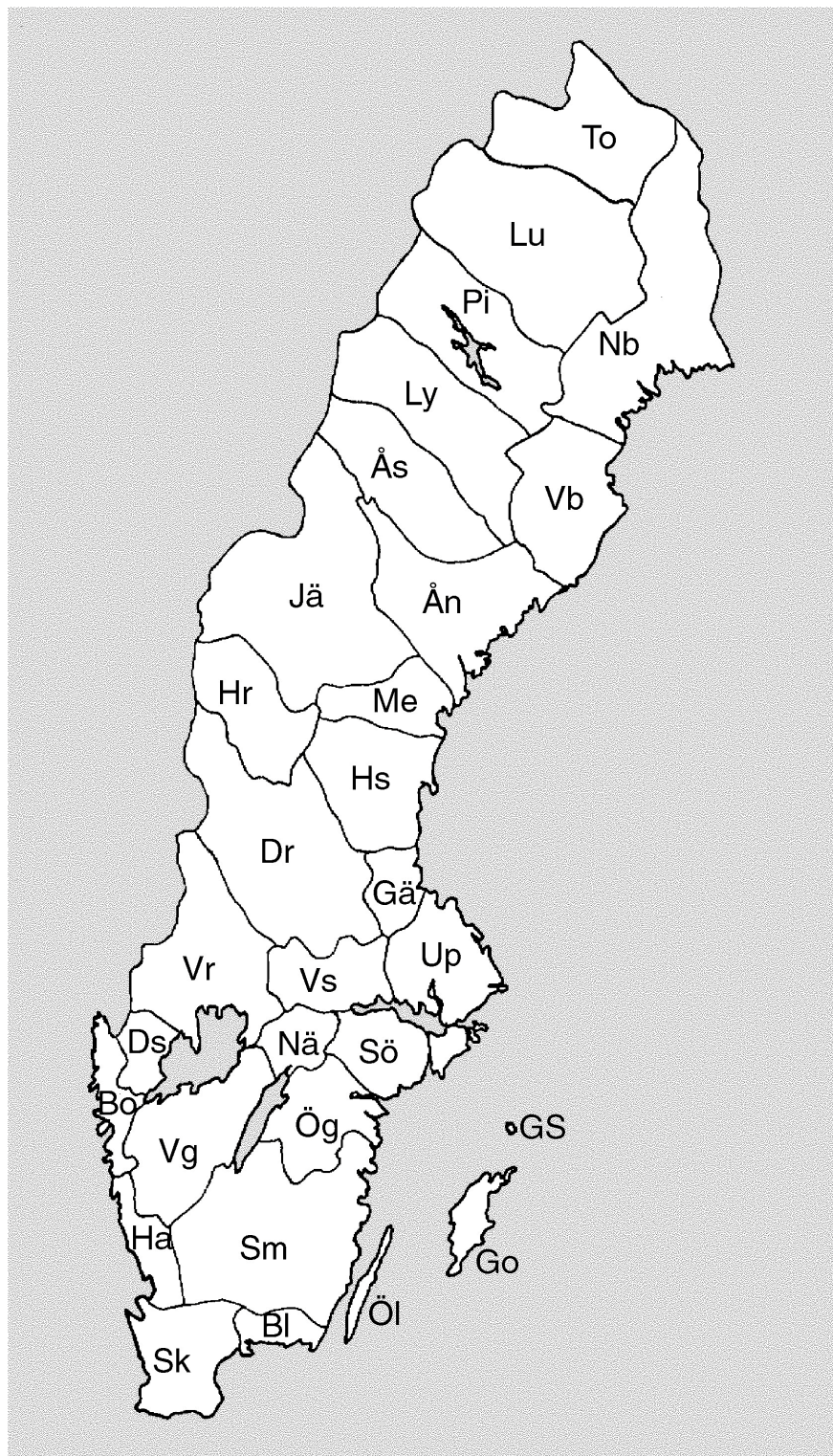
HNHM	=	Hungarian Natural History Museum, Budapest, Hungary (Zoltán Vas)
JA	=	Collection of Johan Abenius, Nynäshamn, Sweden (Johan Abenius)
JH	=	Collection of Jacek Hilszczański, Forest Research Institute, Poland (Jacek Hilszczański)
LW	=	Collection of Lars-Ove Wikars, Borlänge, Sweden (Lars-Ove Wikars)
MNHN	=	Muséum national d'histoire naturelle Paris, France (Claire Villement)
MR	=	Collection of Matthias Riedel, Bad Fallingb., Germany (Matthias Riedel)
MZH	=	Finnish Museum of Natural History, Helsinki, Finland (Juho Paukkunen)
MZLU	=	Zoologiska Museet, Lunds Universitet, Lund, Sweden (Rune Bygebjerg)
NHMUK	=	Natural History Museum, London, United Kingdom (Gavin Broad)

NHRS	=	Swedish Museum of Natural History, Stockholm, Sweden (Hege Vårdal)
NJ	=	Collection of Niklas Johansson, Habo, Sweden (Niklas Johansson)
NMWU	=	Museum of Natural History, Wroclaw University, Poland (Marek Wanat)
OV	=	Collection of Olexandr Varga, Kiev, Ukraine (Olexander Varga)
SLU	=	Collection of the Swedish University of Agricultural Sciences, Uppsala, Sweden (Mats Jonsell)
UPSZ	=	Evolutionsmuseet, Uppsala University, Uppsala, Sweden (Hans Mejlön)
ZIN	=	Zoological Institute, Russian Academy of Sciences, St Petersburg, Russia (Andrey Khalaim)
ZMHB	=	Museum für Naturkunde, Berlin, Germany (Jutta Helbig, Lukas Kirschey)
ZSM	=	Zoologische Staatssammlung München, Germany (Stefan Schmidt)



**Fig. 1.** *Neoxorides striatus* Johansson sp. nov., holotype ♂ (BC ZSM HYM07485). **A.** Habitus, lateral view. **B.** Head, anterior view. **C.** Mesopleuron, lateral view. Photos: Stefan Schmidt.





**Fig. 2.** Map of Sweden with borders and used abbreviations of the faunistic provinces from south to north: Sk = Skåne, Bl = Blekinge, Ha = Halland, Sm = Småland, Öl = Öland, Go = Gotland, Ög = Östergötland, Vg = Västergötland, Bo = Bohuslän, Ds = Dalsland, Nä = Närke, Sö = Södermanland, Up = Uppland, Vs = Västmanland, Vr = Värmland, Dr = Dalarna, Gä = Gästrikland, Hs = Hälsingland, Me = Medelpad, Hr = Härjedalen, Jä = Jämtland, Ån = Ångermanland, Vb = Västerbotten, Nb = Norrbotten, Ås = Åsele lappmark, Ly = Lycksele lappmark, Pi = Pite lappmark, Lu = Lule lappmark, To = Torne lappmark.



### DNA extraction

One to four specimens of *N. collaris*, *N. montanus* and *N. opacus* (Kokujev, 1903) were subjected to molecular analysis. Extractions were unsuccessful for *N. varipes*, for which no suitable material was available. Additional barcodes for *N. striatus* Johansson sp. nov., *N. nitens* and the North American *N. caryae* (Harrington, 1891), as well as a sequence of *Podoschistus vittifrons* (Cresson, 1868) to be used as an outgroup, were obtained from GenBank and from the Barcoding Fauna-Bavarica project.

DNA was extracted from mid or hind legs using the Qiagen DNeasy Blood & Tissue kits according to the manufacturer's instructions, but allowing 16–18 hours for the digestion step. We then first tried to amplify ~700bp of the 5' half of CO1 (barcoding region) using primers from Folmer *et al.* (1994) (forward: LCO 5'-GGTCAACAAATCATAAAGATATTGG-3'; reverse: HCO 5'-TAAACTTCAGGGTGACCAAAAAATCA-3'). If that failed, we used two newly developed primers for ichneumonid wasps to PCR the marker in two parts. The new reverse primer (SK-RA435: 5'-GCTCCTATAATAGAAGATATACCAGC-3') amplifies about 460 bp when combined with LCO, while the new forward primer (SK-FA336: 5'-CAAGGTGTTGGTACTGGATGAAC-3') resulted in about 374 bp when combined with HCO. If sequenced in both directions, the shorter stretches create a 76 bp overlap, which allows robust assembly of the two sequences, so that they encompass the entire barcoding region.

The PCR assays were performed in a total volume of 25 µl using the FIREPol mastermix (Solis Biodyne) according to the manufacturer's instructions. The relative volumes of the PCR components were 17 µl water, 1 µl of each 10 mM primer, 4.5 µl of the master mix and 1.5 µl of the genomic extract. The PCR protocols used 3 min initial denaturation, followed by 36 cycles of 30 s denaturation, 30 s annealing and 45 s extension, plus 3 min of final extension. Annealing temperatures were chosen as 53°C for the primer combination SK-FA336 + HCO and 50°C for the combination of the other two primers. PCR success was assessed on a 1.5% Agarose gel using GelRed DNA staining and UV light to detect bands. PCR products were sent to Macrogen Europe for Sanger sequencing, and resulting AB1 files were analysed and assembled in MEGA X 10.0 (Kumar *et al.* 2018). The sequences newly generated in this study were uploaded on GenBank under accession numbers MT072689 to MT072694.

### Alignment and phylogenetic analysis

The barcodes were translated into amino acids and aligned by hand in MEGAX, which was straightforward as no gaps were detected. We estimated uncorrected pairwise distances (from now on called 'p-distances') under pairwise deletion in cases of missing data. A phylogenetic tree was reconstructed using Bayesian inference in MrBayes 3.2.7 (Ronquist *et al.* 2012). The gene was partitioned into first plus second versus third codon positions and substitution model parameters unlinked across models. We used a mixture-model for nucleotide substitution, invariant sites and a gamma distribution to model among-sites rate variation, and default settings for the other parameters. The analysis was run for 2 Mio generations, sampling every 1000 generations, after which the plotted log-likelihoods and all diagnostics indicated good convergence (ASDSF: 0.009; PRSF values all below 1.003; ESS all above 150). Alignment and resulting trees were uploaded on TreeBase.

## Results

Class Insecta Linnaeus, 1758  
 Order Hymenoptera Linnaeus, 1758  
 Superfamily Ichneumonoidea Latreille, 1802  
 Family Ichneumonidae Latreille, 1802  
 Subfamily Poemeniinae Narayanan & Lal, 1953

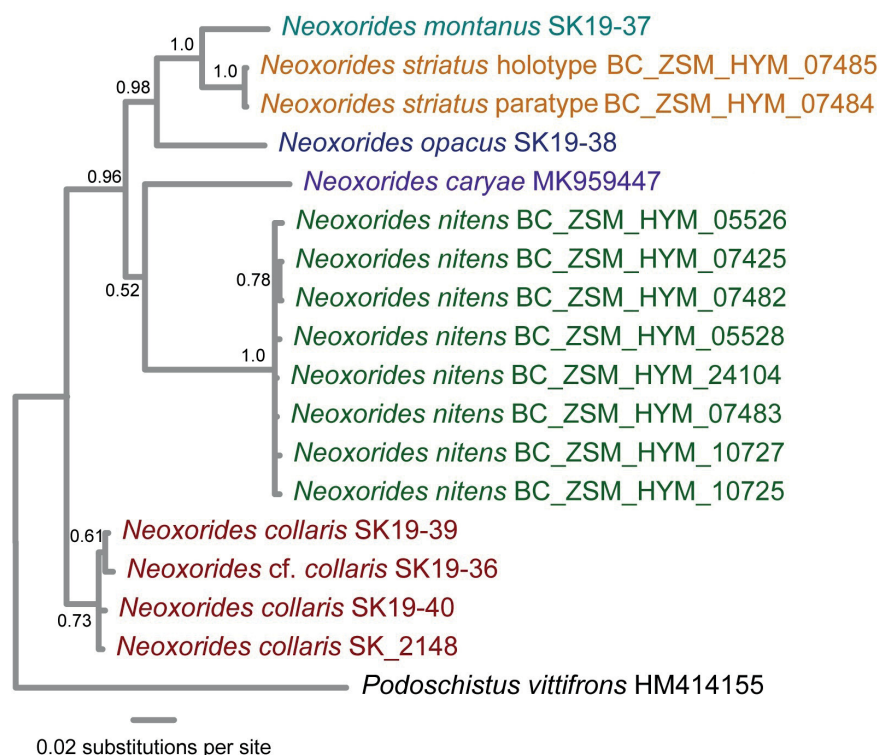
Genus *Neoxorides* Clément, 1938

*Neoxorides* Clément, 1938: 517–519. Type species: *Neoxorides nitens* (Gravenhorst, 1829).

## Molecular Analyses

The barcoding analysis showed small intraspecific and rather large interspecific distances (Table 1), thus confirming all species hypotheses of the taxa treated in this work (with the exception of *N. varipes*, for which we could not obtain a barcode). The largest intraspecific distance was found in *N. collaris* (0.8% p-distance), while the minimum interspecific distance was 4.6% (between *N. striatus* sp. nov. and *N. montanus*), leaving a barcoding gap of 3.6% (but this might decrease when more populations of each species are sampled).

The Bayesian phylogenetic analysis (Fig. 3) recovered all the species as monophyletic, although *N. collaris* was not strongly supported (likely because of one specimen only having half of the barcoding sequence). *Neoxorides collaris* shows a rather isolated position with respect to the morphologically similar *N. striatus* sp. nov. and *N. montanus*, which are recovered as sister groups.



**Fig. 3.** Bayesian majority-rule consensus tree based on CO1 sequences, showing posterior probabilities of the recovered nodes within *Neoxorides* Clément, 1938.



**Table 1.** Uncorrected pairwise distances of species of *Neoxorides* Clément, 1938.

Species	Max. intraspecific	Min. interspecific	Closest species
<i>N. striatus</i> sp. nov.	0.00%	4.63%	<i>N. montanus</i>
<i>N. caryae</i>	–	8.28%	<i>N. collaris</i>
<i>N. collaris</i>	0.8%	7.01%	<i>N. opacus</i>
<i>N. montanus</i>	–	4.63%	<i>N. striatus</i>
<i>N. nitens</i>	0.46%	7.34%	<i>N. collaris</i>
<i>N. opacus</i>	–	7.01%	<i>N. collaris</i>

### Key to the Western Palaearctic species of *Neoxorides*

The key to species is quite straightforward, but when separating *N. collaris*, *N. montanus* and *N. striatus* sp. nov., one should be aware that some of the characters partly overlap (see also Table 2). The determination should, therefore, be supported by a combination of characters. Generally, the yellow marking on the head and coxae are less distinct in small specimens; nevertheless, the colouration can be useful in species diagnostics. Previously used characters as the shape of the male genitalia and the shape of the flagellomeres (Oehlke 1966) have been found to be too variable to be of any significant use and are excluded from the key. The measurements of the metasomal segments represent typical specimens, and the overlap makes it necessary to use this character in combination with the other characters given in the key. While the white spots along the inner orbits above the antennal scobes are surprisingly consistent in shape, the white line below the scrobes is very variable within species and can be distinct, diffuse or missing.

The subfamily Poemeniinae can be keyed out using Broad *et al.* (2018). The genus *Neoxorides* is then separated from other genera of the subfamily by the scale-like structure of the temples in combination with the entirely black scutellum and the indistinct punctures on the tergites.

1. Scutellum and postscutellum with yellow apices; second and third tergite with distinct punctures ..  
..... *Podoschistus scutellaris* (Desvignes, 1856)
- Scutellum and postscutellum black; second and third tergite with indistinct punctures ..... 2
2. Anterior part of pronotum centrally raised as a collar (Fig. 5C); mesopleuron and mesosternum polished with scattered punctures (Fig. 4C); male with face black centrally. Primarily connected to hosts on oak ..... *Neoxorides nitens* (Gravenhorst, 1829)
- Anterior part of pronotum unmodified; mesopleuron and mesosternum with distinct microsculpture (Fig. 4A–B); male with face white ..... 3
3. Propodeum dorsally with rugose sculpture (Fig. 6B); mandibular teeth wide with almost parallel sides (Fig. 7C); pronotum laterally without white line. Possibly connected to hosts on aspen ..... *Neoxorides opacus* (Kokujev, 1903) stat. rev.
- Propodeum dorsally shagreened or with faint striate microsculpture (Fig. 6A); mandibular teeth (when unworn) apically narrowed (Fig. 7D); pronotum usually with white line laterally (sometimes absent in very small specimens). Primarily connected to hosts on conifers ..... 4
4. Hind coxae brown or black; sides of pronotum with weak, reticulate microsculpture (Fig. 5B); white spots along inner orbits above antennal sockets very short (Fig. 5A) .....  
..... *Neoxorides varipes* (Holmgren, 1860)
- Hind coxae orange; sides of pronotum in lower part polished, without microsculpture (Fig. 5D, G); white spots along inner orbits above antennal sockets longer (Fig. 7B) ..... 5

5. Frons weakly transversely striate over most of its surface (Fig. 1B); sides of pronotum in female and male centrally with distinct striae that extend slightly backwards to upper part (as in Fig. 5G); metapleural furrow with distinct transverse carinae (Fig. 1C); pale marks along inner orbits above antennal scrobes in female short, about 2.0–2.5 times as long as wide (Fig. 9B); first tergite in female about 2.0–2.3 times as long as wide (Fig. 9E); mid coxae in female orange; white stripe on pronotum in male and female slender, at most one third as wide as width of fore femur (as in Figs 1A, 5D); face in male narrow (Fig. 9H) ..... *Neoxorides striatus* Johansson sp. nov.
- Frons evenly shagreened without obvious striae (Fig. 7B); metapleural furrow with transverse carinae less distinct (Figs 4B, 6E); if sides of pronotum have striae centrally that extend backwards to the upper part (Fig. 5G), then mid coxae have extensive yellowish markings and white line of pronotum is as wide as the width of the fore femur (Fig. 5G); face in male usually wider (Fig. 9G) ..... 6
6. Sides of pronotum in female and often in male centrally with transverse striae that extend backwards to upper part (Fig. 5G); white stripe on pronotum in male and female wider, about as wide as the width of fore femur (Fig. 5G); mid coxae in female with extensive yellow or whitish marks on outer side (absent in small females); pale marks along inner orbits above antennal scrobes in female usually stouter, about 2.0 times as long as wide, slightly widened in upper part, rounded (Fig. 9C); first tergite in female usually about 2.4–2.5 times as long as wide (Fig. 9F), sometimes shorter, in male usually about 3.5 times as long as wide; ovipositor about as long as metasoma, slender and weak, usually curved downwards, sinuate or partly curled up in dried up specimens, rarely evenly upcurved ..... *Neoxorides montanus* (Oehlke, 1966)
- Sides of pronotum centrally usually without microsculpture (Fig. 5D), if weak striae are present, they do not extend upwards/backwards; white stripe on pronotum in male and female usually slender (wider in large males), at most 0.5 times as wide as width of the fore femur (Fig. 5D); mid coxae orange in female, rarely with small whitish mark apically in large specimens; pale marks along inner orbit above antennal scrobes in female narrower, about 3.0 times as long as wide, parallel or converging in upper part (Fig. 9A); first tergite in female usually about 1.7–1.9 times as long as wide (Fig. 9D), in male usually about 2.0–2.5 times as long as wide; ovipositor about as long as metasoma minus the first tergite, stouter, curved upwards ..... *Neoxorides collaris* (Gravenhorst, 1829)

## Systematics

*Neoxorides collaris* (Gravenhorst, 1829)  
Figs 4B, 5D, 6A, C, E, 7B, D, 9A, D

*Xorides collaris* Gravenhorst, 1829: 848–849.

*Xorides collaris* var. *harpui* Fahringer, 1935 in Schimitschek 1935: 139.

*Neoxorides collaris* – Clément 1938: 517–518. — Oehlke 1966: 890–891, fig. 4. — Kasparyan 1981: 94. — Kanders 2009: 9. — Varga 2015: 3–4, figs 1, 4.

*Xorides collaris* – Ratzeburg 1848: 105. — Holmgren 1860: 65. — Dalla Torre 1901–1902: 381–382. — Schmiedeknecht 1907: 17; 1908: 1368. — Hellén 1915: 20. — Haupt 1917: 82.

## Diagnosis

This species has proven notoriously difficult to identify with previous keys, and we here give a detailed diagnosis to clarify how it is distinct from other species of the genus. *Neoxorides collaris* is a species that is quite variable in size with a fore wing length of 8–12 mm. The metasoma in the female is stout with the first tergite about 1.7–1.9 times as long as wide. The ovipositor is relatively short and stout, curved upwards and usually about as long as the metasoma minus the first tergite. The female has the lateral part of pronotum with irregularly punctate rugose structure only in the upper half, while the



lower half is polished without microsculpture (Fig. 5D). If the central part occasionally has weak striae, they never extend into the upper part backwards/upwards as in *N. montanus* and *N. striatus* sp. nov. (Fig. 5G). The mesopleural furrow usually lacks any distinct transverse carinae and if carinae are present, they are usually less distinct and denser (Figs 4B, 6E). The colouration of the fore coxae ranges from orange, sometimes with the basal half infusate, to having the apical part more or less extensively yellow. The mid coxae are usually entirely orange in the females, thereby differing from the largely yellow apices of the mid-coxae in the female of *N. montanus*. The female is distinguished from *N. nitens* and *N. opacus* by the combination of the unmodified pronotal collar, the weakly aciculate dorsal portion of the propodeum (Fig. 6A) and the tergites, as well as the aciculate/shagreened mesopleuron/mesosternum with weak, but clearly discernible punctures (Fig. 4B). *Neoxorides collaris* is distinguished from *N. varipes* by the orange or partly orange hind coxae and the absence of reticulate microsculpture on the sides of the pronotum. The female is distinguished from *N. montanus* by the shorter and upcurved ovipositor, the usually stouter first tergite, the structure and the narrower white line on the sides of pronotum, and in most cases by the shape of the pale markings along the inner orbits above the antennal scrobes, which are narrower and have more parallel inner sides (Fig. 9A). The most useful character when separating the males of *N. collaris* and *N. montanus* seems to be the relative length of the metasoma, usually expressed in the shape of the first tergite. In *N. montanus*, it is usually longer, about 3.0–3.5 times as long as wide, while it is about 2.5 times as long as wide in *N. collaris*. In small males of *N. collaris*, the hind coxa in the male is apically/dorsally more or less infusate and the hind femur is at least dorsally infusate. The weak infuscation of the hind femur dorsally is evident also in Scandinavian females. Frequently, the entire hind femur in the male is brownish with a reddish ring basally. The hind trochanter and trochantelli in the male are usually dark brown dorsally and white ventrally. In Nordic specimens, the mid coxae are largely yellow on the outer side in *N. montanus*, while they are entirely orange, rarely with a small yellowish spot, in *N. collaris*. From *N. striatus* sp. nov., *N. collaris* is distinguished by the evenly shagreened frons, the structure of the pronotum, the absence of transverse carinae in the mesopleural furrow (Fig. 6E), the wider face in the male (as in Fig. 9G) and the stouter metasoma (Fig. 9D).

### Material examined

#### Lectotype

POLAND • ♂; NMWU.

#### Other material

SWEDEN • 12 ♀♀, 7 ♂♂; NHRS, UPSZ, MZLU, NJ, LW.

GERMANY • 1 ♂; MR.

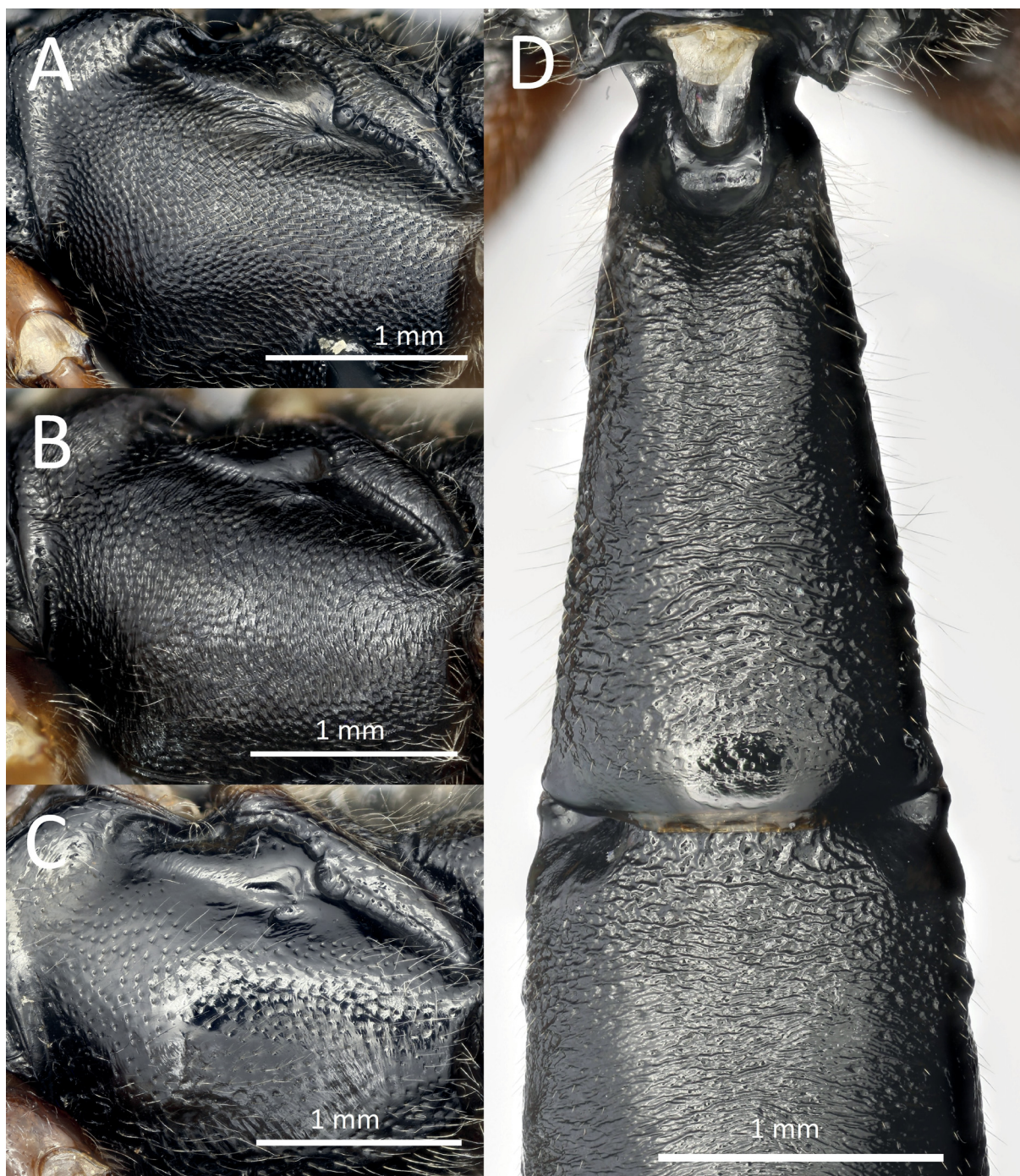
FINLAND • 3 ♀♀, 1 ♂; MZH.

FRANCE • 1 ♀, 3 ♂♂; NHMUK.

UKRAINE • 1 ♀; OV.

### Ecology

*Neoxorides collaris* is connected to cerambycids feeding on conifers. Most specimens have been collected in coniferous forests dominated by scots pine *Pinus sylvestris* L. or on scots pine timber (first author pers. obs.).



**Fig. 4.** A. *Neoxorides opacus* (Kokujev, 1903) stat. rev., ♀ (NJ), mesopleuron, lateral view. B. *N. collaris* (Gravenhorst, 1829), ♀ (NJ), mesopleuron, lateral view. C. *N. nitens* (Gravenhorst, 1829), ♀ (NJ), mesopleuron, lateral view. D. *N. opacus*, ♀ (NJ), basal portion of metasoma, dorsal view. Photos: Alexander Berg.



**Table 2.** Distinguishing characters for *Neoxorides collaris* (Gravenhorst, 1829), *N. montanus* (Oehlke, 1966) and *N. striatus* Johansson sp. nov.

Character/Species	<i>N. collaris</i>	<i>N. montanus</i>	<i>N. striatus</i> sp. nov.
<b>Structure of pronotum laterally, central and upper part</b>	centrally polished, in upper part punctate rugose (Fig. 5D).	striate (Fig. 5G).	striate (as in Fig. 5G).
<b>Mesopleural furrow</b>	without distinct transverse carinae (Fig. 6E).	without distinct transverse carinae (as in Fig. 6E).	with distinct transverse striae (Fig. 1C).
<b>Colour of mid coxae in female</b>	orange, at most with small yellow spot on the outer side	with large yellow spot on the outer side	orange, at most with small yellow spot on the outer side
<b>White spots along inner orbits above antennal scrobes in female</b>	narrow, frequently converging upwards (Fig. 9A).	wide, usually diverging upwards (Fig. 9C).	medium wide with almost parallel sides (Fig. 9B).
<b>White line on pronotum laterally in female</b>	narrow (Fig. 5D).	wide (Fig. 5G).	narrow (as in Figs 5B, D).
<b>Ovipositor in female</b>	shorter, stouter	longer, weaker	longer, weaker
<b>Structure of frons</b>	evenly shagreened (Fig. 7B).	evenly shagreened (as in Fig. 7B).	weakly transversely striate (Fig. 1B).
<b>First tergite in female</b>	1.7–1.9 times as long as wide (Fig. 9D).	2.4–2.5 times as long as wide (Fig. 9F).	2.0–2.3 times as long as wide (Fig. 9E).
<b>First tergite in male</b>	about 2.5 times as long as wide	about 3.5 times as long as wide	about 3.0 times as long as wide
<b>Face in male</b>	wide (as in Fig. 9G).	wide (Fig. 9G).	narrow (Fig. 9H).

### Distribution and status in Sweden

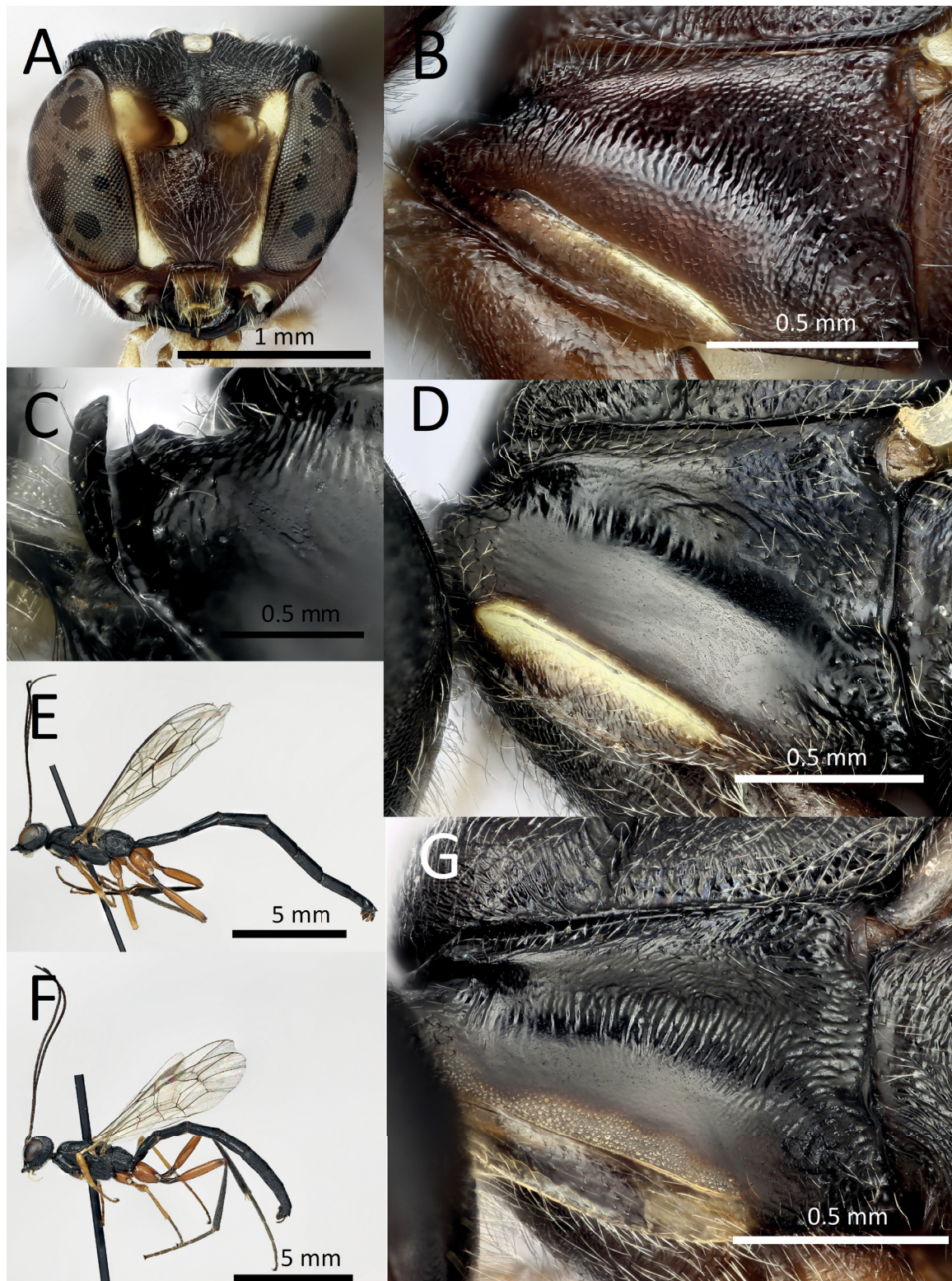
*Neoxorides collaris* occurs over most of the country, especially in light forests with dead wood or in burned forests. Ha, Hs, Sm, Sö, Up, Vb, Ög.

### Remarks

Some of the distinguishing characters previously used to separate this species from *N. montanus*, such as the shape of the male genitalia and the shape of the basal flagellomeres in the female, appear partly unreliable. However, the species is usually easily distinguished by the characters listed in the key and the diagnosis. The type of *N. collaris* var. *harpaii* (Fahringer, 1935 in Schimitschek 1935) is lost (Horstmann 1988). The original description (p. 139) refers to a rearing from *Rhagium inquisitor* (Linnaeus, 1758) and mentions characters that could be attributed to several species of *Neoxorides*. With the current level of knowledge, this variety cannot be properly interpreted and we chose the more conservative point of view and follow the synonymy proposed by the original author.

### DNA barcode

The barcodes of *Neoxorides collaris* are separated from their closest barcodes (in *N. opacus*) by at least 7.0% p-distance. The sequences are available on GenBank under accession numbers: MT072689 (SK19\_39), MT072690 (SK19\_40), MT072694 (SK\_2148), MT072693 (SK19\_36).



**Fig. 5.** A. *Neoxorides varipes* (Holmgren, 1860), ♀, MZH, head, anterior view. B. *N. varipes*, ♀ (MZH), pronotum, lateral view. C. *N. nitens* (Gravenhorst, 1829), ♀ (NJ), central anterior part of pronotum, lateral view. D. *N. collaris* (Gravenhorst, 1829), ♀ (NJ), pronotum, lateral view. E. *N. nitens*, ♂ (NJ), form with long metasoma, lateral view. F. *N. nitens*, ♂ (NJ), form with short metasoma, lateral view. G. *N. montanus* (Oehlke, 1966), ♀ (NJ), pronotum, lateral view. Photos: Alexander Berg.



*Neoxorides montanus* Oehlke, 1966

Figs 5G, 9C, F–G

*Neoxorides montanus* Oehlke, 1966: 889–890, fig. 3.

*Neoxorides montanus* – Kasparyan 1981: 94.

**Diagnosis**

*Neoxorides montanus* is a species that is quite variable in size, with a fore wing length of 9–14 mm, on average slightly larger than *N. collaris*. The metasoma in the female is more elongate with the first tergite about 2.5 times as long as wide (Fig. 9F). The ovipositor in the female is usually as long as the metasoma and quite narrow and weak. In mounted specimens it is usually curved downwards, sinuate or curled up due to this weakness. The mid coxae in both sexes are largely yellow apically. The whitish spots along the inner orbits above the antennal scrobes are large and rounded in females (Fig. 9C) and the white lines on the sides of the pronotum are wide, usually as wide as the width of the fore femur (Fig. 5G). *Neoxorides montanus* is most similar to *N. collaris* and *N. striatus* sp. nov., but is distinguished by the characters given in the key to species and Table 2.

**Material examined**

**Holotype**

CZECH REPUBLIC • ♂; ZMHB.

**Paratypes**

GERMANY • 3 ♀♀; ZMHB • 1 ♂; NHRS.

**Other material**

SWEDEN • 6 ♀♀, 2 ♂♂; MZLU, NJ, LW.

FINLAND • 4 ♀♀, 11 ♂♂; MZH.

FRANCE • 2 ♀♀, 2 ♂♂; NHMUK.

GERMANY • 3 ♀♀, 3 ♂♂; MR, NHMUK, MZH.

UKRAINE • 1 ♀; OV.

**Ecology**

*Neoxorides montanus* is connected to cerambycids feeding on conifers. It has been reared from larch along with the cerambycid *Tetropium gabrieli* Weise, 1905 (first author pers. obs.). Most records are from spruce *Picea abies* (L.) H.Karst. dominated forests, which possibly might indicate that the main hosts are *Tetropium fuscum* (Fabricius, 1787) and/or *T. castaneum* (Fabricius, 1787) (Kenis & Hilszczański 2004).

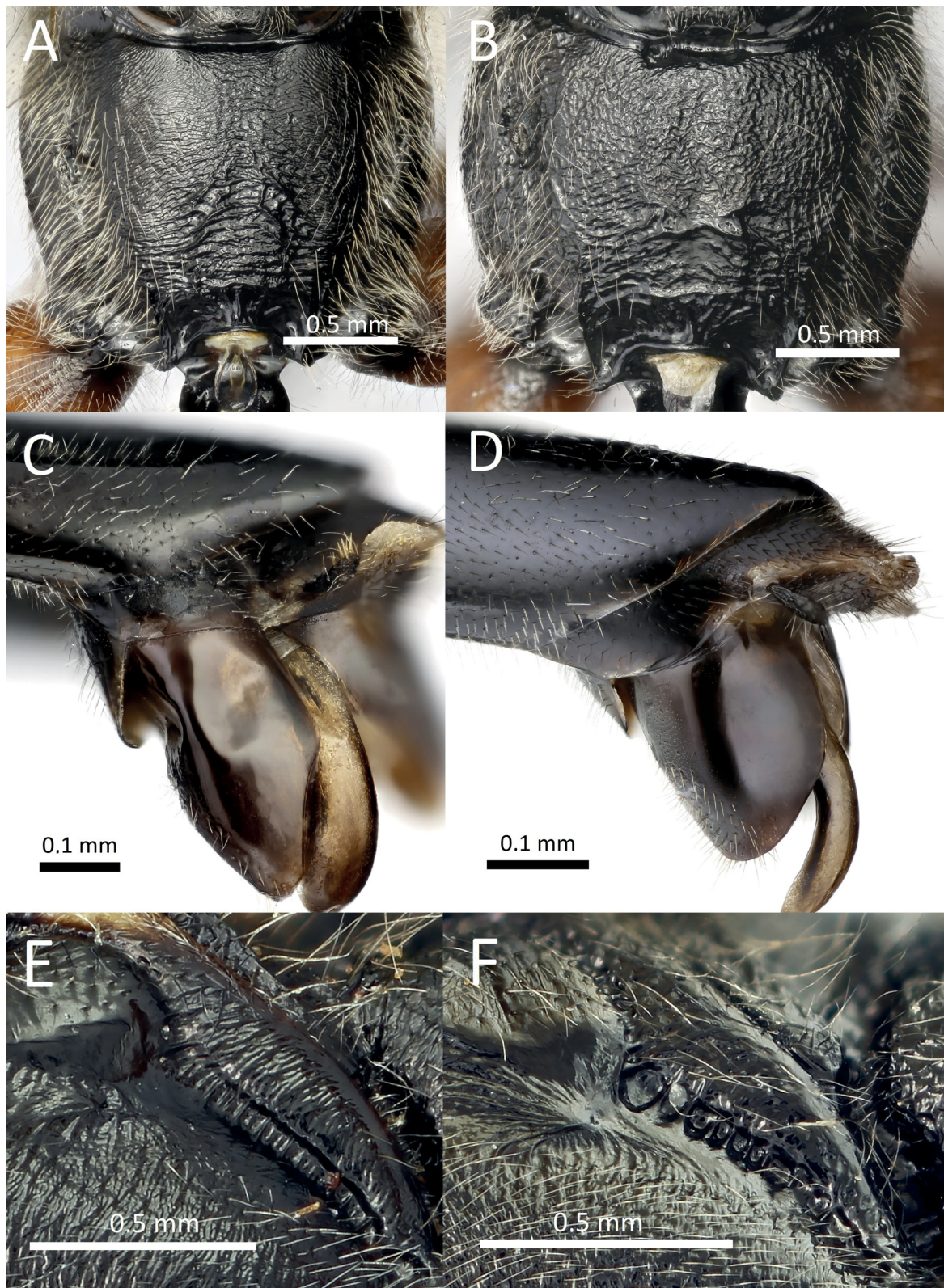
**Distribution and status in Sweden**

Most records are from the southern and central parts of the country, but it can probably be expected to occur also up in the north. Go, Hs, Sm.

**Remarks**

Among the distinguishing characters used to define and describe *N. montanus*, the relative length of the basal flagellomeres in the female and the shape of the male genitalia seem to be of limited use.





**Fig. 6.** A. *Neoxorides collaris* (Gravenhorst, 1829), ♀ (NJ), propodeum, dorsal view. B. *N. opacus* (Kokujev, 1903) stat. rev., ♀ (NJ), propodeum, dorsal view. C. *N. collaris*, ♂ (NJ), parameres, lateral view. D. *N. opacus*, ♂ (NJ), parameres, lateral view. E. *N. collaris*, ♀ (NJ), mesopleural furrow, lateral view. F. *N. opacus*, ♀ (NJ), mesopleural furrow, lateral view. Photos: Alexander Berg.

According to the original description, the female of *N. collaris* is said to have the second flagellomere at most 5.2 times as long as wide while it is at least 5.5 times as long as wide in *N. montanus*. Given the natural variation in the shape of the flagellomeres (which are often oval in cross section) often amplified during preparation and preservation, this small difference is of no practical significance. The male of *N. montanus* usually has the parameres (and the hind margins of the tergites) more weakly sclerotized than in *N. collaris* and *N. striatus* sp. nov., which often makes them heavily deformed during storage or preparation. Newly hatched specimens or specimens of other species stored in ethanol also often display this deformation, making it hard to draw any definitive conclusions from the shape of the genitalia. We, therefore, recommend that the shape of the parameres is only used in combination with other characters. Apart from the shape of the male genitalia and the shape of the flagellomeres, the only diagnostic character used in the original description is the relative length of the metasomal segments. This seems to be a quite consistent character, but one should be aware that overlap frequently occurs with *N. striatus* sp. nov. and even *N. collaris*. During this study, it was also noted that the males of *N. nitens* and also *N. striatus* sp. nov. seem to be rather variable regarding the length of the metasomal segments (Fig. 5E–F). Both the holotype of *N. montanus* (Oehlke 1966) and the lectotype of *N. collaris* (Jałoszyński & Wanat 2014) are males, and this variation regarding the relative length of the metasoma could present a problem regarding the identity of the type specimens. However, all males of *N. collaris* studied by the first author have stouter metasoma, and all males of *N. montanus* have the more slender form, which indicates that these aberrant forms are rare. The additional colour characters of the lectotype of *N. collaris* and the holotype of *N. montanus*, respectively, i.e., the shape of the white spots along the inner orbits above the antennal scobes, also supports the validity of each species.

### DNA barcode

The barcode of this species is separated from its closest barcode (in *N. striatus* sp. nov.) by 4.6% p-distance. The sequence is available on GenBank under accession number: MT072691 (SK19\_37).

### *Neoxorides nitens* (Gravenhorst, 1829)

Figs 4C, 5C, E–F

*Xorides nitens* Gravenhorst, 1829: 847–848.

*Neoxorides nitens* var. *albicollis* Clément, 1938: 518.

*Neoxorides nitens* var. *nigrifacis* Clément, 1938: 518.

*Neoxorides nitens* – Clément 1938: 518. — Oehlke 1966: 888–889. — Kasparyan 1981: 94. — Kolarov 1997: 2014. — Varga 2015: 4, fig. 3.

*Xorides nitens* – Holmgren 1860: 65. — Dalla Torre 1901–1902: 382. — Schmiedeknecht 1908: 1369.

### Diagnosis

Fore wing length 7–13 mm. *Neoxorides nitens* is distinguished from other species of the genus by the more or less polished and scarcely punctate mesosternum and mesopleuron (Fig. 4C). The anterior part of the pronotum is reflexed as a lamella (Fig. 5C), a feature which is sometimes less distinct in small males. The male, however, is easily separated based on the black central area of the face, a feature not present in any other species of the genus in the Western Palearctic. The colouration of both female and male is usually quite dark with the tegulae, sides of the pronotum and palpi black or dark brown, and the coxae orange, devoid of any whitish or yellow spots. However, quite often, the lower part of the pronotum has a white line laterally (var. *albicollis* (Clément 1938)). Based on the colouration alone, the species is most likely to be confused with *N. opacus*, but the male of that species has the face entirely white and both sexes have the mesopleuron and mesosternum more densely punctate-rugose on a shagreened background.



### Material examined

SWEDEN • 14 ♀, 8 ♂♂; NHRS, NJ.

GERMANY • 2 ♀♀, 1 ♂; MR.

### Ecology

In Sweden, *N. nitens* is probably connected to cerambycids feeding on oak *Quercus* L. Kasparyan (1981) lists a variety of hosts and though some of them, such as *Plagionotus detritus* (Linnaeus, 1758) and *Pyrrhidium sanguineum* (Linnaeus, 1758), feed on oak and might have been reared from the same substrate, the only authenticated rearing record seems to be from the cerambycid *Phymatodes testaceus* (Linnaeus, 1758) and the buprestid *Ovalisia mirifica* (Mulsant, 1855) (Broad *et al.* 2018). The latter is monophagous on elm *Ulmus* L. sp. and does not occur in Sweden.

### Distribution and status in Sweden

Locally abundant in Southern Sweden in areas with oak. Bl, Ha, Sk, Sm, Ög, Öl.

### Remarks

The male is very variable regarding the length of the metasoma (Fig. 5E–F).

### DNA barcode

The barcodes of this species are separated from their closest barcode (in *N. collaris*) by 7.3% p-distance. The sequences are stored on BOLD under accession numbers: FBICA016-10 (BC ZSM HYM 05526), FBICA110-11 (BC ZSM HYM 07425), FBICA018-10 (BC ZSM HYM 05528), BCHYM10139-15 (BC ZSM HYM 24104), FBICA168-11 (BC ZSM HYM 07483), FBICA167-11 (BC ZSM HYM 07482), FBICA562-11 (BC ZSM HYM 10727), FBICA560-11 (BC ZSM HYM 10725).

*Neoxorides opacus* (Kokujev, 1903) stat. rev.  
Figs 4A, D, 6B, D, F, 7A, C, 8A–C

*Xorides opacus* Kokujev, 1903: 287.

*Xorides kissi* Ulbricht, 1911: 151.

*Neoxorides opacus* – Clément 1938: 518.

*Neoxorides nitens* (*partim*) – Oehlke 1966: 888–889.

### Diagnosis

*Neoxorides opacus* (Fig. 8A–B) is distinguished from other species of *Neoxorides* by the combination of the densely punctate and partly rugulose mesosternum, mesopleuron and metapleuron (Fig. 4A), the roughly sculptured propodeum (Fig. 6B) and face, the apically wider mandibles (Fig. 7C), the dark pronotum and palpi, and the rounded shape of the male parameres (Fig. 6D). It is, despite the previously suspected synonymy with *N. nitens*, most likely to be confused with dark-coloured specimens of *N. striatus* sp. nov., but has the mandibles stouter and the mesopleuron and mesosternum more densely and distinctly punctate. The structure of the propodeum basally (Fig. 6B) and the basal tergites (Fig. 4D) are largely rugulose in *N. opacus* while they are more or less aciculate in *N. collaris* (Fig. 6A), *N. montanus* and *N. striatus* sp. nov. Furthermore, the white stripe along the inner orbit of both sexes is usually continuous in *N. collaris* (Fig. 7B), while it is interrupted at the level of the antennal scrobes in all known specimens of *N. opacus* (Fig. 7A).



**Material examined**

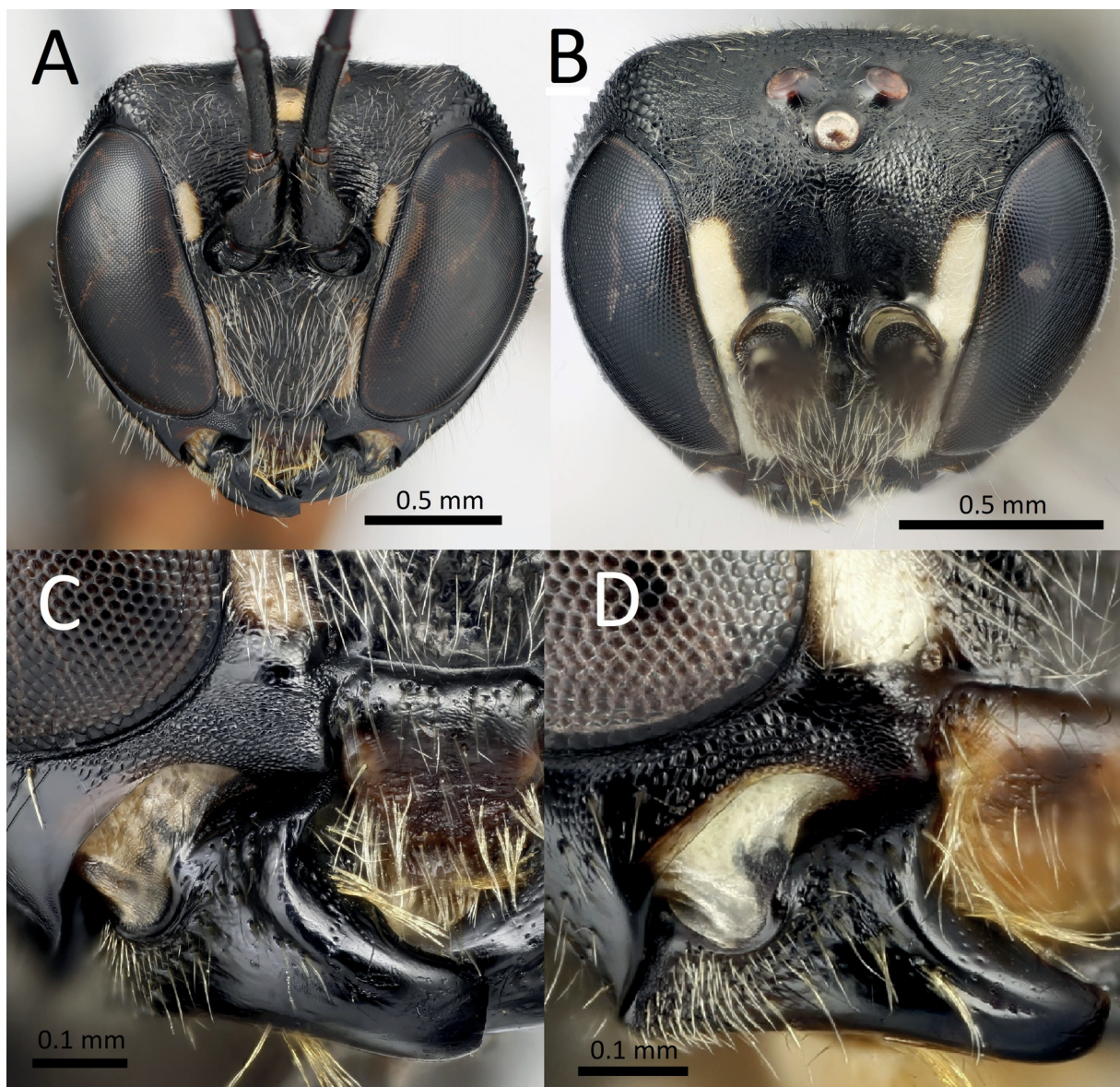
**Neotype** (here designated)

RUSSIA • ♀; “Région du Baïkal, Environ d’Irkoutsk” [Baikal area, surroundings of Irkutsk]; “174-96”; J. Chaffanjon leg.; MNHN.

**Other material**

RUSSIA • 1 ♀; MR.

ROMANIA • 1 ♀, lectotype of *Neoxorides kissi* (Ulbricht, 1911); “Ferenczfalva” [Văliug]; coll. Z. Kiss E.; HNHN-HYM 104461 • 1 ♂, paralectotype of *Neoxorides kissi* (Ulbricht, 1911); “Ferenczfalva” [Văliug]; coll. Z. Kiss E.; HNHN-HYM 104465 (coll. Z. Kiss E.).



**Fig. 7.** **A.** *Neoxorides opacus* (Kokujev, 1903) stat. rev., ♀ (NJ), head, anterior view. **B.** *N. collaris* (Gravenhorst, 1829), ♀ (NJ), head, anterodorsal view. **C.** *N. opacus*, ♀ (NJ), mandible, lateral view. **D.** *N. collaris*, ♀ (NJ), mandible, lateral view. Photos: Alexander Berg.

SWEDEN • 15 ♀♀, 4 ♂♂; NHRS, MZLU, NJ, JA.

SOUTHERN EUROPE • 1 ♀; coll. Förster; ZMHB.

### Redescription

Fore wing length 8.5–13.5 mm. Antenna in both sexes with 29–32 flagellomeres. First to fourth flagellomere about 5.0 times as long as wide. Central flagellomeres stout, about 1.5–1.7 times as long as wide. Subapical flagellomeres approximately 0.8–1.0 times as long as wide. Temple slightly widened behind eyes in dorsal view, with coarse scale-like structure following outer and upper margin of compound eye. Frons above antennal sockets weakly transversely striate (Fig. 7A). Head dorsally, behind compound eyes, with rather distinct punctures that are denser and more distinct than in *N. collaris*. Inner orbits strongly converging (Fig. 7A). Face below antennal sockets rugulose. Mandible chisel-shaped, with more parallel sides and wider edge (Fig. 7C) than in *N. collaris* (Fig. 7D) and *N. nitens*. Malar space short, about 0.1 times as wide as mandibular base (Fig. 7A, C). Wing membrane clear (Fig. 8B). Pronotum centrally unmodified, not raised as in *N. nitens*. Mesosternum and mesopleuron densely punctate, partly rugulose (Fig. 4A) with punctures denser and more distinct than in *N. collaris* (Fig. 4B) and denser than in *N. nitens* (Fig. 4C). Mesopleural furrow with transverse carinae (Fig. 6F). Mesoscutum densely punctate on sides, punctures often merging. Mesoscutum centrally transversely strigose. Notauli deeply impressed, dividing mesoscutum into three lobes. Scutellum with deep punctures on a mostly polished surface. Propodeum basally rugulose (Fig. 6B), while it is smoother and slightly aciculate in *N. collaris* (Fig. 6A), *N. montanus*, *N. striatus* sp. nov. and *N. nitens*, and centrally in front of area petiolaris with irregular transverse ridges. First tergite in female 2–2.5 times as long as wide (Fig. 4D). Sclerotised section of the first sternite with a raised keel-like projection centrally. First tergite with coarse sculpture consisting of transverse striation centrally and irregular punctures on the sides (Fig. 4D), the striae larger than in other species of the genus. Second tergite in female distinctly punctate-rugulose, basally striate, tergites 3–7 weakly transversely aciculate. Second tergite in male distinctly punctate. Tergite 3–7 in male polished with very weak rather scarce punctures that are more distinct basally on tergite 3. Male parameres apically rounded, about as long as wide (Fig. 6D), thereby differing from more elongate and apically narrowed parameres of *N. collaris* (Fig. 6C) and *N. nitens*. Note that the usually more weakly sclerotized parameres in *N. collaris*, *N. montanus*, *N. striatus* sp. nov. and *N. nitens* are more often deformed due to being dried up. Ovipositor sheath pilose, about as long as the fore wing (Fig. 8B).

### Colouration

Body black. Inner orbit in female with a white stripe that is interrupted level with antennal sockets (Fig. 7A). Face entirely, a line along the inner orbits above the antennal sockets, isolated from the white colouration of the face, and the ventral side of scapus white in male. Tegulae and palpi black or brownish. Tegulae in the neotype of *N. opacus* (Figs 8A–C) and lectotype of *N. kissi* more whitish. Palpi occasionally paler light brown. Antennae black. Wing veins fuscous and pterostigma testaceous, fuscous along anterior margin. All coxae orange in male and female without any trace of yellow or white markings. Coxae sometimes with infusate spot basally. Legs orange, hind tibia and hind and mid tarsi black, hind tibia sometimes brownish in basal 0.1. Joint between hind trochantellus and femur slightly infusate. Fore and mid femur and tibia sometimes yellow anteriorly.

### Ecology

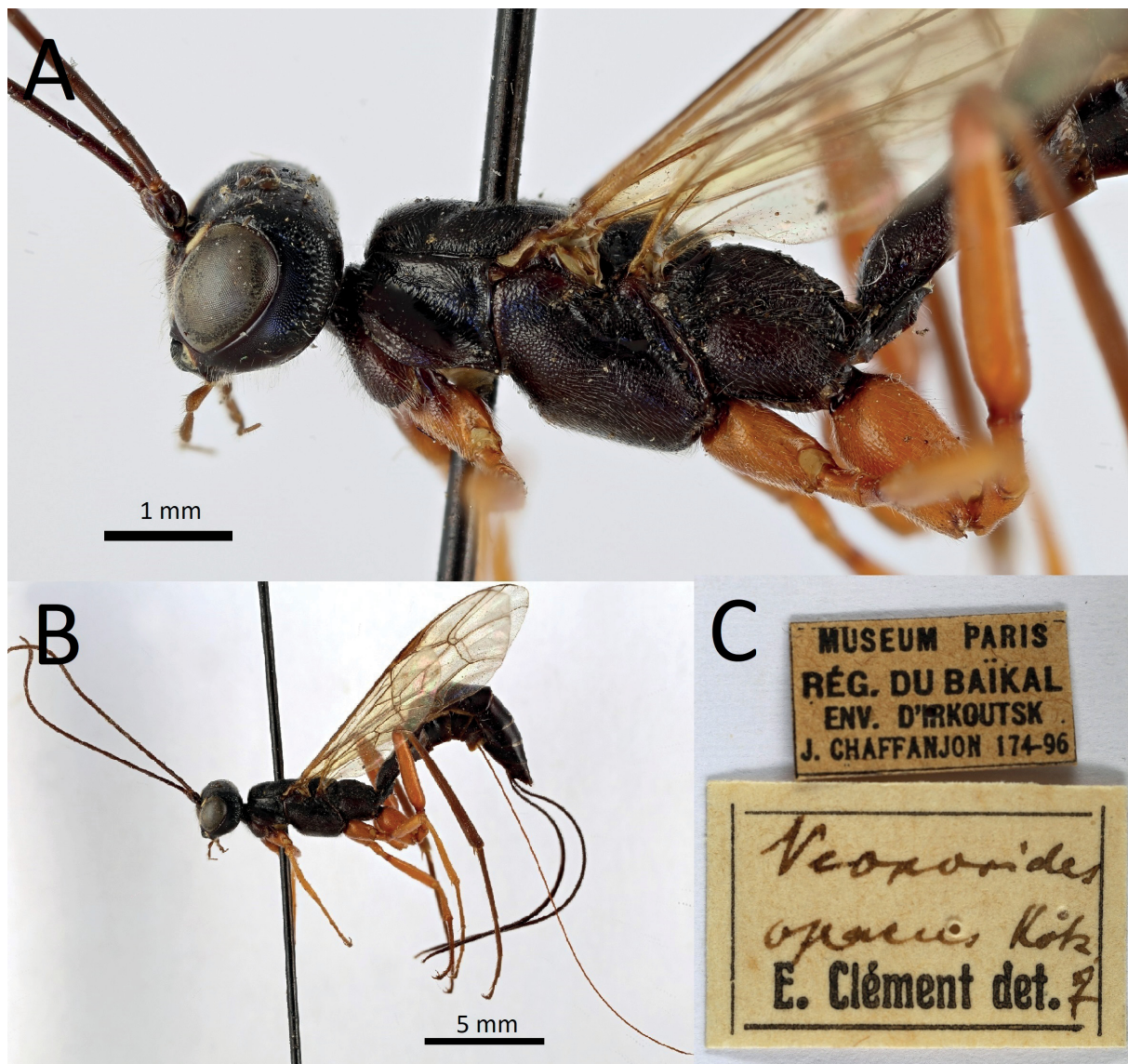
All specimens for which the dates of collection are known were collected between late April and late August, indicating a prolonged period of activity or two overlapping generations. The dates of the collected specimens indicate that the main period of activity is May in Sweden. Two series, each consisting of five specimens, were collected by Malaise Traps placed near fresh logs and high stumps of aspen *Populus tremula* L. An identical trap, next to a pile of logs of *Betula* L. spp., *Alnus glutinosa* (L.)



Gaertn. and *Salix caprea* L. between the two *Populus* L. traps caught no individuals. The two specimens collected with window traps in Grytsbergen and Tasvik in Östergötland have the sclerotization of the cuticula and wing veins weakly developed, indicating that they were newly hatched when they were collected. Both of these localities were involved in a project to investigate the species richness of saproxylic Coleoptera on aspen, and the traps were mounted on dead or dying trunks of aspen (Håkan Andersson, Linköping, pers. com.). Five of the remaining known Swedish specimens were collected in traps adjacent to or attached to dead trunks of aspen. These records could indicate that the host or hosts are to be found among cerambycids feeding on aspen. *Xylotrechus rusticus* (Linnaeus, 1758) and *Saperda perforata* (Pallas, 1773) are both common species at the Björneberg locality, where seven females and four males were collected. Both of these species have wide Palaearctic distributions.

#### Distribution and status in Sweden

Widespread in the eastern parts of Southern and Central Sweden in areas with aspen. Gs, Sö, Ög, Öl.



**Fig. 8.** *Neoxorides opacus* (Kokujev, 1903) stat. rev., ♀, neotype (MNHN). **A.** Head and mesosoma, lateral view. **B.** Habitus, lateral view. **C.** Labels. Photos: Claire Villemant.



### Remarks

The status of *N. opacus* has historically been subject to different interpretations. Clément (1938) treated it as a valid species based on the original description and proposed *N. kissi* to be a junior synonym, but Oehlke (1966) put *N. opacus* and *N. kissi* in synonymy with *N. nitens*, referring to a couple of morphologically deviant females, one from Germany and one from Southern Europe. However, he qualified the synonymy with a question mark and stated that he was doubtful whether *N. opacus* and the apparently conspecific *N. kissi* are to be regarded as varieties of *N. nitens* or as valid species. The holotype of *N. opacus*, a single female collected in Irkutsk in the Siberian Far East (Kokujev 1903), is lost (Townes *et al.* 1960), and there is no known additional material of the species determined by Kokujev (Andrey Khalaim, ZIN, pers. com.). However, in the MNHN, there is a specimen referred to by Clément (1938). This specimen was collected in the vicinity of Irkutsk by the French explorer Jean Chaffanjon (spelled “Chaffaniou” in Clément 1938) and corresponds to the interpretation of *N. opacus* presented in this study. As this specimen originates from the type locality, it is hereby designated as neotype (Fig. 8A–C). One of the two female specimens listed by Oehlke (1966) as “*N. nitens* var. *opacus*”, the one in the Förster collection in Berlin, has been studied and it is in agreement with the interpretation of *N. opacus* presented here. The other, collected in Sachsen, Germany, seems to be lost (Jutta Helbig, ZMHB, pers. com.). The female lectotype of *N. kissi* and one quite badly damaged male paralectotype in the HNHN, collected in Ferenczfalva, Hungary (now Văliug, Romania) also fits the interpretation of *N. opacus* as defined in this study and the synonymy between *N. kissi* and *N. opacus*, previously proposed by Clément (1938), is hereby confirmed.

### DNA barcode

The barcode of this species is separated from its closest barcode (in *N. collaris*) by 7.0% p-distance. The sequence is available on GenBank under accession number: MT072692 (SK19\_38).

*Neoxorides striatus* Johansson sp. nov.

[urn:lsid:zoobank.org:act:E08054F6-B6CC-41A1-8F84-5D221C781D6D](https://zoobank.org/urn:lsid:zoobank.org:act:E08054F6-B6CC-41A1-8F84-5D221C781D6D)

Figs 1A–C, 9B, E, H

### Diagnosis

*Neoxorides striatus* sp. nov. (Fig. 1A) is similar to *N. collaris* and *N. montanus* regarding colour and shape, and is intermediate between those species. The face of the male is usually narrower (Fig. 9H) in comparison with the other two species (Fig. 9G). Furthermore, the frons is weakly transversely striate in *N. striatus* sp. nov. (Fig. 1B) but more evenly shagreened in *N. collaris* and *N. montanus*, and the mesopleural furrow usually has more distinct transverse carinae (Fig. 1C, frequently almost as in Fig. 6F). *Neoxorides striatus* sp. nov. is also distinguished from *N. montanus* by the usually slightly shorter first tergite in the female (Fig. 9E) (overlap exists), the orange mid coxae in the female, the narrower white line on the sides of the pronotum and the smaller white spots along the inner orbits above the antennal scrobes. The latter character is more evident in females, but the marks are usually shorter and narrower in males with the inner margins concave, while the inner margins are usually convex in the male of *N. montanus*. From *N. collaris* it is also distinguished by the longer first tergite (Fig. 9E) and the usually shorter/wider white spots along the inner orbits (Fig. 9B).

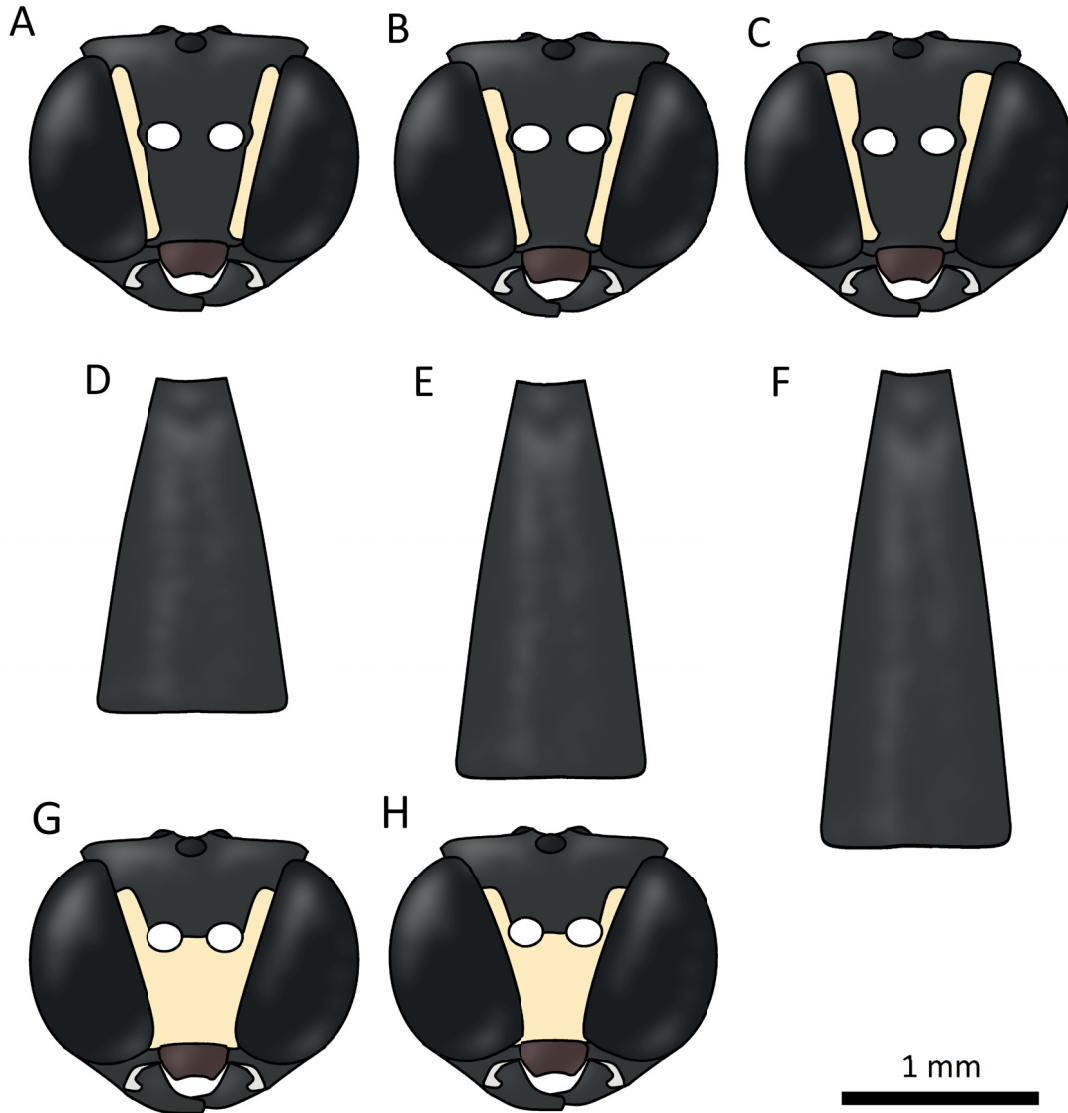
### Etymology

The weak striation of the frons in combination with the striate sides of pronotum and transverse carination of the mesopleural furrow is diagnostic.

**Material examined**

**Holotype**

GERMANY • ♂; Bavaria, Nürnberg; 8 May 2001; R. Bauer leg.; ZSMBC ZSMHYM07485 (Fig. 1A–C).



**Fig. 9.** A–C. ♀, generalized shape of head and colouration of face, anterior view. A. *Neoxorides collaris* (Gravenhorst, 1829). B. *N. striatus* Johansson sp. nov. (lectotype NHRS-HEVA000011623). C. *N. montanus* (Oehlke, 1966). D–F. ♀, generalized shape of first tergite, dorsal view. D. *N. collaris*. E. *N. striatus* Johansson sp. nov. (lectotype NHRS-HEVA000011623). F. *N. montanus*. G–H. ♂, generalized shape of head and colouration of face in anterior view. G. *N. montanus*. H. *N. striatus* Johansson sp. nov. (paratype NHRS-HEVA000011622).

### Paratypes

SWEDEN • 1 ♀; Uppland, Norrtälje, Vaddö; probably 1890–1895; G.A. Ringselle leg. (1868–1944); MZLU 754 2019 • 1 ♀; Ångermanland, Bjurholm, Käringsbergets ekopark; 30 May–30 Jul. 2011; M. Larshagen/Sveaskog leg.; NHRS-HEVA000011623 • 1 ♂; Hälsingland, Ramsjö, Ensjölokarna; 30 May–28 Jun. 2002; window trap; L.-O. Wikars leg.; NHRS-HEVA000011622 • 5 ♀♀; coll. Marklin (1777–1857); UPSZEN 153034 to 153038 • 5 ♂♂; same collection data as for preceding; UPSZEN 153022 to 153026 • 2 ♀♀; coll. Gyllenhaal (1752–1840); UPSZEN 153041, 153042 • 3 ♂♂, same collection data as for preceding; UPSZEN 153031 to 153033 • 1 ♀; coll. Haeffner (active 1800–1815); UPSZEN 153039 • 3 ♂♂; same collection data as for preceding; UPSZEN 153027 to 153029 • 1 ♂; coll. Stenhammar (1783–1866); UPSZEN 153030 • 1 ♀; Småland; C.H. Boheman leg. (1796–1868); NHRS-HEVA000011613 • 1 ♂; same collection data as for preceding; NHRS-HEVA000011599 • 1 ♀; Stockholm; 19<sup>th</sup> century; NHRS-HEVA000011612 • 1 ♀; “Hlm” [Stockholm]; C.H. Boheman leg. (1796–1868); NHRS-HEVA000011611 • 1 ♀; Östergötland; 19<sup>th</sup> century; NHRS-HEVA000011607 • 1 ♂; Uppland; 19<sup>th</sup> century; NHRS-HEVA000011612 • 1 ♀; Östergötland, Norrköping, Kimstad; 15 Jun. (year unknown); probably E. Haglund leg. (1837–1901); NHRS-HEVA000011600 • 1 ♀; Uppland, Uppsala, Vassunda; probably 1905–1910; O. Lundblad leg. (1890–1970); NHRS-HEVA000011598 • 1 ♂; Östergötland, Linköping, Sankt Lars, på Gärdesgård (on wooden fence); 10 Jun. 1914; H. Nordenström leg.; NHRS-HEVA000011597 • 1 ♂; Östergötland, Norrköping, Kimstad; 23 Jun. (year unknown); probably E. Haglund leg. (1837–1901); NHRS-HEVA000011596 • 1 ♂; Halland, Kungsbacka, Särö; 23 Jun. (year unknown); N. Westring leg. (1798–1882); NHRS-HEVA000011595 • 1 ♀; Östergötland (green rhomb); NHRS-HEVA000011594 • 1 ♂; “Hlm” [Stockholm]; C.H. Boheman leg. (1796–1868); NHRS-HEVA000011593.

FINLAND • 1 ♀; Åland, Eckerö; 1939; W. Hellén leg.; MZH 355 (<http://id.luomus.fi/GP.110132>) • 1 ♂; Varsinais-Suomi, Lohja, Kouvola Village; 7–10 Jun. 1910; R. Frey leg.; MZH 339 (<http://id.luomus.fi/GP.110106>) • 1 ♀; Varsinais-Suomi, Turku, Ispois (Ispoinen); E. Reuter leg.; MZH (<http://id.luomus.fi/GP.110107>) • 1 ♂; Satakunta, Loimaa; A. Merisuo leg.; MZH (<http://id.luomus.fi/GP.110117>) • 1 ♀; Etelä-Häme, Hattula; L. von Essen leg.; MZH 4184 (<http://id.luomus.fi/GP.110119>) • 1 ♀; Etelä-Häme, Hattula; A. Wegelius leg.; MZH 574 (<http://id.luomus.fi/GP.110127>) • 1 ♀; Etelä-Häme, Pirkkala; T. Grönblom leg.; MZH 589 (<http://id.luomus.fi/GP.110116>) • 1 ♂; Etelä-Häme, Palkäne; W. Hellén leg.; MZH 842 (<http://id.luomus.fi/GP.110133>) • 1 ♂; Pohjois-Karjala, Nurmes; 17 Jun. 1939; A. Saarinen leg.; MZH (<http://id.luomus.fi/GP.110115>) • 1 ♀; Keski-Pohjanmaa, Haapavesi; unspecified date but probably 1890s; A.G. Helenius leg.; MZH (<http://id.luomus.fi/GP.110113>) • 2 ♂♂; Inarin Lappi, Inari, Ivalo; 24 Jun. 1930; R. Frey leg.; MZH 181, 186 (<http://id.luomus.fi/GP.110121>, <http://id.luomus.fi/GP.110117>) • 1 ♀; Inarin Lappi, Inari, Ivalo; 24 Jun. 1937; W. Hellén leg.; MZH 1178 (<http://id.luomus.fi/GP.110130>) • 1 ♀; Inarin Lappi, Inari, Ivalo; 25 Jun. 1937; W. Hellén leg.; MZH 1254 (<http://id.luomus.fi/GP.110124>) • 2 ♂♂; Inarin Lappi, Inari, Ivalo; W. Hellén leg.; MZH 127 (<http://id.luomus.fi/GP.110128>; <http://id.luomus.fi/GP.110129>).

UKRAINE • 1 ♂; Ivano-Frankivsk Region, Bogorodchany District, Mochary, 5 km NE of Bogorodchany; 300–320 m; 28 Apr. 2018; O. Varga leg.; mixed forest, sweep netting; NHRS-HEVA000011621.

GERMANY • 1 ♂; Bavaria, Nürnberg; 16 May 2001; R. Bauer leg.; ZSM BC ZSM HYM07484 • 1 ♂; Oberbayern, Ammergau Alpen, Oberammergau; 16 Jul. 2017; 850 m; M. Riedel leg.; MR.

EUROPE • 1 ♀; “1881-93”; coll. Buchecker; probably of Central European origin; NHMUK.



## Description

Fore wing length 6–14 mm. Antenna in both sexes with 28–36 flagellomeres. First to fourth flagellomere about 4.5–5.0 times as long as wide. Central flagellomeres stout, about 1.5–1.7 times as long as wide. Subapical flagellomeres approximately 0.8–1.0 times as long as wide. Temple slightly widened behind eyes in dorsal view, with coarse scale-like structure following outer and upper margin of compound eye. Frons between antennal scrobes and central ocellus with weak transverse striation (Fig. 1B). Face shagreened, frequently with weak transverse striation in lower half. Head dorsally, behind compound eyes, with rather indistinct punctures on a shagreened background. Inner orbits strongly converging. Face in male narrower than in *N. collaris* and *N. montanus* (Figs 1B, 9H). Face below antennal sockets quite smooth with indication of transverse striae in lower part. Mandible chisel-shaped, with sides converging as in *N. collaris*. Malar space short, about 0.1 times as wide as mandibular base. Wing membrane clear. Pronotum centrally unmodified, not raised as in *N. nitens*. Sides of pronotum centrally with distinct striae, which extends upwards/backwards to upper part (as in Fig. 6G). Striae often more distinct and larger than in *N. montanus*. Mesosternum and mesopleuron shagreened with quite dense but clearly discernible punctures, slightly denser and more distinct than in *N. collaris* and *N. montanus*. Mesopleuron in front of speculum with weak striae (Fig. 1C). Mesopleural furrow with distinct transverse carinae (Fig. 1C). Mesoscutum shagreened with indistinct punctures, centrally transversely strigose. Notauli deeply impressed, dividing the mesoscutum into three lobes. Scutellum with indistinct punctures on a shagreened background. Propodeum basally weakly aciculate (as in Fig. 6A). Submetapleural carinae complete. First tergite in female 2.0–2.3 times as long as wide (Fig. 9E), in male more variable, about 2.5–3.5 times as long as wide. Sclerotised section of first sternite with a raised keel-like projection centrally often with weak transverse ridges. First to third tergite with transverse rugulose striation that sometimes extends to sides. Male parameres usually more strongly sclerotized, as in typical *N. collaris*.

## Colouration

Body black. Inner orbit in female with a white line which is about two times as long as wide above the antennal scrobes. Face in male entirely white. Spot below the occipital carina centrally white. The white line on the sides of pronotum is very narrow in both sexes and usually at most about  $\frac{1}{3}$  as wide as the width of the fore femur, missing in small specimens. Tegulae and palpi white. Antennae black or brown. Wing veins and pterostigma testaceous. Coxae in female orange. Mid coxae in large males with large yellow spot that covers most of the outer side or a smaller yellow spot, in smaller males coxae entirely orange. Trochanter and trochantelli yellowish. Legs orange, hind tibia and hind- and mid-tarsi infusate. Fore and mid femur and tibia sometimes yellow anteriorly.

## Ecology

No host is known for *Neoxorides striatus* sp. nov. Most records seem to stem from pristine coniferous forests. The available records indicate that the period of flight is June and July in northern Europe.

## Distribution and status in Sweden

Only a few recent records. All present localities consist of relatively large fragments of primeval forests. Numerous old specimens from the 19<sup>th</sup> century in collections from Sweden and Finland indicates a strong decline in numbers during the last century. Ha, Hs, Sm, Up, Ån, Ög.

## DNA barcode

The barcodes of this species are separated from their closest barcode (in *N. montanus*) by 4.6% p-distance. The sequences are stored on BOLD under accession numbers: FBICA170-11 (BC ZSM HYM 07485), FBICA169-11 (BC ZSM HYM 07484).

*Neoxorides varipes* (Holmgren, 1860)

Fig. 5A–B

*Xorides varipes* Holmgren, 1860: 66.

*Xorides collaris* ab. *picicoxis* Hellén, 1915: 20 syn. nov.

*Neoxorides varipes* – Clément 1938: 519. — Oehlke 1966: 891. — Kasparyan 1981: 94. — Varga 2015: 4–5, fig. 2.

*Neoxorides variipes* – Clément 1938: 517.

*Neoxorides varpies* – Kanders 2009: 9.

*Xorides variipes* – Dalla Torre 1901–1902: 382. — Schmiedeknecht 1908: 1369.

### Diagnosis

Fore wing length 6–10 mm. *Neoxorides varipes* is distinguished from other species of *Neoxorides* in the Western Palaearctic by the virtually impunctate and strongly shagreened mesosternum and mesopleuron, the weakly reticulate sides of the pronotum (Fig. 5B) and the infusate hind coxae. The ovipositor in the female is relatively short, about as long as the metasoma minus the first and second tergite. The female has all the coxae infusate, while the mid and fore coxae in the male are mainly whitish. The white spots along the inner orbits above antennal sockets are shorter than in *N. collaris* and *N. montanus* (Fig. 5A). The male has the propleuron with large whitish spots basally, while it usually is infusate in *N. collaris* and *N. montanus*. Four small females from Northern Sweden have all the legs infusate and the anterior side of the mid and fore tibia yellowish. Apart from the darker colour and smaller size, we have found no reliable distinguishing character between these forms and they are treated here as a small northern variety.

### Material examined

#### Lectotype

SWEDEN • ♂; NHRS.

#### Other material

SWEDEN • 4 ♀, 4 ♂♂; JH, NJ, UPSZ, NHRS.

FINLAND • 4 ♀♀; MZH.

NORWAY • 1 ♀; MR.

POLAND • 1 ♀, 2 ♂♂; JH.

UKRAINE • 2 ♀♀, 1 ♂; OV.

### Ecology

*Neoxorides varipes* is probably connected to cerambycids feeding on conifers. Collected in relatively large numbers on logs of *Picea abies* and *Abies alba* Mill. (Varga 2015; O. Varga pers. com.). It has been reared from branches containing *Callidium aeneum* (De Geer, 1775) and *Obrium brunneum* (Fabricius, 1792) (J. Hilszczański pers. com.).

### Distribution and status in Sweden

*Neoxorides varipes* is a very rare species in Sweden with only a few known records. It is an exclusive inhabitant of pristine boreal forests rich in dead wood in the northern part of the country. Vb, Ås.

### Remarks

Due to its rarity, the distinction between *N. varipes* and other species of the genus, primarily *N. collaris*, has mainly relied upon the typical colouration of the hind coxae. There are, however, some additional characters used in the key to species. Two females labelled as *N. collaris* ab. *picicoxis* (Hellén, 1915) syn. nov. in the MZH were studied by the first author and they both represent pale specimens of *N. varipes*.

### DNA barcode

No fresh material suitable for barcoding was available to us.

### Discussion

The results from barcoding and the thorough study of the morphological differences provided here show that previous taxonomical work on the genus in the Western Palaearctic has partly failed to properly define the species involved. This could be explained by several factors, such as the species being relatively rarely collected and the misinterpretation of certain characters and their importance when it comes to species delimitations based on morphology. By integrating morphological data with the molecular barcode, we could here put species delimitations and the suggestion of diagnostic characters on a robust foundation, which will allow reliable identification of the species in the future. In contrast to other groups of ichneumonid wasps for which the barcode region was not informative for many species (Klopfstein 2014), which was at least partly caused by *Wolbachia* Hertig & Wolbach, 1924 endosymbionts (Klopfstein *et al.* 2016), we found large interspecific distances (at least 4.6%) and solid barcoding gaps in all examined species of *Neoxorides*. Even though the latter might decrease somewhat once specimens from a larger part of their distribution range are sequenced (Bergsten *et al.* 2012), the marker has thus proven very useful in this genus, at the very least on the country scale.

The results presented in this study indicate that species of *Neoxorides* possibly show a higher degree of ecological specialization regarding hosts and preferred habitat than previously appreciated, making them potentially useful in a conservation context. On *The 2019 Red List of Finnish Species* (Hyvärinen *et al.* 2019), *N. collaris* is classified as EN (Endangered), *N. varipes* as RE (Regionally Extinct) and *N. montanus* as NT (Near Threatened). The assessment of the situation in Sweden is perhaps more conservative, given the scarcity of data, and *N. varipes* is classified as NT (Near Threatened) in the upcoming version (2020). Note that *N. striatus* sp. nov. was not assessed for the *Red List*. The Swedish classifications are based upon the assumptions of quite a large estimated number of unknown records and common and widespread hosts (*Tetropium* Kirby, 1837, *Phymatodes* Mulsant, 1839, *Rhagium* Fabricius, 1775, *Xylotrechus* Chevrolat, 1860, etc.). However, specimens of *Neoxorides* are quite rare in historical collections, and most modern records stem from surveys of saproxylic insects in areas which are to be regarded as forest biodiversity hotspots. For example, the locality Ensjölokarna in Hälsingland (Fig. 10), one of a few remaining fragments of primeval forest (Wikars 2003) in Central Sweden, houses as least three of the species connected to coniferous forests: *N. collaris*, *N. montanus* and *N. striatus* sp. nov. Very little is known about the occurrence of *Neoxorides* species in biologically impoverished tree plantations, which constitute a growing part of the forested areas in Sweden (Claesson *et al.* 2015). This means that coleopterists and researchers that specialize in saproxylic insects can contribute greatly to the knowledge of these parasitoids by documenting rearing records and recording specimens collected by traps, material that would usually be disposed of. This also reflects another benefit of the work presented here, as correct taxonomy actually enables the unveiling of ecological strategies that otherwise would be obscured by wider and invalid species concepts.

Fundamental taxonomic work of the kind presented here is a prerequisite for all other studies involving the species level, including population and ecosystem dynamics. *Neoxorides* and other genera with similar ecology (parasitoids on well-known saproxylic hosts), i.e., *Xorides* Latreille, 1809, *Odontocolon*



Cushman, 1942, *Ischnoceros* Gravenhorst, 1829, etc., are well suited for studies of boreal forest ecosystems, where the parasitoid level at an early stage can provide information on the stability of the ecosystem (Shaw & Hochberg 2001; Hilszczański *et al.* 2005; Shaw 2006). Sweden still harbors a considerable proportion of the remaining high conservation value forests of Northwestern Europe, and the Nordic countries have a responsibility when it comes to preserving these ecosystems from a European perspective. This calls for an increase in the study of forest ecosystem dynamics also including relatively easily identifiable parasitoids like the ones found in the subfamilies Xoridinae Schuckard, 1840 and Poemeniinae. This highlights the need for easily accessible identification keys based on correct taxonomy and, by extension, the need for basic taxonomic studies as a foundation for any ecological studies based on species populations or population dynamics involving the parasitoid level.



**Fig. 10.** Ensjölokarna in the province of Hälsingland, Sweden. One of a few fragments of primeval forest that remains in Central Sweden. Habitat of *Nexorides collaris* (Gravenhorst, 1829), *N. montanus* (Oehlke, 1966) and *N. striatus* Johansson sp. nov. Photo: Maria von Hofsten and Länsstyrelsen i Gävleborg.

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