

# Co-occurrence of the dragonfly biting midge *Forcipomyia paludis* and the Great fen-sedge *Cladium mariscus* in Europe

Marcel Wasscher<sup>1</sup>, Reinier de Vries<sup>2</sup>, Dominic Dijkshoorn<sup>3</sup>  
and Jan-Freerk Kloen<sup>4</sup>

<sup>1</sup>) Minstraat 15bis, 3582 CA Utrecht, The Netherlands, marcel.hilair@12move.nl

<sup>2</sup>) Nobelweg 50-3, 6706 GD Wageningen, The Netherlands, vries.reinier@gmail.com

<sup>3</sup>) Schieweg 182, 2636 KA Schipluiden, The Netherlands, dominicdijkshoorn@gmail.com

<sup>4</sup>) Gruttoweide 36, 6708 BJ Wageningen, The Netherlands, janfreerk.kloen@gmail.com

## Abstract

The dragonfly biting midge *Forcipomyia paludis* (Diptera: Ceratopogonidae) has been found in many parts of Europe and adjacent countries such as Morocco, Turkey and Georgia, but has a remarkably scattered distribution, with at most a few dozen localities in the countries where it occurs. Its presence appears to be strongly concurrent with the presence of the Great fen-sedge *Cladium mariscus*, a marsh plant with a wide but scattered distribution within Europe. Both species co-occur across the entire known range of *F. paludis*. However, *F. paludis* was also found on a few localities where the Great fen-sedge has not been reported. In most cases these localities are within a limited distance of Great fen-sedge localities, or refer to incidental observations in which *F. paludis* might have been attached to dispersing dragonflies. A probable discrepancy between the two species was found in the southwest of Baden-Wuerttemberg. This overlap in distribution suggests that the presence of *F. paludis* is linked to that of the Great fen-sedge. It is therefore probable that the larvae of *F. paludis* develop in Great fen-sedge stands, where a humid litter layer of dead leaves is formed. This habitat presents similar conditions as those preferred by many other Ceratopogonid larvae. However, the concurrence that is described here does not prove a decisive ecological link while we did find a few exceptions. Additionally, first records for Estonia, Denmark, Portugal and Turkey are reported here.

## Zusammenfassung

**Gemeinsames Vorkommen der Libellengnitze *Forcipomyia paludis* und der Binsenschnede *Cladium mariscus* in Europa** – *Forcipomyia paludis* (Ceratopogonidae) wurde in vielen Teilen Europas und in weiteren Ländern wie Marokko, der Türkei und Georgien gefunden, hat aber bemerkenswert verstreute Vorkommen mit höchstens einigen Dutzend Lokalitäten bzw. belegten Kartenrastern in den Ländern, in denen die Gnitze nachgewiesen ist. Ihre Vorkommen scheinen sich weitgehend mit den Vorkommen der Binsenschnede

zu decken, einer Sumpfpflanze mit weiter, aber verstreuter Verbreitung in Europa. Beide Arten kommen im Verbreitungsgebiet von *F. paludis* meist gemeinsam vor. Für die wenigen Fälle von *F. paludis* an Lokalitäten ohne Binsenschneide nehmen wir an, dass es sich um *F. paludis* auf dispergierenden Libellen handelt. Eine wahrscheinliche Diskrepanz bei der Arten wurde im Südwesten Baden-Württembergs festgestellt. Die sich überlappende Verbreitung beider Arten lässt vermuten, dass die Anwesenheit von *F. paludis* mit dem Vorkommen der Binsenschneide zusammenhängt. Es ist deshalb möglich, dass sich *F. paludis* in Binsenschneidebeständen mit feuchtem zerfallendem Pflanzenmaterial entwickelt. Dieses Habitat weist ähnliche Bedingungen auf wie diejenigen, die von vielen anderen Ceratopogoniden-Larven bevorzugt werden. Weil wir einige Ausnahmen fanden, beweist das hier beschriebene gemeinsame Vorkommen beider Arten allerdings nicht, dass ein ökologischer Zusammenhang zwischen beiden Arten besteht. Daneben werden die Erstnachweise für Estland, Dänemark, Portugal und die Türkei vorgestellt.

## Introduction

The biting-midge *Forcipomyia paludis* (Macfie, 1936), belonging to the species-rich family of Ceratopogonidae (Diptera), is found as a parasite on dragonflies (Odonata). Currently, some 6,000 Ceratopogonidae all over the world have been described (BORKENT & DOMINIAK 2020). Mature individuals feed on nectar, but females also feed on the body fluid of mammals or insects, though some species are known which do not feed at all during their adult life. The larvae are found in various humid substrates such as bogs, humus, moss and dung, aquatic biotopes and even salt water. They feed on organic materials or micro-organisms and some are predators of other invertebrates (OOSTERBROEK et al. 2012). Many species of the subgenus *Pterobosca* (of the genus *Forcipomyia*) are worldwide known as parasitic on the wing veins of insects. Apart from dragonflies they can sometimes be found on lacewings (Chrysopidae) (ORR & CRANSTON 1997) and blister beetles (Meloidae) (MAYER 1962) as well. Currently, 23 species within this subgenus have been described (BORKENT & DOMINIAK 2020).

In Europe, *Forcipomyia (Pterobosca) paludis* seems to be the only species within this (sub)genus which is specialized on dragonflies. The female feeds as an ectoparasite on dragonflies taking haemolymph from wing veins (WILDERMUTH & MARTENS 2007). The biting midge may remain in place for hours or several days at least (ORR & CRANSTON 1997). They are most often seen on veins close to the wing base, where the haemolymph is most easily available and to minimize the centrifugal forces during flight (WILDERMUTH & MARTENS 2007). They choose lower-lying veins that are especially suitable for a safe attachment on the wing when the host is flying (MANGER 2021).

*F. paludis* has been found from the European west coast (Ireland, Spain) to the Caucasus and from southern Scandinavia to North-Africa (WILDERMUTH et al. 2019; BOUDOT et al. 2019). The species seems to be opportunistic in its host selection and has been found on more than 80 dragonfly species (both Zygoptera and

Anisoptera) (WILDERMUTH et al. 2019; DE KNIJF 2021). Because of its small size (2–3 mm) it is most often discovered only by studying dragonfly photographs. In The Netherlands *F. paludis* is most common in June and has been recorded between 18 May (2020) and 5 September (2010) (WASSCHER et al. 2021). In Spain it has been recorded with a longer flight period: from 16 April (2014) to 4 October (2015) (CORDERO et al. 2019). The female leaves the host before ovipositing. Little is known to date about the reproductive cycle of *F. paludis*, the males of the species and the pre-imaginal stages and their habitats. Not even the larva itself has been described yet.

The type locality of *F. paludis* is Wicken Fen (Cambridgeshire, UK) (MACFIE, 1936), but it seemed to have disappeared from the United Kingdom until it was rediscovered on photographs taken near Wicken Fen in 1999 and 2008 (MARTENS & WILDERMUTH 2008; TELFER 2009). Long after its description, the first successive records came from Georgia (REMM 1967) and Italy (DELL'ANNA et al. 1995). In most European countries the species was discovered only after the year 2005 and seems to be rather rare. The distribution records of *F. paludis* show an irregularly scattered pattern of specific localities in all countries where it has been found. This distribution pattern has not been explained so far, and is in contrast with the ample presence of its host species. Although its minimal size enables it to go unnoticed quite often, targeted searches based on dragonfly photographs, initially started by MARTENS et al. (2007), have been made for it in many countries and more and more observers are aware of the chance of finding *F. paludis* on dragonflies. In many countries, dragonflies are increasingly often photographed, e.g. in The Netherlands and Belgium, where almost one million dragonfly photos have been collected on Waarneming.nl and Waarnemingen.be. In spite of this, observations of the midge remain quite rare, which suggests that other factors than the availability of hosts may determine, at least in part, whether or not the species occurs.

In The Netherlands, *F. paludis* has been found in a broad range of habitats such as bogs, fens, and dune lakes. When comparing the vegetation in these different habitats, the first author (MW) noticed in May 2019 that in all known localities, the Great fen-sedge *Cladium mariscus* (L.) (Pohl) seemed to occur (see also WASSCHER et al. 2021). The Great fen-sedge is a cosmopolitan marsh plant which occurs in scattered localities across Europe. It is not listed as a threatened species according to the Bern Convention, but it is mentioned in an annex document from 2019 as one of the characteristic species of “Beds of large sedges normally without free-standing water”, which is in grave decline throughout its range (EUNIS 2021). The species forms dense fields with specific environmental conditions, known as Fen *Cladium mariscus* beds, which is found in Atlantic, Mediterranean, and Central Europe, with its northernmost edge in southern Scandinavia (SCHAMINÉE et al. 2019). This notion led us to scrutinize the possible connection between *F. paludis* and the Great fen-sedge, hypothesizing that the occurrence of *F. paludis* coincides with the occurrence of Great fen-sedge. In this article, we present the results of testing that hypothesis.

## Material and methods

We compared the distribution of *F. paludis* and the Great fen-sedge in various European countries and three countries outside Europe. In the first place, citizen science data platforms from various countries were used: Waarneming.nl for The Netherlands, waarnemingen.be for Belgium, naturbasen.dk for Denmark, and observation.org for other countries. These platforms hold a wealth of opportunistic observations data. To determine the presence of *F. paludis* in specific countries or localities, many thousands of dragonfly photographs were studied. This method had already been used to study the distribution of *F. paludis* in e.g. the Czech Republic (ČERNÝ 2014) and in The Netherlands and Belgium (WASSCHER et al. 2021).

The presence of *F. paludis* in other European countries was analysed using distribution maps, literature, and through communication with local experts. In addition to the above mentioned countries, this data provides a complete overview for the United Kingdom, Germany, and Switzerland, and in less detail data from other European countries, Turkey, Georgia, and Morocco. These countries reflect the total distribution of *F. paludis* as it is presently known.



**Figure 1.** The Great fen-sedge *Cladium mariscus* along the shore of Kromme Rade near Het Hol (Kortenhoeft, The Netherlands). In the mid-1950s huge fields of the species were present, but currently its presence is limited to the shores of small lakes and canals. – **Abbildung 1:** Bestand der Binsenschneide *Cladium mariscus* am Ufer der Kromme Rade bei Het Hol (Kortenhoeft, Niederlande). Mitte der 1950er-Jahre gab es ausgedehnte Flächen davon, heute ist die Pflanze auf die Ufer kleiner Seen und Kanäle beschränkt. Photo: MW

The occurrence of the Great fen-sedge was studied on citizen science data platforms and European and worldwide occurrence maps: CONWAY (1937), LINNAEUS.NRM (2019), DISCOVERLIFE (2019), and GBIF (2021). These maps may offer a fair idea of the occurrence of the species, but its recent presence – e.g. after the year 2000 – is not always clear. Therefore, other publications and websites have been studied as well, e.g. BRC (2019) for the British Isles, the BUNDESAMT FÜR NATURSCHUTZ (2021) for Germany, TELA-BOTANICA (2019) for France, KAPLAN et al. (2015) for the Czech Republic, and INFO FLORA (2021) for Switzerland. The map with the distribution of *F. paludis* in Spain (Cordero et al. 2019) has not been included in this article as we could not find a recent distribution map of the Great fen-sedge for Spain.

## Results

Our study of distribution maps, published literature, and various databases shows that some 200 localities of *F. paludis* in Europe, Turkey, Georgia, and Morocco are known at this moment (Table 1). The highest numbers of localities where this species has been found so far are in Switzerland (29), Germany (26), The Netherlands (24), Spain (22), and France (17). These are also the countries where the occurrence of *F. paludis* has been studied best. Online databases presented first records of *F. paludis* for Turkey, that have not yet been mentioned in scientific literature. Moreover, this study found the first presence of *F. paludis* in Estonia, Denmark, and Portugal on photos of dragonflies (Table 1). We also report here on new localities in listed countries, including a new locality in the United Kingdom (A. Parr, pers. comm.) (Table 2).



**Figure 2.** Pair of *Erythromma viridulum*, with *Forcipomyia paludis* on the right hind wing of the female. Kromme Rade near Het Hol (Kortenhoef, The Netherlands), 07-vii-2020. – **Abbildung 2:** Paarungsrade von *Erythromma viridulum* mit *Forcipomyia paludis* auf dem rechten Hinterflügel des Weibchens. Kromme Rade bei Het Hol (Kortenhoef, Niederlande), 07.07.2020. Photo: Eric Roeland

**Table 1.** Number of localities in European and some surrounding countries with *Forcipomyia paludis* in relation to the occurrence of the Great fen-sedge *Cladium mariscus*. Country (in bold if our knowledge is in detail about both species; with a # where the presence of *F. paludis* had not been published yet), with the number of known localities (or dots on the map) of *Forcipomyia paludis* (total, known and new localities in this publication), with the known presence or absence of *C. mariscus* per location (between brackets if the distribution of *C. mariscus* is not known in detail but only regionally), and with references on the presence of *F. paludis*. For references on the presence of the Great fen-sedge in each country see Material and Methods section. \* This is a *Forcipomyia* sp. (see Discussion). – **Tabelle 1:** Anzahl der Fundorte von *Forcipomyia paludis* und deren Nähe zu *Cladium mariscus*-Vorkommen in europäischen und angrenzenden Ländern. Ländernamen fett, wenn die Kenntnisse zu beiden Arten gut sind. Die Quellen zum Vorkommen von *Cladium mariscus* finden sich im Kapitel Material und Methoden.

Country	Number of localities with <i>Forcipomyia paludis</i>			Great fen-sedge present: number of localities or dots		References on <i>Forcipomyia paludis</i>
	Total	Known	New	Yes	No	
Western Europe						
<b>The Netherlands</b>	24	16	8	21	3	MANGER & VAN DER HEIJDEN (2013); MANGER (2021); WASSCHER et al. (2021)
<b>Belgium</b>	7	6	1	4	3	CLAEREBOUT (2013); WASSCHER et al. (2021); DE KNIJF (2021)
Denmark#	3	–	3	(3)		naturbasen.dk, see Table 2
France	17	17	–	(17)		CLASTRIER et al. (1994); MARTENS et al. (2008); Haas (2013)
United Kingdom	1	1		2		MACFIE (1936); TELFER (2009); see Table 2
Ireland	4	4				DONNITHORNE (2010)
Sweden	10	10	–	10		VINKO et al. (2017)
<b>Germany</b>	26	26	–	22	3 dots	MARTENS et al. (2012); NUSS (2014)
<b>Switzerland</b>	29	29	–	25	1	WILDERMUTH (2012)
Austria	8	–	8	(8)		MARTENS et al. (2008); observation.org
Eastern Europe						
Estonia#	1	–	1	1		observation.org; see Table 2
Lithuania	1	1				LEUTHOLD & WILDERMUTH (2014)
Poland	1	1	–			DOMINIAK & MICHALCZUK (2009)



Country	Number of localities with <i>Forcipomyia paludis</i>			Great fen-sedge present: number of localities or dots		References on <i>Forcipomyia paludis</i>
	Total	Known	New	Yes	No	
<b>Czech Republic</b>	3	3	–	1	2	ČERNÝ (2014)
Slovenia	9	9	–			VINKO et al. (2017)
Croatia	5	5	–			VINKO et al. (2017)
Bosnia and Herzegovina	14	14	–			VINKO et al. (2017)
Southern Europe						
Italy	1	1		(1)		DELL'ANNA (1995)
<b>Spain</b>	22	22	–	22	1*	NIELSEN et al. (2014); CORDERO et al. (2019)
Portugal#		–	1	1		observation.org; see Table 2
Surroundings of Europe						
Turkey#	1	–	1		1	observation.org; see Table 2
Georgia	2	1	1	1		REMM (1967); WILDERMUTH et al. (2019); Asmus Schröter pers. comm.
Morocco	2	2	–			BOUDOT et al. (2019)

In the vast majority of the localities where *F. paludis* occurred, the Great fen-sedge was reported (Table 1). This pattern can be seen comparing the maps with the distribution of both species for The Netherlands, Belgium, Germany, Switzerland, and the Czech Republic (Figs 3–6). In these countries, the Great fen-sedge occurs at the localities where the highest number of *F. paludis* individuals were found. This too was the case for Austria in which the majority of records of *F. paludis* were from the Neusiedler See (G. and P. Peitzner in MARTENS et al. 2008), a locality with Great fen-sedge marshes. Furthermore, the highest number of *F. paludis* ever recorded on one dragonfly (169 individuals) was reported on a teneral *Libellula quadrimaculata* that emerged on Great fen-sedge, at a locality where this plant is abundant (CLASTRIER et al. 1994). However, a small number of *F. paludis* localities in The Netherlands, Belgium, Germany, Switzerland, the Czech Republic, Spain, and Turkey is listed where Great fen-sedge was not reported (Table 1). In most cases, these localities are less than 10 km away from a known Great fen-sedge stand, but several were found at larger distances of 10 to 25 km (e.g. in Southwest Baden-Wuerttemberg, Germany), and four records at a distance of 25 km or more, with a longest distance of 120 km (Table 3).

**Table 2.** Localities of *Forcipomyia paludis* published for the first time in this article. In the countries marked with an # for those had been found in internet databases and those marked with ## we did find ourselves in observation.org on photos made by others; all had not been published before. – **Tabelle 2:** Neue Fundorte von *Forcipomyia paludis* in Europa und angrenzenden Ländern. Bei den Ländern, die mit # sind, stammen die Daten aus Internetforen, in solchen, die mit ## markiert sind, stammen die Angaben aus von uns identifizierten Meldungen bei observation.org.

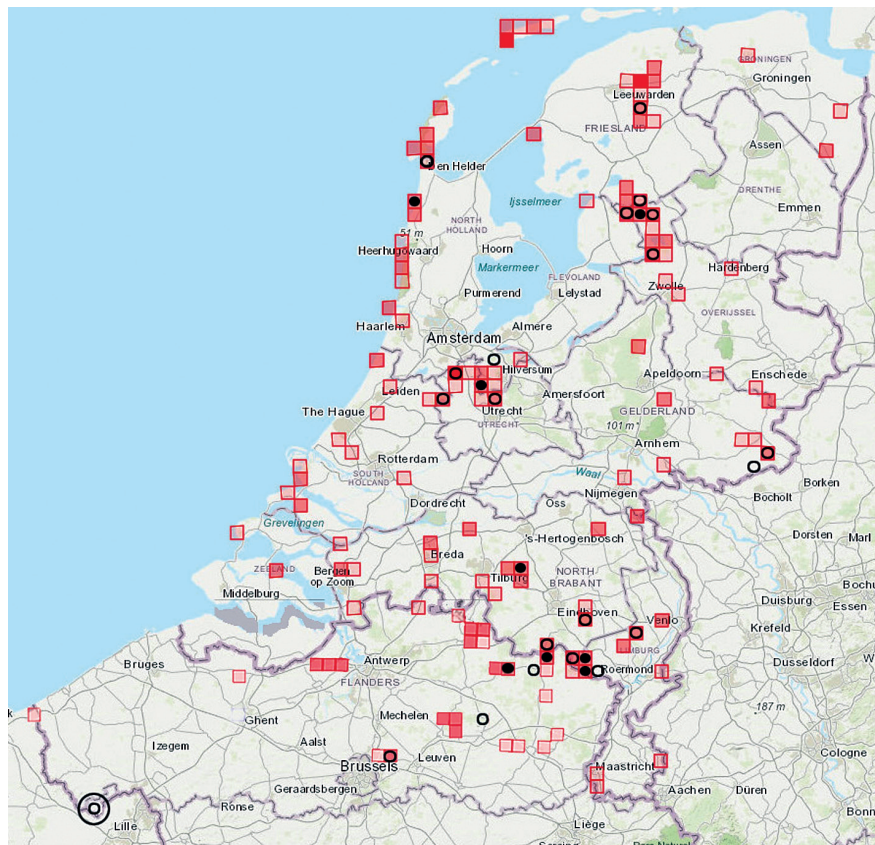
Country	Location	Date	Number of <i>F. paludis</i>	Species or trap	Great fen-sedge present or distance to it	Source
Estonia##	Spithami/ Spithamn küla 59.21, 23.57	06-07-2015	1	<i>Coenagrion pulchellum</i>	Yes	Cees Witkamp (after checking 200 photos), by the authors <a href="https://observation.org/observation/105399087/">https://observation.org/observation/105399087/</a>
Denmark##	Naestfød, Sjælland ±11.76-55.28	06-07-2017	7	<i>Cordulia aenea</i>	Yes	Lars Birk (sent to us by Erland R. Nielsen) <a href="https://www.naturbasen.dk/observation/2322109/forcipomyia-paludis">https://www.naturbasen.dk/observation/2322109/forcipomyia-paludis</a>
United Kingdom	Catfield in the Norfolk Broads 52.73-1.52	05-07-2018	56	<i>Aeshna cyanea</i>	Yes	Lindsay Ogden (sent to us by Adrian Parr)
Portugal##	Lagoa de Albufeira 38.52 -9.14	11-05-2018	1	<i>Anax parthenope</i>	Yes	Paulo Roncon (after checking 500 photos), by the authors <a href="https://observation.org/observation/156382194/">https://observation.org/observation/156382194/</a>
Turkey#	Dalyan, creek, 36.89-28.57	27-05-2013	14	<i>Anax immaculifrons</i>	1 km from lake Köyceğiz, where <i>Cladium</i> occurs	Ez & Faz (posted on Facebook) <a href="https://observation.org/observation/76502683/">https://observation.org/observation/76502683/</a>
Georgia	Kolhekti bogs north side Pallostomi lake	08-06-1963	94 males, 22 females	Field trap (probably a malaise trap)	Yes	New literature: REMM (1967), sent to us by Asmus Schröter



## Discussion

### Overlap in the presence of *Forcipomyia paludis* and *Cladium mariscus*

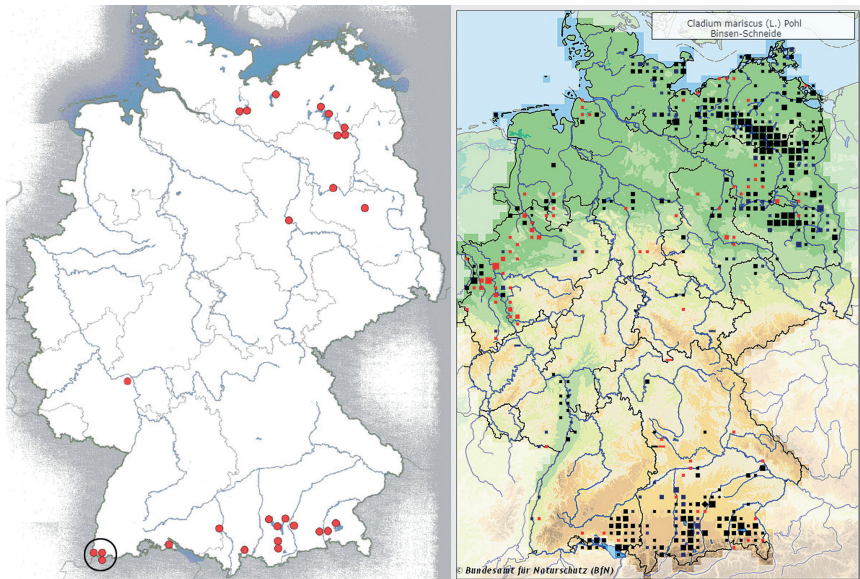
The distribution of *Forcipomyia paludis* shows a strong overlap with the distribution of the Great fen-sedge all over Europe, and there is no clear pattern in the exceptions. In Sweden the northern distribution limits of *F. paludis* (VINKO et al. 2017) and the Great fen-sedge (CONWAY 1936) are concurrent. All main localities



**Figure 3.** Distribution maps for *Forcipomyia paludis* and the Great fen-sedge *Cladium mariscus* in The Netherlands and Belgium (WASSCHER et al. 2021; DE KNIJF 2021; waarneming.nl). The squares show the presence of the Great fen-sedge (the more reddish, the higher numbers); the black dots refer to 3 or more records of *Forcipomyia paludis* in that 10-km square, the open dots refer to 1 or 2 records. The circled dot is a record far outside the distribution area of the Great fen-sedge (see Table 3). – **Abbildung 3:** Vorkommen der Libellengnitze *Forcipomyia paludis* (Kreise) und der Binsenschneide *Cladium mariscus* (Quadrate) in den Niederlanden und Belgien.

for *F. paludis* in The Netherlands (nine localities) and Belgium (two localities) and most of the other localities in these two countries correspond with the distribution of Great fen-sedge, which has large populations on the hotspots of *F. paludis*, while this species lacks in marshes where the plant is absent (WASSCHER et al. 2021; DE KNIJF 2021). Most of our collected data (Table 1) and the Figures 3a to 3d endorse this pattern, which might suggest that *F. paludis* is linked to the Great fen-sedge. Across European and a few neighbouring countries, the Great fen-sedge is generally present at localities of *F. paludis*: often at site level, sometimes at regional level (e.g. in Morocco; BOUDOT et al. 2019).

However, we also found several exceptions to this overlap in distribution, which does not necessarily mean falsification of the hypothesis posed in this article. Firstly, these discrepancies may be a result of either hosts, or *F. paludis* itself, dispersing far. Since many dragonfly species cross large distances relatively easily and *F. paludis* has been found for a maximum time of 43 hours on the same host (WILDERMUTH & MARTENS 2007), we could expect *F. paludis* to show up in unusual localities. Secondly, the link between *F. paludis* and the Great fen-sedge need not be exclusive. It is possible that the habitat requirements of *F. paludis* are also

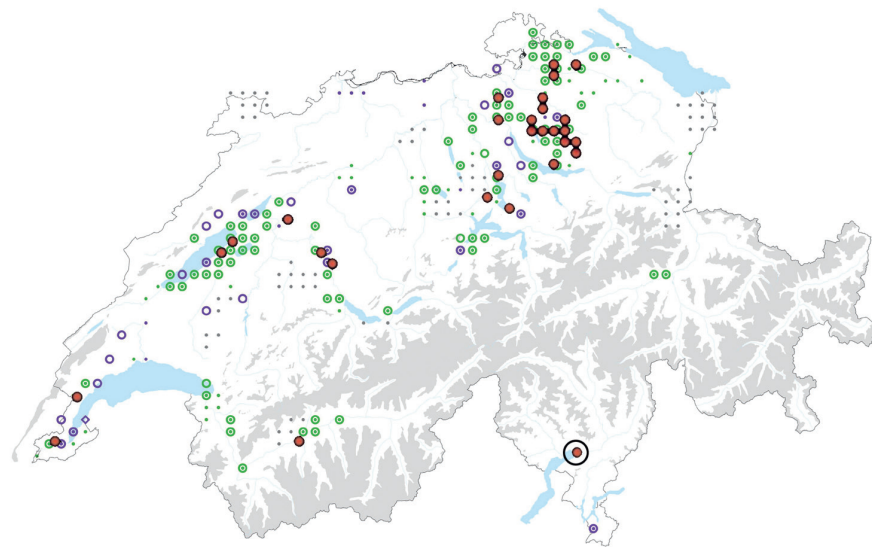


**Figure 4.** Distribution maps for *Forcipomyia paludis* (left panel, red dots; MARTENS et al. 2012 & Nuss 2014) and the Great fen-sedge *Cladium mariscus* (right panel; FLORAWEB 2021) in Germany. The squares show the presence of the Great fen-sedge (red only before 2000, black after 2000, the larger the squares the higher numbers). The circled red dots are finds of *F. paludis* outside the distribution area of the Great fen-sedge (see Table 3). – **Abbildung 4:** Vorkommen von *Forcipomyia paludis* (Karte links, rote Kreise) und *Cladium mariscus* (rechts, Quadrate) in Deutschland.

present in other microhabitats in some regions. This would not be different from the well-known link between *Aeshna viridis* and *Stratiotes aloides* (ANDERSEN et al. 2016). Thirdly, it may be that at localities where the Great fen-sedge has disappeared, *F. paludis* larvae will continue to find a suitable habitat in the litter layer of the former Great fen-sedge stands for some time afterwards.

The majority of ‘anomalous’ localities are situated at less than 10 km away from a Great fen-sedge locality and involve incidental observations, which may refer to dispersing individuals. In The Netherlands and in Belgium we found after targeted searching that *F. paludis* could actually be recorded at localities without the Great fen-sedge, but only rarely and often on a fairly mobile host such as *Aeshna isoceles* (WASSCHER et al. 2021). The incidental records of *F. paludis* at distances of over 25 to 120 km from the nearest known Great fen-sedge locality might also be attributed to dispersing dragonflies: these were always single midges that were often found on mobile hosts like *Aeshna isoceles* (Table 3).

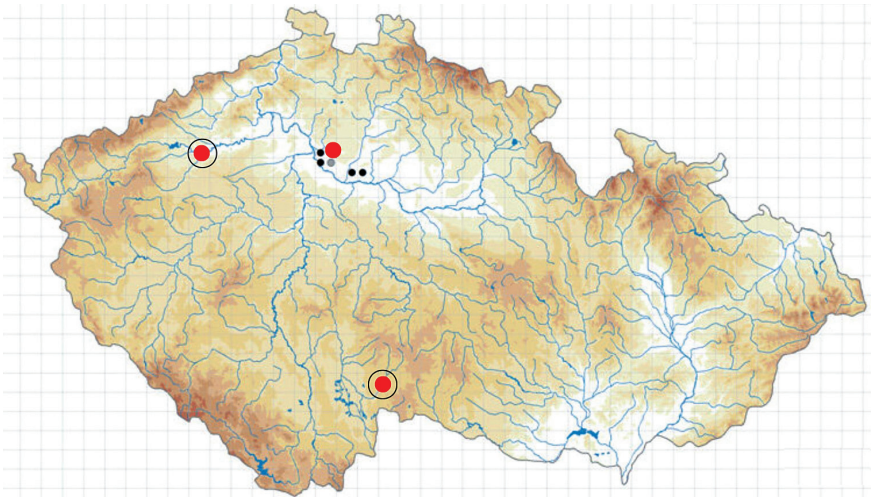
An important mismatch of *F. paludis* and the Great fen-sedge is found in South-west Germany (Lörrach District, Baden-Wuerttemberg in the years 1993–2010), where 34 individuals of *F. paludis* were found at seven localities within three grid squares (Fig. 3b; A. Schröter in MARTENS et al. 2012). In this part of Germany,



**Figure 5.** Distribution maps for *Forcipomyia paludis* (red dots; WILDERMUTH et al. 2012) and the Great fen-sedge *Cladium mariscus* (year 2008 chosen; INFO FLORA 2021) in Switzerland. The grey, purple, and green dots show the presence of the Great fen-sedge (green certainly valid, purple perhaps valid, grey old records before 1994; open dots after 2008, small dots before 2008). The circled red dot is a find of *F. paludis* far outside the distribution area of the Great fen-sedge (see Table 3). – **Abbildung 5:** Vorkommen von *Forcipomyia paludis* (rote Punkte) und *Cladium mariscus* (grüne und violette Kreise) in der Schweiz.

no recent records of the Great fen-sedge are known (Fig. 3b; BUNDESAMT FÜR NATURSCHUTZ 2021), though the species has once been reported at Kandern (year not specified locality in GBIF 2021), 10 km north of the most northern record of *F. paludis* in this region. Only old records are known from nearest parts of Switzerland (INFO FLORA 2021). The nearest certain recent locality where the Great fen-sedge occurs is 'la Petite Camargue' on the French side of the river Rhine, just north of Saint-Louis, a nature reserve where the Great fen-sedge is abundant (REGIONATUR 2021). The records of *F. paludis* near Lörrach could originate from wanderers from la Petite Camargue, which lies at a distance of 8–21 km from the seven German localities, e.g. nine midges on a male *Onychogomphus forcipatus* at a distance of 13 km. However, the relatively high number of individuals found in Lörrach makes it not very likely that they originate from wandering behaviour. Therefore, this is one region where the (non-)presence of the Great fen-sedge cannot explain the presence of *F. paludis*.

Lastly, at the locality of Sartichala, Georgia (GPS 41.69° N, 45.21° E, just east of Tbilisi) where *F. paludis* was found at a brook on seven dragonfly species (WILDERMUTH et al. 2019), the nearest known Great fen-sedge locality is 35 km to the south (west of Gardabani at GPS 41.45° N, 45.01° E), but the occurrence of the Great fen-sedge closer to the locality cannot be excluded (A. Schröter, pers. comm.).



**Figure 6.** Distribution maps for *Forcipomyia paludis* (red dots; CERNÝ 2014) and the Great fen-sedge *Cladium mariscus* in the Czech Republic (KAPLAN et al. 2015). The grey and black spots show the presence of the Great fen-sedge (black dots show the higher numbers). The circled red dots are finds of *F. paludis* far outside the distribution area of the Great fen-sedge (see Table 3). – **Abbildung 6:** Vorkommen von *Forcipomyia paludis* (rote Punkte) und *Cladium mariscus* (schwarze und graue Punkte) in der Tschechischen Republik. Die beiden schwarz umrandeten roten Punkte zeigen Nachweise von *F. paludis* ohne Vorkommen von *C. mariscus* in deren Nähe.



**Table 3.** *Forcipomyia paludis* imagines found in Europe at the largest distances from Great fen-sedge *Cladium mariscus* locations ( $\geq 25$  km). Note that the timing of these sightings corresponds with the peak in occurrence of *F. paludis*, and that (except for one case) all were found on large Anisoptera species. Second note: on GBIF (2021) is an undated location spot of the occurrence of the Great fen-sedge at Gambarogno in the Canton of Ticino (Switzerland), which is not presented on the map from Infoflora (2021) we used. – **Tabelle 3:** Funde von Imagines von *Forcipomyia paludis* auf Libellen in größerer Distanz zu Vorkommen von *Cladium mariscus* ( $> 25$  km).

Country & locality	Date	Host species	Number of midges	Nearest known Great fen-sedge locality	Distance and wind direction towards the nearest Great fen-sedge locality	Reference
Belgium, Ploegsteert	29-05-2010	<i>Coenagrion pulchellum</i>	1	Béthune, Northern France	25 km NNE	CLAEREBOUT (2013)
Switzerland, Canton of Ticino	1995	<i>Aeshna isoeles</i>	1	South of Angera (45.768056° N, 8.583889° E).	60 km S	WILDERMUTH (2012); A. Schröter, pers. comm.
Czech Republic, Karlovy Vary	3-06-2011	<i>Aeshna isoeles</i>	1	East of Praha	85 km E	ČERNÝ (2014)
Czech Republic, Jindřichův Hradec	6-06-2011	<i>Aeshna isoeles</i>	1	East of Praha	120 km NNW	ČERNÝ (2014)

Ecological interpretation

Considering the life cycle of other *Forcipomyia* species, we may expect that the link of *F. paludis* to Great fen-sedge would concern the larval rather than the adult stage of the species. We would expect the ecology of these undescribed larvae to be similar to that of other Ceratopogonidae; they occur in various humid substrates or aquatic biotopes, feed on organic material, microorganisms, or small invertebrates, and are not known to specialize on specific plants (OOSTERBROEK et al. 2012). Therefore, it is most likely not the Great fen-sedge plant itself but specific habitat conditions at Great fen-sedge stands that influence the presence of *F. paludis*. The Great fen-sedge creates a specific habitat with a layer of organic material based on dead leaves in which few other plant species could flourish (SCHAMINÉE et al. 2019). This substrate resembles the biotopes of other ceratopogonid larvae, and in the Great fen-sedge marsh of Wicken Fen (UK), the type locality of *F. paludis*, larvae of *Forcipomyia* have been found (DAWSON et al. 1965). However, there is also the possibility that *F. paludis* is not linked to the Great fen-sedge habitat, but that both the Great fen-sedge and *F. paludis* are linked to

other external factors. The Great fen-sedge prefers a habitat of water that is relatively rich in nutrients and oxygen, with a basic to weakly acidic pH level, often in combination with seepage (SCHAMINÉE et al. 2019), and these circumstances could influence the larval stage of *F. paludis*. The exact link cannot be understood until the larva of *F. paludis* and its ecology have been described.

### Unusual reports of midges on dragonflies

It is possible that not all reports of *Forcipomyia* on dragonflies discussed in this paper concern *F. paludis*. For instance, in Georgia a somewhat related species *F. (Microhelea) fuliginosa*, known for parasitizing caterpillars and Sawfly larvae, was found on a dragonfly. Contrary to *F. paludis*, this species was found on the thorax of a freshly emerged *Aeshna juncea* and only remained on the host for a few minutes (SEEHAUSEN et al. 2019). A record of *Forcipomyia* sp. is from a series of six photos on which two biting midges were photographed landing on and sucking on the eye and abdomen of a recently emerged *Onychogomphus uncatus* (CORDERO et al. 2019); this locality was on the bank of the Ulla river in NW Spain. Two other reports of *F. paludis* not sucking on wing veins exist, i.e. on the thorax (Italy: DELL'ANNA et al. 1995) or between the wing attachments on the thorax of a *Libellula quadrimaculata* (France: HAAS 2013) and in both cases it concerned mature dragonflies. For certain, in the latter case it was *F. paludis*, while eight other females on the photo are sucking from the wing veins.

### Prospects for further research

At first, a better understanding of the ecology of the larval stages of *F. paludis* is critical to acquire a detailed understanding of its possible relationship with the Great fen-sedge. This requires finding the larvae of *F. paludis*, which could be sought in Great Fen-sedge stands or reared from litter material. Secondly, further research into the locations where the presence of *F. paludis* does not match the presence of Great fen-sedge, most notably in southwestern Germany, could yield new insights in its habitat use. Lastly, the distribution of *F. paludis* in many countries, especially in eastern Europe and the Mediterranean region, can still be much better understood.

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