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Revision of the genus *Pelecocera* Meigen, 1822 (Diptera: Syrphidae) from France: taxonomy, ecology and distribution

XAVIER LAIR[1], LISE ROPARS[2,8], JEFFREY H. SKEVINGTON[3,9], SCOTT KELSO[3,7], BENOÎT GESLIN[2,5], ELISE MINSSIEUX[4] & GABRIEL NÈVE[2,6*]

[1] *3 le Pujol, 66730 Sournia, France. x.lair@laposte.net; https://orcid.org/0000-0001-6985-4563*
[2] *Institut Méditerranéen de Biodiversité et d'Ecologie (IMBE), Case 421, Aix-Marseille Univ CNRS IRD Avignon Univ, 13397 Marseille cedex 20, France*
[3] *Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, 960 Carling Avenue, K.W. Neatby Building, Ottawa, ON, K1A 0C6, Canada.*
[4] *1 Carrer del Trot, 66500 Mosset, France. elise.minssieux@gmail.com; https://orcid.org/0000-0002-3484-512X*
[5] *benoit.geslin@imbe.fr; https://orcid.org/0000-0002-2464-7998*
[6] *gabriel.neve@imbe.fr; https://orcid.org/0000-0002-0304-8937*
[7] *scott.kelso@agr.gc.ca; https://orcid.org/0000-0001-5559-9477*
[8] *lise.ropars@imbe.fr; https://orcid.org/0000-0001-7621-2825*
[9] *jhskevington@gmail.com; https://orcid.org/0000-0002-1445-9870*
[*] *Corresponding author*

Abstract

The occurrence and distribution of the various species of the genus *Pelecocera* Meigen, 1822 (Diptera: Syrphidae) occurring in France are revised and a new species, *Pelecocera garrigae* Lair & Nève, 2022 **sp. nov.**, is described from Mediterranean France. Distribution and ecological data of the six French species of *Pelecocera* are provided and an identification key is given to all these species. Sequences of the cytochrome c oxidase subunit I (COI) from all European *Pelecocera* species support the morphological species concept, except for *Pelecocera scaevoides* (Fallén, 1817). The binomen *Pelecocera lugubris* Perris, 1839 is recovered to name the *Pelecocera lusitanica* (Mik, 1898) of authors in France.

Key words: Identification key, new synonym, description, new species, Rhingiini, *Chamaesyrphus*

Introduction

Within the family Syrphidae, *Pelecocera* Meigen, 1822 is a small genus with eleven species from the Holarctic and Oriental Regions. Based on a phylogenetic analysis of three DNA markers (COI, 28S, 18S) and morphology, Vujić *et al.* (2019) proposed treating *Chamaesyrphus* Mik, 1895 as a subgenus of *Pelecocera* and this proposal is followed here. The subgenus *Chamaesyrphus* includes five species listed in the Palaearctic Region (Peck 1988), of which *Chamaesyrphus japonicus* Shiraki, 1956 does not occur in France. The subgenus *Chamaesyrphus* may be distinguished from *Pelecocera s.s.* by the position and thickness of the arista, which is hair-like and near the base of the basoflagellomere in *Chamaesyrphus*, while it is thick and near the tip of the basoflagellomere in *Pelecocera* s.s..

Pelecocera species are among the smallest hoverflies of the French fauna. Their length is from 4 to 8 mm and they have a narrow thorax and abdomen (Bot & Van de Meutter 2019). The abdomen is black or black with yellow spots and may be partly pollinose. These flies are rarely collected, with a sparse distribution; i.e., usually only single specimens are found, but locally high densities do occur occasionally in small areas, which may explain the intraspecific variability found in some species (Van Valen 2005). Several species may occur together, as in the case of "La Lande du Camp" at Lessay (Manche, France) where three species have been recorded (Lair 2007). Their flight is inconspicuous, slow and low in the vegetation. This, together with their small size and dark colour, may explain why they are rarely photographed in the field (Ball & Morris 2015), and thus probably under-recorded by field entomologists.

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The current number of described *Pelecocera* species in Europe is six, all known to occur in France. The Palaearctic fauna (Table 1) also includes *P. japonicus* Shiraki, 1956 from Japan, *P. persiana* Kuznetzov, 1989 from Iran, *P. nigricornis* Santos Abreu, 1924 from the Canary Islands and *P. hederae* van Eck, 2021 from Cyprus on top of the European species. The Nearctic Fauna includes only three species (Skevington 2020), none of which are found elsewhere: *Pelecocera apichaetus* (Curran, 1923), *Pelecocera pergandei* (Williston, 1884) and *Pelecocera willistoni* Snow, 1895.

TABLE 1. Known species of the genus *Pelecocera*, their distribution, and recent keys if available.

Currently recognised species of *Pelecocera*	**Distribution**	**Key**
Pelecocera apichaetus (Curran, 1923)	Nearctic	–
Pelecocera caledonica (Collin, 1940)	Palaearctic (Europe)	Speight & Sarthou (2017)
Pelecocera garrigae **sp. nov.**	Palaearctic (Europe)	Present study
Pelecocera hederae van Eck, 2021	Palaearctic (Cyprus)	van Eck & Mengual (2021)
Pelecocera japonica (Shiraki, 1956)	Palaearctic (Japan)	Shiraki (1968)
Pelecocera lugubris Perris, 1839	Palaearctic (Europe)	Speight & Sarthou (2017)
Pelecocera nigricornis (Santos Abreu, 1924)	Palaearctic (Canary Is.)	Báez (1986)
Pelecocera pergandei (Williston 1884)	Nearctic	Skevington *et al.* (2019)
Pelecocera pruinosomaculata Strobl, 1906	Palaearctic (Europe)	Speight & Sarthou (2017)
Pelecocera scaevoides (Fallén, 1817)	Palaearctic (Europe)	Speight & Sarthou (2017)
Pelecocera tricincta Meigen, 1822	Palaearctic	Speight & Sarthou (2017)
Pelecocera willistoni Snow, 1895	Nearctic	–

The French catalogue by Gobert (1887) lists two species of *Pelecocera* then recognized in France: *Pelecocera tricincta* Meigen, 1822 and *P. lugubris* Perris, 1839. Séguy (1961) recognised three genera and seven species of Pelecocerini, now included in Rhingiini: *Pelecocera latifrons* Loew (then not recorded in France), *P. lugubris* Perris, *P. tricincta* Meigen, *Ischyroptera bipilosa* Pokorny, *Chamaesyrphus caledonicus* Collin (then not recorded in France), *C. lusitanicus* Mik and *C. scaevoides* (Fallén). *Ischyroptera bipilosa* is found at high altitude in the Alps, and its generic status is dealt with by Vujić *et al*. (2019).

Báez (1986) recognized *Chamaesyrphus nigricornis* Santos Abreu, 1924, from the Canary Islands and provided a table of distinguishing characters between it and *C. lusitanicus*. The anterior anepisternum has pile in *C. lusitanicus*, while it is bare in *C. nigricornis*.

Peck (1988) listed ten Palaearctic species of what was then known as Pelecocerini, placed in four genera: *Pelecocera latifrons* Loew, 1856, *Pelecocera lugubris* Perris, 1839, *Pelecocera tricincta* Meigen, 1822, *Ischyroptera bipilosa* Pokorny, 1887, *Macropelecocera paradoxa* Stackelberg, 1952, *Chamaesyrphus caledonicus* Collin, 1940, *Chamaesyrphus japonicus* Shiraki, 1956, *Chamaesyrphus lusitanicus* Mik, 1898, *Chamaesyrphus pruinosomaculatus* (Strobl, 1906), *Chamaesyrphus scaevoides* (Fallén, 1817). Peck (1988) considered *C. nigricornis* as a synonym of *C. lusitanicus*.

The following year, Kuznetzov (1989) reviewed the Palaearctic species of *Pelecocera* sensu Peck (1988) and provided an identification key to the following five species: *P. lugubris*, *P. conjungens* Enderlein, 1937, *P. latifrons*, *P. tricincta* and *P. persiana* Kuznetzov, 1989, the latter of which he described from Iran.

Dirickx (1994) mentioned six species for the Mediterranean area: *P. latifrons*, *P. tricincta*, *C. lusitanicus*, *C. nigricornis*, *C. pruinosomaculatus* and *C. scaevoides.* Recent phylogenetic data suggest that *P. latifrons* does not belong to the genus *Pelecocera* (Ståhls et al. 2004) and the genus *Pseudopelecocera* Vujić & Radenković was erected specifically for this species (Vujić et al. 2019). Dirickx (1994) included very few data from the eastern Mediterranean area; and stated that the data of *C. pruinosomaculata* from Israel needed confirmation. Speight & Sarthou (2017) mentioned that at least four undescribed *Pelecocera* taxa are found in the Mediterranean area. Ståhls *et al.* (2004) mentioned an unknown species from Greece and Van Steenis *et al*. (2019) one from Cyprus, which has recently been described as *Pelecocera hederae* van Eck, 2021 *in* van Eck & Mengual, 2021.

Since 2013, we captured a series of individuals of *Pelecocera* in France which we could not identify with available keys (Verlinden 1994, Stubbs & Falk 2002, Van Veen 2004, Haarto & Kerppola 2007; Speight & Sarthou 2017). Comparison of our specimens, all of which came from similar Mediterranean scrublands, with reference specimens of all described European *Pelecocera* species suggested that these newly captured specimens belonged to a single, new species, which is described in the present paper. In addition, we reviewed the data on the *Pelecocera* species from France, tracing historical data as much as possible. The species *Pelecocera lugubris* Perris, 1839 is absent from recent reviews. We studied the type material of this species and assessed the validity of its name according to the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 1999).

The aim of this study is to present a key to the French species of *Pelecocera* and to give details on the ecology and distribution of all *Pelecocera* species known from France. Monophyletic groups from molecular data analysis for each species are used to confirm the specific status of specimen clusters on the basis of morphological identification.

Material and methods

Fieldwork and literature revision. A *Pelecocera* female belonging to none of the five species then known in France was collected using an entomological hand net on 24 April 2013 in Sournia (Pyrénées-Orientales). This specimen showed pile on the anterior anepisternum, like *P. lugubris* Perris, 1839, but with a number of differences from this species. No further specimens could be found over the next few years, despite regular visits to the site. A female and a male collected in 2017 within the Parc National des Calanques, near Marseilles (Bouches-du-Rhône, France) were very similar to the Sournia individual. They were captured in the same habitat type: calcareous Mediterranean scrubland dominated by *Thymus* and *Cistus* bushes. These specimens, and further ones obtained since, are here formally assigned to a new species, which we describe below.

Published data from France on *Pelecocera* species were gathered, and these data were supplemented with unpublished data supplied by French colleagues. A critical review of available data allowed us to clarify the habitats and phenologies of the six French *Pelecocera* species. In the list of French data, the text always starts with the name of the French department and its number. For each datum, we recovered latitude and longitude, and produced maps using R package (R Core Team 2018) and the package mapdata (Becker *et al.* 2018).

Morphological study. For each species, several specimens were examined to establish reliable identification criteria. All morphological terms follow Thompson (1999) and Skevington *et al.* (2019). The specimens were studied and drawn with either a 'Nature et Découverte' 20× or a Wild Heerbrugg M5 binocular microscope. Photographs of the *P. lugubris* lectotype were done with a Keyence VHX 5000. Other photographs were taken using a Canon 80D with MP-E 65mm f/2,8 1-5x Macro Photo Canon lens, except the genitalia which were photographed using a Tucsen HD Lite camera on a Nikon SMZ 800 microscope. Measurements were taken using ImageJ (Rasband 2012) with photographs of specimens. Total length was from the foremost part of the face to the tip of the abdomen. Wing length was from the wing insertion on the thorax to the tip of the wing.

Molecular study. A single leg (the right mid leg where possible) was removed from specimens and the 5′-end of the Cyctochrome *c* Oxidase I mitochondrial gene (COI), or Barcoding region, was sequenced at the Canadian National Collection of Insects, Arachnids and Nematodes (CNC). Total genomic DNA was extracted using the DNeasy Blood and Tissue Kit (Qiagen Inc., Santa Clara, CA, USA) following the manufacturer's protocol. For DNA amplification, we largely used custom primers developed for use in Diptera, available in Table 2. These custom primers allowed us to sequence the Barcoding region in a single fragment or in three smaller segments to be assembled as a full barcode, allowing fragmented DNA from older specimens and specimens stored in suboptimal conditions to be successfully sequenced.

TABLE 2. Primers used to sequence the COI Barcoding region of *Pelecocera* specimens.

Primer Name	Reference	Primer Sequence
Heb-F	Folmer *et al*. 1994	GGT CAA CAA ATC ATA AAG ATA TTG G
COI-Fx-A-R	Young *et al*. 2020	CGD GGR AAD GCY ATR TCD GG
COI-Fx-B-F	Young *et al*. 2020	GGD KCH CCN GAY ATR GC
COI-Fx-B-R	Young *et al*. 2020	GWA ATR AAR TTW ACD GCH CC
COI-Fx-C-F	Young *et al*. 2020	GGD ATW TCH TCH ATY YTA GG
COI-780R	Gibson *et al*. 2011	CCA AAA AAT CAR AAT ARR TGY TG

PCR amplifications were carried out in 25 µl volumes, including 15.7µl ddH_2O, 2.5µl 10X Ex Taq PCR buffer (containing 20 mM $MgCl_2$), 0.65 µl 25 mM $MgCl_2$, 1µl of each 10 µM primer, 2 µl 10 mM dNTPs, 0.15 µl Ex Taq HS DNA polymerase (TaKaRa Bio USA, Madison, WI, USA), and 2 µl total DNA. Amplification cycles were performed on an Eppendorf ep Gradient S Mastercycler (Eppendorf AG, Hamburg, Germany). All PCR and sequencing reactions were performed with the following thermal cycler conditions: 94°C for 3 minutes × 1 cycle, 94°C for 45 seconds, 45°C for 45 seconds, 72°C for 1 minute × 45 cycles, 72°C for 5 minutes × 1 cycle, followed by an unlimited step at 10°C. Amplification products were visualized on 1% agarose electrophoresis gels and purified prior to sequencing using either Clone-Well 0.8% Egels (Invitrogen™, Carlsbad, CA, USA) for full barcode amplicons, or an ExoSAP-IT protocol (USB Corp., Cleveland, OH, USA) for COI-Fx amplicons. Sequencing reactions were carried out in 10µl volumes, using the ABI BigDye Terminator v3.1 Cycle Sequencing kit (PE Applied Biosystems, Foster City, CA, USA). Bidirectional sequencing reactions were purified using the ABI ethanol/EDTA/sodium acetate precipitation protocol and analyzed on an ABI 3500xl Genetic Analyzer (PE Applied Biosystems, Foster City, CA, USA).

All 53 new sequence data obtained for the present study are stored on the BOLD website (www.boldsystems.org) in the *Pelecocera* of the World (DS-PELECOC) dataset, available at dx.doi.org/10.5883/DS-PELECOC. Raw sequence reads were scored using Sequencher 5.4.6 (Gene Codes Corp., Ann Arbor, MI, USA) and aligned using Mesquite (Maddison & Maddison 2010). Additionally, ten sequences were mined from the NCBI data set, where we looked specifically for COI sequences from the genera *Chamaesyrphus* and *Pelecocera*. We ended up with 64 *Pelecocera* sequences at least 550 bp long. A sequence from *Pseudopelecocera latifrons* (Loew, 1856) was used to root the tree. All complete sequences used in this project are also available on GenBank (https://www. ncbi.nlm.nih.gov/genbank/), with accession numbers listed in Table 3.

Alignments and analyses were performed using MEGA X (Kumar *et al*. 2018). All positions with less than 90% site coverage were eliminated, i.e., fewer than 10% alignment gaps, missing data, and ambiguous bases were allowed at any position (partial deletion option), leaving 550 positions in the final dataset. A neighbor-joining tree of all available *Pelecocera* barcodes was produced in MEGA (Kumar *et al*. 2018) using the Maximum Composite Likelihood method (Tamura *et al* 2004). The neighbor-joining tree was examined for evidence of a barcoding gap (Hebert *et al*. 2003, Čandek & Kuntner 2015) of 2% or more interspecific difference between species. Although interspecific differences in COI have been used to successfully identify species (e.g. Gutiérrez *et al*. 2014, Renaud *et al*. 2012, Young *et al*. 2020), it fails to distinguish between some species (for example see Whitworth *et al*. 2007). The distances between samples were computed using the Maximum Composite Likelihood method (Tamura *et al*. 2004) and a bootstrap analysis (1000 replicates) was performed. The percentage of replicate trees in which the associated taxa clustered together are shown next to the branches in the obtained consensus tree. The obtained consensus tree was used to checked whether the sequences clusters match morphologically defined species.

Repository collections.

CBGP	Collection Édouard Perris, Centre de Biologie pour la Gestion des Populations, Institut Agro Montpellier, Montferrier-sur-Lez, France, DOI: https://doi.org/10.15454/D6XAKL.
CNC	Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Canada.
FMNH	Finnish Museum of Natural History, Zoological Museum, Helsinki, Finland.
GN	Private Research Collection of Gabriel Nève, Marseille, France.
IMBE	Institut Méditerranéen de Biodiversité et d'Ecologie Reference Collection, Marseille, France.
KW	Private Research Collection of Kaj Winqvist, Turku, Finland.
MHNG	Muséum d'Histoire Naturelle, Genève, Switzerland.
MNHN	Muséum National d'Histoire Naturelle, Paris, France
NBC	Naturalis Biodiversity Center, Leiden, The Netherlands
NUST	Norwegian University of Science and Technology, University Museum, Department of Natural History, Trondheim, Norway.
OCIC	Observatoire Conservatoire des Invertébrés de Corse, Office de l'Environnement de la Corse, Corte, France.
XL	Private Research Collection of Xavier Lair, Sournia, France.

TABLE 3. Accession numbers and origins of all *Pelecocera* sequences used. Abbreviations: CNC: Canadian National Collection of Insects, Arachnids and Nematodes; FMNH: Finnish Museum of Natural History, Zoological Museum; KW: Research Collection of Kaj Winqvist; NA: data not available; NCBI: data mined from Genbank, NCBI; NUST: Norwegian University of Science and Technology, University Museum, Department of Natural History.

GenBank Number	Unique Identifier	Process ID	Identification	Collection Date	country	**Province/state**	**institution**
MW478415	jka10-00604	FIDIP2030-12	*P. caledonica*	15 Jul 2010	Finland		FMNH
MW478436	JKA12-0440	FIDIP2259-12	*P. caledonica*	16 Aug 2004	Finland		FMNH
MH521941	MH521941	GBMNA27323-19	*P. caledonica*	NA	Finland		NCBI
MW478402	NORSY438	NORSY438-15	*P. caledonica*	20 Aug 2009	Norway	Ostfold	NTNU
MW478400	NORSY439	NORSY439-15	*P. caledonica*	20 Aug 2009	Norway	Ostfold	NTNU
MW478408	CNC1619206	CNCTW072-20	*P. garrigae* **sp. nov.**	7 May 2018	France	Bouches-du-Rhône	CNC
AY533321	AY533321	GBDP1257-06	*P. lugubris*	NA	Sweden		NCBI
MW478410	jka-05-02946	FIDIP1379-12	*P. lugubris*	3 Aug 2005	Finland		FMNH
MH521939	MH521939	GBMNA27322-19	*P. lugubris*	NA	Finland		NCBI
MW478434	S._BOT_SPECIMEN275	CNCNG3031-19	*P. lugubris*	18 Sep 2016	Belgium	Limburg	CNC
MH521943	MH521943	GBMNA27334-19	*P. nigricornis*	NA	Spain		NCBI
MW478401	CNC1078271	CNCTW005-20	*P. pruinosomaculata*	2 May 2016	France	Pyrénées-Orientales	CNC
MW478431	CNC1078286	CNCTW004-20	*P. pruinosomaculata*	14 May 2017	France	Pyrénées-Orientales	CNC
MW478440	CNC1078290	CNCTW006-20	*P. pruinosomaculata*	4 Oct 2018	France	Pyrénées-Orientales	CNC
MH521942	MH521942	GBMNA27320-19	*P. pruinosomaculata*	NA	Greece		NCBI
MK959049	MK959049	GBMNB15509-20	*P. pruinosomaculata*	NA	Cyprus		NCBI
MW478417	BIOUG15596-A02	GMNWG605-14	*P. scaevoides*	8 Jun 2014	Norway	SorTrondelag	NTNU
MW478453	BIOUG15600-D03	GMNWG1022-14	*P. scaevoides*	8 Jun 2014	Norway	SorTrondelag	NTNU
MW478398	BIOUG15798-C12	GMNWI656-14	*P. scaevoides*	6 Jul 2014	Norway	SorTrondelag	NTNU
MW478441	BIOUG15807-D09	GMNWI1045-14	*P. scaevoides*	6 Jul 2014	Norway	SorTrondelag	NTNU
MW478412	BIOUG15895-D08	GMNWI3170-14	*P. scaevoides*	6 Jul 2014	Norway	SorTrondelag	NTNU
MW478427	BIOUG16299-B02	GMNWK957-14	*P. scaevoides*	3 Aug 2014	Norway	SorTrondelag	NTNU
MW478403	BIOUG16301-G06	GMNWK1211-14	*P. scaevoides*	3 Aug 2014	Norway	SorTrondelag	NTNU
MW478454	BIOUG16478-E06	GMNWL958-14	*P. scaevoides*	17 Aug 2014	Norway	SorTrondelag	NTNU

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TABLE 3. (Continued)

GenBank Number	Unique Identifier	Process ID	Identification	Collection Date	country	**Province/state**	**institution**
MW478446	BIOUG16591-D01	GMNWL2909-14	*P. scaevoides*	17 Aug 2014	Norway	SorTrondelag	NTNU
MW478432	BIOUG16591-D05	GMNWL2913-14	*P. scaevoides*	17 Aug 2014	Norway	SorTrondelag	NTNU
MW478438	BIOUG16591-D11	GMNWL2919-14	*P. scaevoides*	17 Aug 2014	Norway	SorTrondelag	NTNU
MW478424	BIOUG16591-E04	GMNWL2924-14	*P. scaevoides*	17 Aug 2014	Norway	SorTrondelag	NTNU
MW478435	BIOUG16624-D01	GMNWN137-14	*P. scaevoides*	14 Sep 2014	Norway	SorTrondelag	NTNU
MW478404	CNC DIPTERA 101680	CNCDB282-11	*P. scaevoides*	19 May 1993	France	Alpes-de-Haute-Provence	CNC
MW478451	CNC DIPTERA 101681	CNCDB283-11	*P. scaevoides*	19 May 1993	France	Alpes-de-Haute-Provence	CNC
MW478420	CNC1078289	CNCTW002-20	*P. scaevoides*	1 Jun 2019	France	Pyrénées-Orientales	CNC
MW478397	CNC483055	CNCNG389-19	*P. scaevoides*	15 Jun 2015	Austria		CNC
MW478405	FiDip20	DIPFI020-12	*P. scaevoides*	26 Jul 2010	Norway	Finnmark	NTNU
MW478449	jka10-01576	FIDIP2084-12	*P. scaevoides*	14 Jul 2010	Finland		FMNH
MW478423	KWi-101	DIFIA545-12	*P. scaevoides*	22 Jun 2009	Finland		KW
MW478399	KWi-102	DIFIA546-12	*P. scaevoides*	19 Aug 2009	Finland		KW
MH521940	MH521940	GBMNA27321-19	*P. scaevoides*	NA	Finland		NCBI
MW478429	MPZ-A0002	SRCNC528-16	*P. scaevoides*	25 Jun 2015	Germany	Bavaria	CNC
MW478442	MZH_HP.56	FIDIP056-11	*P. scaevoides*	17 Jul 2010	Finland	Lapland	FMNH
MW478407	NorSy243	NORSY243-12	*P. scaevoides*	22 Aug 2010	Norway	Buskerud	NTNU
MW478422	NorSy63	NORSY063-12	*P. scaevoides*	21 Jun 2019	Norway	Telemark	NTNU
MK959048	MK959048	GBMNB15508-20	*P. hederae*	9 Oct 2017	Cyprus		NCBI
MW478437	CNC DIPTERA 102446	CNCDB1306-11	*P. tricincta*	23 May 1974	Italy	Veneto	CNC
MW478452	CNC1584211	CNCTW014-20	*P. tricincta*	22 Sep 2018	Albania		CNC
MW478396	CNC463840	CNCFF777-16	*P. tricincta*	8 Sep 2012	Netherlands	Gelderland	CNC
MW478443	jka06-01170	FIDIP1583-12	*P. tricincta*	5 Jul 2006	Finland		FMNH
MW478428	JKA12-0441	FIDIP2260-12	*P. tricincta*	16 Aug 2004	Finland		FMNH

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TABLE 3. (Continued)

GenBank Number	Unique Identifier	Process ID	Identification	Collection Date	country	**Province/state**	**institution**
MH521937	MH521937	GBMNA23947-19	*P. tricincta*	NA	Greece		NCBI
MW478406	MPZ-A0005	CNCNG2995-19	*P. tricincta*	23 Aug 2015	Netherlands	Gelderland	CNC
MW478418	MPZ-A0054	CNCNG3012-19	*P. tricincta*	4 Sep 2015	Germany	Lower Saxony	CNC
MW478419	NorSy343	NORSY343-12	*P. tricincta*	29 Jul 2009	Norway	Telemark	NTNU
MW496848	S. BOT SPECIMEN276	SRCNC625-17	*P. tricincta*	18 Sep 2016	Belgium	Limburg	CNC
MW478426	Sander_Bot_Specimen#47	SYROC325-15	*P. tricincta*	11 Jul 2015	Netherlands		CNC
MW478411	CNC DIPTERA 101682	CNCDB284-11	*P. willistoni*	16 Sep 1994	USA	New Mexico	CNC
MW478455	CNC DIPTERA 106487	CNCDB3823-11	*P. willistoni*	17 Aug 1999	USA	New Mexico	CNC
MW478421	CNC DIPTERA 106488	CNCDB3824-11	*P. willistoni*	17 Aug 1999	USA	New Mexico	CNC
MW478433	CNC DIPTERA 10841	CNCDB3890-11	*P. willistoni*	8 Aug 2007	USA	Arizona	CNC
MW478416	CNC DIPTERA 10991	CNCDB3891-11	*P. willistoni*	13 Aug 2007	USA	New Mexico	CNC
MW478414	CNC DIPTERA 135876	CNCSY503-12	*P. willistoni*	12 Aug 2007	USA	Arizona	CNC
MW478444	CNC DIPTERA 135884	CNCSY505-12	*P. willistoni*	12 Aug 2007	USA	Arizona	CNC
MW478425	CNC DIPTERA 158253	CNCSY514-12	*P. willistoni*	16 Aug 2007	USA	New Mexico	CNC
MW478450	CNC DIPTERA 158514	CNCSY518-12	*P. willistoni*	16 Aug 2007	USA	New Mexico	CNC
MW478413	CNC DIPTERA 160649	CNCSY521-12	*P. willistoni*	16 Aug 2007	USA	New Mexico	CNC
AY533322	AY533322	GBDP1258-06	*Pseudopelecocera latifrons*	NA	Croatia	Dubasnica	NCBI

Results

Description of a new *Pelecocera* species from France

Pelecocera garrigae Lair & Nève sp. nov.

Figs 1, 2, 7D, 8B, 9B, 10B

Type material. **HOLOTYPE:** FRANCE: Pyrénées-Orientales: Sournia, Chemin de Roquebert, 42.7250°N 2.4660°E, alt. 480 m, 1 ♂ 17 April 2019 (X. Lair). Holotype deposited in the MNHN, specimen ED11396. **PARATYPES :** FRANCE, Bouches-du-Rhône: Marseilles, National Park of Calanques, La Panouse, 43.2564°N 5.4401°E, alt. 160 m, 1 ♂, 2 April 2017, IMBE1001 and 1 ♀, 5 April 2018 (L. Ropars), paratype deposited in the MNHN, specimen ED11397; National Park of Calanques, La Gardiole, 43.2406°N 5.4781°E, alt. 203 m, 1 ♀, 3 May 2017, IMBE1002; 1 ♀ 7 May 2018 (L. Ropars), CNC1619206; Pyrénées-Orientales: 1 ♀, Sournia, chemin de Roquebert, 42.7250°N 2.4660°E, alt. 480 m, 24 April 2013 (X. Lair), this specimen was mentioned as *P. lusitanica* by Speight *et al*. (2013) and in Lair *et al*. (2021), XL01001; 1 ♀, 3 May 2018, (X. Lair), XL01002; 3 ♂, 17 April 2019 (X. Lair & C. Kassebeer), XL01003-01005; 1 ♂, 25 April 2020 (X. Lair), XL01006; 1 ♂ and 1 ♀, 28 April 2020, (X. Lair & E. Lecointe), XL01007-01008; 1 ♀, 4 May 2020 (A. Parret), XL01009; Alpes-de-Haute-Provence: 1 ♂, Saint-Michel l'Observatoire, 43,9300°N 5.7189°E, alt. 650 m, Malaise trap, 19-26 May 2010 (J.P. Orts & G. Nève), GN00524.

Additional examined material: SPAIN, Malaga: ♀, Istan, 500 – 600m [ca. 36.5828°N 4.9494°W], 5 April 1972 (leg V.S. van der Goot & J.A.W. Lucas), NBC (mentioned as *Pelecocera* (*Chamaesyrphus*) Lair & Nève spec. nov in van Eck & Mengual 2021). **FRANCE,** Vaucluse: ♀, Caromb, Lac du Paty [ca. 44.1322° N 5.1136° E], 30 May 1995 (leg. Merz & Eggenberger), det. G. Pétremand 2020, MHNG.

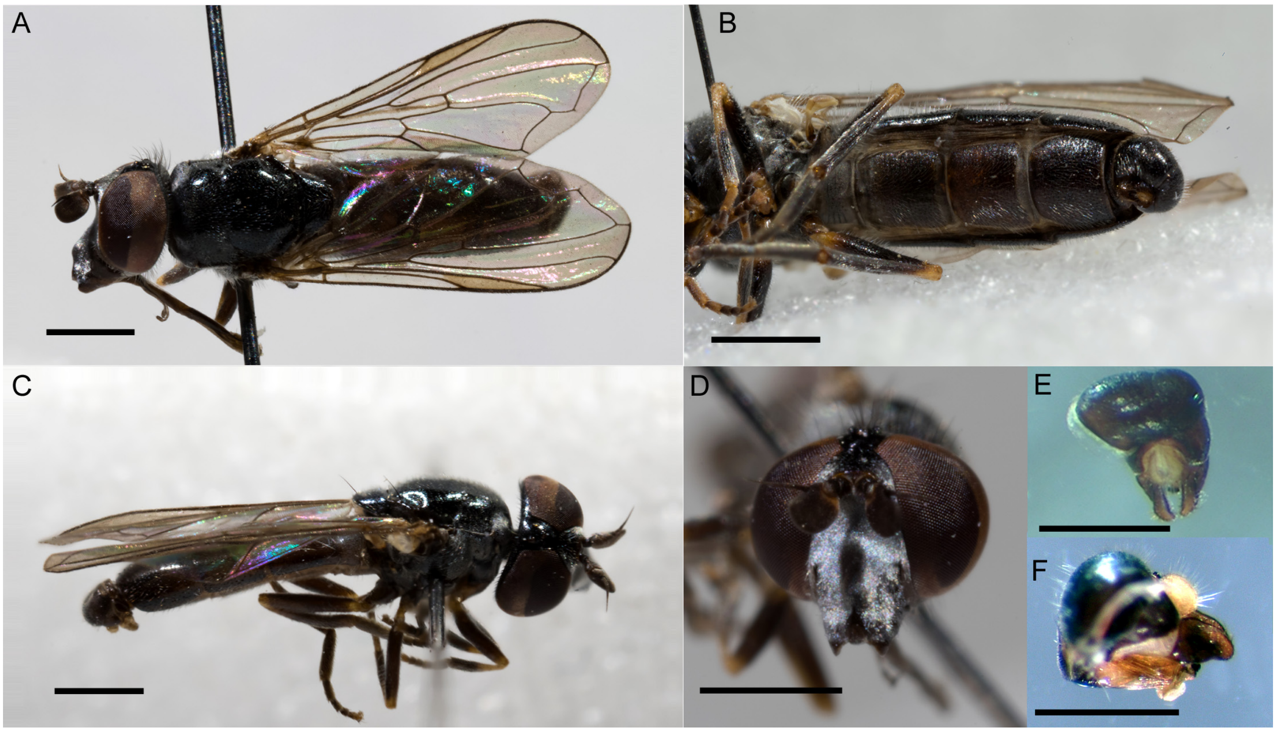

FIGURE 1. *Pelecocera garrigae* **sp. nov**. holotype male (A, C, D) and paratype male (B, E, F): A and C: habitus lateral views, B: abdomen, ventral view, C head, frontal view, E: genitalia, ventral view, F genitalia lateral view. Scale bars (A, B, C, D) = 1 mm, scale bars (E, F) = 0.5 mm.

Diagnosis. *Pelecocera garrigae* **sp. nov.** is readily identified as belonging to the *Chamaesyrphus* subgenus due to the hair-like arista located dorsally on the basoflagellomere, and the anterior anepisternum with some white pile anterodorsally. In *P. garrigae*, the face protrudes forward and is entirely black with a shiny median stripe and mouth edge; the face sides are strongly pollinose, appearing light grey. The parafaces along the eyes are wide, reminiscent of *Cheilosia* Meigen, 1822. The lunule is slightly shiny and not pollinose. The frons is punctuate and not pollinose.

The abdominal pattern is variable, either entirely black, or with pairs of lateral reddish-brown spots of varying size on tergites 3 to 5 (females), or 4 to 5 (males), or only on tergite 5 (females).

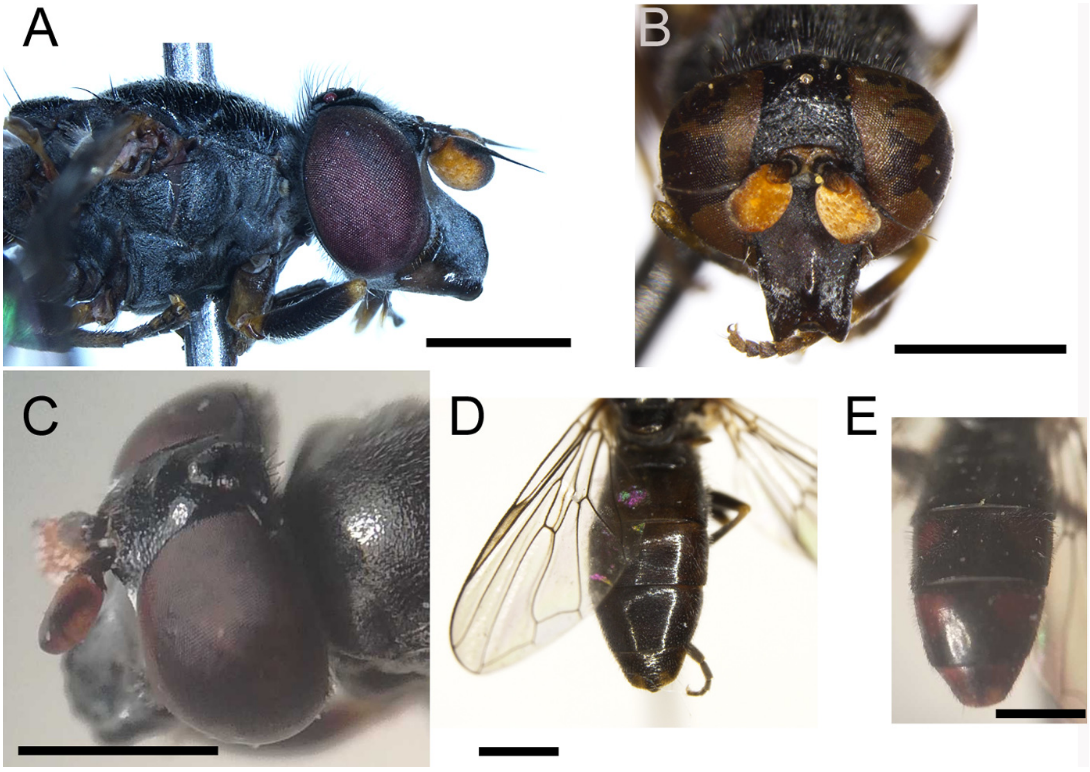

FIGURE 2. *Pelecocera garrigae* **sp. nov.** paratype female: A: head and abdomen: lateral view, B head frontal view, C: head, dorso-lateral view, D and E: abdomen: dorsal views. Scale bars = 1 mm.

Description. **MALE.** ***Measurements***. total body length (without antennae): 4.8 mm; wing length: 3.6 mm (holotype). Total body length: 4.8−6.4 mm; wing length: 3.6-4.7 mm (n = 3). ***Head***. Antenna black, basoflagellomere with small ventral posterior orange spot. Arista black, bare, inserted dorsaly before the apex (from the middle to the three quarters of the ridge). Face: protrudes forward, entirely black and strongly pollinose, appearing whitish, except shiny mouth edge. Paraface narrower than in females. Frons: punctate and hardly polished, delimited by a curved transverse line (ridge) between the two eyes: the distance between the anterior ocellus and the ridge is 2 to 3 times the diameter of the anterior ocellus. Lunule: black, slightly shiny. Eyes bare. ***Thorax***. Mesoscutum and scutellum shiny black, finely punctuate. covered with semi erected short white pile. Postpronotum and notopleuron pollinose. Scutellum shiny black. Pleura black, entirely pollinose. Anterior anepisternum with 3 or 4 white pile. One black seta on posterior anepisternum, postero-dorsally. Legs: Mainly black, with yellow trochanters. Covered with short white hairs. Femora 1-3 black, narrowly yellow at basal and apical ends. Tibiae 1-2 black, with third to half basal yellow bases and apex narrowly yellow. Tibia 3 black with yellow knees. Tarsi 1 and 2 yellowish to entirely black. Tarsus 3 black. Wing: Entirely covered with microtrichia. Upper outer cross-vein M1 strongly sloping. Stigma pale yellow. Alula: narrow, entirely covered with microtrichia. ***Abdomen***. Narrow, with parallel edges. Tergites entirely black or with badly defined red brown lateral spots on tergites 3 and 4. Pregenital segment with white pile. Sternites: lustrous black, slightly pollinose, densely punctuated. ***Genitalia***. The surstyli are symmetrical. Viewed laterally, their shape is subtriangular with a blunt apex covered with whitish pile. The cerci are semicircular, with long whitish pile. The hypandrium is elongate, subcylindrical, with a black cap at its apex and a bifid appendix ventrally.

FEMALE. Very similar to males. **Measurements:** Total length (without antennae): 5.1 to 8.0 mm, wing length 4.4 to 6.5 mm (n=4). **Head:** Antenna black, basoflagellomere orange ventrally, with black upper ridge, the face protrudes forward and is entirely black, with a shiny mouth edge and a black shiny median stripe, the lateral face is pollinose, appearing light grey. The paraface are wider than in the male, reminiscent of *Cheilosia*. The anterior half of the frons is punctate and hardly polished, without any transverse pollinose band above the lunule unlike all other *Pelecocera* species. The lunule is dark brown or black, slightly shiny. **Abdomen:** The tergites are completely black, or with pairs of reddish-brown lateral spots on tergites 3 to 5, or only on tergite 5.

Etymology. From the French noun “garrigue” (Bigot & Picard 1989), describing the Mediterranean scrubland on limestone where the species was found.

Distribution. This species is known only from the locations mentioned above, in the French administrative departments of Pyrénées-Orientales, Bouches-du-Rhône, Alpes-de-Haute-Provence and Vaucluse (Fig. 3). In the Parc National des Calanques it has been found at localities up to 5.5 km apart. The species is probably still to be found in other limestone areas of Mediterranean France. The specimen from the Spanish province of Malaga indicates that the species is also be present in Spain.

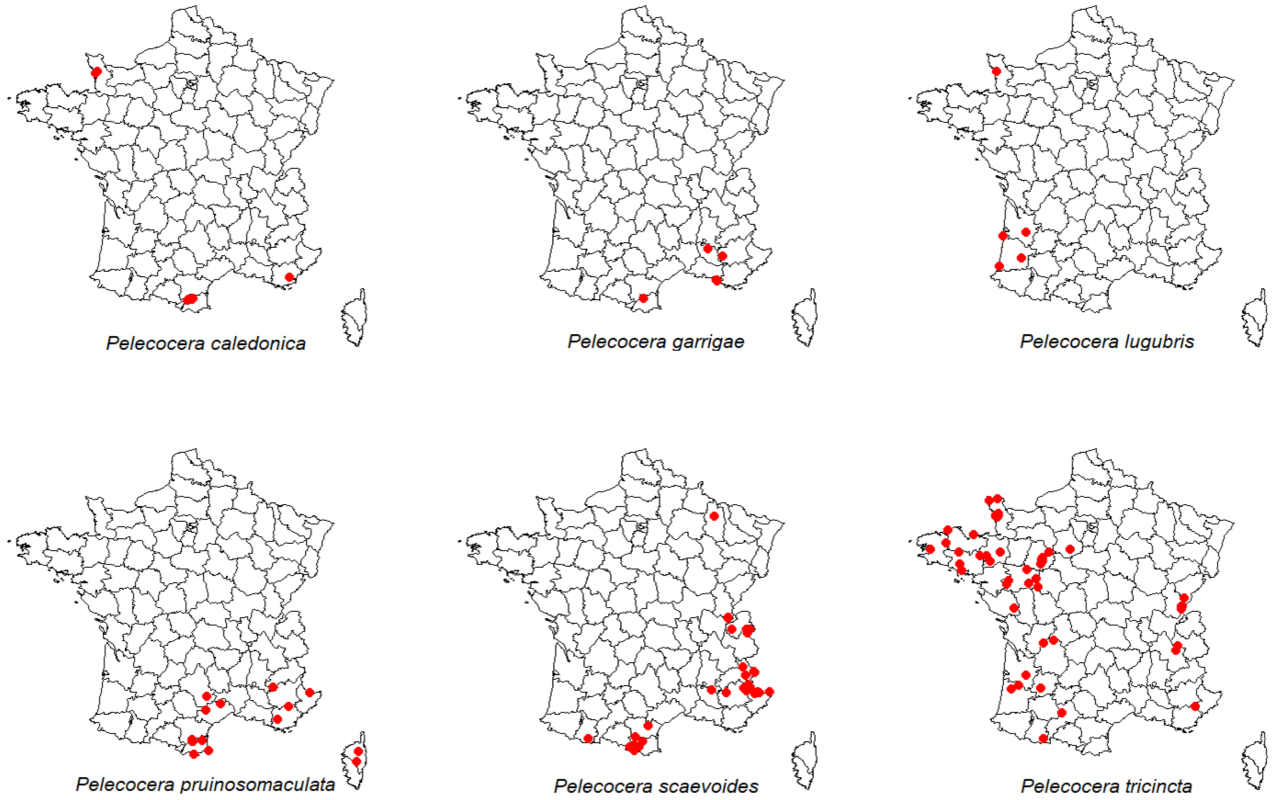
Pelecocera caledonica
Pelecocera garrigae
Pelecocera lugubris
Pelecocera pruinosomaculata
Pelecocera scaevoides
Pelecocera tricincta

FIGURE 3. Distribution of the six *Pelecocera* species in France.

Molecular study

A total of 53 COI sequences were obtained for the present study (Table 3), and 11 were mined from NCBI database. The consensus NJ grouping with all known COI sequences of *Pelecocera* shows that *P. garrigae* **sp. nov.** is distinctly separate from all other *Pelecocera* species (Fig. 4). The species genetically closest to *P. garrigae* **sp. nov.** is *Pelecocera caledonica* (7.2 % pairwise difference) (Table 4). *Pelecocera garrigae* **sp. nov.** is also distinct from the Greek undescribed *Pelecocera* species mentioned in Ståhls *et al*. (2004), as there is a 4.1% difference between their sequences (G. Ståhls pers. comm.). *Pelecocera hederae* van Eck, 2021 was found in Cyprus (specimen MK959048) and has been described in a recent separate paper (van Eck & Mengual 2021).

Altogether, the consensus tree (Fig. 4) recognised unambiguously seven species: *P. caledonica, P. garrigae, P. lugubris, P. nigricornis, P. tricincta, P. willistoni* and *P. hederae*, all with differences larger than 1.6 % (Table 4). The remaining two species, *P. scaevoides* and *P. pruinosomaculata* are mixed with each other. The COI mean distance between their sequences (0.8 %) is the smallest difference between species, of the same order of magnitude as its standard deviation (0.5 %). Notably, *P. scaevoides* from Germany, the Pyrenees and Alpes-de-Haute-Provence form singletons distinct from the main *P. scaevoides* cluster of Norway and Finland. We have been unable to find any morphological characters that support separate clusters of *P. scaevoides*, so we are not describing a new species based on these specimens at this time. As the morphological characters we have used to distinguish *P. scaevoides* from *P. pruinosomaculata* have shown consistency, we think the intermingled clusters of these species may reflect an introgression event, a lack of differentiation on the COI gene, or both.

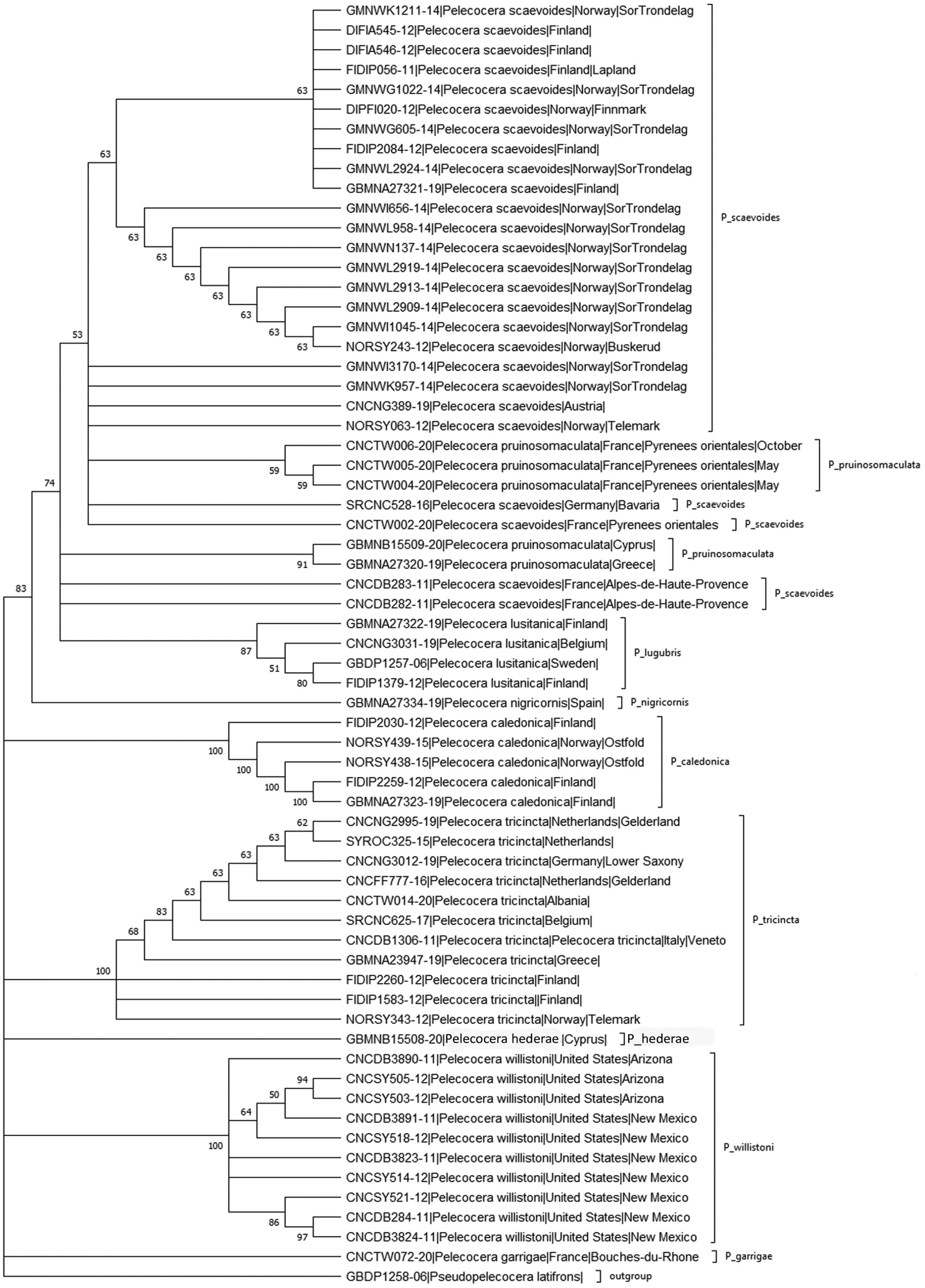

FIGURE 4. Consensus NJ tree of COI *Pelecocera* sequences based on 1000 bootstraps. Only clusters found in more than 50 % of the trees are shown.

TABLE 4. Within-species variation and mean pairwise sequence differences (bottom semi-matrix) and s.d. (top semimatrix) between the nine *Pelecocera* species and the outgroup *Pseudopelecocera latifrons*. NA: data not available.

	Within species		Among species									
	distance	s.d.	*P. caledonica*	*P. garrigae* **sp. nov.**	*P. lugubris*	*P. nigricornis*	*P. pruinosomaculata*	*P. scaevoides*	*P. hederae*	*P. tricincta*	*P. willistoni*	*P. latifrons*
P. caledonica	0.00000	0.00000		0.00000	0.00449	0.00000	0.00253	0.00342	0.00000	0.00200	0.00345	0.00000
P. garrigae **sp. nov.**	NA	NA	0.07221		0.00987	NA	0.00184	0.00341	NA	0.00112	0.00228	NA
P. lugubris	0.00248	0.00177	0.04300	0.08405		0.00171	0.00237	0.00379	0.00175	0.00593	0.00350	0.00201
P. nigricornis	NA	NA	0.04393	0.08520	0.02368		0.00105	0.00230	NA	0.00279	0.00305	NA
P. pruinosomaculata	0.00695	0.00516	0.04387	0.08342	0.01284	0.03073		0.00538	0.00001	0.00276	0.00345	0.00153
P. scaevoides	0.00284	0.00280	0.04054	0.07953	0.01619	0.02895	0.00809		0.00671	0.00352	0.00507	0.00237
P. hederae	NA	NA	0.05374	0.09091	0.05577	0.06427	0.06197	0.06365		0.00282	0.00275	NA
P. tricincta	0.00358	0.00262	0.06899	0.10538	0.07394	0.07049	0.07184	0.07135	0.08069		0.00306	0.00431
P. willistoni	0.00768	0.00425	0.07845	0.10073	0.08393	0.07601	0.08923	0.08753	0.07509	0.08971		0.00178
P. latifrons	NA	NA	0.10269	0.13398	0.10518	0.09675	0.11076	0.10915	0.12402	0.12755	0.12951	

The species *P. pruinosomaculata* shows variability in its colour pattern, and occurs either in spring or in autumn, raising the question of its identity as a single taxon. The NJ tree clusters May and October specimens from Pyrenees, therefore supporting the current taxonomic treatment of this taxon as a single species. Specimens identified as *P. pruinosomaculata* from Cyprus (MK959049) and Greece (MH521942) are grouped together in a distinct cluster with a difference of 1.1 % (sd=0) to the Pyrenees specimens, suggesting a genetic differentiation from the French population probably as a result of their island isolation.

Taxonomic notes on *Pelecocera lubrugris*/*Pelecocera lusitanica*

Mengual *et al*. (2015) recognized *P. lugubris* as a synonym of *C. lusitanicus*, now known as *P. lusitanica* by most recent authors (e.g. Bot & Van de Meutter 2019; Speight 2020), following the unpublished notes of F. C. Thompson. *Pelecocera lugubris* was described by Perris (1839) on the basis of specimens from Mont-de-Marsan, France, and the name was used by entomologists reviewing French species (Gobert 1887; Séguy 1961) or Palaearctic ones (Sack 1935; Peck 1988; Kuznetzov 1989). Therefore, according to the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 1999), the name *Pelecocera lugubris* cannot be considered as nomen oblitum. Perris' collection, together with his original notebook, is now hosted at CBGP, Institut Agro Montpellier (Lichtenstein 1879, *contra* Dupuis & Matile 1990). Entry number 2731 of Perris' notebook mentions "*Pelecocera lugubris* mihi M^{t} M^{an}". The note "mihi", Latin for "me", indicates that Perris himself described the species, and "M^{t} M^{an}" is an abbreviation for Mont-de-Marsan where Perris had been living most of his life (Laboulbène 1879). Perris' collection hosts four specimens labelled "*lugubris* Perris M^{t} M^{an}". These specimens are all females. We hereby designate the specimen, now labelled EPER0030, number 2731a in Édouard Perris collection, CBGP, Institut Agro Montpellier, Montferrier-sur-Lez, France as the lectotype of *Pelecocera lugubris* Perris, 1839 (Fig. 5), and the three other specimens from the original syntype series, now labelled EPER0031 to EPER0033, numbers 2731b to 2731d in Perris collection, as paralectotypes; specimens EPER0031 and EPER0032 have been badly damaged by *Anthrenus* sp. beetles. It should be noted that Perris' species, named in 1839, predates the original description of *C. lusitanicus,* given by Mik (1898). If these two taxa are found to be conspecific, then the name *P. lusitanica* should be treated as a junior objective synonym of *P. lugubris*. The original description of *P. lugubris* by Perris (1839) and the associated plate (repeated here as Fig. 6) refer to a convex frons, a specific character now recognised for this species. The lectotype of *P. lugubris* has the arista at a nearly apical position of the flagellum. This hair-like arista is consistent with Perris' drawing of *P. lugubris*, and with known characters of *C. lusitanicus* such as the notably hairy anterior anepisternum, convex frons, and the shape of the lunule. We thus recover *P. lugubris* Perris, 1839 to name French specimens of *P. lusitanica*, until new studies assess the validity of the species *P. lusitanica*. Whether very similar Iberian specimens currently known as *P. lusitanica* belong to the same species as the French *P. lugubris* or represent a distinct lineage remains an open question, pending comparative genetic and morphological studies of specimens on a European scale.

FIGURE 5. Habitus of the female lectotype of *Pelecocera lugubris* Perris, 1839: specimen 2731a, Perris collection, CBGP, with the original label of the syntype series (photos J.-C. Streito & É. Pierre, CBGP, INRAE, CIRAD, IRD, Institut Agro Montpellier, Univ. Montpellier).

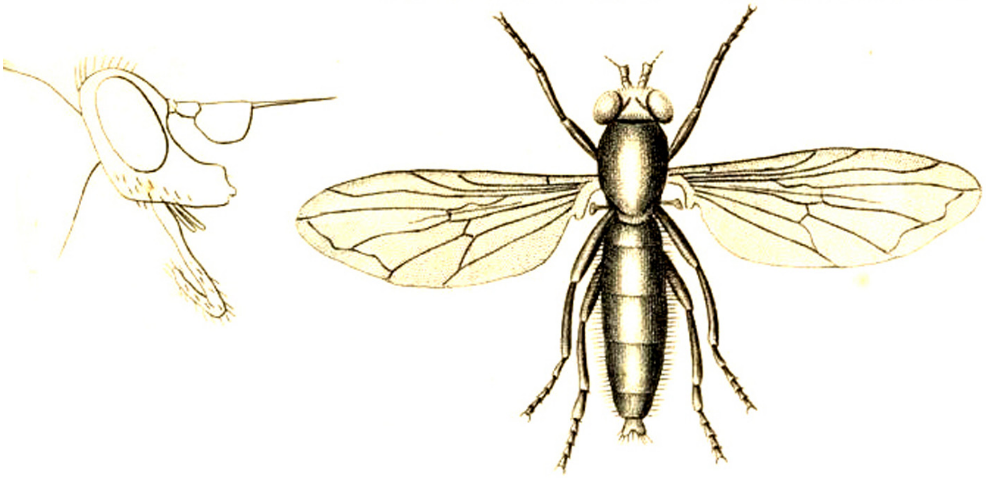

FIGURE 6. Plates from Perris (1839) with illustrations of *Pelecocera lugubris* (photo Bibliothèque nationale de France).

Key to the French species of *Pelecocera*

For several years we have used various keys to identify our specimens: Verlinden (1994), Stubbs & Falk (2002), Van Veen (2004), Haarto & Kerppola (2007), Speight & Sarthou (2017), but some features were not satisfactory: the colour of the legs is variable; the tergites may or may not have pairs of yellow or grey spots for the same species, especially on the autumn specimens (*P. pruinosomaculata, P. caledonica*), as already noted by Mik (1896) who recognised *Pelecocera rectinervis* Kertész, 1896 as a black morph of *Pelecocera latifrons*, now *Pseudopelecocera latifrons*; and the presence or absence of a few white or black bristles on the anterior anepisternum is also variable for four of the six species.

For this work we examined about twenty-five characters and retained the most reliable ones. Characters examined, but not retained are: shape of the basoflagellomere, position of the arista on the basoflagellomere, shape of the face on lateral view, colour and pruisosity of the face, occiput width behind the inner corners of the eyes, colour of the setae on anterior anepimeron, pruinosity of the notopleuron, length of pili on the scutellum, leg colour, alula shape and distribution of microtrichia, pterostigma colour, pruinosity of the sternites, abdomen colour pattern, and genitalia shape.

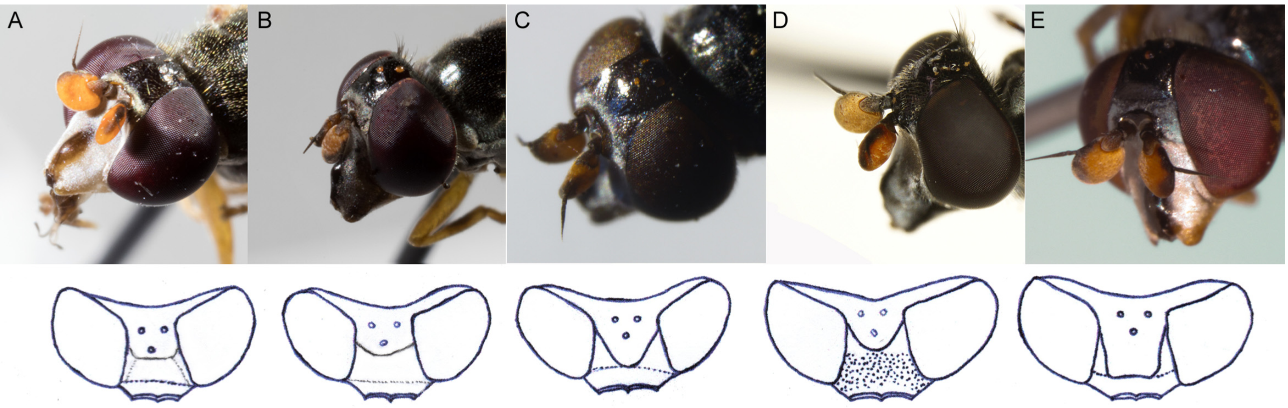

FIGURE 7. Photographs and schematic dorsal views of *Pelecocera* heads, showing the shape of the swollen part of the vertex in females of A: *P. scaevoides*, B: *P. pruinosomaculata*, C: *P. lugubris*, D: *P. garrigae* **sp. nov.** and E: *P. caledonica*.

For females, the most diagnostic feature is the shape of the vertex and frons, which is unique for each species (Fig. 7). In *P. lugubris* and *P. caledonica*, the vertex appears as a continuation of the upper frons. In the other species, there is a discontinuation (ridge) between the lower and the upper frons, the latter being continuous with the vertex. The length from the anterior ocellus to the ridge of the vertex is also characteristic of each species. *Pelecocera gar-*

rigae females have the peculiarity of not having any pollinose transverse band above the lunule (Fig. 2C), unlike all the other species.

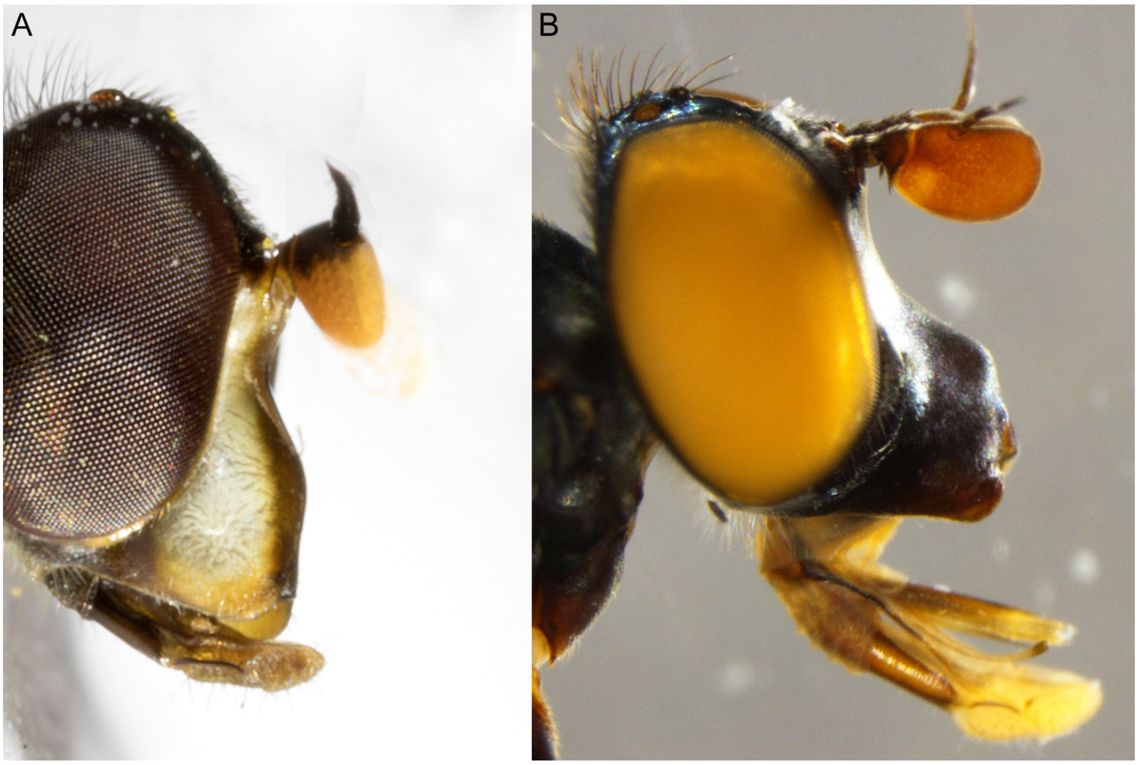

FIGURE 8. Head, lateral view, A: *Pelecocera tricincta*, B: *Pelecocera garrigae* **sp. nov.**.

1. Arista thick, inserted apically on basoflagellomere, composed of 3 highly visible segments in females, very short in males (Fig. 8A). Anepimeron, katepisternum and katepimeron partly shiny black . . . . **P. tricincta** (Abdomen with 3 yellow fasciae, sometimes narrowly interrupted in the middle)

\- Arista hair-like, inserted dorsally on basoflagellomere (Fig. 8B). Anepimeron, katepisternum and katepimeron entirely grey pollinose . . . . **2** (Abdomen with orange or greyish pairs of maculae, or completely black)

2. Basal radial (r) and basal medial (bm) wing cells partly bare . . . . **P. caledonica** (Lunule polished on lateral arms and median triangle. Female frons polished black and slightly swollen and regularly convex, flanked by two parallel lines along the eyes, which reach the transverse pollinose band above the lunule, without being reduced anteriorly as in *P. lugubris*)

\- Basal radial (r) and basal medial (bm) wing cells entirely covered with microtrichia. **3**

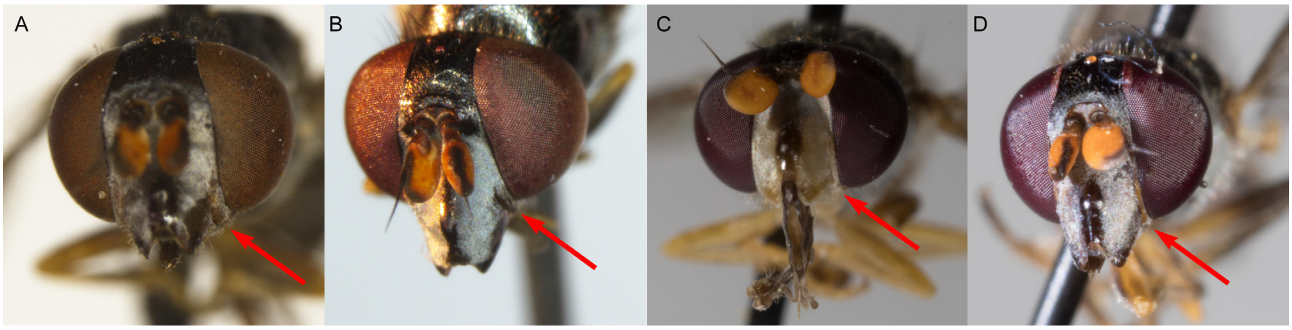

FIGURE 9. Head, frontal view to show parafaces (arrow) of different *Pelecocera* species from France. A. *Pelecocera lugubris*, B: *Pelecocera garrigae* **sp. nov.**, C: *Pelecocera scaevoides*, D: *Pelecocera pruinosomaculata*.

3. Anterior anepisternum with some white pile on the anterodorsal part (few and short in *P. garrigae*). Middle paraface wider (or as wide) than the diameter of the anterior ocellus (Figs. 9A and 9B) **4**

\- Anterior anepisternum without pile. Paraface narrower than the diameter of the posterior ocellus (Fig. 9C and 9D) **5**

4. Lunule entirely grey pollinose (Fig 10A). Paraface wider than diameter of anterior ocellus (Fig. 9A) . . . . **P. lugubris** (Female: Frons strongly swollen after the vertex, forming a large, polished triangle bordered by two lines directed towards the lunule. Distance between the anterior ocellus and the apex of the triangle is approximately 4-5 times the diameter of the anterior ocellus. Punctation of the frons very thin and sparse. Transverse pollinose band above the lunule. Male: grey pollinose frons.)

- Lunule brownish or blackish, slightly polished, and not pollinose (Fig 10B). Paraface as wide as diameter of anterior ocellus (Fig. 9B) . . . . ***P. garrigae*** **sp. nov.**
(Female: Frons polished posteriorly to the vertex, delimited by a curved transverse line (ridge) between the two eyes: the distance between the anterior ocellus and the ridge is 2 to 3 times the diameter of the anterior ocellus. Anterior half of the frons strongly punctate, hardly polished, without transverse pollinose band above the lunule unlike all other *Pelecocera* species. Male: Frons punctate, slightly polished.)

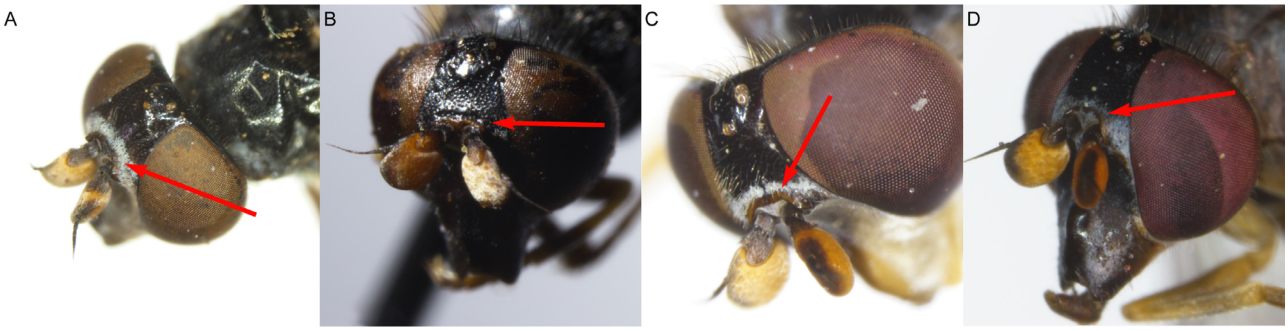

FIGURE 10. Head semi-lateral view to show the lunules (arrow) of: A. *Pelecocera lugubris*, B: *Pelecocera garrigae* **sp. nov.**, C: *Pelecocera scaevoides*, D: *Pelecocera pruinosomaculata*.

5. Lunule with grey pollinose median triangle strongly contrasting with polished lateral arms (Fig. 10C). No setae on posterior anepisternum and notopleuron. Metafemora and metatibia completely yellow . . . . ***P. scaevoides***
(Female: Distance between anterior ocellus and ridge very short, barely as long as diameter of the anterior ocellus. Ridge straight in the middle between the two eyes. In some specimens there is no visible ridge, the curvature of the frons is regular. Narrow transverse pollinose band above lunule.)

- Lunule completely grey pollinose (Fig. 10D). Setae present on posterior anepisternum and notopleuron. Metafemora and metatibia usually with black ring . . . . ***P. pruinosomaculata***
(Female: Distance between anterior ocellus and ridge short, about 1.5 - 2 times longer than diameter of the ocellus. Male: Flagellum almost entirely black or only black on the distal half. Spring specimens have more contrasting black and yellow legs, and less variability on the abdomen, especially males with obvious yellow spots. In large populations of autumn, there is a high variability in the coloration of the legs and the abdominal pattern. We do not know any locality with both generations, spring and autumn).

Ecological data and distribution of the French *Pelecocera*

General comments. Most *Pelecocera* species are usually found in semi-open habitats with shady areas and occur in heathlands, littoral dunes, Mediterranean scrublands and mountains. In spring, they can be found in damp places (especially with *Caltha* sp.) or else in dry places, such as dry slopes with *Buxus* sp. or *Erica arborea*, or on dry calcareous grasslands. In autumn, from September to November, *Pelecocera* have been generally found under pine trees, where they likely obtain nectar from lingering flowers of *Calluna vulgaris*, various species of *Odontites* and other available nectar sources, while the dry surrounding vegetation does not offer any food supply at this time of the year. *Pelecocera* imagoes are mostly seen flying quietly at low elevation (< 1 m above the ground), which makes them easy to collect.

We present data for the six species of *Pelecocera* known in France. The asterisk (*) indicates new data, i.e. previously unpublished. All the data, including latitude and longitude, are to be found in table format in the Supplementary Material.

Pelecocera tricincta **Meigen, 1822**. This species is found in open ground and conifer forests and is the most widely distributed *Pelecocera* species in France (Fig. 3), with data from 19 departments, from 22 May to 28 September. As the revision did not change identification of collection material, the data is only presented in the Supplementary Material Due to the large number of known localities, this species is currently listed as “Least Concern” in the European Union by the IUCN (Pennards 2021a).

Pelecocera lugubris **Perris, 1839**. This species was listed in five departments in France by Speight *et al.* (2018). Upon revision of available data, we could confirm the presence of this species only in three of these departments along the Atlantic coast (Fig. 3). *Pelecocera lugubris* is found in sandy heathlands and pine plantations not far from the coast and sometimes on coastal dunes. In Barsac (Gironde), the species was found from March to November. Otherwise, the data are either from early spring (March-May), or in autumn (a single specimen in Manche on

7.X.2015), leaving open the question as to its activity at other times. The species is thus probably mainly univoltine, with a partial second generation in autumn.

In Finland, all data except one (from early June) are from July to September (Haarto & Kerppola, pers. com.). In The Netherlands all recent data come from the autumn, with a few old data from April and May in NBC (Sander Bot, pers. com.). This species is listed as "Near Threatened" by the IUCN (Pennards 2021b).

Confirmed or maintained data:

Gironde (33): Barsac. VI, X, XI. 1994: ♀, and III, IV. 1995: ♀. J.-P. Sarthou leg. & coll. (Sarthou & Speight 1997) / Lair vidit. 2019 ; La Teste*, La Salie, dunes, 06.III.2011: 2 ♀ and 1 ♂. A. Livory & R. Coulomb leg., X. Lair coll.

Landes (40): Mont-de-Marsan, Spring 1839, on *Potentilla* (Perris 1839) ; Capbreton. 20.V.1913: 1 ♀, and 1 ♂. Brolemann/Hesse coll., in MNHN (Sarthou & Speight 1997).

Manche (50) : Lessay, Lande du Camp. - Heathland, 07.X.2005: 1 ♀. (Lair *et al*. 2005).

Unchecked data:

Var (83): Hyères. No date, Abeille de Perrin leg. (Séguy 1961), this datum is open to question, as it is the only one from the French Mediterranean area. Other species are possible, such as *P. garrigae* or *P. pruinosomaculata.*

Corrected identifications from published material:

Hérault (34): Caroux-Espinasse. 25.V.2000: 2 ♂ and 14.VI.2000: 3 ♀. T. Noblecourt leg., J.-P. Sarthou coll. (Speight *et al*. 2018): these are P. *pruinosomaculata*, X. Lair det. 2019.

Pyrénées-Orientales (66): Sournia, 24.IV.2013: 1 ♀, X. Lair coll. (Speight *et al.* 2013): This is *P. garrigae* **sp. nov.**

***Pelecocera scaevoides* (Fallén, 1817)**. *Pelecocera scaevoides* is a species that lives in the French mountain areas (Jura, Alps: Mercantour, Écrins and Queyras, and Pyrenees) (Fig. 3). This species is usually found around 1500 m of altitude, with some data up to 2500 m (Tissot *et al.* 2018) and some data from 500 m (Pyrénées-Orientales) to 900 m altitude (Aude and Hérault). Only one confirmed specimen is from lower altitudes: Verdun (Meuse), at 380 m altitude. Old data from low altitude locations in the French Mediterranean area are deemed as highly unlikely, and none of these could be confirmed.

The main habitats are open *Pinus* forests and subalpine meadows, often along streams and wet areas (Ssymank & Lair 2015; Lair pers. obs.). The species may be found from the end of May (Alpes-de-Haute-Provence) to the beginning of November in alpine habitats (Hautes-Alpes).

Confirmed or maintained data:

Ain (01): Thoiry, R.N. Le Reculet and Crêt de la Neige, alt. 1480-1683 m, from 03.VII.2014 to 25.IX.2014: 10 ♀ and 7 ♂. B. Tissot coll. (Tissot *et al.* 2015).

Alpes-de-Haute-Provence (04) : Montagne de Lure*, Jas des Bailles, 19.V.1993: 1 ♂ and 1 ♀, C. Kassebeer leg. and det., CNC Diptera 101680 and 101681 ; Jausiers*, Meyries, vers le col de Restefond., 1650 m, 31.V.2016: 1 ♀, C. Lauriaut leg. & coll. (pers. com.); Allos*, S. Cavaillès *leg.* & coll. (pers. com.); Colmars-les-Alpes*, S. Cavaillès leg. & coll. (pers. com.).

Hautes-Alpes (05) : Prelles, Saint-Martin-de-Queyrières [>1000 m], 27.VII.1979: 1 ♀, D.N. Dowling leg. (Speight *et al.* 2005) ; Ristolas (Réserve Naturelle) – Mont-Viso, 2400-2500 m, 10.VIII.2016 and 07.IX.2017: 2 ♀. B. Tissot & M. Speight leg. (Tissot *et al.* 2018) ; Vars Sainte Catherine, 15.IV.1995: 1 ♂; 29.V.1997: 2 ♀ (Verlinden 2020).

Alpes-Maritimes (06): Saint-Delmas-le-Selvage, Bois de Sestrières, [ca. 1500 m], 08.VIII.1994 C. Cocquempot leg. (Speight *et al.* 2005) ; Tende, Massif de Marguareis (Parc National du Mercantour), 1600 m, 27 to 31.VII.2009: 1 ♀ and 1 ♂, J. Molto leg., X. Lair det. & coll. (Ssymank & Lair 2015) ; Le Boréon, col de la Salèse (Parc National du Mercantour), *Picea abies* forest, along a stream, alt. 1690 m, 21.VI.2011: 1 ♀, A. Ssymank leg. & coll. (Ssymank & Lair 2015); Roubion*, S. Cavaillès leg. & coll. (com. pers.) ; Saint-Sauveur-sur-Tinée*, S. Cavaillès leg. & coll. (com. pers.).

Aude (11) : Coudons/Espezel, col de Coudon [883 m], 27.V.1971: 1 ♂, P.J. Chandler leg., M.C.D. Speight coll. (Sarthou & Speight 1997).

Aveyron (12) : Verrières*, Engayresque (Centre médical Fesnaille), [930m], 20.IX to 20.X.2006: 1 ♀, J.-P. Sarthou coll., X. Lair vidit. 2019.

Hérault (34): (*in* Speight *et al*. 2018), we do not know the data and did not find the original publication.

Meuse (55): Verdun*, Calcareous grasslands, 380 m, 26.VI to 13.VII.2001: 2 ♀, E. Carrières leg; 29.V to

15.VI.2017: 1 ♀. R. Desvois leg. & coll., X. Lair det.

Hautes-Pyrénées (65): No locality (« en juillet, sur le pin »). Pandellé leg. (Séguy 1961) ; [Aragnouet], Bugatet, Sapinière de Couplan. 30.VI - 06.VIII.2006: ♂ and ♀, J.-P. Sarthou / V. Sarthou leg. & coll. (Speight *et al*. 2018).

Pyrénées-Orientales (66) : Fontrabiouse/Formiguères, Val de Galbe, *Pinus uncinata* forest (mountain), September 1999-August 2001, 1600-1800 m. (Sarthou & Speight 2002); Alpine grassland, 1707 m, 5.VI.2020: 3 ♀. X. Lair leg. ; Matemale*, forêt de la Matte. 12.VI.1998: 3 ♀ , 26.VI.1998: 2 ♀. T. Noblecourt & C. Cocquempot leg., C. Dussaix coll. / X. Lair vidit. (2019) ; Matemale*, forêt de la Matte. 14.VI.2000: 1 ♀ and 1 ♂; 03.VIII.2000: 1 ♀, T. Noblecourt leg., J.-P. Sarthou coll. / X. Lair vidit. (2019) ; Eyne*, Réserve Naturelle Vallée d'Eyne, Alpine grassland, near a stream, alt. 1875 m and alt. 1930 m, 10.VIII.2012: 1 ♀ and 1 ♂, X. Lair coll. ; Jujols*, Réserve Naturelle de Jujols, 23.VI.2000 to 3.VIII.2000: 5 ♀ and 6 ♂, T. Noblecourt leg., J.-P. Sarthou coll. / X. Lair vidit. (2019); Rieutort*, 1.VI.2019: 1 ♀, X. Lair leg, COI sequence identifier CNC1078289, specimen deposited at the CNC; Sournia*, Gouffre Saint-Michel, meadow with *Potentilla*, near Pine forest, alt. 527 m, 4-29.IV.2020: 2 ♀ and 4 ♂, E. Lecointe & A Parret leg., X. Lair vidit.

Haute-Savoie (74) : Epagny. 01.IX.1976: 1 ♀ and 1 ♂, R. Siffointe coll. (Speight *et al*. 2005); "Pormenaz, Sixt" [probably commune of Passy], 1-15.VII.2005, E. Castella / M. Speight leg. (Speight *et al*. 2005) ; Chamonix*, Réserve Naturelle des Aiguilles Rouges, bois de la Joux. 30.V-15.VI.2005: 1 ♀ and 13-31.VIII.2005: 1 ♀, J.-P. Sarthou coll. / X. Lair vidit. 2019 ; Les Contamines-Montjoie*, Réserve Naturelle des Contamines-Montjoie, 30.VIII- 15.IX.2005: 1 ♀, J.-P. Sarthou coll. / X. Lair vidit. 2019.

Vaucluse (84) : Beaumont du Ventoux, Mont Serein, August, H. Audcent leg. (Séguy 1961), this latter datum is considered doubtful in Speight *et al.* (2018), but the altitude at this location and the mentionned month make us think that this is most probably valid.

Invalid data in publications:

Aude (11): Moux, [altitude around 100 m], 18.X.1994: 1 ♂ and 1 ♀, J.-P. Sarthou leg. & coll. (Sarthou & Speight 1997), upon examination, these specimens are *P. pruinosomaculata,* X. Lair det. 2019.

Hérault (34): Caroux-Espinasse, 25.V.2000: 2 ♂; and 14.VI.2000: 3 ♀. T. Noblecourt leg., J.-P. Sarthou coll. (Speight *et al*. 2018): these are *P. pruinosomaculata*, X. Lair det. 2019.

Var (83): Hyères. Abeille de Perrin leg. (Séguy 1961), this old datum of *P. scaevoides* in the low altitude Mediterranean area is doubtful. We could not verify its identity from a specimen but given our present knowledge of the distribution of *P. scaevoides*, its presence at low altitude in Mediterranean France seems highly unlikely**.** Abeille de Perrin's specimen is likely to have been a *P. pruinosomaculata* or *P. garrigae*.

Pelecocera caledonica **(Collin, 1940)**. Based on unpublished notes from F. C. Thompson, *Chamaesyrphus escorialensis* (Czerny & Strobl, 1909) is the valid name for *Chamaesyrphus caledonicus* Collin, 1940. For the sake of stability, we have chosen to follow the most common usage, and refer to *P. caledonica*, pending published justification of this suggested synonymy.

Four localities are currently known in France (Fig. 3). *Pelecocera caledonica* was found in September near the coast in Manche department in a heathland habitat, in areas akin to its known habitats in Scotland and Fennoscandia (Lair 2007). At 1500 m altitude in the Pyrénées-Orientales it was found in September, then in October on cool north-facing slopes with *Pinus* and *Calluna* at low altitudes (500 m), in habitats otherwise covered with Mediterranean scrublands. The species may be locally abundant in this habitat. It thus flies earlier at high altitude where it is found in September, then at lower altitudes later in autumn, up to November, when it found in lowland open *Quercus suber* forests of Var. The species is found at low altitude, but always under maritime influence, and probably with a combination of mild winters and summers.

Pelecocera caledonica is a rare species in France, but new localities should be found if new research is conducted in its identified habitats in the autumn.

Confirmed or maintained data:

Aude (11) / Pyrénées-Orientales (66) : Counozouls* (11), col de Jau. heathland with *Pinus, Juniperus* and *Calluna*, 1550 m, 12.IX.2018: 1 ♀ and 1 ♂, X. Lair & E. Minssieux leg*.,* X. Lair coll.

Manche (50) : Lessay, Lande du camp. Heathland with *Pinus* and *Calluna*. 22-28.IX.2006 and 30.IX.2007: 6 ♀ and 4 ♂, X. Lair leg. & coll., M. Speight coll. & A. Ssymank coll. (Lair 2007); Pirou, forêt de Pirou. heathland with *Pinus* and *Calluna*. 28.IX.2006 and 30.IX.2007: 3 ♀ and 1 ♂, X. Lair leg. & coll., M. Speight coll. & A. Ssymank coll. (Lair 2007).

Pyrénées-Orientales (66): Sournia, Route de Campoussy, North-facing slope with *Pinus*, *Cistus laurifolius* and *Calluna*, with Mediterranean scrublands around, alt. 614 m, 20.X.2013: 8 ♀ and 1 ♂, X. Lair leg. & coll., M. Speight coll. (Speight *et al.* 2013), 04.X.2018: 2 ♀, X. Lair leg. & coll.; Mosset*, col de Jau. heathland with *Pinus, Juniperus* and *Calluna*, 1500 m, 12.IX.2018: 1 ♀ and 1 ♂, X. Lair & E. Minssieux leg., X. Lair coll.

Var (83) : Les Mayons*, Plaine des Maures (Réserve Naturelle), XI.2015: 1 ♀, D. Guicheteau leg., C. Lauriaut det. (pers. com.).

***Pelecocera pruinosomaculata* Strobl, 1906**. This is a little-known species. Prior to the Speight & Sarthou (2015) key, this species did not appear in general works on Syrphidae. Examination of numerous French specimens led to new data from specimens originally identified as other species (notably *P. lugubris* and *P. scaevoides*). The French data all come from Mediterranean France (Fig. 3).

This species seems more eurytopic than the other *Pelecocera* species as it has been found on Mediterranean sand dunes, scrublands with *Buxus* and *Thymus* on limestone or metamorphic schist at 500 m altitude, calcareous grasslands with *Juniperus* at 700–800 m altitudes, heathlands with *Erica arborea* or *Pinus* and *Cistus laurifolius*, *Calluna* heathlands at 600 m altitudes (Speight 2020). Depending on the location, the species is found in spring (April-May) or autumn (September-October). Autumn populations may be numerous, while spring observations are usually of single individuals. This species is listed as "Near Threatened" in the European Union by the IUCN (Pennards 2021c).

Morphologically this is the most variable species, probably due to its wide ecological and phenological preferences. Autumn *P. pruinosomaculata* specimens were found to be morphologically polymorphic, with the abdomen either black or with yellow or grey spots, fore- and median legs either yellow or with black areas, frons width variable, basoflagellomere either entirely black or half yellow.

Confirmed or maintained data:

Haute Corse (2B): Ghisoni*, Col de Sorba, 12.V.2015: 1 ♂ and 2 ♀ , 27.V.2015: 1 ♀, 08.VI.2015: 1 ♀, 15.VI.2015: 1 ♀ , 25.VIII.2015: 1 ♂ and 1 ♀, 18.IX.2015: 8 ♂ and 4 ♀, 02.X.2015: 6 ♂ (OCIC leg., Th. Lebard det.) ; Morosaglia*, Ruisseau de Quercione, 14.X.2021: 1 ♂ (A. Cornuel-Willermoz leg., X. Lair det.).

Hautes Alpes (05) : Barrett s/Meouges*. 13.IV.2019: 1 ♀ (Chr. Lauriaut leg.).

Alpes-Maritimes (06) : Caussols, Forêt de Caussols. 16.V.1994: 1 ♂. (Speight & Sarthou 2006).

Aude (11): Moux*, [altitude around 100 m], 18.X.1994: 1 ♂ and 1 ♀. J.-P. Sarthou leg & coll. / X. Lair det. 2019. These specimens were identified as *P. scaevoides* in Sarthou & Speight (1997).

Aveyron (12) : Millau, 8 km east from La Cavalière. 18.IX.1990: 1 ♂ (Speight & Sarthou 2006).

Hérault (34) : Rosis*, Point Sublîme (Réserve Nationale de Chasse du Caroux-Espinouse), 1050 m, 24.V.2000: 2 ♂; and 14.VI.2000 : 3 ♀, T. Noblecourt leg., J.-P. Sarthou coll. / X. Lair det. 2019, previously identified as *P. lusitanica ;* Pégairolles-de-Buèges. V.2005: 2 ♀ and 2 ♂ (Speight & Sarthou 2006).

Pyrénées-Orientales (66) : Banuyls, Jardin Méditerranéen. 15-28.XI.2011: ♀♀, J. Garrigue & M. Speight leg. & coll. (Speight *et al.* 2013) ; Argelès-sur-mer, Mas Larrieu Nature Reserve, Mediterranean sand dune, 2014 (Speight & Garrigue 2016) ; Sournia*, Route de Campoussy, North-facing slope with *Pinus*, *Cistus laurifolius* and *Calluna*, on granitic rock, alt. 527-614 m, 20.X.2013: 9 ♀ and 11 ♂, X. Lair coll , 04.X.2018: 2 ♀ and 4 ♂ (1 ♂ COI sequence identifier CNC1078290, deposited at the CNC), 04-30.IV.2020: 5 ♀ and 3 ♂, E. Lecointe and A. Parret leg., X. Lair det.; Lamanère*, Chapelle Sainte-Christine, in an open deciduous forest and calcareous grassland with *Buxus*, *Juniperus communis*, *Prunus*, young *Pinus* and *Betula*, *Polygala*, alt. 940 m, 02.V.2016: 1 ♂. E. Minssieux leg., X. Lair det., COI sequence identifier CNC1078271, specimen deposited at the CNC ; Fosse*, Les Cabanes. Slope with *Buxus* and *Thymus*, open forest with *Erica arborea*, alt. 494 m, 14.V.2017:1 ♂ (COI sequence identifier CNC1078286, specimen deposited at the CNC), on *Odontites lutea*, 24.IX.2019: 7 ♂ and 6 ♀, X. Lair leg. ; * Peyrestortes*, El Piló Roig, fallow land with *Scilla autumnalis*, alt. 84 m, 18.IX.2020: 1 ♂ and 1 ♀, X. Lair leg.

Var (83): Aiguines/Trigances, Pont de l'Artuby, 19.V.2003 (Speight & Sarthou, 2006) ; Mazaugues*, on *Hedera helix*, 29.IX.2019, 1 ♀, G. Nève leg.

Discussion

Since the Diptera catalogue of Gobert (1887), the number of *Pelecocera* has increased from two to six species in France. These species are morphologically distinguishable with the criteria we provide in the identification key. Within populations, variation may be found in other features, such as the abdomen or leg colour patterns. Our revision of the available material allowed us to dismiss some of the old faunistic data, as they came from unusual habitats for the then recognised species, and hence these data most probably referred to other species; this proved to be the case for a few recent data for which we could examine the specimens.

The new species here described, *P. garrigae*, is a morphological outlier, as specimens of this species were readily recognised as not belonging to any other known species on the basis of the shape of the face and punctuation of the frons. On top of our specimens from Sournia and Marseille, very few specimens could be located in other collections, suggesting that the species is rare, with a short flight period, from mid-April to mid-May.

Pelecocera lugubris occurs from March to November in a small area near the Atlantic coast. The single observation in October in Normandy may however raise questions. Genetic data is lacking to test whether *P. lugubris* is specifically distinct from *P. lusitanica*, described from Portugal, and from the populations of northern Europe, currently designated with the same name. Other insects occurring in the Mediterranean area show their northern limit in Normandy or northern France, such as *Tabanus eggeri* Schiner (Lair *et al*. 2010) and *Podalonia luffii* (Saunders) (Livory *et al*. 2008). *Pelecocera lugubris* may show a similar distribution pattern, and thus extend from Portugal to Normandy and as far north as Scandinavia. Whether all of these belong to a single species remains an open question. The single specimen from Normandy may belong to the same group of populations as the ones known from Belgium (Bot & Van de Meutter 2019) to Scandinavia (Bartsch 2009).

The present synthesis allows a better understanding of the ecology of the various species of *Pelecocera*. *Pelecocera scaevoides* is mainly a mountain species, which may occur at low altitude (380 m) in March, but will be found at higher and higher altitudes as the season progresses from spring to late summer, when it may be found at up to 2400 m. It should be noted that the climatic conditions occurring in March at low altitudes and in August at high altitudes are similar. This species thus appears univoltine at any site, even if the overall flight period is very long. *Pelecocera pruinosomaculata* was found either in spring or in autumn at any location, except one locality where it is bivoltine. It was usually present in low density in spring, and higher density in late summer or early autumn. Genetic analyses showed that spring and autumn specimens belong to the same species. The occurrence of *P. pruinosomaculata* in either spring or autumn may be because these sites may be unfavourable for the species at one of these seasons. It was shown recently that *Pelecocera japonica* larvae feed on the fruit bodies of the basidiomycete *Rhizopogon* (Okada *et al.* 2021). European species of *Rhizopogon* are associated with various species of *Pinus* trees (Molina & Trappe 1994). As French *Pelecocera* occur where *Pinus* are present, it is likely that they would also feed on *Rhizopogon* fungi, of which seventeen species are listed for France (MNHN & OFB 2022). However, the specificity of the *Pelecocera/Rhizopogon/Pinus* associations are completely unknown. It would therefore be useful to keep a record of the *Pinus* species present in the areas where *Pelecocera* are found.

The present study showed that the French specimens of *P. scaevoides* are very stable morphologically, and that they occur from 380 to 2400 m altitudes, hence in habitats with different *Pinus* and *Rhizopogon* species. Combined with the fact that they appear as three clusters in our genetic analysis raises the question of whether *P. scaevoides* could be complex of cryptic species. The spatio-temporal distribution of *P. caledonica* is even more puzzling: It occurs in mid-September in mountain habitats (ca. 1500 m altitude), and it occurs lower and lower up to November, when it is found in Mediterranean habitats. If breeding occurs in these locations, it seems likely that the larval food cannot be the same between these extremes, while as for *P. scaevoides* the climatic conditions remain similar along these seasonal and altitudinal shifts. It thus seems that the phenology of the various *Pelecocera* within France shows the adaptation to different climatic conditions, increasing in elevation through the year in *P. scaevoides*, going lower and lower in autumn for *P. caledonica*, while potentially retaining two emergence periods in *P. pruinosomaculata* and *P. lugubris*.

Conclusion

At least six species of *Pelecocera* occur in France. The low number of records is partly due to their rarity and partly to their secretive habits and unusual flight periods of some populations, occurring in the Autumn. We hope that this synthesis will stimulate the generation of more data on these fascinating insects.

Supplementary material

The French distribution data of Pelecocera has been deposited on Zenodo in csv format, and is available from https://doi.org/10.5281/zenodo.6559050.

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