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New records of Adelidae from forested habitats of Calabria (South Italy) with an update of the Italian ckecklist (Lepidoptera: Adeloidea)

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Abstract
Adelidae fauna of South Italy is poorly known. For example, the knowledge concerning this family in the Calabria region is very poor being the most recent record 107 years old. In this paper we reported original faunistic data for the Calabria region concerning eight species most of which new for the regional fauna and *Nematopogon robertella* (Clerck, 1759) new for the fauna of peninsular Italy. To the light of faunistic and taxonomic advances of recent years, the Italian checklist of this family was updated because of the discovery of taxa new to the science and new records that significantly modified the Italian range of some species. According to these recent additions, the Italian fauna of Adelidae is now composed by 34 species, but we found that some populations of South Italy deserve deep studies to ascertain their taxonomic status.

Keywords: microlepidoptera, *Adela*, *Nemophora*, *Nematopogon*, DNA barcoding, Calabria.

Introduction

In Europe the family Adelidae consists of 55 species included in the genera *Nemophora*, *Adela*, and *Cauchas* belonging to the subfamily Adelinae, and *Nematopogon*, the only genus in the subfamily Nematopogoninae (Bryner 2020). The Italian checklist was compiled 27 years ago and listed 32 species of which *Nematopogon prolai* and *N. sericinellus* are endemic (Karsholt et al. 1995).

Recent studies led to the discovery of two species new to the science present in Italy, namely *Nemophora scopolii* (Kozlov et al. 2017) and the endemic *Nematopogon garganellus* (Bryner & Huemer 2019). The Italian range of 14 more species was refined thanks to records published in comprehensive lepidopteran lists (Kranebitter & Hilpold 2006; Vegliante & Zilli 2007; Huemer & Morandini 2009; Pinzari et al. 2010; Raviglione et al. 2011; Pinzari et al. 2015; Scalercio 2016a; Bendazzi & Pezzi 2019; Zandigiacomo et al. 2019; Huemer 2020), with a maximum of 7 species in an individual paper. Among these species, only *Cauchas albiantennella* was new to the Italian fauna (North and Central Italy: Kranebitter & Hilpold 2006; Pinzari et al. 2010). According to these recent additions, the Italian fauna of Adelidae is now composed by 34 species.

The investigation of microlepidoptera fauna of Calabria has recently increased thanks to papers devoted to individual families (Scalercio 2009; Scalercio 2016b; Leonetti et al. 2018; Trematerra et al. 2018; Scalercio et al. 2019), genera (Scalercio 2022), and species (Scalercio & Slamka 2015; Scalercio & Bertaccini 2017), or to papers devoted to restricted areas (Baldizzone & Scalercio 2018). However, the knowledge concerning the Adelidae is still scarce as only four very old records were available so far, being the most recent 107 years old. The first record belongs to *Nemophora scopolii*, listed as *Alucita degeerella* for the "Calabria Ulteriore" (Petagna 1787), now generically representing the South part of the region. After 76 years, Costa (1863) added *Nemophora raddaella* and *Adela reaumurella* also generically reported for the Calabria Ulteriore, and after 52 more years Stauder (1915) added *Nemophora metallica* for the locality San Fili, the first and up to date the only known Calabrian locality of an Adelidae species.

In this paper we reviewed available literature for updating the Italian checklist of Adelidae. Furthermore, we reported original data for eight species collected in Calabria, one of which recorded for the first time in peninsular Italy.

Material and methods

Specimens were collected during the last decade in different localities of the Calabria region, the southernmost tip of Italian peninsula. Most of *Nematopogon* specimens were collected by light traps (Infusino et al. 2017), whilst *Nemophora* and *Adela* species were exclusively collected by nets during daytime.

Microscope slides were prepared according to the protocol available in Parenti (2000). Mounted genitalia were photographed with a biological microscope model BM 60 (Exacta+Optech Labcenter spa) equipped with a camera Invenio-10SIII (DeltaPix Co.), and images were elaborated using the software DeltaPix InSight. Morphological identifications and nomenclature were based on Bryner (2020).

We analyzed the DNA barcode fragment of the mitochondrial DNA (mtDNA) COI gene for 36 specimens and from 29 of them we recovered a sequence deposited in the public dataset DS-ADELCAL available in the Barcode of Life Data System (BOLD). For barcoding, the prescribed standards using the high-throughput protocol of deWaard et al. (2008) were used. The samples were processed at the Canadian Centre for DNA Barcoding (CCDB, Biodiversity Institute of Ontario, University of Guelph).

The BOLD Identification Engine was used to confirm morphological identifications on a molecular basis, to generate a Neighbor-joining tree for successfully barcoded specimens, and to evaluate similarity of sequences with those publicly available in BOLD. Intraspecific pairwise distance was evaluated for Calabrian specimens using the distance summary tool available among sequence analysis options available in BOLD Systems (http://www.boldsystems.org/).

Detailed collecting data were provided for studied material, namely environmental province according to Scalercio (2014), exact site, municipality, province, geographic coordinates, altitude, data, number of specimens, collectors, BOLD ID if available, slide number if available.

Results

We collected 45 specimens belonging to eight species (Figs 1-8).

Nemophora metallica (Poda, 1761) (Fig. 1)

Records: **Italy:** Calabria, Sila – Croce di Magara, Spezzano della Sila, Cosenza province (39.322°N, 16.474°E), 1390 m, 8 Jul 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01209); Calabria, Fossiata, Longobucco, Cosenza (39.393°N, 16.605°E), 1300 m, 24 Jul 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01208).

The only successfully barcoded specimen showed a sequence very different from the best match found in BOLD among public sequences (Table 1). It belongs to a Barcode Index Number (BIN) including only one more Italian specimen (Fig. 9) and with a distance equal to the 3.28% from the BIN including all other European populations of *N. metallica*.

Nemophora scopolii Kozlov, Mutanen, Lee & Huemer, 2016 (Fig. 2)

Records: **Italy:** Calabria, Catena Costiera – Monte Martinella, San Lucido, Cosenza province (39.3047°N, 16.1193°E), 1000 m, 24 May 2015, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01214). Sila – Croce di Magara, Spezzano della Sila, Cosenza (39.322°N, 16.474°E), 1390 m, 8 Jul 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01213).

Although collected in different environmental provinces, the sequences of the two barcoded specimens were identical and seem to be only slightly differentiated from specimens collected in Central Europe (Table 1).

Adela mazzolella (Hübner, 1801) (Fig. 3)

Records: **Italy:** Calabria, Sila – Righio, Casali del Manco, Cosenza province (39.316°N, 16.530°E), 1355 m, 23 May 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01210), 9 Jun 2017, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01211); Longobucco, Cosenza (39.444°N, 16.612°E), 885 m, 20 May 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01212).

Barcoded specimens showed a low genetic divergence and seem to be only slightly differentiated from specimens collected in Central Europe (Table 1).

Adela reaumurella (Linnaeus, 1758) (Fig. 4)

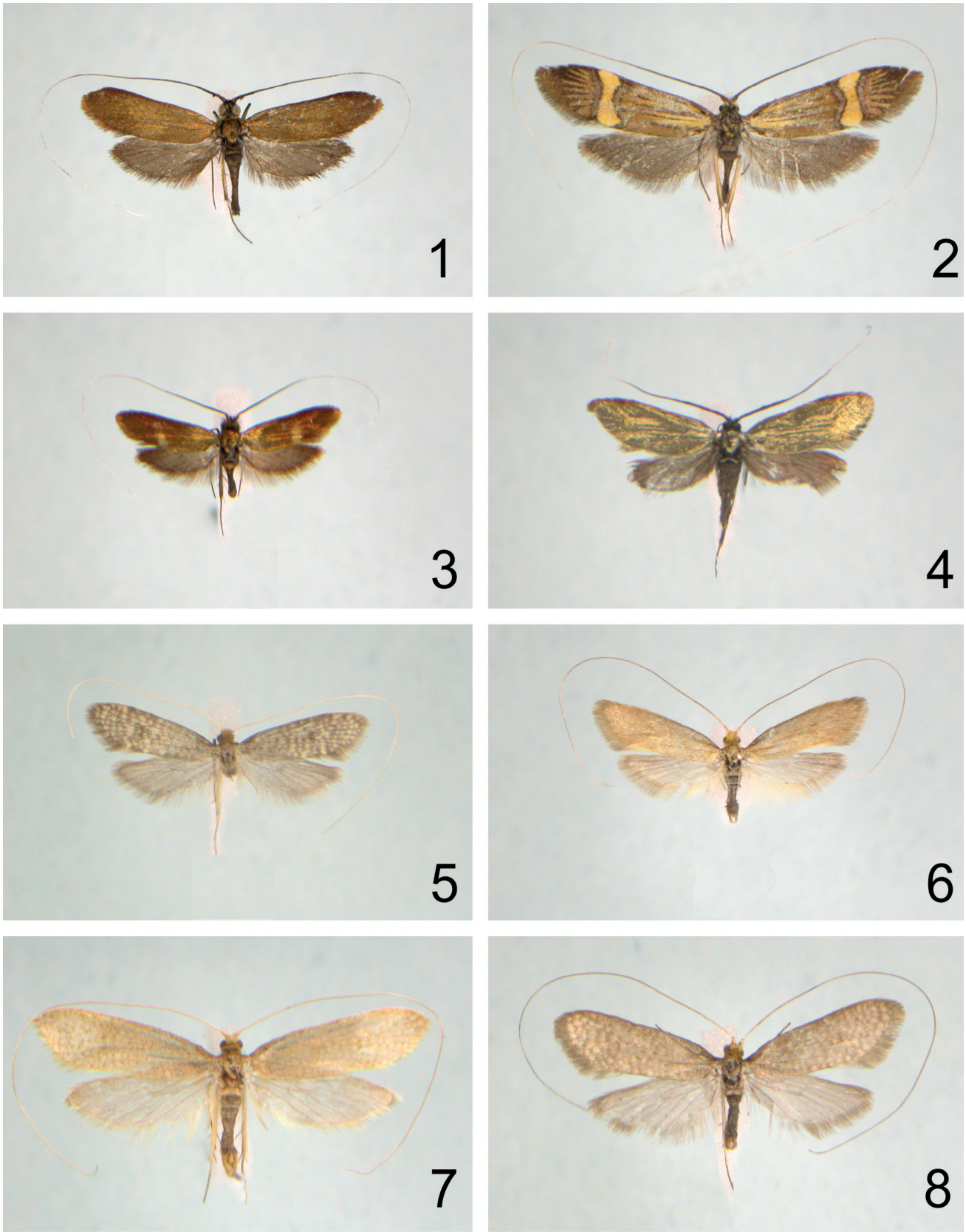
Records: **Italy:** Calabria, Catena Costiera – Passo della Crocetta, Paola, Cosenza province (39.321°N, 16.112°E), 980 m, 13 May 2015, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01216); Calabria, Sila – Fosso Cucolo, Donnici, Cosenza province (39.237°N, 16.297°E), 550 m, 12 May 2014, Scalercio S. leg., 2 specimens (BOLD IDs: LEP-SS-01215, LEP-SS-01217).

Barcoded specimens showed a low genetic divergence and one of them (LEP-SS-01215) is identical to an Austrian specimen (Table 1), showing a low intraspecific divergence.

Nematopogon robertella (Clerck, 1759) (Fig. 5)

Records: **Italy:** Calabria, Serre – Pietra del Signore, Serra San Bruno, Vibo Valentia province (38.5401°N, 16.3309°E), 1080 m, 26 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01209) (microscope slide: CREA-0237).

This is the first record for peninsular Italy. Species identification was confirmed by genitalia examination (Fig. 10) and habitus of antennae, completely white in *N. robertella* (Fig. 11) and checkered in *N. garganellus* (Fig. 12). Barcoding was unsuccessful.



Figs 1-8 – Adults of Adelidae. **1**, *Nemophora metallica*, Croce di Magara, 17mm; **2**, *Nemophora scopolii*, Croce di Magara, 21mm; **3**, *Adela mazzolella*, Righio, 12mm; **4**, *Adela reaumurella*, Passo della Crocetta, 15mm; **5**, *Nematopogon robertella*, Pietra del Signore, 15mm; **6**, *Nematopogon sericinellus*, Carraci, 14mm; **7**, *Nematopogon swammerdamella*, Timpone Magara, 22mm; **8**, *Nematopogon garganellus*, Bosco Gesuiti, 19mm.

Nematopogon sericinellus Zeller, 1847 (Fig. 6)
Records: Calabria, Pollino-Orsomarso – Timpone Magara, Saracena, Cosenza province (39.7939°N, 16.0520°E), 1465 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01219); Calabria, Bruscata, Saracena, Cosenza (39.8103°N, 16.0468°E), 1370 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01234); Calabria, Serrapaolo, Saracena, Cosenza (39.8225°N, 16.0911°E), 990 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01235); Calabria, Carraci, Lungro, Cosenzaprovince (39.7547°N, 16.0864°E), 1270 m, 15 Apr 2016, Scalercio S. & Infusino M. leg., 2 specimens (BOLD IDs: LEP-SS-01226, LEP-SS-01227); Calabria, Sila – Tirivolo, Taverna, Catanzaro province (39.1028°N, 16.6197°E), 1580 m, 18 May 2020, Scalercio S. & Di Marco C. leg.,

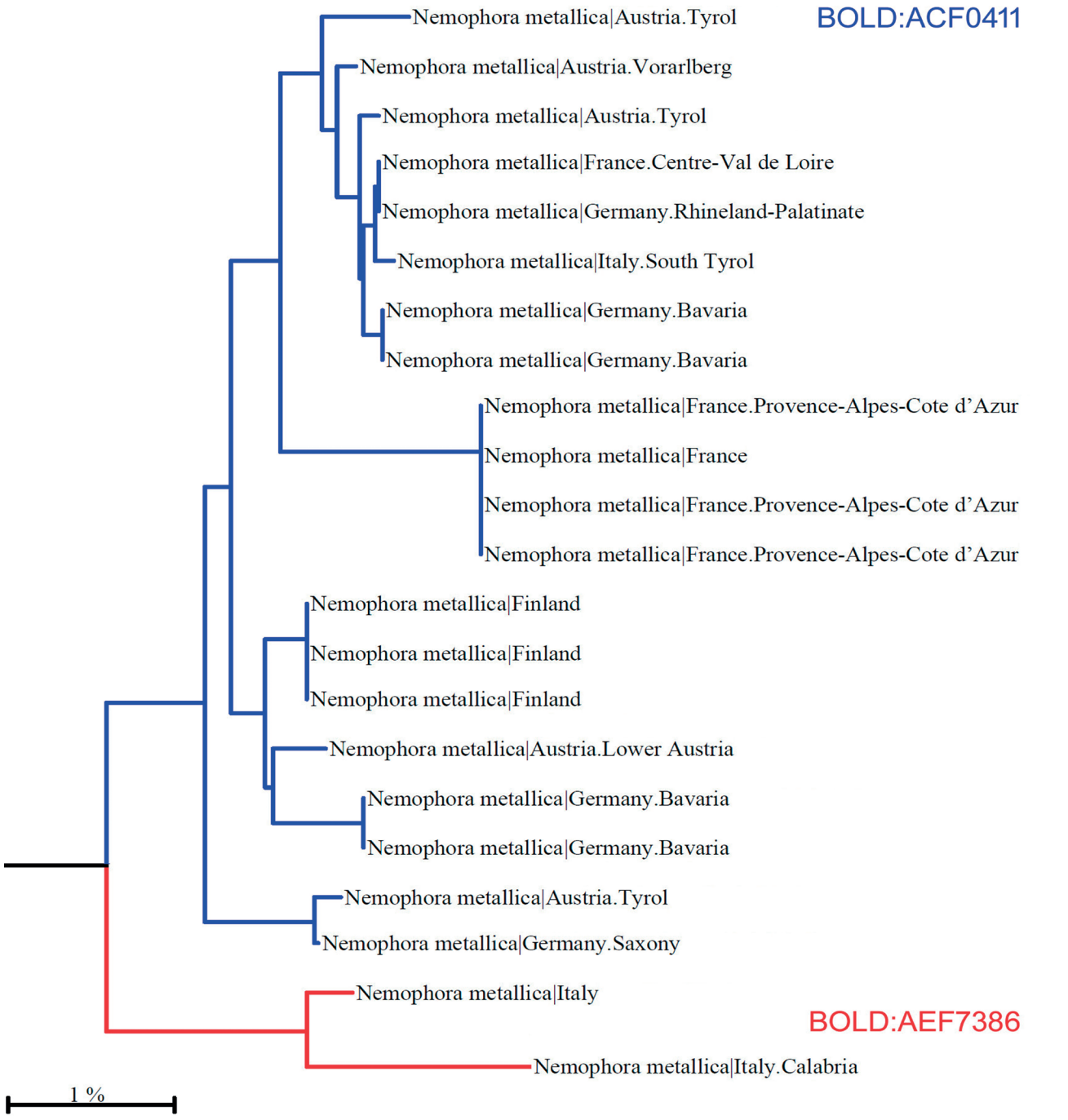


Fig. 9 – Neighbor-joining tree generated by the identification engine of BOLD for the successfully barcoded Calabrian specimen of *Nemophora metallica* (BOLD ID: LEP-SS-01209).

1 specimen (BOLD ID: LEP-SS-01241); Calabria, Vivaio Sbanditi, Longobucco, Cosenza province (39.3891°N, 16.6019°E), 1350 m, 23 May 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01236); Calabria, Vallone Tasso, Spezzano della Sila, Cosenza province (39.3324°N, 16.4185°E), 7 Jun 2018, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01222); Calabria, Spinarva, Taverna, Catanzaro province (39.0900°N, 16.6800°E), 1570 m, 30 May 2017, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01232); Calabria, Montagna Grande, San Giovanni in Fiore, Cosenza province (39.276°N, 16.610°E), 1370 m, 11 May 2016, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01233); Malagieca, Sellia, Catanzaro (38.9571°N, 16.6263°E), 193 m, 15 Apr 2021, Scalercio S. leg., 1 specimen; Calabria, Serre – Santa Maria, Serra San Bruno, Vibo Valentia province (38.5454°N, 16.3039°E), 924 m, 6 Apr 2016, Scalercio S. & Infusino M., 1 specimen (BOLD ID: LEP-SS-01223).

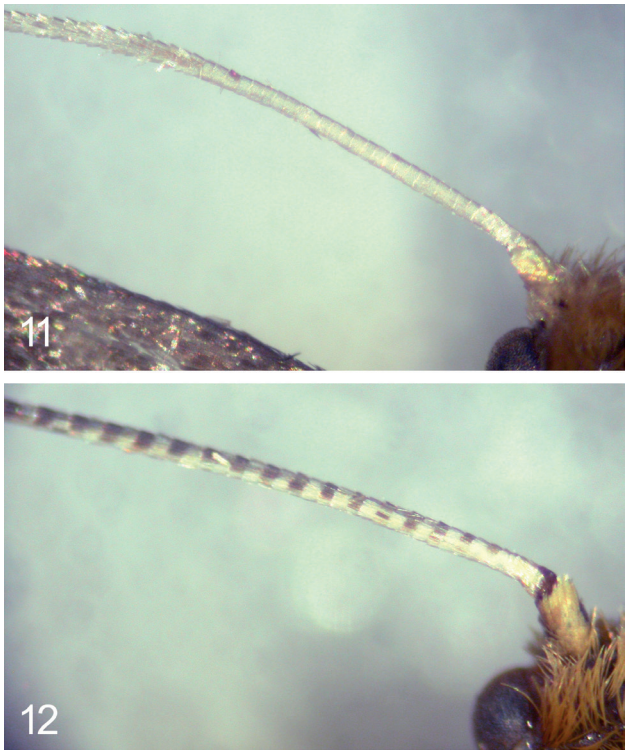
Barcoded Calabrian specimens showed a high genetic divergence, sometimes higher than those registered with specimens collected in other Italian regions (Table 1).

Nematopogon swammerdamella (Linnaeus, 1758) (Fig. 7)
Records: Calabria, Pollino-Orsomarso – Serrapaolo, Saracena, Cosenza province (39.8225°N, 16.0911°E), 990 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01229); Calabria, Timpone Magara, Saracena, Cosenza province (39.7939°N, 16.0520°E), 1465 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01218); Calabria, Bocca di Novacco, Saracena, Cosenza province (39.8140°N, 16.0451°E), 1340 m, 20 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01231); Calabria, Sila – Cappiglione, Sellia, Catanzaro province (38.9732°N, 16.6243°E), 533 m, 15 Apr 2021, Scalercio S. leg., 1 specimen (microscope slide: CREA-0238); Ariabrutta, Sellia, Catanzaro (38.9887°N, 16.6218°E), 470 m, 15 Apr 2021, Scalercio S. leg., 2 specimens; Calabria, Serre – Il Palmento, Serra San Bruno, Vibo Valentia (38.5625°N, 16.3140°E), 840 m, 26 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01230).

The successfully barcoded specimen showed a low similarity with the best match found in BOLD among public sequences (Table 1), and a perfect identity with a specimen from South Italy (Fig. 13). The identification of Calabrian specimens as *N. swammerdamella* was confirmed by the examination of genitalia (Fig. 14).

Nematopogon garganellus Bryner & Huemer, 2019 (Fig. 8)
Records: Calabria, Pollino-Orsomarso – Timpone Magara, Saracena, Cosenza province (39.7939°N, 16.0520°E), 1465 m, 20 May 2015, Scalercio S. & Infusino M. leg., 2 specimens (BOLD IDs: LEP-SS-01194, LEP-SS-01220); Calabria, Catena Costiera –

Fig. 10 – Male genitalia of *Nematopogon robertella*, Pietra del Signore (microscope slide: CREA-0237).



Figs 11-12 – Comparison of antennae in the genus *Nematopogon*. **11**, *N. robertella*, Pietra del Signore; **12**, *N. garganellus*, Bosco dei Gesuiti.

Bosco Gesuiti, San Fili, Cosenza province (39.3618°N, 16.1313°E), 620 m, 23 Apr 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01221); Calabria, Passo della Crocetta, Paola, Cosenza province (39.321°N, 16.112°E), 980 m, 13 May 2015, S. Scalercio leg., 1 specimen (BOLD ID: LEP-SS-01224); Calabria, Purgatorio, San Benedetto Ullano, Cosenza province(39.3939°N, 16.1024°E), 880 m, 6 May 2015,

Fig. 13 – Neighbor-joining tree generated by the identification engine of BOLD for the successfully barcoded Calabrian specimen of *Nematopogon swammerdamella* (BOLD ID: LEP-SS-01230).

Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01240); Calabria, Sila – Croce di Magara, Spezzano della Sila, Cosenza province (39.322°N, 16.474°E), 1390 m, 27 May 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01237); Calabria, Torre Scarda, Aprigliano, Cosenza province (39.2382°N, 16,5129°E), 1340 m, 18. May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01238); Calabria, Colle Macchie, Casali del Manco, Cosenza province (39.2589°N, 16.5272°E), 1440 m, 18 May 2015, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01239); Calabria, Righio, Casali del Manco, Cosenza province (39.316°N, 16.530°E), 1355 m, 23 May 2014, Scalercio S. leg., 1 specimen (BOLD ID: LEP-SS-01107); Calabria, Serre – Il Palmento, Serra San Bruno, Vibo Valentia province (38.5625°N, 16.3140°E), 830 m, 10 May 2016, Scalercio S. & Infusino M. leg., 1 specimen (BOLD ID: LEP-SS-01225).

Barcoded Calabrian specimens showed a high genetic divergence, in some cases higher than those registered with specimens collected in other Italian regions (Table 1).

Discussion and Conclusions

In this paper we provided faunistic data concerning the Adelidae family in the Calabria region after 107 years from the last record, increasing the regional fauna from four to nine species. We confirmed the presence of *Nemophora metallica*, *N. scopolii*, and *Adela reaumurella*, whilst after 139 years the presence of *A. raddaella* due to Costa (1863) deserves a confirmation. All these species have day active adults as *Adela mazzolella*, here recorded for the first time in the Calabria region but yet recorded from South Italy (Karsholt et al. 1995). The four listed *Nematopogon* species are all new for the regional fauna. They are mainly active during the night and several specimens were collected by light traps. The most interesting record concerns *Nematopogon robertella*, known in Italy only from the north (Karsholt et al. 1995). It has been collected in an *Abies alba* forest that grows in the rainiest

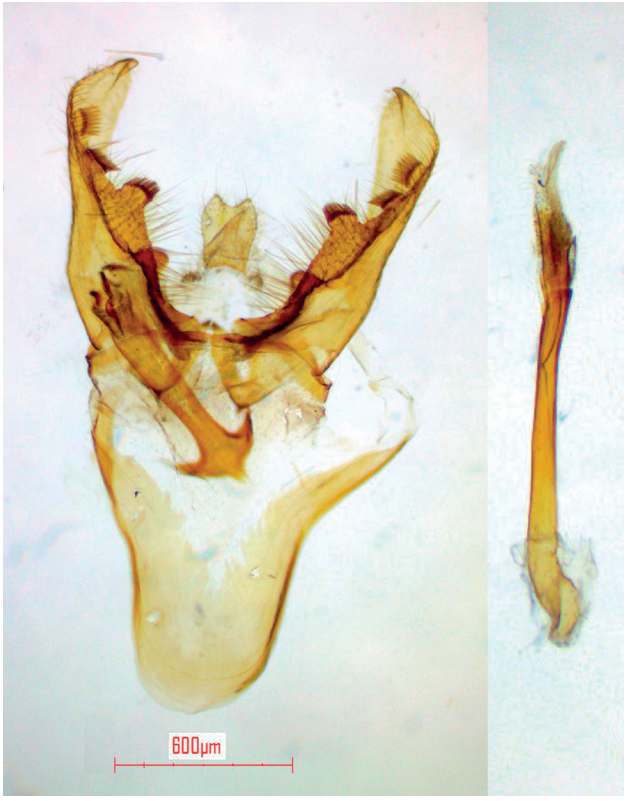


Fig. 14 – Male genitalia of *Nematopogon swammerdamella*, Cappiglione (microscope slide: CREA-0238).

area of the region. Unfortunately, the barcoding of the collected specimen was unsuccessful, and we are not able to evaluate the genetic divergence of this very isolated population. However, the morphology of male genitalia matches those of Alpine specimens (Bryner 2020) allowing a confident identification.

The great divergence in the COI sequence of barcoded Calabrian *Nematophora metallica* deserve accurate taxonomic studies. In fact, it belongs to a BIN different from those including *N. metallica* collected across the rest of Europe. However, more material is needed to ascertain the taxonomic status of Calabrian populations even if the genetic divergence is significantly higher than those found between *Nematopogon prolai* and its recently described sister species *Nematopogon garganellus*, both Italian endemics with a shared BIN (Bryner & Huemer 2019). Another remarkable COI divergence was found in *Nematopogon swammerdamella*, even if not supported by the morphology of genitalia.

Updated checklist of Italian Adelidae

Faunistic records of Adelidae in Italy are pulverised within several papers with very few records. However, 37 years after the publication of the Checklist of the Italian Fauna (Karsholt et al. 1995), distributions and taxonomy of Italian Adelidae need to be updated. In the following checklist, changes to the previously published checklist are underlined and marked in bold, and a comment is provided when appropriate.

Family Adelidae

Nematopogon Zeller, 1839
Nematopogon adansoniella (Villers, 1789) (N, **S?**)
No confirmed record is available from the South after the description of *N. garganellus*.
Nematopogon metaxella (Hübner, 1813) (N)
Nematopogon pilella ([Denis & Schiffermüller], 1775) (N)
Nematopogon prolai (Hartig, 1941) (S) [E]
Nematopogon robertella (Clerck, 1759) (N, **S**)
Found also in the South (present paper).
Nematopogon schwarziellus Zeller, 1839 (N, S)
Nematopogon sericinellus Zeller, 1847 (S, Si) [E]
Nematopogon swammerdamella (Linnaeus, 1758) (N, S)
***Nematopogon garganellus* Bryner & Huemer, 2019 (S) [E]**
Species of recent description, close to *N. prolai* (Bryner & Huemer 2019).

Nemophora Illiger & Hoffmannsegg, 1798
***Nemophora prodigellus* (Zeller, 1853)** (N)
Nemophora auricella (Ragonot, 1874) is a junior synonym (Bryner 2020).

Species	*N*	Pairwise distance		Selected ID	bp	Best match ID	%	Country
		mean	max					
Nemophora metallica	1	N/A	N/A	LEP-SS-01209	641	MM06620	97.03	Finland
Nemophora scopolii	2	0	0	LEP-SS-01214	632	TLMF Lep 14529	99.35	Austria
Adela mazzolella	3	0.11	0.16	LEP-SS-01211	658	TLMF Lep 06526	99.39	Austria
Adela reaumurella	2	0.31	0.31	LEP-SS-01215	658	TLMF Lep 18177	100	Austria
Nematopogon sericinellus	11	0.47	1.22	LEP-SS-01235	658	TLMF Lep 20506	99.85	Italy
Nematopogon swammerdamella	1	N/A	N/A	LEP-SS-01230	658	BC ZSM Lep 25115	98.55	Germany
Nematopogon garganellus	9	0.50	1.67	LEP-SS-01225	658	TLMF Lep 20500	99.23	Italy

Table 1 – Best match of barcode sequences obtained for Calabrian species of Adelidae with those published and deposited in BOLD. The most different Calabrian sequence for each species was selected.

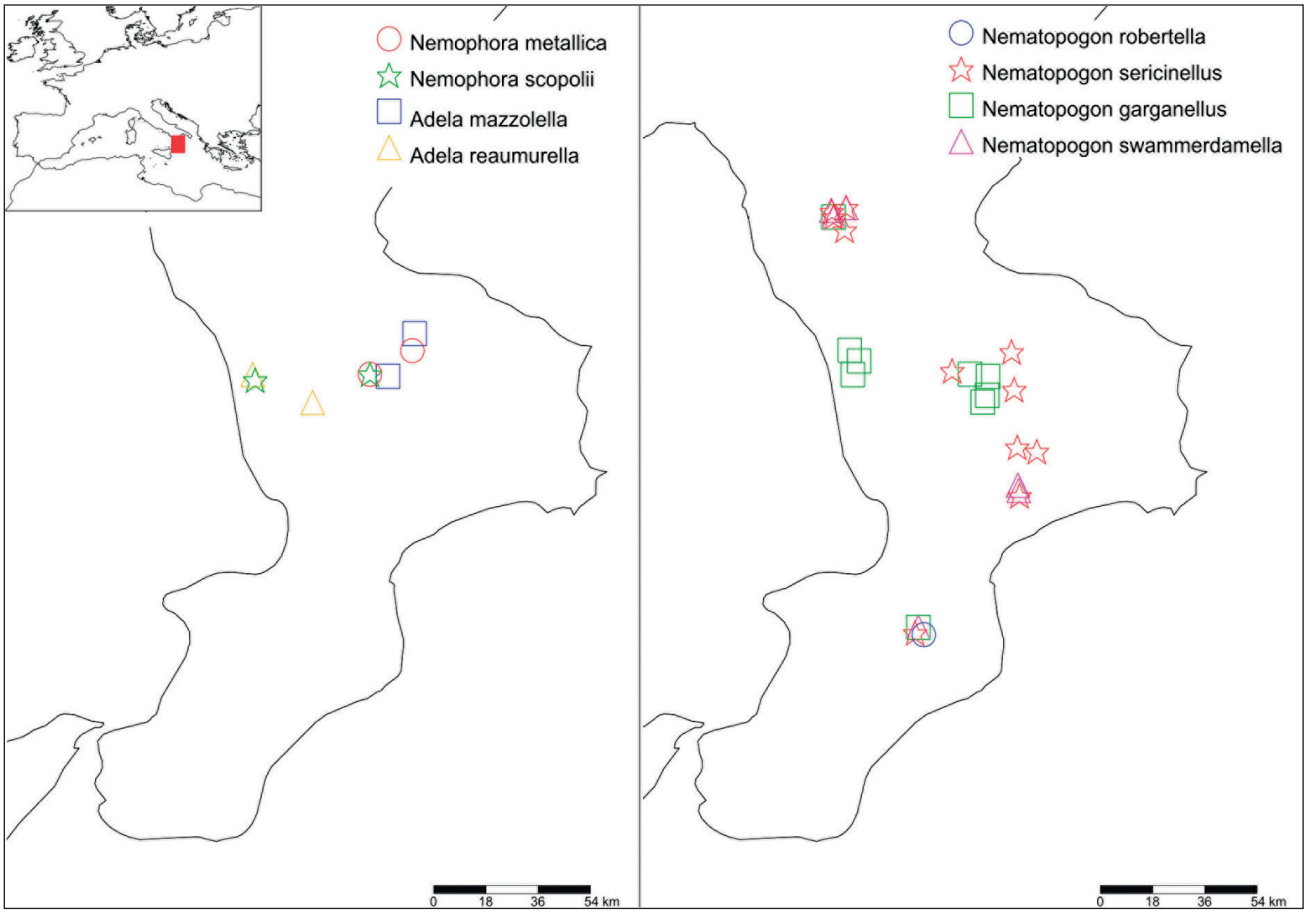


Fig. 15 – Distribution of Adelidae in the Calabria region. Map created with SimpleMappr (http://www.simplemappr.net).

barbatellus (Zeller, 1847) (S, Si, Sa)
Nemophora congruella (**Zeller, 1839**) (N)
Author's name fixed according to Bryner (2020).
Nemophora cupriacella (Hübner, 1819) (N)
***Nemophora scopolii* Kozlov, Mutanen, Lee & Huemer, 2016 (N, S)**
Allopatric sister species of *N. degeerella* (Linnaeus, 1758), absent in Italy.
Nemophora fasciella (Fabricius, 1775) (N)
Nemophora metallica (Poda, 1761) (N, **S,** Si)
Found also in the South (Pinzari et al. 2010).
Nemophora minimella ([Denis & Schiffermüller], 1775) (N)
Nemophora ochsenheimerella (Hübner, 1813) (N)
*Nemophora radd**a**ella* (Hübner, 1793)
*Nemophora radd**a**ella latreillella* (Fabricius, 1798) (S, Si)
N. raddella is an incorrect spelling.
Nemophora violellus (Herrich-Schäffer, 1851) (N, **S**)
Author's name fixed according to Bryner (2020). Found also in the South (Pinzari et al. 2015).
***Nemophora** associatella* **(**Zeller, 1839**)** (N, S)
Formerly in the genus *Adela*.
Adela Latreille, 1796
Adela albicinctella Mann, 185**3**
Year of description fixed according to Bryner (2020).
Adela australis **(Heydenreich, 1851)** (N, S, Si)
Author's name fixed according to Bryner (2020).
Adela croesella (Scopoli, 1763) (N, S, Si)
Adela cuprella ([Denis & Schiffermüller], 1775) (N, S)
Adela reaumurella (Linnaeus, 1758) (N, S, Si)
Adela violella ([Denis & Schiffermüller], 1775) (N, **S**)
Found also in the South (Pinzari et al. 2010).
***Adela** mazzolella* (Hübner, **1801**) (N, S)
Formerly in the genus *Cauchas*. Year of description fixed according to Bryner (2020).
***Adela** paludicolella* Zeller, 1850 (S, Sa)
Formerly in the genus *Cauchas*.

Cauchas Zeller, 1839
*Cauchas **fibulella*** ([Denis & Schiffermüller], 1775) (N, S)
exiguella ([Denis & Schiffermüller], 1775) is a junior synonym (Bryner 2020).
Cauchas leucocerella (Scopoli, 1763) (N)
Cauchas rufifrontella (Treitschke, 1833) (N, S)
Cauchas rufimitrella (Scopoli, 1763) (N, S)
***Cauchas albiantennella* (Burmann, 1943) (N, S)**
New to the Italian fauna (Kranebitter & Hilpold 2006; Pinzari et al. 2010).

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