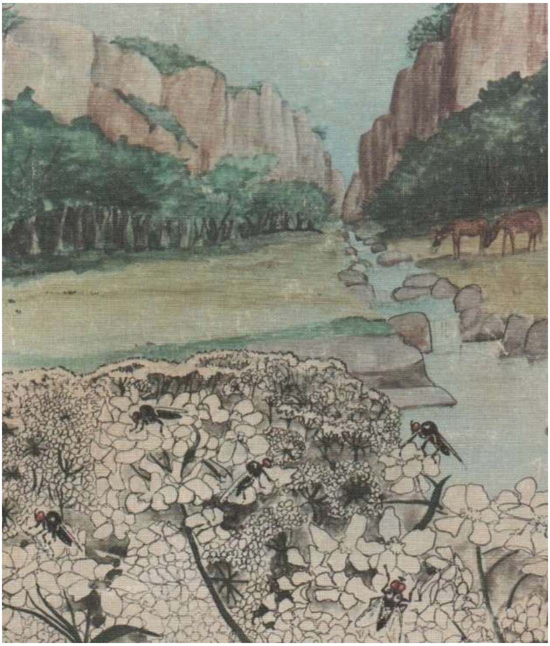
The Simuliid Bulletin

Number 60 July 2023



THE SIMULIID BULLETIN

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CONTENTS

Cover Image: Leo Rivosecchi's painting depicting the ideal habitat for black flies. Painting was published as the cover image of the identification key: Rivosecchi (1978): Simuliidae (Diptera Nematocera), Fauna d'Italia.

From the Editor

This is already issue number 60 of the Simuliid Bulletin and it is 31 years since the first British Simuliid Group Bulletin was published in May 1992.

Sadly, this issue brings the obituary for the excellent Italian entomologist and black fly specialist Prof. Leo Rivosecchi, who passed away in December 2022. We published an interview with Prof. Rivosecchi about his life and work in July 2013 (Bulletin No. 40). The paper written by Leo Rivosecchi, describing 100 years of black fly research in Italy was published in July 2016 and January 2017 (Bulletin No. 46 and 47). If you are interested in his extensive research of Italian black flies, you can find the paper and the interview in the Simuliid Bulletin archive.

Another of the European countries with long tradition of black fly research is the United Kingdom. In this issue, David López-Peña and Robert A. Cheke provide a comprehensive review of blackflies of the United Kingdom. They focus on their medical and veterinary importance, as well as parasites and predators of simuliids.

Tatiana Kúdelová, Editor

FORTHCOMING MEETINGS

XI International EMCA Conference

&

4th EMCA Training Course

November 7-10, 2023,

Palma Mallorca, Spain

The president Dr. Francis Schaffner and the Board together with the heads of the organising committee, Dr. Carlos Barceló and Prof. Miguel Á. Miranda (UIB), cordially invite you to attend our XI International Conference of the EMCA to be held in Palma de Mallorca, Spain, from 7th to 10th November 2023, entitled

"SHAPING THE FUTURE OF THE VECTOR CONTROL IN EUROPE".

The 4th EMCA Training Course on laboratory activities with two parts:
A- IDENTIFICATION OF NON TARGET FAUNA IN TRAPPING;
B- MOSQUITO REARING AND REPELLENT TESTING
will precede the Conference on the **6th November 2023**. Participation to this training course is limited to 25 trainees.

Detailed information available on conference website:

https://www.emca2023.com/95673/detail/xi-international-emca-conference-and-4th-emca-training-course.html

emca
European Mosquito
Control Association

20th Annual North American Black Fly Association (NABFA) Meeting

February 6-9, 2024

Harrisburg, Pennsylvania

The 20th Annual meeting of the North American Black Fly Association will take place along with a 2-day taxonomic workshop focusing on basic black fly taxonomy in Harrisburg, PA. The taxonomic workshop will be led by Mr. Denny Keen of the PADEP, Ms. Carey LaMere of the MMCD and Dr. Peter Adler, Professor Emeriti at Clemson University. The workshop will be held February 6 & 7 and the NABFA meeting will take place on the 8th & 9th. Workshop participants are encouraged to participate and present in the NABFA meeting. The workshop will take place at the PADEP laboratory, which has facilities for 25 participants. Workshop participants are encouraged to collect and preserve samples this season to bring to the event.

Dr. Adler has offered the following suggestions:

"People can collect larvae and pupae into either Carnoy's (3 parts absolute ETOH/1 part Glacial Acetic acid) or high-strength alcohol (ca. 90% or more). Adults can go in 70% or 80% ethanol. Participants can get an idea of what's in their area by checking the maps in the black fly book, which shows distributions within counties. They could also try running some of their specimens through the keys in the black fly book, so they will know what some of the difficulties will be and what questions they'll have."

John Walz – NABFA President
Metropolitan Mosquito Control District
St. Paul, Minnesota US 55104
Office: 651-643-8388
Email: johnwalz@mmcd.org

The X International Simuliidae Symposium,

September 23-27, 2024

Cappadocia, Turkey

Dear Friends and Colleagues,

We are pleased to announce that the **10th International Simuliidae Symposium** will be held in the richly historic area of Cappadocia, Turkey, in 2024 with tentative dates of 23-27 September. The symposium will be organized by Erciyes University and Turkish Society for Parasitology. Erciyes University is located in Kayseri, a large modern city of about 1.5 million people, with a convenient airport.

Further information and a call for abstracts will be announced through this mailing list near the beginning of 2024. In the meantime, for any questions, please contact the Chair of the Symposium Organizing Committee, Prof. Dr. Alparslan Yildirim: yildirima@erciyes.edu.tr

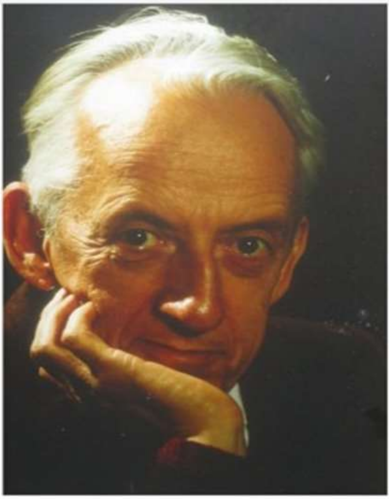
We look forward to welcoming the international community of simuliid workers and other interested researchers and public health workers to Turkey in 2024.

Prof. Dr. Alparslan Yildirim
Department of Parasitology
Faculty of Veterinary Medicine,
Erciyes University
Kayseri, TURKEY

OBITUARIES

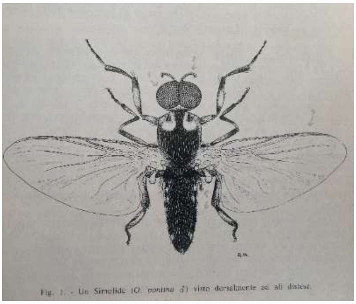
Prof. Leo Rivosecchi
1923 – 2022

Simone Ciadamidaro



Prof. Leo Rivosecchi, who died in Rome in December 2022, aged 99, was worldwide accepted as an authority in blackfly systematics and ecology and a valuable expert in several other insect groups, a scientist who always generously shared his knowledges and research ideas with other experts, pupils and friends.

Leo Rivosecchi was born in Grottammare (in the Province of Ascoli Piceno, Marche region, Central Italy) on August 28, 1923, and spent his childhood in Tolentino (Macerata). He moved to Rome while attending the middle schools and received his secondary school graduation at the "Liceo Visconti" Institute. He was fond of Lepidoptera and Coleoptera and, supported by his family, he started studying insects, graduating in Natural Sciences at the University of Rome "La Sapienza" with a thesis on Diptera Tephritidae, even though the outbreak of the Second World War, in which he was militarily not involved, noticeably delayed the end of his studies. Afterwards, he was employed in the Italian National Institute of Health (ISS), where he worked on parasites and biological control for several years. He carried out 40 years of intensive field sampling and laboratory study on the black fly fauna of Italy. He has written 32 "Contributi alla conoscenza dei Simulidi italiani" (Contributions to the knowledge of the Italian black flies), published in the Italian journal "Rivista di Parassitologia", and together with a considerable number of other works, they constitute the largest source of



information on the presence, distribution and ecology of this family of Diptera in Italy.

Prof. Rivosecchi used to tell that he decided to study black flies following a very accidental event. In fact, he was working with some workers of the "Antimalarial committee" for the control of the residual *Anopheles* mosquitoes when, while the team was having breakfast close to a sulfur spring, he was attracted by a dark-coloured stone standing out in sharp relief against the white bed of the spring. The dark colour was caused by a large number of larvae mixed with several small cocoons. Then he put the stone in a plastic bag and put it in his car's boot, but when he arrived to his laboratory in Rome, he found that the bag was full of small flies. He then studied them and realized that he was facing a new species, that he described as *Simulium pontinum*, thereafter found in all the sulfur springs of the Southern Latium region.

Prof. Rivosecchi was lately induced to approach the study of simuliids by Prof. Edoardo Zavattari (zoologist and physician), who underlined the relatively scarce knowledge of these dipterans in Italy during the first congress of the Italian Society of Entomology. In fact, only Emilio Corti had studied

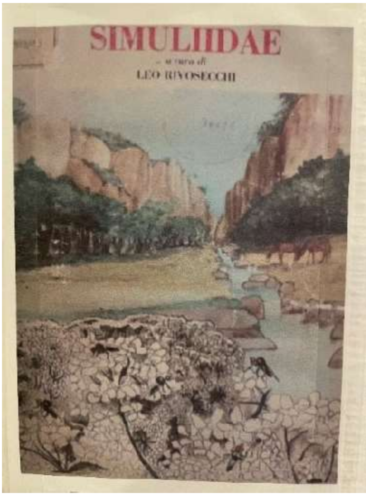
them in the Province of Pavia (Lombardy) in order to verify if they could be vectors of Pellagra (the cause of this disease had not been identified yet). However, Corti described a fine, still-valid species, *Simulium bezzii* (complex).

Meanwhile, when Rivosecchi found employment at the Italian National Institute of Health, the Director of the department of Parasitology told him that he had to work on domestic flies (Musca domestica), due to the health vocation of our public institute. He followed his recommendations and, studying the genitalia of some African specimens he had received from Prof. Saccà, he described a new taxon, *Musca domestica curviforceps*, which is still considered a valid subspecies.

Actually, in the beginning, he was only allowed to work on the black flies from a reclaimed area of the Pontine marshes (Province of Latina, Southern Latium), with the help of a driver of the anti-malaria committee. Following the description of *S. pontinum*

(1960), he carried out an ecological study on the concentrations of oxygen and sulfuric acid compatible with the life of this species' larvae in several other sulfur springs. But, when he discovered a new species in the southern area of the Region (*S. liriense*, 1961) he had the idea to perform an ecofaunistic study of the zonation of rivers through the black fly fauna, from the springs to the river mouth. So, he discovered some new species: *Prosimulium albense* (1961) and *S. (Nevermannia) fucense* (1962). Thereafter, taken with enthusiasm, his research followed a mainly faunistic course. He extended his research to the mountains of Central-Southern Apennines, including Sicily. Thanks to this research he was no more considered as a "technician" by his colleagues; rather they recognized him as an autonomous researcher, even though he was also strongly criticized since his studies had limited utility for National health. But two relatively "lucky" events occurred and radically changed the situation: in 1974, a massive attack of black flies on cattle in Trentino region and, in 1984, several attacks on humans in Friuli region reclaimed the need for a black fly expert. Then his competence was finally necessary!

He definitely became a great admirer of Rubtzov while studying the species of the "aureum" group (then considered as a single species in the Western World). But this admiration turned into "desperation" when, in 1962, Rubtzov was invited by Prof. Goidanich of the University of Torino to study the Simuliid fauna of Italy, funded by the Italian CNR (National Research Centre). It was a dreadful humiliation and he was close to abandoning the research on black flies. It was thanks to the encouragement of Prof. Sandro Ruffo, Director of the Museum of Natural History of Verona, that he decided to endure. Then he started to communicate with several researchers. Collaborating with Vera Zivkovic, from Belgrade, was easy thanks to the friendship existing between their Directors (Corradetti and Simic), and they exchanged material and visits. He also exchanged material with Knoz and Raastad. He tried to do the same with Couvert, a great drawer collaborating with Rubtzov, but he remained doubtful and tragically died coming back from a journey in India. He only had epistolary contacts with Crosskey, Zwick, Davies and Fallis, with the latter teaching him to capture adult flies with CO2 traps. He had other contacts, but he always complained he did not develop any collaborations with other researchers, as he would have liked. He considered this fact a limit for his research, since he felt partly isolated from the rest of the



black fly research community. Also for this reason, he appreciated Aleksandra Cupina’s attempt to keep him informed by sending him the proceedings of several International Symposia on black flies, since Berlin 2004. In fact, he only attended the first International Congress of Entomology and the VI International Simuliidae Symposium in Torino in 2014, where he gave a lectio magistralis about his life research, invited by his pupil Ciadamidaro, finally having the chance to meet some of the most highly regarded international experts in black fly research.

Professor Leo Rivosecchi was able to perform his huge field activity and laboratory research with a very limited budget. For the missions during faunistic research, he only had a day allowance and the repayment of the train tickets and car rental. However, his personal expenses were always higher than the Institute’s funding. So, he worked all alone on the Apennines, with a little help in Sicily from the Hygiene Institute; in Trentino, he was helped by the Zooprophylactic Institute and in Friuli by the Local Health Company (ASL). A great help he received from Giovanni Dell’Uomo, a technician with the ISS. Actually, all the research on the Apennines was supported by a great personal enthusiasm and required big efforts. His research in the Italian North-East was initially of public interest, and then turned to faunistics, too.

Thanks to the considerable knowledge he achieved of the Italian black fly fauna, Professor Rivosecchi edited "Fauna d'Italia - Simuliidae" (1978) for Calderini. “Fauna d’Italia” contains the state of the art, at the end of the 1970s, of the immense work of systematic research, in the field and in the laboratory, carried out by Prof. Rivosecchi, without neglecting the work of other specialists who worked in Italy.

He reported that he had argued with the editors of the series, even animatedly, over his choice to put on the cover of a systematic key an image of landscape, rather than one or more morphological drawings (in making which he was in any case a master, and in fact the key is full of them).

According to Professor Rivosecchi, however, it was essential to highlight the indissoluble link between the family of Diptera Simulidae and the presence of all the Landscape elements of which they are a part and on which they depend: an intact watercourse for preimaginal stages; shrubs and trees for adult roosting; flowering meadows and pastures for nectarivorous feeding; mammals and/or birds for the blood meal of females. The presence of the different species is related to local characteristics and how these elements are integrated.

In addition to the key, the work contains detailed descriptions of all species and subspecies known at the time for Italy, with separate and very precise sections on the different stages and sexes: larvae, pupae, male and female adults, as well as information on distribution and ecology.

The iconographic apparatus is vast and extraordinarily detailed. So much so that still even abroad (Spain, Germany, the Balkans...) it is widely used, despite difficulties with Italian. Prof. Rivosecchi liked drawing very much, but finally he became aware of the fact that a scientific designer must be able to give himself some limits, meaning that the drawing should be as schematic as possible, omitting all the details that are not useful for the identification. A too detailed drawing confuses the ideas. In this way, drawing is important since it represents what a researcher really understood of the feature he was facing, and sometimes what he didn’t. Notwithstanding this fact, in some cases (for example, shading through punctuation) it is necessary to appeal to a professional designer, as he did for the mesonotum of black flies (made by Ms Giuliana Micozzi).

The systematics of Simulidae has changed a great deal in the last 40 years, also due to the choice made at the international level to merge numerous genera and species and not recognizing subspecies; for this reason, “Fauna d'Italia” can be arduous to use for a neophyte who has to reconcile modern keys with this fundamental (and still unsurpassed if one wants to identify Italian Simulidae) text. However, with the help of Adler's "Inventories of the world’s Simuliidae" (published annually) and the new "Check-list of the Fauna of Italy" (Ciadamidaro and Mancini, 2022; https://www.lifewatchitaly.eu/iniziative/checklist-fauna-italia-it/checklist-table/), it is possible fairly easily to reconcile all the taxa in the Fauna with the current nomenclature.

Currently, 17 species described by Prof. Rivosecchi are considered valid:

1	***Metacnephia nuragica***	Rivosecchi, Raastad & Contini, 1975
2	***Metacnephia sardoa***	(Rivosecchi & Contini, 1965)
3	***Prosimulium albense***	Rivosecchi, 1961
4	***Prosimulium calabrum***	Rivosecchi, 1966
5	***Prosimulium italicum***	Rivosecchi, 1967
6	***Simulium (Eusimulium) petricolum***	(Rivosecchi, 1963)
7	***Simulium (Hellichiella) saccai***	(Rivosecchi, 1967)
8	***Simulium (Nevermannia) dolomitense***	(Rivosecchi, 1971)
9	***Simulium (Nevermannia) ibleum***	(Rivosecchi, 1966)
10	***Simulium (Nevermannia) ichnusae***	Rivosecchi & Contini, 1994
11	***Simulium (Nevermannia) fucense***	(Rivosecchi, 1962)
12	***Simulium (Nevermannia) marsicanum***	(Rivosecchi, 1962)
13	***Simulium (Simulium) liriense***	Rivosecchi, 1961
14	***Simulium (Simulium) pontinum***	Rivosecchi, 1960
15	***Simulium (Simulium) sicanum***	(Rivosecchi, 1963)
16	***Simulium (Trichodagmia) continii***	(Rivosecchi & Cardinali, 1975)
17	***Urosimulium aculeatum***	(Rivosecchi, 1963)

In recent years, moreover, some of the taxa described by Prof. Rivosecchi that had fallen into synonymy have been "restored" thanks to cytogenetic and molecular analysis techniques. An example of this is *Prosimulium italicum*, an endemic species of the Italian peninsula that an international team has recognized as valid to the rank of species after even Prof. Rivosecchi in the Fauna d'Italia had resigned himself to place it as a subspecies of *P. hirtipes*. An ongoing study of the vast "*Simulium ornatum*" species complex (for which Prof. described 8 taxa in Italy alone) may hold further surprises.

Leo Rivosecchi's collection of Diptera, preserved both in alcohol and dry, belonging to various families, are at the museum of zoology of Sapienza University – Rome. Culicidae are at the Istituto Superiore di Sanità (Rome). Larvae of aquatic Diptera are at the Museum of Entomology, Rome. Finally, for the Simuliidae: the collection in alcohol is at the Trento Museum of Natural Sciences, while the dry collection (adults) is at the Museo di Scienze Naturali di Verona.

It is well known to black fly specialists that Prof. Rivosecchi's interest for black flies and their study never declined, not even in his elderly age, as exemplified by his response to the last question Ignatovic-Cupina, Adler and Ciadamidaro asked him during an interview for the *The Simuliid Bullettin*:

On the basis of your wide experience with black flies and their importance in ecology, could you suggest an aspect that you consider an interesting issue for future research on black flies?

I think that population dynamics should be studied further in depth; I find extraordinary the fact that sudden increases of a black fly population can be suddenly followed by a complete disappearance of these insects in the following years. The factors leading to this clamorous change lie not only with the quality of river waters, but also with the conditions of the entire landscape, where, it should not be forgotten, half of the black fly life cycle takes place. I am increasingly convinced that no other insect group can represent, as black flies do, the perfect conservation indicators for natural environments.

In his well-rounded knowledge of river and insect ecology, Prof. Rivosecchi was already aware of the importance of landscape changes, like those due to climate changes, on the group of Dipterans that were the professional passion of his long and successful life.

Aknowledgements

Many thanks to Aleksandra Ignatovic-Cupina and Peter Adler who worked with me in the realization of the interview from which I obtained a great amount of information about Professor Rivosecchi's professional life.

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SCIENTIFIC PAPERS

Blackflies (Diptera: Simuliidae) of the United Kingdom with comments on species of public health and veterinary importance, their parasites and predators

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Introduction

In many cases the biting habits of blackflies (Diptera: Simuliidae) are associated with transmission of pathogens such as the protozoan *Leucocytozoon* spp. to birds and *Onchocerca* spp. to mammals, including *Onchocerca volvulus* the causative agent of human onchocerciasis or "River blindness" (Brattig *et al*., 2021). Even if they do not transmit pathogens the extent of blackfly biting can be an intolerable nuisance to people and livestock. But on the other hand, they are also an important link in the trophic chain of environments associated with rivers and streams, where they form part of the diet of other macroinvertebrates, as well as of various species of both aquatic and terrestrial vertebrates.

In addition to transmitting *Onchocerca* spp. to cattle, several species of Simuliidae are known to cause other veterinary problems in the UK such as "sweet itch" which affects horses and cattle, as well as being biting nuisances to people, sometimes causing intense itching and allergic reactions. A means of monitoring and perhaps controlling them arose in 2017, when it was noticed that numerous adult females of *Simulium* spp. were caught in Mosquito Magnet traps (Fig. 1) set in various parts of the UK primarily to catch adult female mosquitoes (Cheke *et al*., 2018). During 2018

Fig. 1: Mosquito Magnet trap used for attracting blackfly females. (Photo: David López Peña).

and 2019 additional samples of blackflies were obtained from such mosquito traps at numerous sites including some deployed by entomologists working for the UK Health Security Agency (then known as Public Health England) (López-Peña *et al*., 2021). Amongst the catches were many *S. equinum*, known to be responsible for "sweet-itch", so it was important to determine where they were breeding in relation to the trap catches. So, in 2020 we surveyed rivers near many of the catching sites and we also checked a selection of other aquatic habitats in southern England to study the ecology of immature stages of the blackflies, results of which were reported by López-Peña *et al*. (2022). During that study, photographs of larvae and pupae were taken, some of which are presented here in a short review of aspects of the biology of the various species of blackfly that are of veterinary or public health importance, with comments on their parasites and predators. These sections are preceded by a list of the known British species, together with geographical distribution maps of many of them supplied by the National Biodiversity Network Atlas (NBN, 2023).

Larvae and pupae sampling methodology

To obtain samples of immature simuliids, we walked through 5-10 metre lengths of streams from one bank to the other for 15 min (5 min on the left bank, 5 min on the right and 5 min in the central part of the streambed), while collecting any larvae and pupae found on inorganic substrates such as rocks, stones and pebbles and from organic substrates such as submerged and emerged macrophytes, tree branches, leaves etc. (Fig. 2), as described by Wright *et al*. (1984), and McCreadie & Colbo (1993). At each sampling point measurements of abiotic features were taken *in situ*. These included water temperature (ºC), pH, conductivity (µS cm^{-1}), total dissolved solids (TDS; mg l^{-1}), turbidity (NTU), dissolved oxygen concentration ($mg\ l^{-1}$) and percentage oxygen saturation, details of which were provided by López-Peña *et al*. (2022).

Fig 2: Robert Cheke measuring abiotic features in a stream and David López-Peña seeking and collecting immature simuliids. (Photo: D. López Peña (up) and R. A. Cheke (down)).

List of native blackflies of the United Kingdom and their distributions according to the National Biodiversity Network website (NBN Atlas)

Currently, in 2022, three genera, six subgenera and 35 blackfly species have been reported in the United Kingdom (Adler, 2022). The species' geographical distributions in the UK are shown below using maps from the National Biodiversity Network Atlas (NBN, 2023). The data in the maps presented are only for England, Wales and Scotland as, so far, no records of identified simuliids have been added to the NBN atlases for the Isle of Man (https://isleofman-species.nbnatlas.org/species/NBNSYS0000137777) and Northern Ireland (https://northernireland.nbnatlas.org/), although there are 8 and 6880 records of unidentified Simuliidae from these areas, respectively. Similarly, the maps do not encompass the Channel Islands but where a species is known to occur there this is mentioned.

Genus *Metacnephia*

Metacnephia amphora Ladle & Bass, 1975. England and Wales.

Genus *Prosimulium*

HIRTIPES species-group

Prosimulium hirtipes (Fries, 1824). England and Scotland.

P. hirtipes

P. latimucro

P. tomosvaryi

Prosimulium latimucro (Enderlein, 1925). England, Scotland, and Wales.

Prosimulium tomosvaryi (Enderlein, 1921). England and Scotland.

Genus *Simulium*

Subgenus *Boophthora*

Simulium (Boophthora) erythrocephalum (De Geer, 1776). England, Scotland and Wales.

Subgenus *Eusimulium*

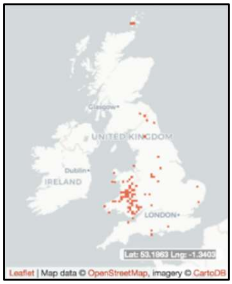
Simulium (Eusimulium) angustipes Edwards, 1915. England, the Channel Islands and Wales.

Simulium (Eusimulium) aureum Fries, 1824. England, Scotland, and Wales.

Simulium* (*Eusimulium*) *petricolum (Rivosecchi, 1963). England. No map available.

Simulium* (*Eusimulium*) *rubzovianum (Sherban, 1961). England, Scotland and Wales. No map available.

S. angustipes



S. aureum

CONGAREENARUM species-group

Subgenus *Hellichiella*

Simulium* (*Hellichiella*) *latipes (Meigen, 1804). England and Scotland.

RUFICORNE species-group

Simulium* (*Nevermannia*) *angustitarse (Lundström, 1911). England and Wales.

Simulium* (*Nevermannia*) *lundstromi (Enderlein, 1921). England.

S. angustitarse

S. lundstromi

VERNUM species-group

Simulium* (*Nevermannia*) *armoricanum Doby & David, 1961. England, Scotland and Wales.

Simulium* (*Nevermannia*) *costatum Friederichs, 1920. England and Scotland.

Simulium* (*Nevermannia*) *cryophilum (Rubtsov, 1959). England, Scotland, and Wales.

Simulium* (*Nevermannia*) *dunfellense Davies, 1966. England and Scotland.

Simulium* (*Nevermannia*) *juxtacrenobium Bass & Brockhouse, 1990. England.

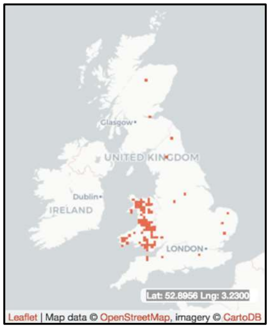
Simulium* (*Nevermannia*) *naturale Davies, 1966. England, Scotland, and Wales.

Simulium* (*Nevermannia*) *urbanum Davies, 1966. England.

Simulium* (*Nevermannia*) *vernum Macquart, 1826. England, Scotland, and Wales.

S. armoricanum

S. costatum



S. cryophilum

S. dunfellense

S. juxtacrenobium

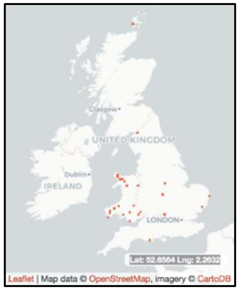
S. naturale

S. urbanum

S. vernum

NOELLERI species-group

Simulium* (*Simulium*) *noelleri Friederichs, 1920. The Channel Islands, England, Scotland and Wales.



ORNATUM species-group

Simulium* (*Simulium*) *intermedium Roubaud, 1906. England, Scotland, and Wales.

Simulium* (*Simulium*) *ornatum Meigen, 1818. The Channel Islands, England, Scotland and Wales.

S. costatum

S. intermedium

S. ornatum

S. trifasciatum

Simulium* (*Simulium*) *trifasciatum Curtis, 1839. England and the Channel Islands.

REPTANS species-group

Simulium* (*Simulium*) *reptans (Linnaeus, 1758). England, Scotland and Wales.

Simulium* (*Simulium*) *reptantoides Carlsson, 1962. England and Wales. No map available.

S. reptans

TUBEROSUM species-group

Simulium* (*Simulium*) *tuberosum (Lundström, 1911). England, Scotland, and Wales.

VARIEGATUM species-group

Simulium* (*Simulium*) *argyreatum Meigen, 1838. England, Scotland and Wales.

S. argyreatum

S. variegatum

Simulium* (*Simulium*) *variegatum Meigen, 1818. England, Scotland and Wales.

VENUSTUM species-group

Simulium* (*Simulium*) *morsitans Edwards, 1915. England, Scotland and Wales.

Simulium* (*Simulium*) *posticatum Meigen, 1838. England.

Simulium* (*Simulium*) *rostratum (Lundström, 1911). England and Scotland.

S. morsitans

S. posticatum

S. rostratum

EQUINUM species-group

Simulium* (*Wilhelmia*) *equinum (Linnaeus, 1758). England, Scotland, and Wales.

Simulium* (*Wilhelmia*) *lineatum (Meigen, 1804). England and Wales.

Simulium* (*Wilhelmia*) *pseudequinum Séguy, 1921. England. No map available.

S. equinum

S. lineatum

Public health issues associated with simuliids

The medical importance of the simuliids is twofold. Firstly, the family includes all of the vectors of human onchocerciasis and secondly because it includes species whose populations can be considered pests since they bite both humans and wild and domestic animals (Crosskey, 1993). Blackflies are telmophagous insects, meaning that using their mouthparts they cut into the skin, severing peripheral blood capillaries to elicit blood flow and then they feed on the resultant pools of blood. During the biting process, they inoculate saliva that includes an anaesthetic, together with vasodilatory, anticoagulant and antithrombin substances responsible for ensuring that the host does not feel pain at the time of the bite, prevents blood clotting, and contributes to increasing blood flow, which facilitates the blood intake (Cupp & Cupp, 1997; Ribeiro & Francischetti, 2003). Thus, the females of the anthropophilic species can be really annoying and unbearable when they land on people in search of the appropriate place to draw blood, on any part of the body with bare skin, such as in the vicinity of the eyes, the mouth, the nostrils or ears (Crosskey, 1993).

Sensitive people can suffer severe allergic reactions to blackfly bites that can be acute or chronic, lasting up to several months, sometimes with dermatitis (De Villiers, 1987). However, insensitive people are often not aware that they have been bitten, since the blackfly sits on the skin of its host very quietly and because there is no instant pain after the bite. Later, bitten people realize what has happened when they notice a small bleeding haemorrhage at the place where the attack took place (Fig. 3). And in these insensitive patients, the only symptom or reaction after the bite suffered is the appearance of a welt at the incision site (Fig. 4). On the other hand, sensitive people can suffer considerable and painful inflammation in the area where the bite took place, even causing oedema (Crosskey, 1993). In continental Europe and in the United Kingdom, the species *S. erythrocephalum* for example, can cause a medically recognized syndrome, called "Blackfly fever", that consists of headache, feverish sweating, chills, inflammation of the lymphatic glands, severe joint pain, nausea, lack of energy, laziness, a feeling of fatigue and even depression. These symptoms are probably due to a reaction to a compound secreted by the salivary glands (Benelli & Pavela, 2018). The symptoms include itching or dermatitis in the area of the bite that can persist for several days. In such cases blood poisoning called “simuliotoxicosis”

Fig. 3. Small bleeding haemorrhages at places where simuliid bites took place (López-Peña & Jiménez-Peydró, 2019)

(Adler *et al*., 2004) may occur which is associated with an exacerbated allergic reaction by the immune system to salivary secretions. This can be especially severe during mass emergencies of adults of univoltine species that occur in a short period and lead to numerous bites on hosts (Cupp, 1986). Other symptoms include haemorrhagic syndromes, such as those described in immigrants who travelled to areas of South America crowded with blackflies (Pinheiro *et al*., 1974; Noble *et al*., 1974); and the most severe cases may lead to asphyxia due to airway obstruction (Tucker, 1918) in both animals and people (Rühm, 1983).

In the Palaearctic region there are several anthropophilic species of simuliids, of which the most important are *S. equinum*, *S. ornatum*, *S. tuberosum* and *S. posticatum*. Between 1960 and 1972 there were numerous cases of massive attacks on people in England. So much so that, in the outbreak caused by the Blandford Fly *S. posticatum* that occurred in 1972, about 600 people had to receive medical attention (Hansford & Ladle, 1979). Among the signs presented by those affected, there was a marked lymphangitis and hyperthermia of up to 39ºC, symptoms of "Blackfly fever" (Harwood & James 1979). Such massive attacks on animals and humans (Leclercq, 1987) are infrequent but they can be harmful, causing serious problems for both human and animal populations (Ignjatović-Ćupina *et al*., 2006; Rivosecchi, 1986). Therefore, blackfly bites can have a significant economic impact due to the resultant sick leave, disability compensation, the provision of prolonged treatment, hospitalization in some cases and even job losses (Crosskey, 1993). The blackfly bites can also negatively affect tourist and recreational activities associated with rivers and streams, causing economic losses in the tourist and services sectors (Cupp & Cupp, 1997, Adler *et al*., 2004).

Usually simuliid bites do not involve the transmission of disease-causing pathogens. However, in Africa, Latin America and Yemen, they transmit species of endoparasitic filarial nematodes such as *Mansonella ozzardi* and *Onchocerca volvulus*. Both affect humans exclusively, although the former is not pathogenic (Crosskey, 1993). Cupp (1986) and Morales-Hojas *et al.* (2006) suggested that human onchocerciasis could have arisen due to a jump of host from cattle to humans, thus implying that the domestication of bovids was linked to grazing activity and the frequenting of the banks of African rivers, which could have enabled the pathogen’s development and evolution into humans as a new host.

Fig. 4. Reaction to bite of *Simulium damnosum* with coagulated blood at site of bite surrounded by a welt and inflammation. (Photo: R.A. Cheke).

Veterinary importance

In the case of animals, the most important pathogens are those that affect domestic birds such as the protozoon *Leucocytozoon simondi* which is an endoparasite of ducks, and *L. smithi* which causes a virulent infection in turkeys, known as "turkey malaria" and which has economic repercussions (Skidmore, 1931; Urquhart *et al*., 1987). In addition, they also transmit microfilariae such as *Ornithofilaria fallisensis* (Anderson, 1956) and trypanosomes to ducks (Bennett, 1961). Among mammals, blackflies can transmit several species of filarial nematodes of the Onchocercidae family, which affect ungulates (Cupp, 1986).

The effects that blackfly bites have on animal welfare and production can be important. The toxic properties of some components of the saliva of these Diptera cause health problems in cattle. Furthermore, numerous bites on a single animal (Leclercq, 1987) can cause their death (Cupp, 1986; Cupp & Cupp, 1997). The attacks of blackflies, can cause weight loss and alterations in reproductive success (Fredeen, 1977), decreased egg and milk production (Jamnback, 1973; Steelman, 1976; Watts, 1976), the appearance of dermatitis and skin lesions (Gräfner, 1981), and even death of animals due to toxaemia or anaphylactic shock (Watts, 1976; Steelman, 1976).

Bovine onchocerciasis

Cattle (Fig. 5) suffer from various filarial complaints (Mikhailyuk, 1967). The species *O. gutturosa* (Neuman, 1910; Urquhart *et al*., 1987) and *O. lienalis* (Johnston, 1921) affect the cattle nuchal and gastrosplenic ligaments, respectively. The geographical distributions of these two species include Great Britain (Trees *et al.*, 1987).

Fig. 5. Beef cattle grazing at Greywell, Hampshire, close to the Whitewater River where blackflies were breeding (Photo: David López Peña).

Equine onchocerciasis

Fig. 6. Horse using head and body protection (Photo: David López Peña).

The species *O. gutturosa* and *O. lienalis* responsible for bovine onchocerciasis, can also affect equids (Bianco *et al*., 1980). Another filarial worm that affects Equidae is *O. reticulata*, widely distributed throughout Europe. Likewise, blackflies can also transmit the pathogens that cause equine encephalitis (Urquhart *et al*., 1987). In many parts of the United Kingdom you can see horses and their foals wearing protective mesh on their heads, as well as clothing that, in addition to protecting them from the inclemency of British weather and other blood-sucking insects, also offer protection against the bites of female simuliids (Fig. 6).

Profiles of species of public health and veterinary importance

Each and every of the next species, with the exception of *Simulium tuberosum*, are represented by means of original photographs took by the authors, either of their pupae (with or without cocoon), and/or by their empty pupal cases.

Simulium argyreatum (a) and *Simulium variegatum* (b)

Veterinary importance

Females bite a variety of farm animals (Edwards, 1920; Zahar, 1951; Davies *et al*., 1962; Davies, 1966).

Simulium equinum

Health importance

Shows tropism for humans (Beaucournu-Saguez *et al*., 1990).

Veterinary importance

Shows preference for equines and has a strong predilection for biting inside the ears of horses (Sutcliffe, 1986; Crosskey, 1993) causing discomfort, nervousness and behavioural changes that affect their physiology and metabolism.

Could act as a vector for the filarial nematode *O. lienalis* (Ham & Bianco, 1983b).

Biting habits affect horses and cattle leading to the condition known as "sweet itch"

Simulium erythrocephalum


David López Peña

Health importance	Veterinary importance
 Anthropophilic (Živković, 1970; Rivosecchi, 1978; Ignjatović-Ćupina *et al*., 2006) causing "blackfly fever" (Crosskey, 1993) in occasional outbreaks (Crosskey, 1993). Females bite together and move in swarms (Ignjatović-Ćupina *et al*., 2006).Laboratory studies have shown that *Onchocerca volvulus* can develop in it (Ham & Bianco, 1983a).	 Feed on bovids and tend to bite those areas of the animal that protrude such as the ears (Wenk, 1981; Wenk, 1987; Kettle, 1995). In Europe, can act as a vector of bovine onchocerciasis such as *O. gutturosa* (Crosskey, 1990; Ruiz-Arrondo *et al*., 2017) and *O. lienalis* (Mikhailyuk, 1967; Ham & Bianco, 1983b; Cupp, 1996).

Simulium intermedium


David López Peña

Veterinary importance

Large emergences of adults in spring and summer can occur and females can bite cattle and horses (Davies, 1966).

Health importance

Biting habits are similar to those of *S. ornatum* (Davies, 1966). Females could cause nuisance to human populations (Crosskey, 1993).

Simulium lineatum

Health importance	Veterinary importance
MAMMALS	Shows a preference for biting mammals (Beaucournu-Saguez *et al*., 1990; Bernotienė, 2003; Bažienė *et al*., 2004).
Laboratory studies have shown that *O. volvulus* can develop in it (Ham & Bianco, 1983a; Bažienė *et al*., 2004).	Transmits *O. lienalis* to cattle (Ham & Bianco, 1983a, 1983b; Bažienė *et al*., 2004).

Simulium morsitans

Health importance	
HUMANS	Edwards (1915) reported that female *S. morsitans* were biting humans in the New Forest.

Simulium ornatum

Health importance

Female *S. ornatum* cause significant nuisance to humans (Crosskey 1993, (Živković, 1970; Rivosecchi, 1978; Ignjatović-Ćupina *et a*l., 2006).

Veterinary importance

Shows a preference for bovids (Sutcliffe, 1986; Crosskey, 1993). Usually bite in those parts of the animal that are more vulnerable and less protected, such as the lower belly area (Wenk, 1981; Kettle, 1995), mainly because these areas are devoid of hair, thereby facilitating laceration of the epidermal tissue.

Transmits *O. gutturosa* (Eichler, 1973; Reid, 1979) and *O. lienalis* (Ham & Bianco, 1983b; Cupp, 1996) to cattle and *Onchocerca tarsicola* to deer (*Cervus elaphus*) (Schulz-Key & Wenk, 1981; Cupp, 1996).

Simulium pseudequinum

Veterinary importance

Attack cattle, horses and pigs (Rivosecchi, 1978; Villanúa-Inglada *et al*., 2013).

Simulium posticatum

Health importance

Highly anthropophilic, but restricted geographically in the UK, where reported from southern England, especially in East Dorset along the River Stour. A very seasonal and univoltine species, the adults mainly occur during a few weeks of May and early June, and fortunately only appear in high numbers in certain years, when they cause intense itching and allergic reactions in bitten people. Also known as the "Blandford fly".

Simulium reptans

Health importance

Show tropism for humans (Živković, 1970; Crosskey, 1993). Large emergences may constitute a local biting nuisance (Davies, 1966)

Veterinary importance

Obtains 90% of its blood requirement from cattle (Kettle, 1995). Very high biting rates on belly region (Zanin & Rivosecchi, 1974). Seldom bite horses or other equines (Crosskey, 1990). Can also bite a variety of domestic mammals (Edwards *et al*., 1939; Davies *et al*., 1962).

Can transmit *Onchocerca lienalis* (Ham & Bianco, 1983b; Cupp, 1996). Can bite cattle heavily at high altitudes causing deaths in Austria (Kutzer *et al*., 1981) and northern Italy (Rivosecchi, 1986).

Simulium tuberosum

Health importance | **Veterinary importance**

Often appears in vast numbers during spring and summer when the females usually bite a variety of mammals, including humans (Edwards *et al*., 1939; Davies *et al*., 1962).

Pathogens, parasites and predators of simuliids

Blackfly larvae, pupae and imagoes can be affected by several species of predators and parasites (Crosskey, 1990). The main set of pathogens that influence them are microspores, fungi (Phycomycetes), nematodes and mites.

Microspores

The microsporidia, unicellular organisms belonging to the phylum Microspora (Sprague, 1977; Levine *et al*., 1980), are obligate intracellular parasites, for which only the mature spore is able to withstand the conditions of the outside environment, remaining in a latent, inactive and resistant state. Blackflies become infected through oral ingestion of spores (horizontal transmission) or by infected females transmitting the pathogen in eggs (vertical transmission) (Larson, 1986). The infections induce hypertrophy of the simuliid larval abdomen, leaving large white globular masses (xenoms), which are lobes of fatty tissue invaded by the parasite (Fig 7). The most common consequences of infection are the death of the larva by starvation due to the digestive tract being affected (Liu, 1984), the prevention of the metamorphosis from larva to pupa or from pupa to imago due to the production of a substance with a juvenilising action attacking the fat tissue (Fisher & Sanborn, 1962). They also cause a decrease in fertility and mating frequency (Armstrong & Bass, 1986) as well as a reduction in food consumption. The importance of microsporidia lies in their pathogenicity, as well as in their ease of dispersion and their specificity so they are candidates for use in biological control of insects (McLaughlin, 1971; Henry, 1981).

Fig. 7. Larva of blackfly with fatty tissue invaded by microsporidia (Photo: David López Peña)

Protozoa

There are several types of protozoans that are endoparasites of blackfly adults, including the apicomplexan genus *Leucocytozoon* (Crosskey, 1990).

Fungi

Fig. 8. Pupa of blackfly affected by fungal mycelia (Photo: David López Peña)

Fungi can affect larvae, pupae and adults. They are usually endoparasites, but their mycelia can go through their bodies and fructify on the exterior (Crosskey, 1990) (Fig. 8). Of the Phycomycete fungi, the species *Coelomycidium simulii* is one of the most prominent pathogens of blackflies (Debaisieux, 1919). This microorganism invades the whole body of the simuliid larva developing the fungus at the expense of the larva's tissues, together with the secretion of enzymes that dissolve the fatty and muscular body, the Malpighian tubes and the salivary glands, preventing larval metamorphosis and leaving countless whitish spheres (sporangia) which release uniflagellate zoospores once the larvae have died (Weiser & Undeen, 1981).

Viruses

Cytoplasmic polyhedrosis viruses, densonucleosis viruses and iridescent viruses (Weiser & Undeen, 1981) have been recorded in blackflies. The larval infection of simuliids by viruses was discovered for the first time thirty-seven years ago in the *Simulium ornatum* complex (Weiser, 1986).

Nematodes

Fig. 9. Larva of blackfly parasitised by a nematode (Photo: David López Peña)

There are many worms of several genera that affect simuliids internally (Fig. 9). Indeed, the families Mermithidae and Filarioidae are endoparasites of larvae and adults, respectively (Crosskey, 1990). Several species of nematodes, members of the Mermithidae family, parasitise simuliids (Welch, 1962). The parasitic phase is whitish coloured and occurs in the posterior part of the larva's abdomen where it generally remains coiled, although it can sometimes occupy practically the entire cavity of the larva's body. Mermithids are long and slender, living within the body cavity of invertebrates such as blackflies during their juvenile stage. The life cycle consists of 5 stages: egg, pre-parasitic juvenile stage, parasitic juvenile stage, post-parasitic juvenile stage and adult stage. The egg attaches itself to objects within the stream, hatches, and the pre-parasitic form penetrates a simuliid larva where it develops in the haemocoel, altering the endocrine system and thereby reducing adipose tissue (Condon & Gordon, 1977). Subsequently, it emerges through the body of the larva, which as a consequence loses its internal fluids and dies. The post-parasitic phase develops freely in the water, and without feeding it undergoes moults until reaching maturity, mating and starting the cycle again (Poinar, 1981). In parasitized females the ovaries atrophy and longevity is reduced (Poinar, 1981). Several species of Simuliidae such as *S. ornatum*, *S. reptans* and *S. variegatum*, present in the United Kingdom, are parasitized by this pathogen (Gradinarov, 2014), perhaps a good thing given that *S. ornatum* and *S. reptans* are species of medical importance! Moreover, although they generally affect larvae, they can also be found in pupae and imagoes. This allows the parasite to maintain itself in the blackfly population since the currents distribute the free-living stages (Welch, 1964). For all of the above reasons, mermithid nematodes could be taken into account to be used for future blackfly biological control (Gordon *et al.*, 1973; Finney, 1981).

Predators

Predators contribute to population control of Simuliidae, with most of the predation on simuliids being attributed to fish. There are several families of fish living in rivulets, streams and rivers that are predators of all the simuliid development stages. These include starlet (*Acipenser tuthenus*), eel (*Anguilla anguilla*), carp (*Cyprinus carpio*), pike (*Esox lucius*), roach (*Rutilus rutilus*), bullhead (*Cottus gobio*), gudgeon (*Gobio gobio*),

Fig 10. Stickleback *Gasterosteus aculeatus* (Photo: David López Peña)

Fig. 11. European dipper, *Cinclus cinclus* (Photo: R.A.Cheke)

stickleback species (*Gasterosteus aculeatus* (Fig. 10) and *Pungitius pungitius*), dace (*Leuciscus leuciscus*), stone loach (*Noemacheilus barbatulus*), minnow (*Phoxinus phoxinus*), brown trout (*Salmo trutta*), rainbow trout (*Salmo gairdneri*), Atlantic salmon (*Salmo salar*) and grayling (*Thymallus thymallus*). Simuliid eggs, larvae and pupae are particularly susceptible to fish when they are crowded. The salmonid species are the most important fish predators eating huge quantities of immature and mature simuliid stages (Crosskey, 1990).

Amphibians, generally frogs and salamanders, as well other vertebrates such as water birds can attack blackfly larvae (Crosskey, 1990). Many species from several families of land birds, but mostly water birds such as the European dipper (*Cinclus cinclus*) (Fig. 11) are predators of larvae, pupae and adults (Crosskey, 1990).

Among the arthropod invertebrates, 12 families of Diptera including Chironomidae (Mwango *et al*., 1995; Boakye *et al*. 2009), Empididae (Vaillant, 1952, 1953; Werner & Pont, 2003; Ivković *et al*., 2017), Muscidae, Asilidae, Dolichopodidae, Phoridae, Drosophilidae and Scathophagidae (Werner & Pont, 2003; Ivković *et al*., 2017), crustaceans (e.g. *Aegla platensis* Magni & Py-Dniel, 1989) and insects such as coleopterans, odonatans, stoneflies, trichopterans (Burton & McCrae, 1972; Malmqvist, 1994) and mayflies (Mwango *et al*., 1995) are predators of blackflies. Stoneflies of the Perlodidae family also prey on simuliids (Malmqvist, 1994).

Fig. 12. Larva of Diptera Chironomidae (Photo: David López Peña).

The simuliids themselves can control their own populations since they can become cannibalistic when very high densities occur and large larvae attack smaller ones. Other dipteran predators include Asilidae (Robber flies), Chironomidae (Midges) (Fig. 12),

Fig. 13. Pupa of Diptera Muscidae, *Limnophora riparia* (Photo: David López Peña).

Dolichopodidae, Drosophilidae (Fruit flies), Empididae, Phoridae and Scathophagidae. A member of the Muscidae common in Europe is *Limnophora riparia* (Fig. 13), which is a formidable predator of immature simuliids (Grenier, 1945), and it also occurs in England (Merritt & Wotton, 1988; Wotton & Merritt, 1988).

Larvae of caddisflies (Fig. 14) are predators of eggs, larvae and pupae. The Hydropsychidae family, commonly known as net-spinning caddisflies owing to their behaviour of building trapping nets, but also other families such as Hydroptilidae consume blackfly immature stages (Crosskey, 1990).

Fig. 14. A larva of caddisfly (Trichoptera) (Photo: David López Peña).

The nymphs of stoneflies (Plecoptera) (Fig. 15) such as the Perlodidae and Perlidae families are predators of simuliid larvae (Hynes, 1953). High spring larval blackfly populations favour these predators (Crosskey, 1990).

Mayfly nymphs (Fig. 16) are able to feed on simuliid larvae although they are usually herbivores and detritivores (Crosskey, 1990).

Fig. 15. A stonefly (Plecoptera) nymph (Photo: David López Peña).

Nymphs and adults of both dragonflies and damselflies (Fig. 17) are predators of larvae and adults of blackflies (Crosskey, 1990).

Fig. 16. A mayfly (Ephemeroptera) nymph (Photo: David López Peña).

But perhaps the most important of the predators are the freshwater mites of the Hydrachnidae family (Fig. 18), which are frequently overlooked due to their small size and difficulty in observing them in the field (Mwango *et al*., 1995). Some species are ectoparasites of adult blackflies. The families Erythraeidae and Trombididae, belonging to the Prostigmata suborder, stand out for their characteristics as parasites and predators of invertebrates (Iraola, 1998, 2001). In general, the nymphs of these mites are found inside the cocoons of metamorphosing Simuliidae pupae, where they wait until the imago emerges. They quickly anchor onto the adult blackfly and emerge into the air with it. These hydracarides feed on the haemolymph of the host, and benefit from its dispersal (Renz *et al*., 2003). The Hydrachnidae family are usually ectoparasites of simuliid pupae and adults. There are other families that also do the same such as the Sperchontidae, of which the genus *Sperchon* is the most important one with several species parasitizing simuliids. The main effects are a shorter life span, a reduction of adult fecundity, and also reduced survival of the simuliids. The water-mites feed by sucking haemolymph from the simuliid body using their chelicerae (mouthparts) seeking the thinnest area of the blackflies' cuticular exoskeleton such as the neck and the leg articulations. In addition, it is common to see several water-mites fixed onto a simuliid body (Crosskey, 1990).

Figure 17. Beautiful demoiselle male, *Calopteryx virgo* (Photo: David López Peña).

Figure 18. An adult water mite (Acari: Hydrachnidia) (Photo: David López Peña).

Other invertebrates, for instance

leeches (Hirudinea) such as the common European leech (*Erpobdella octoculata*) are significant simuliid predators. They inhabit rivers and usually feed from larvae (Paclichenko, 1977).

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Appendix

List of suppliers of data on simuliids to the NBN Atlas
In each case, the data are occurrence datasets on the NBN Atlas downloaded in 2023
Biological Records Centre, Diptera records from iRecord for families not covered by a recording scheme,10.15468/iwy9yi;
Bristol Regional Environmental Records Centre, BRERC species records from all years at full resolution excluding Notable Species within the last 10 years, doi:10.15468/h1ln5p;
Buglife;
Cumbria Biodiversity Data Centre;
Dipterists Forum: Field Week 2017 (Snowdonia),10.15468/u77728 and Dipterists Forum: Field Week 2002 (Inverness),doi:10.15468/u6lxic;
Environmental Records Information Centre North East (ERIC NE) Combined dataset to 2017;
Fife Nature Records Centre combined dataset,10.15468/ccc1ip;
Dr Mary Gillham Archive Project,10.15468/ajv47f,SEWBReC;
Gloucestershire Centre for Environmental Records Gloucestershire Historic Wildlife Sightings prior to 1st Jan 2000, doi:10.15468/dgf5es;
Highland Biological Recording Group, HBRG Insects Dataset Vol 1, doi:10.15468/u1p4wc;
Lancashire Environment Record Network, LERN Records,doi:10.15468/esxc9a;
Leicestershire and Rutland Environmental Records Centre records pre 2000, 10.15468/res3cx, 2000-2009, 10.15468/cs2zzf, 2010-2014, 10.15468/9n92x3 and all taxa records for Leicestershire and Rutland, doi:10.15468/i46are;
Manx Biological Recording Partnership;
Merseyside BioBank (unverified), doi:10.15468/iou2ld, Merseyside BioBank (2020) www.merseysidebiobank.org.uk;
Montgomeryshire Wildlife Trust records held by BIS, doi:10.15468/vozyfp,BIS for Powys and Brecon Beacons National Park;
Natural England Invertebrate Site Register, England (1738-2005), doi:10.15468/7wbiu7;
Natural History Museum (2023), Collection Specimens, https://doi.org/10.5519/0002965, Data Portal query on 1 resource created at 2023-02-01 00:00:05.844482 PID https://doi.org/10.5519/qd.a7x65kmo;

Nature Conservancy Council (NCC) Scotland, North West Region Report 387,"Invertebrate Survey of Selected East Ross Lochs, Streams and Rivers, 1986/87", Hogg, S (1987) An invertebrate survey of selected East Ross lochs, streams and rivers;

Natural Resources Wales Regional Data, Mid-Wales, doi:10.15468/whj6d7, Miscellaneous records held by BIS, doi:10.15468/mo7peo, BIS for Powys and Brecon Beacons National Park, Stackpole National Nature Reserve Species Inventory, Ad-hoc Sightings from Across Pembrokeshire, doi:10.15468/k6hvb8, West Wales Biodiversity Information Centre, Welsh Invertebrate Database (WID), doi:10.15468/bv8fcj, "NRW Regional Data: all taxa (excluding sensitive species), West Wales",doi:10.15468/q3d1hl and KiEco Freshwater Ecology: River Macroinvertebrates, 10.15468/qggn2f;

National Trust Species Records,doi:10.15468/opc6g1, National Trust;

Norfolk Biodiversity Information Service, NBIS Records to December 2016, doi:10.15468/jca5lo;

North East Scotland Biological Records Centre NE Scotland other invertebrate records 1800-2010, doi:10.15468/ifjfxz;

North Wales Environmental Information Service, Miscellaneous records held on the Cofnod database, Cofnod doi:10.15468/hcgqsi, 2019;

Nottinghamshire Biological and Geological Records Centre; Nottingham City Museums & Galleries (NCMG) UK abstract from Insect Collection Baseline database, doi:10.15468/9gnkwk;

Outer Hebrides Biological Recording, Outer Hebrides Insect Records from Literature, 10.15468/jdqghc;

Royal Horticultural Society, RHS monitoring of native and naturalised plants and animals at its gardens and surrounding areas, doi:10.15468/mjksef;

Patrick Roper's Notebooks, doi:10.15468/ntnedq;

Rotherham Biological Records Centre, Non-sensitive Records from all taxonomic groups, doi:10.15468/d3tufo and Sheffield and Rotherham Wildlife Trust;

Scottish Environment Protection Agency 2015, Scottish river macro-invertebrate records from 2007 collected by SEPA, doi:10.15468/l82tvb, and River macroinvertebrate data for 2005 and 2006, doi:10.15468/knxcqi, licensed under the Open Government Licence v3.0;

Scottish Wildlife Trust, Commissioned surveys and staff surveys and reports for reserves, Unassessed data,doi:10.15468/dfwjgc;

Shropshire Ecological Data Network database, doi:10.15468/5v5pvk;

South East Wales Biodiversity Records Centre SEWBReC Diptera - True Flies (South East Wales), doi:10.15468/keiszh;

Staffordshire Ecological Record SER Species-based Surveys, doi:10.15468/q8qen3, Staffordshire Ecological Record Data from Defra Family Organisations supplied to Staffordshire Ecological Record, doi:10.15468/giebpp and Stoke-on-Trent Environmental Survey results (1982-1984), doi:10.15468/8gryb6;

Malcolm Storey personal records and images http://www.bioimages.org.uk/;

Suffolk Biodiversity Information Service (SBIS) Dataset, doi:10.15468/ab4vwo;
Tullie House Museum Natural History Collections, doi:10.15468/epewfs;
TWIC Biodiversity Field Trip Data (1995-present), doi:10.15468/ljc0ke;
WildFish, "SmartRivers - Aquatic invertebrate occurrence and pressure biometric scores in English, Welsh and Scottish rivers"; Yorkshire Wildlife Trust - Non-sensitive records from all taxonomic groups,doi:10.15468/2razk5.

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