Monopis jussii, a new species (Lepidoptera, Tineidae) inhabiting nests of the Boreal owl (Aegolius funereus)

Marko Mutanen¹, Peter Huemer², Jonna Autto³, Ole Karsholt⁴, Lauri Kaila⁵

¹ Ecology and Genetics Research Unit, P.O.Box 3000, FI-90014 University of Oulu, Finland ² Tiroler Landesmuseen-Betriebsgesellschaft m.b.H., Innsbruck, Austria ³ Apajatie 11, FI-96800 Rovaniemi, Finland ⁴ Zoological Museum, Natural History Museum of Denmark, Universitetsparken 15, DK-2100 Copenhagen, Denmark ⁵ Finnish Museum of Natural History, Zoology Unit, P.O.Box 17, FI-00014 University of Helsinki, Finland

Corresponding author: Marko Mutanen (marko.mutanen@oulu.fi)

Abstract

Monopis jussii Kaila, Mutanen, Huemer, Karsholt & Autto, sp. nov. (Lepidoptera, Tineidae) is described as a new species. It is closely related to the widespread and common M. laevigella ([Denis & Schiffermüller], 1775), but differs in its distinct COI DNA barcode sequences, four examined nuclear loci as well as details in forewing coloration and pattern. Most reared specimens of M. jussii have emerged from the nest remnants of the Boreal owl (Aegolius funereus (Linnaeus, 1758)), but also nests of the Ural owl (Strix uralensis Pallas, 1771) and the Great tit (Parus major Linnaeus, 1758) have been observed as suitable habitats. Based on the present knowledge, the new species has a boreo-montane distribution as it is recorded only from northern Europe and the Alps. Several extensive rearing experiments from Strix spp. nest remnants from southern Finland did not produce any M. jussii, but thousands of M. laevigella, suggesting that the species is lacking in the area or, more unlikely, that the nest of these owl species do not serve as good habitat for the new species. This unexpected species discovery highlights, once again, the usefulness of DNA barcoding in revealing the cryptic layers of biodiversity. To serve stability we select a neotype for Tinea laevigella [Denis & Schiffermüller], 1775, and discuss the complicated synonymy and nomenclature of this species.

Copyright Marko Mutanen et al. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
Keywords
boreo-montane, cryptic diversity, DNA barcoding, nuclear marker

Introduction

The lepidopteran fauna of Central and North Europe has been investigated for a longer time and more intensively than that of any other region in the world. Consequently, discoveries of species new to the region are nowadays uncommon and usually involve expansive or invasive species. Large-scale efforts to build taxonomically comprehensive regional DNA barcode reference libraries have, however, resulted in a boost in discoveries of overlooked species during the last 15 years, as demonstrated by the increase of new species descriptions e.g. in the family Gelechiidae by Huemer et al. (2020). Characteristic to the new discoveries is that they often concern unexpected cases of cryptic diversity among well-known and often widespread species. Examples of such recent findings, originally detected as deep intraspecific splits in DNA barcode sequences, include *Leptidea reali* Reissinger, 1990 (Dinca et al. 2011), *Olethreutes subtilana* (Falkovitsh, 1959) (Segerer et al. 2010), *Phalonidia udana* (Guenée, 1845) (Mutanen et al. 2012a), *Epinotia cinereana* (Haworth, 1811) (Mutanen et al. 2012b), *Nemophora scopollii* Kozlov, Mutanen, Lee & Huemer, 2016 (Kozlov et al. 2017), several *Elachista* spp. (Mutanen et al. 2013) and *Hoplodrina alsinides* (Costantini, 1922) (Huemer et al. 2020).

There are many more additional cases of potential cryptic diversity in European Lepidoptera, as dozens of species show high levels of genetic polymorphism in their mitochondrial DNA (Mutanen et al. 2016, Huemer et al. 2020). While polymorphism in the mitochondrial DNA may result from multiple other phenomena, including mitochondrial introgression and retained ancestral polymorphism, many of those cases are likely to result from cryptic diversity.

An intraspecific split of the mitochondrial DNA being reflected in the nuclear genome in sexually reproducing species and in sympatry would strongly suggest the presence of cryptic diversity, because, unlike mitochondrial DNA, nuclear DNA is subject to genetic recombination. From this starting point, we sequenced four nuclear markers of *Monopis laevigella* ([Denis & Schiffermüller], 1775), a widespread and common species of tineid moths, showing a deep sympatric genetic split in its DNA barcode region in Europe (Gaedike 2019). Despite the limited number of analyzed specimens, the results provided unequivocal genetic support for the presence of two biologically distinct species. Subsequent morphological examination revealed consistent differences in the adult wing patterns, providing additional support for the overlooked cryptic diversity. Additionally, based on the presently available data, the two species show overlapping, but different ranges and based on the present knowledge, also a different ecology. Based on these grounds, we here describe one of the taxa as new to science.
Material and methods

The material examined was acquired from the following collections:

| Acronym | Description |
|---------|-------------|
| ITJ     | Research collection of Juhani Itämies |
| MUT     | Research collection of Marko & Tomi Mutanen |
| MZH     | Finnish Museum of Natural History, Helsinki, Finland |
| TLMF    | Tiroler Landesmuseum Ferdinandeum, Innsbruck, Austria |
| ZMUO    | Zoological Museum, University of Oulu, Finland |
| ZSM     | Zoologische Staatssammlung München, Germany |

Terminology of genitalia follows Robinson and Nielsen (1993) and Gaedike (2019). Preparation of genitalia generally follows the method outlined by Robinson (1976). Male genitalia were mounted in dorso-ventral position as it was considered to best show shapes of diagnostic structures, even if the shape of the gnathos is not optimally expressed. Male genitalia were stained using Eosin, female genitalia as well as abdominal pelts of both sexes using Chlorazol black. Structures were embedded in Euparal. Images were edited using Corel PHOTO-PAINT (2019).

Species of Tineidae have been systematically sequenced for the standard barcode region of the mitochondrial COI (cytochrome c oxidase subunit 1) in the connection of ongoing regional or national DNA barcoding projects in the Alps (Lepidoptera of the Alps campaign) and Finland (FinBOL). DNA barcode sequencing was conducted at the Canadian Centre for DNA Barcoding (CCDB, Biodiversity Institute of Ontario, University of Guelph) using standard Sanger protocols as explained in deWaard et al. (2008). We successfully sequenced 87 specimens of Monopis representing twelve species, the newly described species included. Five European species of Monopis (M. luteocos-talis Gaedike, 2006, M. henderickxi Gaedike & Karsholt, 2001, M. christophi Petersen, 1957, M. pallidella Zagulajev, 1955 and M. barbarosi (Koçak, 1981)) were not included in this sampling. Each of them is morphologically clearly distinct from M. jussii sp. nov. (Gaedike 2019). Full collection and taxonomic data as well as voucher photographs, DNA sequences and GenBank accession numbers of all these specimens are available in the Barcode of Life Data Systems (BOLD; Ratnasingham and Hebert 2007) in the public dataset DS-MONOJUS at https://dx.doi.org/10.5883/DS-MONOJUS. Collection data of the specimens are also given in Table 1. Some of the COI sequences used in this study were previously published in Mutanen et al. (2016), the others are novel.

Four nuclear genes, carbamoylphosphate synthase domain protein (CAD), elongation factor 1 alpha (EF-1a), cytosolic malate dehydrogenase (MDH) and wingless, were sequenced at the University of Oulu, Finland. These genes were chosen primarily based on the high amplification success rate in other Tineidae, but also based on our previous experience on their general good functionality to provide useful taxonomic information between closely related species. In these analyses, three specimens of M. laevigella and two specimens of M. jussii, all collected from Finland, were included. Legs
Table 1. Summary of the collection data of barcoded specimens of *Monopis* used in this study. For more details, see the public BOLD dataset at https://dx.doi.org/10.5883/DS-MONO1US.

| Species          | Sample ID          | Sequence length | Collector(s)         | Collection date | Country | Province | Site                          | Latitude | Longitude |
|------------------|--------------------|-----------------|----------------------|-----------------|---------|----------|-------------------------------|----------|-----------|
| *Monopis burmanni* | TLFM Lep 06512     | 658             | Huemer P.            | 13-Jun-2004     | Austria | Tyrol    | Nordensteirdorf               | 47.265   | 11.323    |
|                  | TLFM Lep 03882     | 658             | Huemer P.            | 05-Jun-2015     | Austria | Tyrol    | Ellbachtal, unterer Kaisereck | 47.539   | 11.936    |
| *Monopis crocicapitella* | TLMF Lep 06511 | 658             | O. Rist             | 21-Sep-2005     | Austria | Tyrol    | V Lenin, Albaica              | 50.312672 | 16.407    |
| *Monopis fenestratella* | TLMF Lep 06510 | 658             | Huemer P.            | 21-May-2004     | Austria | Comunidad Valenciana          | 40.312972 | 16.407    |
|                  | TLMF Lep 03882     | 658             | Huemer P.            | 21-May-2004     | Spain   | Valenica | Valencia                      | 45.6688  | 25.168    |
| *Monopis imella* | MM18899            | 658             | Marko Mutanen        | 13-Jul-2002-19-Jul-2002 | Finland | Al         | Kangerman                  | 59.9031 | 20.85832 |
|                  | MM18898            | 658             | Pekka Sundell, M. Varesvuo, L. Jalonen, Kalle Lundsten             | 25-Aug-2004-10-Sep-2004 | Finland | Al         | Al                           | 59.92    | 20.85832 |
|                  | MM26020            | 658             | Pekka Sundell, M. Varesvuo, L. Jalonen, Kalle Lundsten             | 13-Jul-2002-19-Jul-2002 | Finland | Al         | Al                           | 59.9031 | 20.85832 |
| *Monopis jussii* | MM17525            | 658             | Marko Mutanen        | 2001             | Finland | Oulu      | Ylikiiminki                  | 64.984   | 26.153    |
|                  | MM18626            | 658             | Marko Mutanen        | 2006             | Finland | Oulu      | Ylikiiminki                  | 64.9768  | 25.3056   |
|                  | TLMF Lep 09795     | 658             | Huemer P.            | 23-Jun-2006     | Italy   | South Tyrol | Pantelleri Wald | 39.0512 | 21.1811   |
| Species          | Sample ID | Sequence length | Collector(s) | Collection date | Province | Country | Site                                      | Latitude | Longitude |
|------------------|-----------|-----------------|--------------|----------------|----------|---------|------------------------------------------|----------|-----------|
| Monopis laevigella | TLMF Lep 09306 | 658             | Huemer P.    | 19-Jun-2012    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.301  | 11.125    |
| Monopis laevigella | TLMF Lep 10441 | 658             | Huemer P.    | 16-Jun-2013    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | TLMF Lep 07809 | 658             | Huemer P.    | 16-May-2013    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | TLMF Lep 10584 | 658             | Huemer P.    | 25-May-2008    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | TLMF Lep 07389 | 658             | Huemer P.    | 25-May-2012    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | TLMF Lep 10354 | 658             | Huemer P.    | 16-Jun-2013    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | TLMF Lep 07970 | 658             | Huemer P.    | 25-May-2012    | Tyrol    | Austria | Nonditol, Oberpint, Patten               | 47.384  | 11.864    |
| Monopis laevigella | MM19355    | 658             | O. Martin    | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 60.667  | 21.587    |
| Monopis laevigella | MM15724    | 658             | Toni Maarinen | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 61.057  | 21.612    |
| Monopis laevigella | MM21025    | 658             | Ali Karhu    | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 61.237  | 21.612    |
| Monopis laevigella | MM21026    | 658             | Ali Karhu    | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 61.237  | 21.612    |
| Monopis laevigella | MM21028    | 658             | Ali Karhu    | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 61.237  | 21.612    |
| Monopis laevigella | MM21029    | 658             | Ali Karhu    | 14-Oct-2004    | Kjeller | Denmark | Sjaellandskabatet                       | 61.237  | 21.612    |
| Species               | Sample ID   | Sequence length | Collector(s)                  | Collection date | Country    | Province     | Site                           | Latitude  | Longitude |
|-----------------------|-------------|-----------------|-------------------------------|-----------------|------------|-------------|--------------------------------|-----------|-----------|
| *Monopis laevigella*  | TLMF Lep 12113 | 658            | Huemer P.                    | 17-Jul-2013     | Italy      | South Tyrol | Suedtirol, Zwischenwasser/St. Lorenzen | 46.739    | 11.873    |
| *Monopis laevigella*  | TLMF Lep 11818 | 658            | Huemer P.                    | 25-Jul-2013     | Italy      | South Tyrol | Suedtirol, Franzenshohe/Stilfserjoch | 46.534    | 10.486    |
| *Monopis laevigella*  | TLMF Lep 02066 | 658            | Huemer P.                    | 01-Jul-2010     | Italy      | South Tyrol | Suedtirol, Ritten/Obergruenwald    | 46.597    | 11.439    |
| *Monopis laevigella*  | TLMF Lep 05368 | 658            | Huemer P., Tarmann G. M.     | 01-Aug-2011     | Macedonia  |             | Mavrovo NP, Radika valley, around bridge, 10 km NNW Sveta Voda | 41.789    | 20.547    |
| *Monopis monachella*  | TLMF Lep 08436 | 658            | Huemer P.                    | 25-Jul-2012     | Austria    | Vorarlberg  | Lustenau, Schweizer Ried, AZE Haeusle S | 47.446    | 9.69      |
| *Monopis monachella*  | TLMF Lep 19839 | 658            | Buchner P.                   | 07-Jun-2014     | Austria    |             | Niederoesterreich, Solkenu | 47.905    | 16.266    |
| *Monopis monachella*  | MM13366      | 658            | Marko Mutanen, Panu Välimäki | 2008            | Finland    | Ab          | Dragfljärden                   | 60.011    | 22.498    |
| *Monopis monachella*  | MM11934      | 658            | Marko Mutanen, Panu Välimäki | 2007            | Finland    | N           | Hanko                          | 59.836    | 23.236    |
| *Monopis monachella*  | MM17249      | 658            | Lauri Kaila                  | 21-Aug-2005     | Finland    | N           | Tammsaaren                      | 59.829    | 23.612    |
| *Monopis monachella*  | MM12377      | 658            | Marko Mutanen, Panu Välimäki | 2007            | Finland    | Sa          | Imatra                         | 61.108    | 28.799    |
| *Monopis neglecta*    | TLMF Lep 07250 | 658            | Sumpich J.                   | 10-Jun-2010     | Austria    | Lower Austria | Hardegg Umgebung/Thaya Haengen | 48.854    | 15.858    |
| *Monopis neglecta*    | TLMF Lep 17583 | 658            | Deutsch H.                   | 30-Aug-2002     | Austria    | Tyrol       | Osttirol, Lengberg              | 46.801    | 12.891    |
| *Monopis neglecta*    | TLMF Lep 06608 | 658            | Rist O.                      | 11-Jun-2010     | Austria    | Vienna      | Wien Mauer                      | 48.15     | 16.25     |
| *Monopis nigricantella* | TLMF Lep 03881 | 658            | Huemer P.                    | 07-Sep-2005     | Spain      | Comunidad Valenciana | Valencia, El Saler, Albufera | 39.3255 | -0.312972 |
| *Monopis nigricantella* | TLMF Lep 03879 | 658            | Huemer P.                    | 18-May-2004     | Spain      | Comunidad Valenciana | Valencia, El Saler, Albufera | 39.3255 | -0.312972 |
| *Monopis nigricantella* | TLMF Lep 03878 | 658            | Huemer P.                    | 22-May-2004     | Spain      | Comunidad Valenciana | Valencia, Santa Pola, Playa del Pinet | 38.1583 | -0.625278 |
## Description of a new species of Monopis

| Species       | Sample ID | Sequence length | Collector(s)                  | Country        | Province     | Site Description                           | Latitude | Longitude |
|---------------|-----------|-----------------|------------------------------|----------------|-------------|--------------------------------------------|----------|-----------|
| Monopis nigricantella | TLMF Lep 83880 | 658             | Huemer P.                    | Spain          | Valencia    | Valtellina                                  | 49.3255 | 10.1297   |
| Monopis obviella | TLMF Lep 09086 | 636             | Huemer P.                    | Austria        | Tyrol       | Valdidenten, Bludersch.                      | 47.296   | 11.552    |
| Monopis obviella | TLMF Lep 09087 | 636             | Huemer P.                    | Austria        | Tyrol       | Bludersch.                                  | 47.296   | 11.121    |
| Monopis obviella | TLMF Lep 09084 | 636             | Haumer P.                    | Austria        | Vorarlberg  | Bludersch, Magersassen E, Ung Jodan         | 47.205   | 9.747     |
| Monopis obviella | TLMF Lep 25739 | 636             | Haumer P.                    | Austria        | Vorarlberg  | Ungt Langenge-Leren, Fuhren                 | 47.467   | 9.883     |
| Monopis obviella | TLMF Lep 09082 | 658             | Huemer P.                    | Austria        | Vorarlberg  | Niederschleur, Solzau                       | 59.5964 | 19.016    |
| Monopis obviella | TLMF Lep 10922 | 658             | Huemer P.                    | Austria        | Vorarlberg  | Langenge-Leren, Fuhren                    | 59.5964 | 19.016    |
| Monopis obviella | TLMF Lep 09083 | 658             | Huemer P.                    | Austria        | Vorarlberg  | Langenge-Leren, Fuhren                    | 59.5964 | 19.016    |
| Monopis obviella | TLMF Lep 09082 | 658             | Huemer P.                    | Austria        | Vorarlberg  | Langenge-Leren, Fuhren                    | 59.5964 | 19.016    |
| Monopis obviella | TLMF Lep 27794 | 630             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 02169 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 10922 | 658             | Haumer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 02169 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 10922 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 02169 | 658             | Haumer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 10922 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 02169 | 658             | Haumer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 10922 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 02169 | 658             | Haumer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Monopis obviella | TLMF Lep 10922 | 658             | Huemer P.                    | Italy          | Piedmont    | Fenestrelle, ca. 0.7 km NE Pequerel         | 45.0497 | 10.1354   |
| Species                  | Sample ID | Sequence length | Collector(s)                                           | Collection date | Country | Province | Site | Site Details | Latitude | Longitude |
|-------------------------|-----------|-----------------|--------------------------------------------------------|-----------------|---------|----------|------|--------------|----------|-----------|
| *Monopis spilotella*    | MM24137   | 658             | Marko Mutanen, Anttoni Mutanen, Nestori Mutanen        | 05-Jul-2014     | Finland | Lkoc     | Muonio |             | 67.9178  | 23.7466   |
| *Monopis spilotella*    | MM03158   | 658             | Marko Mutanen                                         | 2006            | Finland | Oba      | Kiiminki |             | 65.071   | 25.725    |
| *Monopis spilotella*    | MM02304   | 658             | Marko Mutanen, Panu Välimäki                           | 2006            | Finland | Sa       | Imatra  |             | 61.108   | 28.799    |
| *Monopis weaverella*    | TLMF Lep 15166 | 658         | Huemer P.                                              | 09-Jun-2014     | Austria | Tyrol    | Nordtirol, Ellbachtal, unterer Kaiserboden | 47.539   | 11.926    |
| *Monopis weaverella*    | TLMF Lep 15178 | 658         | Huemer P.                                              | 09-Jun-2014     | Austria | Tyrol    | Nordtirol, Ellbachtal, unterer Kaiserboden | 47.539   | 11.926    |
| *Monopis weaverella*    | TLMF Lep 18561 | 658         | Huemer P.                                              | 20-Jul-2005     | Austria | Tyrol    | Nordtirol, Umg. Innsbruck, Samertal, Jaegerkar | 47.34    | 11.382    |
| *Monopis weaverella*    | TLMF Lep 07388 | 658         | Huemer P.                                              | 25-May-2008     | Austria | Tyrol    | Nordtirol, Telfs/ Moriten SW, Innau | 47.299   | 11-May     |
| *Monopis weaverella*    | TLMF Lep 09220 | 658         | Huemer P.                                              | 06-Jun-2010     | Austria | Tyrol    | Nordtirol, Walchsee/ Schwemm N | 47.661   | 12.298    |
| *Monopis weaverella*    | MM21138   | 658             | Marko Mutanen, Tomi Mutanen                            | 18-Jun-2011     | Finland | Ab       | Nauvo   |             | 60.192   | 21.923    |
| *Monopis weaverella*    | MM13581   | 658             | Marko Mutanen, Panu Välimäki                           | 2008            | Finland | Ab       | Dragsfjärd |             | 60.011   | 22.498    |
| *Monopis weaverella*    | MM21027   | 658             | Ali Karhu                                              | 21-Jun-2004-23-Jun-2004 | Finland | Ka       | Liperi  |             | 62.552   | 29.167    |
| *Monopis weaverella*    | MM04159   | 658             | Marko Mutanen                                         | Finland         | Le       | Enontekiö | 68.997   | 20.744    |
| *Monopis weaverella*    | MM04158   | 658             | Marko Mutanen                                         | Finland         | Le       | Enontekiö | 68.997   | 20.744    |
| *Monopis weaverella*    | MM02600   | 639             | Marko Mutanen, Panu Välimäki                           | 2006            | Finland | Sa       | Imatra  |             | 61.108   | 28.799    |
| *Monopis weaverella*    | TLMF Lep 22008 | 658         | Schaefer W.                                            | 07-Aug-2015     | Germany | Kefenrod |             | 50.35    | 9.21667   |
of dry and pinned adult specimens were used for extraction of genomic DNA with DNeasy Blood & Tissue Kit (Qiagen). We largely followed the sequencing protocol by Wahlberg and Wheat (2008), but PCR clean-up was carried out with ExoSAP-IT (Affymetrix, Santa Clara, CA, USA) and Sephadex columns (Sigma-Aldrich, St. Louis, MO, USA). Additionally, sequencing was performed using an ABI 3730 DNA Analyzer (Applied Biosystems, Foster City, CA, USA). Sequences were checked and edited using BioEdit software (Hall 1999). The sequences were uploaded to a VoSeq database (Peña and Malm 2012). The same dataset was used to generate fasta files for Neighbor-Joining analyses.

Minimum genetic p-distance barcode divergence between \textit{M. laevigella} and \textit{M. jussii} was calculated using analytical tools in BOLD Systems v. 4.0 (http://www.bold-systems.org). Neighbor-joining trees for the barcode region for all included \textit{Monopis} species and specimens as well as four nuclear genes for five analyzed specimens of \textit{M. laevigella} and \textit{M. jussii} were constructed under p-distance model using Mega 7.0 (Kumar et al. 2016). The trees were stylized using CorelDraw v. 20.0.0.633.

**Results**

DNA sequencing resulted in a barcode of 552 bp or longer for 81 specimens. All except seven specimens yielded a full-length (654 bp) barcode. BOLD’s barcode gap analysis showed that all included species have highly species-specific DNA barcodes with the mean of minimum divergences (p-distance model) to the nearest species being 10.01% (range 4.43–17.58%) (Figure 1). The minimum divergence between \textit{M. laevigella} and \textit{M. jussii} is 4.43%.

For each nuclear gene, data of only a single specimen of two analyzed \textit{M. jussii} specimens were retrieved. Informative (i.e. data from both species available) sequence lengths by genes were as follows: CAD: 336 bp, EF-1a: 410 bp, MDH: 334 bp, wingless: 307 bp. Genetic p-distances between the two species were: CAD: 2.1%, EF-1a: 2.2%, MDH: 1.5%, and wingless: 4.1%. As a rule, the specimen of \textit{M. jussii} formed a sister to the two or three specimens of \textit{M. laevigella} (Figure 2).

**Monopis jussii** Kaila, Mutanen, Huemer, Karsholt & Autto, sp. nov.

http://zoobank.org/288523EF-4785-4711-B5DF-483D42057841

Figures 3–9

**Type material.** \textbf{Holotype} ♂ (Figure 3): FINLAND, PPe Yli-Kiiminki, larva 2001, ex nest of \textit{Aegolius funereus}, M. Mutanen leg. R. Gaedike prep. 8607. (ZMUO).

\textbf{Paratypes.} FINLAND • 7 ♂ 16 ♀, PPs Kiiminki, 65.1163°N, 25.8291°E, Larva 1995, ex nest of \textit{Aegolius funereus}, L. Kaila prep. 6317, 6325, 6326, M. Mutanen leg. (ZMUO); Finland: 10 ♂, 16 ♀, PPe Yli-Kiiminki, larva 2001, ex nest of \textit{Aegolius funereus}, L. Kaila prep. 6314, 6315, 6316, 6322, 6323, 6324, R. Gaedike prep. 8606,
Figure 1. A compressed Neighbor-Joining tree DNA barcode region of European *Monopis* with most European species represented. The depth of the triangle is proportional to the intraspecific genetic variability within species and the height to sampling intensity.

8607, 8698, DNA samples MM15526, MM17525, M. Mutanen leg. (ZMUO); • 2 ♀, Oba Utajärvi, Pälli, 64.8363°N, 26.21°E, larva 1980 ex nest of *Aegolius funereus*, J. Itämies leg. (ITJ); • 3 ♂ 3 ♀, K no Puolanka, Piltunkijärvi, 64.7618°N, 27.3151°E, larva 18.6.1976 ex nest of *Aegolius funereus* (1974), M. Rikkonen leg. (ZMUO); • 2 ♂, Kn Vaala, Otermajärvi, 64.6724°N, 27.1047°E, larva 12 Jun 1976 ex nest of *Aegolius funereus* (1974), M. Rikkonen leg. (ZMUO); • 1 ♀, Kn Kajaani, 64.2263°N, 27.932°E, VYÖ 1210 *ad luc* 15. – 21 Jun 2006, DNA sample MM 17523, R. Leinonen leg. (ZMUO). ITALY • 1 ♀, Südtirol, Tiers E, Plafetscher Wald, 1600–1650 m, 46.472°N, 11.596°E, 23 Jun 2006, leg. Huemer, DNA sample TLMF Lep 09795 (TLMF).

**Other material.** FINLAND • 7 ♂ 4 ♀, Ta Valkeakoski, Sääksmäki, 61.2326°N, 24.1137°E, ex larva (host unknown); 1992, S. Karhula leg. (MZH); • 2 ♀, Kn Kajaani,
Figure 2. Comparison of genetic variability in four nuclear genes, CAD, EF-1a, MDH and wingless, between Monopis laevigella and M. jussii sp. nov.

Diagnosis. Monopis jussii sp. nov. is externally close to M. laevigella, but the forewing appears darker, as it is less mottled with pale scales, especially along the margins (Figures 4, 5). Fringes are yellow and with a clear fringe line in M. laevigella but grey and without the fringe line in M. jussii. Besides the genetic markers, the forewing col-
our is indeed the best clue to separate these species. There is nevertheless some variation, especially in *M. laevigella*. Both male and female genitalia vary considerably, as do those of *M. laevigella*. The variation in all characters of genitalia overlaps between these species, and, apparently, they cannot be identified by genital characters. For variation of *M. laevigella* see also Gaedike (2019). Moreover, *M. weaverella* (Scott, 1858) and *M. neglecta* Šumpich & Liška, 2011 may occasionally fall within the morphological variation of these two species, especially in females. The males of *M. weaverella* and *M. neglecta* can however be distinguished from *M. laevigella* and *M. jussii* by the shape of gnathos, best decipherable in lateral view (see Gaedike 2019): gnathos arms are straight, triangular in *M. weaverella* and *M. neglecta*, angled particularly in anterior margin in *M. laevigella* and *M. jussii*.

**Description.** Forewing length 5.8–8.5 mm (n = 8 ♂ and 8 ♀) (note that the specimens are reared which may have affected their size). Maxillary palpus, labial palpus and head ochreous yellow; outer side of labial palpus with dark grey scales, second segment distally bristled. Scape of antenna ochre with pecten formed of bristle-shaped scales, pedicel and flagellum dark brown. Thorax dark grey, dorsomedially variably intermixed or entirely with pale ochre scales; tegula dark grey, apically often paler grey or ochre. Fore and mid leg inwardly ochre, outwardly leaden grey, apex of tibia and tarsal segments
Description of a new species of Monopis

Figure 4. Comparison of habitus between Monopis laevigella and M. jussii sp. nov. A–C M. laevigella female D–F M. laevigella male G–I M. jussii paratype, females J–L M. jussii paratype, males.

ochre. Hind leg inwardly pale, outwardly ochre, intermixed with grey scales; spurs and apex of tibia and tarsal articles ochre. Forewing dark grey, variably mottled with pale grey scales; costa narrowly and variably sometimes ochre; basal scales of termen with alternating pale ochre and grey scales, distal scales of termen unicolorous grey, contrast between distally paler basal scales and darker distal scales giving an impression of faint fringe line; silvery grey spot somewhat basal of middle of wing length at fold. Hind wing bluish grey with somewhat darker grey veins; fringe basally narrowly ochre, otherwise grey. Underside of wings grey with ochre margin; underside of hindwing dark grey along costal margin. Abdomen leaden grey, basal segments ventrally more or less ochre.

Male genitalia (Figure 6). Uncus elongate, triangular, laterally with long, hair-like scales, distally pointed, bifid. Gnathos arms angled in the middle, tapered toward hook-shaped apex. Basal and distal margins of tegumen reinforced, U-shaped, anter-
Figure 5. Comparison of forewing patterns of *Monopis laevigella* (A) and *M. jussii* sp. nov. (B). The arrows indicate differences in fringe colour (yellow/grey), fringe line (present/absent; chequered/non-chequered) and forewing costa (many white scales between the costa and the dorsal spot/few white scales between the costa and the dorsal spot).

ior margin more deeply. Shape of valva highly variable, gradually varying from ovoid and basally broadest to somewhat elongate and medially widest; distally round. Every aspect of saccus variable; straight or somewhat undulate, apically little or very much widened; length also very variable. Phallus straight and nearly parallel-sided, slightly widened at basal 1/3; length compared to that of saccus impossible to establish due to variation in length of saccus. Phallus distally inserted in cylindrical, internally spinose anellus. Vesica distally densely spinose, devoid of cornuti.
Description of a new species of Monopis

Female genitalia (Figures 7–9). Papilla analis membranous, elongate, distally round, with a few setae. Apophysis posterioris as long as segments 7+8, posteriorly starting as continuation of papilla analis, slender, anteriorly slightly widened, apex cut. Apophysis anterioris 1/3 length of and slightly stouter than apophysis posterioris, twice as long as 8th segment, distally not widened. Ovipositor telescopic, with two retractile nodes; with a few stout setae. Ventral pseudapodemes (sensu Davis and Robinson 1999) not decipherable. Tergum 8 posteriorly somewhat sclerotized. Ostium a widely U-shaped opening, laterally bordered as posteriorly curved rim, laterad shallowly emarginated in posterior direction, emargination with a few long setae; devoid of microtrichia but minutely granulose. Length of antrum variable, narrowed toward colliculum; colliculum tubular, length variable, 2–4 times as long as wide, usually narrowed in the middle. Ductus bursae between colliculum and corpus bursae membranous, as long as apophysis anterioris. Corpus bursae oval, 3 times as long as wide; in approximately the middle to posterior 1/3 ca. 12 elongate, sharply spicular or dentate signa forming transverse band.

Genetic characterisation. Clearly distinguishable by its DNA barcode from all other species of Monopis barcoded globally so far (Figure 1). Genetically the closest species with a minimum divergence of 4.43% is M. laevigella. Intraspecific divergence among four barcoded specimens from Finland and Italy is 0.15%. Additionally, the species show 1.5–4.1% interspecific divergence in the nuclear genes of CAD, EF-1a, MDH and wingless (Figure 2).

Etymology. The species is dedicated to Dr Juhani (Jussi) Itämies, a Finnish expert of Lepidoptera who, as far as we know, is the first to have reared this species. He has
also spent most of his life on faunistic research of Finnish Lepidoptera and has done incredible work in elucidating the life history of numerous microlepidopteran species.

**Distribution.** From our available observations *M. jussii* seems to have a boreo-montane distribution pattern. It is widely distributed in Finland and also recorded from Norway (Finnmark) and Sweden (Härjedalen). Records from the Alps seem rare with a proved, barcode-based locality in the Italian Dolomites and two further unpublished records (ZSM, A. Segerer) in the Bavarian Alps.

**Biology.** So far reared on five different occasions from the nest bottoms of the Boreal owl (*Aegolius funereus*). Two specimens in the collection of ZMUO have been reared from the nest of the Ural owl (*Strix uralensis*) and one specimen from the nest
Description of a new species of Monopis

Figure 8. Details of ostium bursae and colliculum of female genitalia of Monopis jussii sp. nov. A paratype, Finland, Yli-Kiiminki, M. Mutanen leg., L. Kaila prep. 6324 B paratype, Finland, Kiiminki, M. Mutanen leg., L. Kaila prep. 6325 C paratype, Finland, Yli-Kiiminki, M. Mutanen leg., L. Kaila prep. 6322 D paratype, Finland, Kiiminki, M. Mutanen leg., L. Kaila prep. 6326.
Figure 9. Signa of corpus bursae of female genitalia of *Monopis jusii* sp. nov. A paratype, Finland, Yli-Kiiminki, M. Mutanen leg., L. Kaila prep. 6324 B paratype, Finland, Kiiminki, M. Mutanen leg., L. Kaila prep. 6325 C paratype, Finland, Yli-Kiiminki, M. Mutanen leg., L. Kaila prep. 6322 D paratype, Finland, Kiiminki, M. Mutanen leg., L. Kaila prep. 6326.
of the Great tit (*Parus major*). Additionally, three reared specimens of two different rearing events do not state anything about the origin. One specimen has been found in a vacated house. Thirteen specimens in coll. ZMUO and a specimen from the Italian Alps in coll. TLMF have been collected in the wild between 17 June to 21 July, which matches well with the flight time of other *Monopis* species of these regions.

**Taxonomic remarks on Monopis laevigella**

*Monopis jussii* sp. nov. is most closely related to *M. laevigella* and can easily be confused with that species (see above). We therefore re-evaluate available names in the *M. laevigella* species group.

*Monopis laevigella* ([Denis & Schiffermüller], 1775).
*Tinea laevigella* [Denis & Schiffermüller], 1775: 139.

**Misidentifications**

*Tinea rusticella* Hübner, 1796: 61, pl. 3, fig. 17; a junior synonym of *Haplotinea insectella* (Fabricius, 1794) (Zeller, 1852: 153–154).

*Recurvaria rustica* Haworth, 1828: 548; unjustified emendation of *Tinea rusticella* Hübner, 1796.
*Tinea saturella* Haworth, 1828: 562, unavailable.
*Tinea vestianella* sensu Stephens, 1835: 344; a misidentification of *Phalaena* (*Tinea*) *vestianella* Linnaeus, 1758.

*Blabophanes rusticella* ab. *semispilotella* Strand, 1900: 225; unavailable name, deemed infrasubspecific according to ICZN Art. 45.6.2 from use of the term “ab.”; a misidentification of *M. weaverella* (Scott, 1858) (Gaedike 2019).

**Neotype selection**

*Tinea laevigella* was described from an unspecified number of specimens collected in the area of Vienna, Austria ([Denis & Schiffermüller], 1775). The collection was later deposited in the “Hof-Naturalien-Kabinett” and destroyed by fire during the Vienna Rebellion on 31st of October 1848 (Speta 2003). Since this species can be confused with *M. jussii* sp. nov. and several other congeneric taxa we designate as neotype a male specimen from Austria to preserve stability (Figure 10). It is labelled “AUSTRIA occ. Nordtirol / Brandenberg / Tiefenbachklamm / 11°51'52"E, 47°29'4"N / 645 m, 16.6.2013 / leg. Huemer” “DNA Barcode / TLMF Lep 10354” (TLMF).

*Tinea rusticella* was figured twice by Hübner in the eighth volume of his *Sammlung europäischer Schmetterlinge*, first it was validly described on page 61, pl. 3, fig. 17 (1796) and later a different species was figured on pl. 49, fig. 339 (1813). Hübner (1825) considered them conspecific, and he referred to both figures when he erected the monotypic genus *Monopis.*
Figure 10. Neotype male of *Monopis laevigella* from Austria, here designated. AUSTRIA occ. Nordtirol / Brandenberg / Tiefenbachklamm / 11°51'52"E, 47°29'4"N / 645 m, 16.6.2013 / leg. Huemer” “DNA Barcode / TLMF Lep 10354”. (Coll. TLMF).

Zeller (1852) was probably the first to question whether Hübner’s two figures of *Tinea rusticella* represented the same species. He referred to Hübner’s fig. 339 (1813) when dealing with the species, which became known as *Monopis rusticella* [= *Monopis laevigella* ([Denis & Schiffermüller], 1775)], and rejected that Hübner’s fig. 17 (1796) could be of a specimen of that species, suggesting that it could be *Tinea misella* Zeller, 1839 [= *Haplotinea insectella* (Fabricius, 1794)]. *Tinea rusticella* Hübner, 1813 is both a misidentification and a homonym of *Tinea rusticella* Hübner, 1796 and thus permanently invalid.

Haworth (1828: 548) named the species twice. First with reference to Hübner’s pl. 3, fig. 17 as *Recurvaria rustic*ica, which is an unjustified emendation and thus an objective synonym of *Tinea rusticella* (Hübner, 1796) [= *Haplotinea insectella* (Fabricius)], and later in the same work Haworth (op. cit.: 339), again with reference to Hübner’s pl. 3, fig. 17, proposed the name *Tinea saturella* in synonymy with *Tinea rusticella*. Because *Tinea saturella* was described in synonymy with *Tinea rusticella* it was always considered a synonym of that species (viz. *Monopis rusticella*), but because Haworth referred only to Hübner’s fig. 17 (and not to fig. 339) it is an objective junior synonym of *Tinea rusticella* Hübner, 1796, and thereby a subjective junior synonym of *Haplotinea insectella* (Fabricius). However, as the name *Tinea saturella* has never been made available under the provision of Art. 11.6. of the Code (ICZN 1999) and adopted as the name of a taxon before 1961, we consider it as unavailable.
Although *Monopis* Hübner 1825 was described as a monotypic genus, it is based on a partly misidentified species. We consider Zeller (1852) as First Reviser of *Tinea rusticella* Hübner, restricting the name to the species now (and also by Zeller 1852) known as *Monopis laevigella* ([Denis & Schiffermüller], 1775).

**Discussion**

Compared with many other groups of Lepidoptera, the species diversity of Tineidae is generally poorly investigated. Hundreds of species deposited in museum collections remain undescribed (Robinson 2009). It is likely that many more species remain entirely undiscovered globally. The European fauna is comparatively well understood, and the fauna of the entire continent has recently been taxonomically reviewed in two monographs (Gaedike 2015, 2019). New species discoveries are uncommon, particularly for central and northern parts of Europe. An example of a recent species discovery is that of *Monopis neglecta* Šumpich & Liška, 2011, a species that morphologically is nearly indistinguishable from *M. weaverella* (Scott, 1858) (see Gaedike 2019). While no genetic data were provided for *M. neglecta* in the original description, the DNA barcode sequences provided in the present study confirm its status as a separate species from *M. weaverella*. It is encouraging that although the species of Tineidae are often difficult to tell apart from each other morphologically, no cases of barcode sharing in the European fauna are known. Evidently, therefore, DNA barcoding provides an efficient way to investigate their diversity in less thoroughly explored areas as well.

Based on the available distributional data, *Monopis jussii* has a much more limited range than *M. laevigella*. It is possible, if not likely, that it is a member of boreo-montane faunal elements, being distributed in the boreal region on the one hand and in the Alps below the timberline on the other hand. It is likely absent from the lowlands of Central Europe. It would not be surprising if the species turns out to be present in other European mountain systems and the eastern Palearctic. Based on the large number of examined museum specimens from the ZMUO and MZH collections, the species is widely present in northern Finland south to ca. 64° N but becomes much scarcer towards the more southern localities. The southernmost verified records from Finland are from the province of Tavastia australis (ca. 61° N).

Based on our own and other experiences (Robinson 2009, Gaedike 2019), *Monopis laevigella* is not strict regarding the source of its food, but it seems to prefer cavity-breeding birds, possibly because their nests are usually dry. Several extensive rearing experiments of nest bottoms of various birds, mostly the Tawny Owl (*Strix aluco* Linnaeus, 1758) and the Ural Owl (*S. uralensis* Pallas, 1771), from southern Finland have yielded large numbers of *M. laevigella*, which is usually present in every nest in large numbers. In an experiment by MM in 2017 with 13 nest bottoms of *Strix* spp., probably thousands of *M. laevigella* emerged. Among several dozen pinned specimens sampled from each nest, none represents *M. jussii*. Other species that are regularly or often
present in the nests of *Strix* spp. in Finland are *Niditinea striolella* (Matsumura, 1931) (usually emerges in great numbers too), *Tinea svenssoni* Opheim, 1965 (present in almost all nests), *Tinea steueri* Petersen, 1966 (not present in every nest) and *Monopis fenestratella* (Heyden, 1863) (present in most nests but is cryptic in behaviour). While it is possible that *M. jussii* has stricter habitat requirements and that it has a strong preference for the Boreal Owl, we find this possibility unlikely. The Boreal owl, the Ural owl, as well as the Great tit are all cavity breeders, rendering the nest conditions between these species very similar. In rearing conditions, tineids are not selective for the origin of food and readily feed on mammal hairs too. It is more likely that *Monopis jussii* has been reared mostly from the nests of the Boreal owl just because it is a more common owl species within the moth’s main distribution in Finland than either of the two *Strix* species present in Finland. Further rearing experiments, optimally systematically from different species of birds, would bring additional valuable information on the habitat requirements of *M. jussii* and several other species of Tineidae.

*Monopis laevigella* has a Holarctic distribution (Landry and Pohl 2018, Gaedike 2019). Many specimens of this species have been barcoded from the Nearctic region, both from Canada and the U.S.A. They fall in two clusters, both of which are highly distinct from the clade consisting of *M. jussii* and the Palearctic *M. laevigella* (data only partially public in BOLD). In the Neighbor-Joining trees neither of these clusters is placed as sister to the Palearctic *M. laevigella* + *M. jussii* clade, suggesting that they represent distinct taxa and even that their closest relative is not *M. laevigella*. However, due to the limited phylogenetic information content of the DNA barcode region, verification of both scenarios requires more rigorous and thorough taxonomic and phylogenetic scrutiny.

**Acknowledgements**

We are grateful to Leif Aarvik, Reinhard Gaedike, Peter Buchner, Bob Heckford, and Juhani Itämies for providing information and help with many kinds of matters during the preparation of this study. DNA barcoding was conducted at the Centre for Biodiversity Genomics, to whose staff we are grateful for their continuous support. Thomas Pape, Natural History Museum of Denmark, kindly advised on questions about nomenclature. Sequencing was financially supported by the Academy of Finland, Kone foundation and Finnish Cultural foundation through grants to the Finnish Barcode of Life project and furthermore supported by the Promotion of Educational Policies, University and Research Department of the Autonomous Province of Bolzano - South Tyrol with funds to the projects “Genetische Artabgrenzung ausgewählter arktialpiner und boreomontaner Tiere Südtirols” and “Erstellung einer DNA-Barcode-Bibliothek der Schmetterlinge des zentralen Alpenraumes (Süd-, Nord- und Osttirol)”. Andrew Liston kindly checked the English language. Finally, we are indebted to Bengt Å. Bengtsson, an anonymous reviewer, and Erik J. van Nieukerken for many useful comments on the earlier version of this paper.
References

Davis DR, Robinson GS (1999) The Tineoidea and Gracillarioidea. In: Kristensen NP (Ed.) Lepidoptera, moths and butterflies. Vol 1: Evolution, systematics and biogeography. Handbook of Zoology 4(35), Walter de Gruyter, Berlin, New York, 91–119.

Denis M, Schiffermüller J (1775) Ankündigung eines systematischen Werkes von den Schmetterlingen der Wienergegend herausgegeben von einigen Lehrern am k. k. Theresianum. Augustin Bernardi, Wien, 322 pp. [pls. frontispecie, 1–1b]

Dinca V, Lukhtanov VA, Talavera G, Vila R (2011) Unexpected layers of cryptic diversity in wood white *Leptidea* butterflies. Nature Communications 2: 324. https://doi.org/10.1038/ncomms1329

Gaedike R (2015) Tineidae I (Dryadaulinae, Hapsiferinae, Euplocaminae, Scardiinae, Nematopogoninae and Mecssinae). In: Nuss M, Karsholt O, Huemer P (Eds) Microlepidoptera of Europe 7. Brill, Leiden/Boston, 308 pp. https://doi.org/10.1163/9789004289161

Gaedike R (2019) Tineidae II (Myrmecocozelinae, Perissomasticinae, Tineinae, Hieroxestinae, Teichobiinae and Stathmopolitiniae). In: Karsholt O, Mutanen M, Nuss M (Eds) Microlepidoptera of Europe 9. Brill, Leiden/Boston, 248 pp. https://doi.org/10.1163/9789004387515

Haworth AH (1828) Lepidoptera Britannica, sistens digestionem novam insectorum Lepidopterorum quae in magna Britannica reperiuntur, larvarum pabulo, temporeque pasceindi; expansion alarum, mensibusque volandi, synonymis atque locis observationibusque variis vol 4. J. Murray, London, 513–609. https://doi.org/10.1080/14786442808674667

Hübner J (1796–1836) Sammlung europäischer Schmetterlinge 8. Augsburg. (Tineae-Schaben): 1–78 [1796], 71 pls 1–71 (1796-[1836]).

Hübner J (1816–1825) Verzeichniss bekannter Schmettlinge. Augsburg, 431 pp. https://doi.org/10.5962/bhl.title.48607

Huemer P, Haixaire J, Lee KM, Mutanen M, Pekarsky O, Ronkay L (2020) Revision of the genus *Hoplodrina* Boursin, 1937 (Lepidoptera, Noctuidae, Xyleninae). I. *Hoplodrina octogenna* (Goeze, 1781) and its sister species *H. alsinides* (Costantini, 1922) sp. rev. in Europe. ZooKeys 927: 75–97. https://doi.org/10.3897/zookeys.927.51142

Huemer P, Karsholt O (2010) Gelechiidae II. (Gelechiinae: Gnorimoschemini). Microlepidoptera of Europe vol 6. Apollo Books. Stenstrup, Denmark, 586 pp. https://doi.org/10.1163/9789004260986_002

Huemer P, Karsholt O, Aarvik L, Berggren K, Bidzilya A, Junnilainen J, Landry J-F, Mutanen M, Nupponen K, Segerer A, Šumpich J, Wieser C, Wiesmair B, Hebert PDN (2020) DNA barcode library for European Gelechiidae (Lepidoptera) suggests greatly underestimated species diversity. ZooKeys 921: 141–157. https://doi.org/10.3897/zookeys.921.49199

ICZN (1999) International Code of Zoological Nomenclature, Fourth Edition. International Trust for Zoological Nomenclature, The Natural History Museum London, London, 306 pp.

Kozlov MV, Mutanen M, Lee KM, Huemer P (2017) Cryptic diversity in the long-horn moth *Nemophora degeerella* (Lepidoptera: Adelidae) revealed by morphology, DNA barcodes and genome-wide ddRAD-seq data. Systematic Entomology 42: 329–346. https://doi.org/10.1111/syen.12216
Kumar S, Stecher G, Tamura K (2016) MEGA7: Molecular evolutionary genetics analysis version 7.0. Molecular Biology and Evolution 33: 1870–1874. https://doi.org/10.1093/molbev/msw054

Landry JF, Pohl GR (2018) 16. Family Tineidae Latreille, 1810. In: Pohl GR et al. Annotated Checklist of the Moths and Butterflies (Lepidoptera) of Canada and Alaska. Pensoft series Faunistica 118: 46–50.

Mutanen M, Aarvik L, Huemer P, Kaila L, Karsholt O, Tuck K (2012a) DNA barcodes reveal that the widespread European tortricid moth Phalonidia manniana (Lepidoptera: Tortricidae) is a mixture of two species. Zootaxa 3262: 1–21. https://doi.org/10.11646/zootaxa.3262.1.1

Mutanen M, Aarvik L, Landry JF, Segerer A, Karsholt O (2012b) Epinotia cinereana (Haworth, 1811) bona sp., a Holarctic tortricid distinct from E. nisella (Clerck, 1759) (Lepidoptera: Tortricidae: Eucosmini) as evidenced by DNA barcodes, morphology and life history. Zootaxa 3318: 1–25. https://doi.org/10.11646/zootaxa.3318.1.1

Mutanen M, Kaila L, Tabell J (2013) Wide-ranging barcoding aids discovery of one-third increase of species richness in presumably well-investigated moths. Scientific Reports 3: 2901. https://doi.org/10.1038/srep02901

Mutanen M, Kivelä SM, Vos RA, Doorenweerd C, Ratnasingham S, Hausmann A, Huemer P, Dincă V, van Nieukerken EJ, Lopez-Vaamonde C, Vila R, Aarvik L, Decaëns T, Efetov KA, Hébert PDN, Johnsen A, Karsholt O, Pentinsaari M, Rougerie R, Segerer A, Tarmann G, Zahirí R, Godfray HCJ (2016) Species-Level Para- and Polyphyly in DNA Barcode Gene Trees: Strong Operational Bias in European Lepidoptera. Systematic Biology 65: 1024–1040. https://doi.org/10.1093/sysbio/syw044

Peña C, Malm T (2012) VoSeq: a voucher and DNA sequence web application. PLoS One.7(6), e39071. https://doi.org/10.1371/journal.pone.0039071

Robinson GS (1976) The preparation of slides of Lepidoptera genitalia with special reference to the Microlepidoptera. Entomologist’s Gazette 27: 127–132.

Robinson GS (2009) Biology, distribution and diversity of tineid moths. Natural History Museum, Kuala Lumpur, 143 pp.

Robinson G, Nielsen ES (1993) Tineid genera of Australia (Lepidoptera). Monographs on Australian Lepidoptera 2. CSIRO Publishing, Melbourne, 344 pp. https://doi.org/10.1071/9780643105102

Scott J (1858) A supposed new species of Tinea allied to rusticella. The Zoologist 16: 5964–5965.

Segerer AH, Haslberger A, Grünewald T (2010) Occurrence of Olethreutes subtilana (Falkovitsh, 1959) in Central Europe uncovered by DNA barcoding (Tortricidae: Olethreutinae). Nota Lepidopterologica 33: 209–218.

Speota F (2003) Ignaz Schiffermüller (1727–1806) – eine Biographie. Denisia 8: 11–14.

Stephens JF (1834) Illustrations of British Entomology or, a Synopsis of Indigenous Insects: containing their generic and specific distinctions with an account of their metamorphoses, times of appearance, localities, food, and economy, as far as practicable. London. Insecta Haustellata 4: 1–436, pls 23–41.

Strand E (1900) Einige arktische Aberrationen von Lepidopteren. Entomologische Nachrichten 26: 225–226.
Šumpich J, Liška J (2011) In: Šumpich, J.: Motýli Národních parku Podyjí a Thayatal. Die Schmetterlinge der Nationalparke Podyjí und Thayatal. Správa Národního parku Podyjí, Znojmo, 1–488.

Wahlberg N, Wheat CW (2008) Genomic outposts serve the phylogenomic pioneers: designing novel nuclear markers for genomic DNA extractions of Lepidoptera. Systematic Biology 57: 231–242. https://doi.org/10.1080/10635150802033006

Zeller PC (1852) Die Schaben mit langen Kiefertastern. Linnaea Entomologica 6: 81–197.