Bulletin de la Société royale belge d'Entomologie/Bulletin van de Koninklijke Belgische Vereniging voor Entomologie, 149 (2013) : 150-159

Distribution and ecology of soldier fly larvae captured in Flemish surface waters (Diptera : Stratiomyidae)

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Abstract

To assess the ecological water quality in Flanders, macroinvertebrates have been collected by the Flemish Environment Agency (VMM). During the present study, larvae of soldier flies collected between 1997 and 2009 were identified to species level. In total, 722 specimens were identified, belonging to 18 different species. *Oxycera meigenii* Staeger, 1844 and *Oxycera pardalina* Meigen, 1822, two species from calcareous running water, are reported here for the first time from Flanders. Most species were found in waters with a moderate conductivity, however, a few were also found in waters with a high conductivity. Some species were only found at high oxygen levels, but most species also occurred at moderate concentrations. Almost all species were found in small streams, but larger watercourses and lakes also contained several species. Soldier flies were quite rare in macroinvertebrate samples and when present, they occurred at low densities. Most species did not seem to be indicators of (good nor bad) ecological water quality.

Keywords : distribution maps, Flanders, macroinvertebrates, *Oxycera pardalina*, *Oxycera meigenii*.

Samenvatting

Macroinvertebraten werden bemonsterd door de Vlaamse Milieumaatschappij (VMM) voor het beoordelen van de ecologische waterkwaliteit. Tijdens deze studie werden de larven van wapenvliegen die werden gevangen van 1997 tot 2009 tot op soortniveau gedetermineerd. In totaal werden 722 individuen gedetermineerd, die behoorden tot 18 verschillende soorten. *Oxycera meigenii* Staeger, 1844 en *Oxycera pardalina* Meigen, 1822, twee soorten van kalkrijke stromende wateren, worden hier voor het eerst uit Vlaanderen gemeld. De meeste soorten werden gevonden in water met een matige conductiviteit, maar enkele soorten kwamen ook voor bij hoge waarden. Enkele soorten werden enkel waargenomen in water met een hoge zuurstofconcentratie, maar de meeste soorten werden ook gevonden bij matige zuurstofniveaus. Bijna alle soorten werden waargenomen in kleine beken, maar grotere waterlopen en meren bevatten ook verschillende soorten. Wapenvliegen waren vrij zeldzaam in stalen van macroinvertebraten en indien aanwezig was dit in lage aantallen. De meeste soorten leken geen indicatoren voor (goede noch slechte) ecologische waterkwaliteit.

Résumé

Dans le cadre de l'évaluation de la qualité écologique des eaux de surface en Flandre, des macroinvertébrés ont été capturés par la Société flamande pour l'Environnement (VMM). Au cours de cette étude, les larves des Stratiomyidae capturées entre 1997 et 2009 ont été déterminées jusqu'au

niveau de l'espèce. Au total, 722 spécimens appartenant à 18 espèces ont été identifiés. *Oxycera meigenii* Staeger, 1844 et *Oxycera pardalina* Meigen, 1822, deux espèces des eaux courantes calcaires, sont rapportées ici pour la première fois de Flandre. La plupart des espèces ont été trouvées dans des eaux de conductivité modérée, mais quelques-unes étaient aussi présentes dans des eaux de conductivité élevée. Quelques espèces ont été observées seulement dans des eaux bien oxygénées, mais la plupart sont également présentes dans des eaux moyennement oxygénées. Presque toutes les espèces ont été trouvées dans des petites ruisseaux, mais des cours d'eau plus grands et des eaux stagnantes hébergeaient également différentes espèces. Les Stratiomyidae étaient en général assez rares dans les échantillons de macroinvertébrés et lorsqu'ils étaient présents, c'étaient toujours en nombre bas. La plupart des espèces ne semblent pas des indicateurs de (bonne ni mauvaise) qualité écologique.

Introduction

Habitat destruction and degradation, pollution, flow modification and invasion by alien species reduced fresh waters biodiversity much more than most affected terrestrial ecosystems. Flanders has made considerable progress in reducing water pollution from domestic and industrial point sources, however, threats from excessive nutrient enrichment are still present (VMM, 2010) and the number of alien species keeps rising (MESSIAEN *et al.*, 2010). Until present, river management in Flanders has mainly been conducted at the river basin level by installing wastewater treatment plants and imposing standards for effluent concentrations. Although these measures already resulted in a significant improvement of the chemical and ecological water quality since the eighties (VMM, 2010), most Flemish water bodies still lack the good ecological status which is required by 2015 by the European Union Water Framework Directive (WFD) (EUROPEAN COUNCIL, 2000).

Multiple threats affect surface waters in Flanders. Flanders has a very high population density of 456 citizens per km², about 88% of the households is connected to a sewage system, but only 70.3% is actually treated (VMM, 2009). Because rainwater is often not collected separately, untreated water is regularly discharged after heavy rains, resulting in problematic drops in dissolved oxygen concentration and peak levels of substances such as ammonium. Flanders is also heavily industrialised and exhibits (mainly intensive) agriculture on 53% of the land (VMM, 2009). In addition, structural integrity of surface waters is threatened by thousands of weirs that have been built for flood control, hundreds of kilometres of artificial banks that have been installed and the majority of river channels are straightened.

To assess the ecological water quality, the use of biotic indicators (macrophytes, phytoplankton, phytobenthos, fish fauna and macrobenthic fauna) is required by the WFD. The Multimetric Macroinvertebrate Index Flanders (MMIF) was recently developed to meet the requirements of the WFD (GABRIELS *et al.*, 2010). This is a type-specific multimetric index consisting of five equally weighted metrics : taxa richness, the number of EPT-taxa (Ephemeroptera, Plecoptera and Trichoptera), the number of other sensitive taxa, the Shannon-Wiener diversity index and the mean tolerance score.

Soldier fly larvae can be either terrestrial, semi-aquatic or aquatic. Terrestrial larvae can be found under bark, in soil, among dead leaves, in compost, in dung and one species even in ant nests. Semi-aquatic forms occur in moist moss along streams and springs. Aquatic larvae such as *Odontomyia*, *Oplodontha*, *Oxycera* and *Stratiomys* live in stagnant and running waters, especially where there is an abundant growth of floating algae. Larvae have a flattened body and a protruding highly sclerotised head. The two-segmented antennae are usually inconspicuous. The thick cuticle shows a mosaic appearance due to calcareous deposits of calcium carbonate, which enables them to survive during periods of drought, high salinity or moderate pollution. Aquatic larvae often possess a coronet of pinnate float-hairs on the posterior end. Larvae are microphagous : they feed on micro-organisms, algae and periphyton, which they scrape from the substrate with specialised mouthparts. Soldier flies hibernate in the larval stage and emergence occurs in spring or early summer. Pupation takes place in the cuticle of the last larval stage. The distribution of soldier flies in Belgium is still poorly known, as can be deduced from the low number of records for most species (BRUGGE, 2002). During the present

study, the larvae of soldier flies captured by the Flemish Environment Agency were identified to species level and their presence was linked to the measured environmental parameters.

Material and Methods

In the context of water quality monitoring, the Flemish Environment Agency sampled macroinvertebrates at several thousand sampling points. Macroinvertebrates were sampled using a standard handnet as described by GABRIELS *et al.* (2010). A stretch of 10-20 m was sampled for approximately five minutes. Sampling effort was proportionally distributed over all accessible aquatic habitats, including bed substrate (stones, sand or mud), macrophytes (floating, submerging, emerging), immersed roots of overhanging trees and all other natural or artificial substrates, floating or submerged in the water. Each aquatic habitat was explored in order to collect the highest possible richness of macroinvertebrates. For this purpose, kick sampling was performed. In addition to handnet sampling, animals were manually picked from stones, leaves and branches.

Conductivity, dissolved oxygen and pH were measured in the field during each sampling event. Other chemical variables (content of ammonium, nitrite, nitrate, Kjeldahl nitrogen, orthophosphate, total phosphorus, chemical and biological oxygen demand) were retrieved from monitoring data of the chemical water quality, which is also performed by the Flemish Environment Agency. As the chemical monitoring, which is usually performed on a monthly basis, was not performed simultaneously with macroinvertebrate sampling, measurements from the last date before macroinvertebrate sampling were used. The slope of a watercourse was determined based on the difference in height between two points 1000m apart using GIS-software applied on the Flemish Hydrographic Atlas (AGIV, 2006). The same database was used to determine the sinuosity on a stretch of 100m.

The Flemish Environment Agency identifies Diptera larvae only to family level. During the present study, all sampled larvae of soldier flies were identified to species level by using the identification keys developed by ROZKOŠNÝ (1973, 1982, 1983, 2000). A direct gradient analysis was applied to determine which environmental parameters might be responsible for the differences in species composition, since environmental variables were explicitly incorporated in the analysis. To test whether a linear or unimodal method was needed, a Detrended Correspondence Analysis (DCA) was performed (TER BRAAK, 1988). Since the Length of Gradient was greater than four, a unimodal method was needed and therefore, the Canonical Correspondence Analysis (CCA) was applied (TER BRAAK, 1988). A log-transformation (log (x+1)) was applied prior to the CCA to normalise the data. Only the seven most explanatory environmental variables were used for the CCA. *Microchrysa polita*, *Oxycera nigricornis* and *Stratiomys cf. potamida* were not included in the gradient analysis, because these species never co-occurred with other species.

Results

During the present study, 722 soldier flies were identified belonging to 18 different species (Table 1). Two of these, *Oxycera meigenii* and *Oxycera pardalina*, are reported here for the first time from Flanders. *O. meigenii* was encountered on 3.IV.2002 in the Dorenbosbeek in Brakel, on 26.IV.2004 in the Terkleppenbeek in Brakel and on 12.V.2004 in the Voer in Voeren. Larvae of *O. meigenii* can be recognised by the absence of a pair of posterior hooks on the ventral side of the penultimate abdominal segment, the presence of two pairs of thickened setae on the ventral side of the penultimate abdominal segment just above the middle in addition to the usual row of hairs just below the middle and the anal segment being rounded posteriorly (Fig. 1). *O. pardalina* was encountered on four occasions in the forest Hallerbos : on 26.VI.2002 and 9.V.2008 in the stream Kapittelbeek in Beersel and on 13.IV.2004 and 17.IX.2004 in a tributary of the Kapittelbeek in Halle. Larvae of *O. pardalina* can be recognised by the presence of a pair of - not especially long - posterior hooks on the ventral side of the penultimate abdominal segment, the presence of a pair of thickened setae on the ventral side of the penultimate abdominal segment just above the middle in addition to the usual row of hairs just below the middle and the anal segment being longer than the width at its base and has pointed posterolateral angles (Fig. 2).

Stratiomys cf. potamida could not be identified with certainty because it is very similar to *Stratiomys chamaeleon* (Linnaeus 1758) and the diagnostic hairs on the head were damaged.

Table 1. Sampled soldier flies (Diptera : Stratiomyidae), with indication of the number of samples per water type where each species was found.

River type : Catchment area :	Large river 600-10000 km²	Small river 300-600 km²	Large brook 50-300 km²	Large Campine brook 50-300 km²	Small brook < 50 km²	Small Campine brook < 50 km²	Polder water-course Not applicable	Lake Not applicable	Total
Beris clavipes (Linnaeus, 1767)	2	1	5	1	96	5	1	2	113
Chloromyia formosa (Scopoli, 1763)	3	4	2	6	58	8	3	5	89
Microchrysa flavicornis (Meigen, 1822)			1		6	1	1		9
Microchrysa polita (Linnaeus, 1758)	1				1				2
Odontomyia ornata (Meigen, 1822)								3	3
Odontomyia tigrina (Fabricius, 1775)		2	3		7		2	6	20
Oplodontha viridula (Fabricius, 1775)	3	6	2	2	55	3	15	5	91
Oxycera meigenii Staeger, 1844					3				3
Oxycera morrisii Curtis, 1833		3			5			1	9
Oxycera nigricornis Olivier, 1812					1			2	3
Oxycera pardalina Meigen, 1822					4				4
Oxycera trilineata (Linnaeus, 1767)					12		7	2	21
Pachygaster atra (Panzer, 1798)	1	2			17	11	1	1	33
Pachygaster leachii Curtis, 1824			5		11	1			17
Sargus iridatus (Scopoli, 1763)	1		1		8	1	1		12
Stratiomys longicornis (Scopoli, 1763)					2		1	2	5
Stratiomys cf. potamida Meigen, 1822					1				1
Stratiomys singularior (Harris, 1776)					6		3		9
Number of species	6	7	8	3	18	7	10	9	18

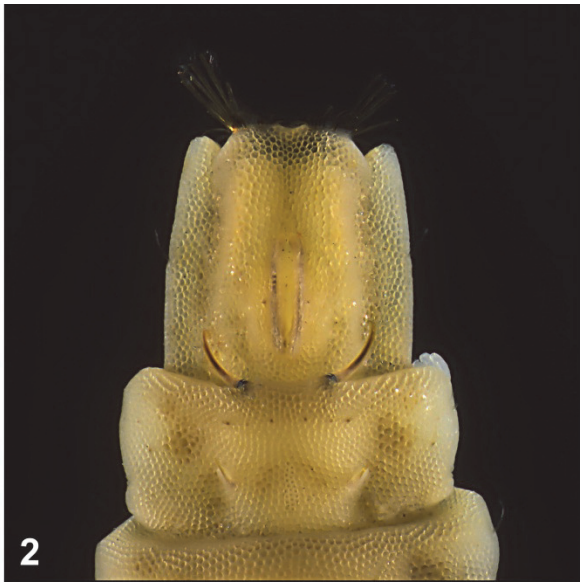


Fig. 1. Ventral side of the posterior end of the abdomen of *Oxycera meigenii* Staeger, 1844 (photograph by Koen Lock).
Fig. 2. Ventral side of the posterior end of the abdomen of *Oxycera pardalina* Meigen, 1822 (photograph by Koen Lock).

However, since the species was found in a small stream, it was considered more likely to be *S. potamida* because *S. chamaeleon* usually lives in stagnant waters.

Of the 443 records, 78% consisted of only one specimen, while in hardly 4%, more than 5 individuals were sampled. Nearly all species were encountered in small brooks, but most species also occurred in larger watercourses or lakes (Table 1). Soldier flies were mostly found in waters with a moderate conductivity (Fig. 3A). Some species such as *Odontomyia tigrina*, *Oplodontha viridula*, *Oxycera trilineata* and *Stratiomys singularior* often occurred in waters with high conductivities. A few

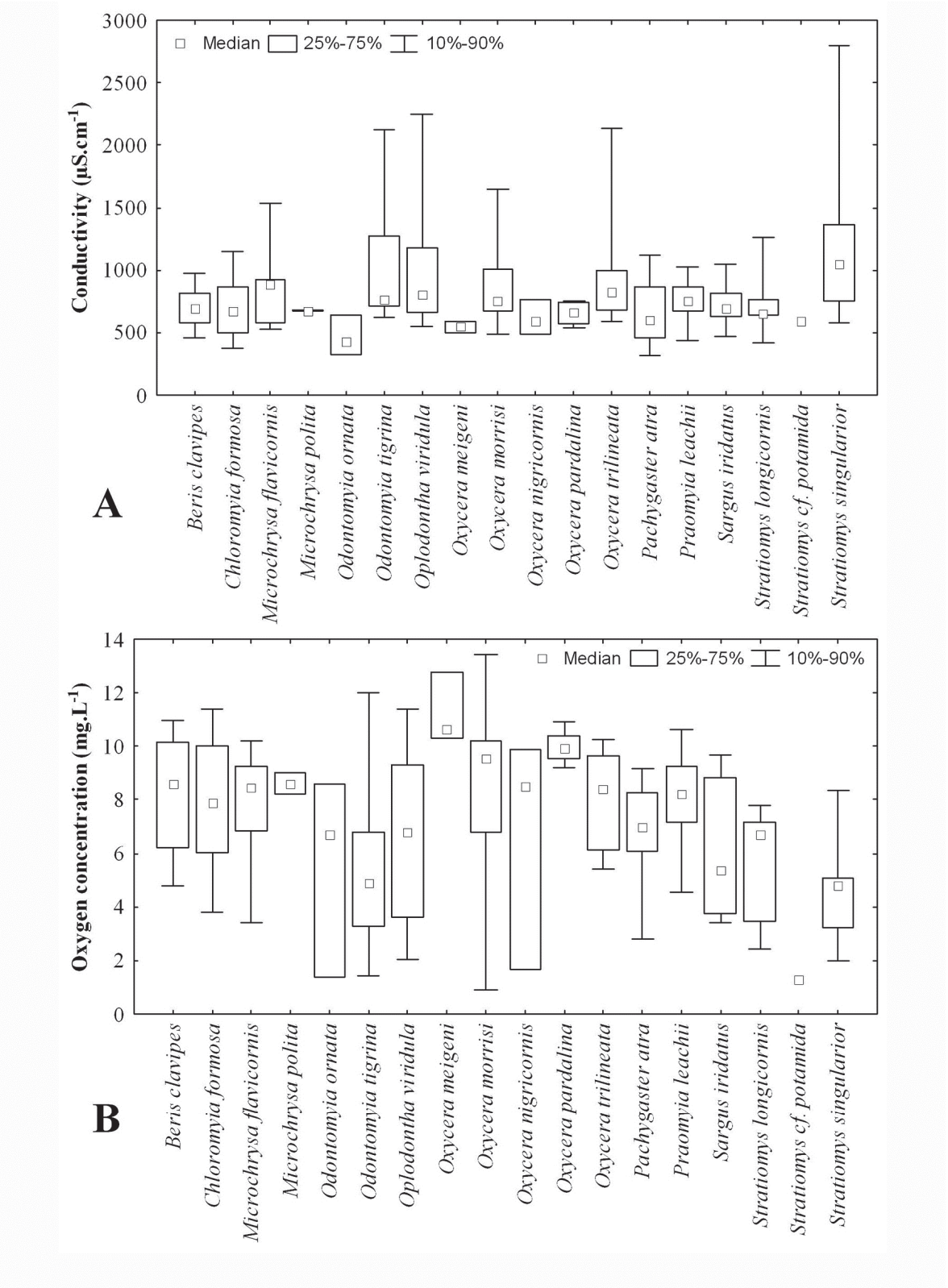


Fig. 3. Box & Whisker plots of the conductivity (A) and the oxygen concentration (B) for the encountered soldier flies.

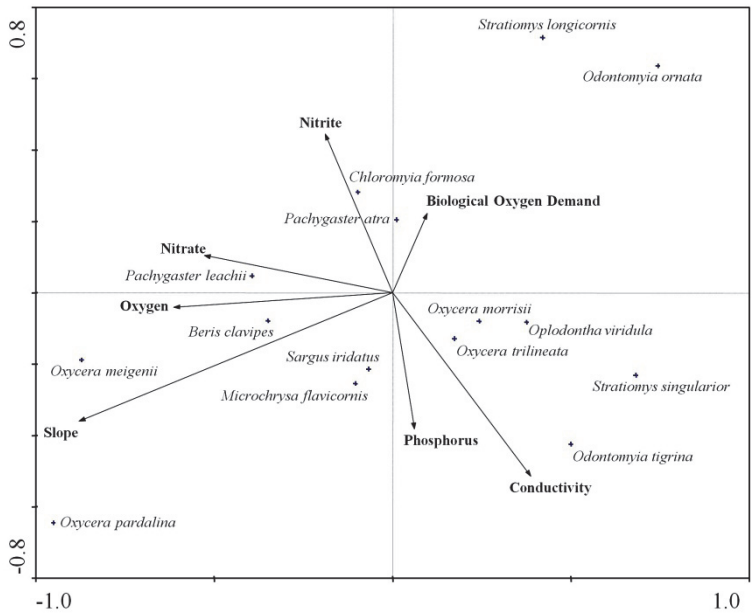


Fig. 4. Canonical Correspondence Analysis biplot of the species scores and the environmental variables biological oxygen demand, conductivity, phosphorus, slope, oxygen, nitrate and nitrite.

species, including *O. pardalina* and *O. meigenii*, were only found in well oxygenated watercourses, however, most species also occurred in waters with lower oxygen concentrations (Fig. 3B).

In the Canonical Correspondence Analysis with the seven most explanatory variables, the first axis (Eigenvalue of 0.30) coincided mainly with high values of conductivity and low values of slope, oxygen and nitrate (Fig. 4). The second axis (Eigenvalue 0.12) coincided mainly with a high values of nitrite and biological oxygen demand and low values of conductivity, phosphorus and slope. Species from running waters, such as *O. meigenii* and *O. pardalina*, were plotted on the left side of the biplot, while stagnant water species from the genera *Stratiomys* and *Odontomyia* were plotted on the right. Distribution maps of the observations of the 18 species encountered in Flanders are presented in Fig. 5.

Discussion

It should be noted that the range of conductivities and oxygen concentrations at which the different species were found (Fig. 3), gives only a reflection of the environmental conditions in their habitat. It is expected that soldier fly larvae are usually not directly affected by the conductivity and the oxygen concentration of the water.

During the monitoring of the ecological water quality by the Flemish Environment Agency, 18 species of soldier flies were sampled. This is only a small portion of the 47 species that have been reported from Belgium (POLLET & GROOTAERT, 1991 ; BAUGNÉE, 2003). This can be explained by the fact that a lot of soldier fly larvae are terrestrial or semi-aquatic, while only a few species are aquatic. MEURISSE *et al.* (2011) reported also larvae of *Oxycera rara* (Scopoli, 1763) from the Flemish stream Schoorbroekbeek in Hoegaarden. The latter species was apparently missed during the sampling of the Flemish Environment Agency. Four rare aquatic species are also known from Flanders, but were not found during the present study : *Odontomyia angulata* (Panzer, 1798), *Odontomyia argentata* (Fabricius, 1794), *Oxycera analis* Meigen, 1822 and *Stratiomys chamaeleon* (Linnaeus, 1758) (BRUGGE, 2002).

Two species are reported here for the first time from Flanders : *O. pardalina* and *O. meigenii*. Both species are associated with aquatic mosses and live along springs with calcareous water (ROZKOŠNÝ, 1983). Both species had previously been recorded from Wallonia and the Netherlands (BRUGGE, 2002) and were also reported from calcareous streams in the southernmost part of the Netherlands (KORSTEN & VAN MAANEN, 2010). Their presence in Flanders could therefore be expected.

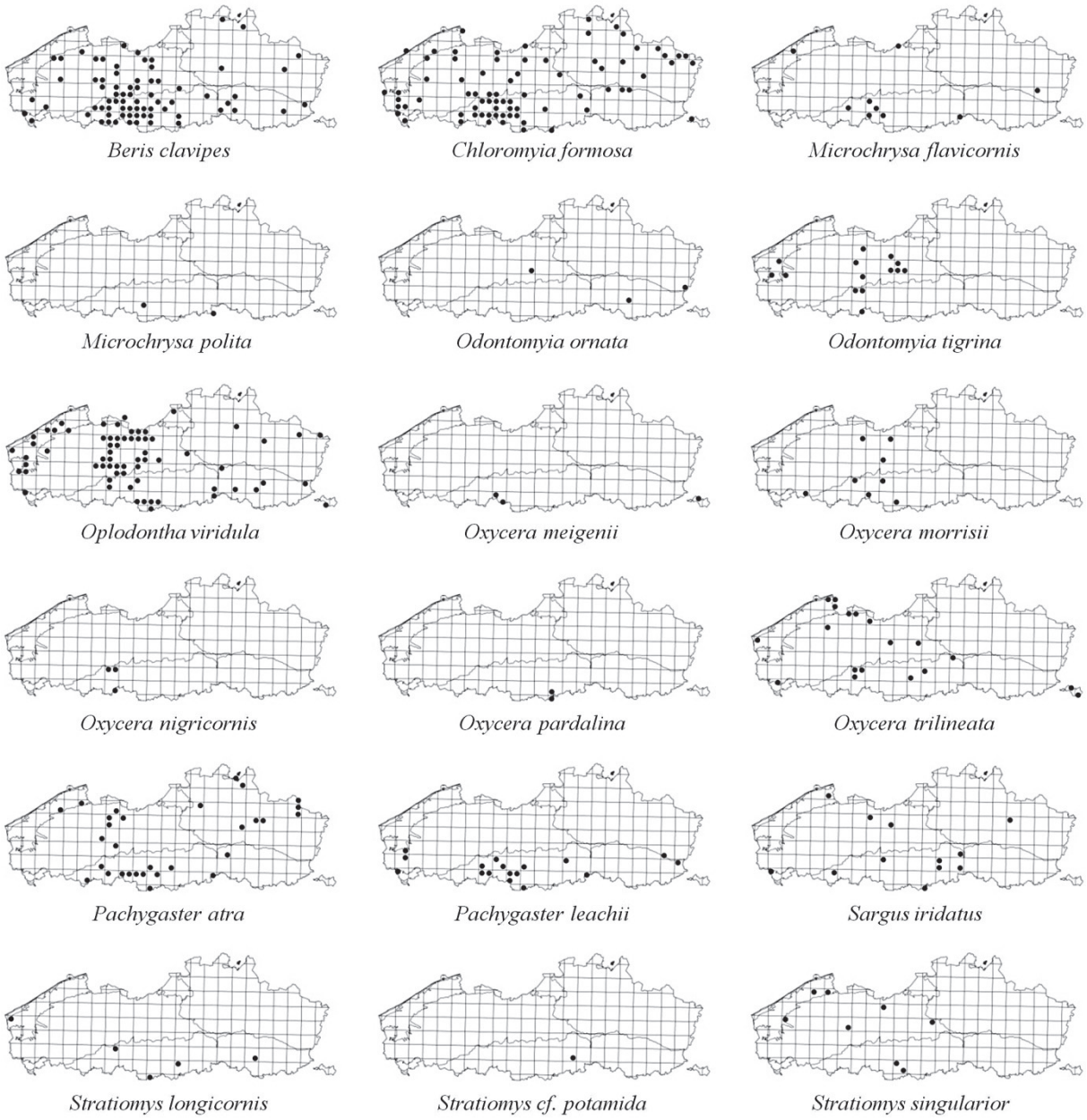
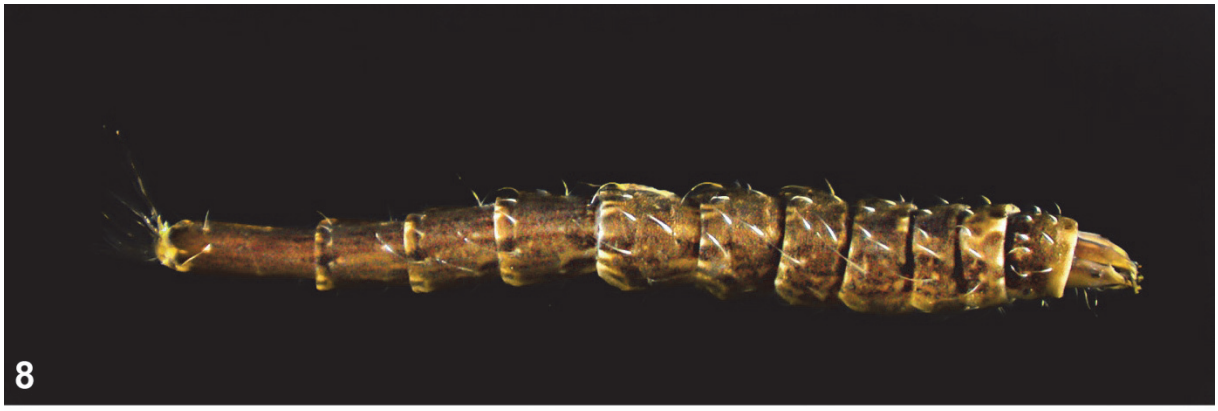


Fig. 5. Distribution of the encountered soldier flies in Flanders, with indication of the ecoregions and a grid of 10x10 km UTM-squares.

O. tigrina and *O. ornata* could not be identified accurately with the existing identification keys (ROZKOŠNÝ, 1973, 1982, 1983, 2000). According to those keys, the penultimate segment of *O. tigrina* does not bear any posterior hooks ventrally. However, during the present study, most specimens bared at least one pair of hooks on the penultimate segment and in most cases also on the segment before that. *O. ornata* can be distinguished by the presence of larger yellow-brown hooks (Fig. 6), while those hooks, if present, are smaller and blackish in *O. tigrina* (Fig. 7). In addition, *O. ornata* is a slender species : the last segment is more than two times as long as wide (Fig. 6), while the last segment is less than two times as long as wide in *O. tigrina* (Fig. 7). However, *O. ornata* can be most easily recognised because it is sparsely covered with long hairs (Fig. 8), while *O. tigrina* is densely covered with short hairs (Fig. 9). Finely, the setae Lb2 are branched in *O. ornata* (Fig. 10), while the setae Lb2 is a simple finely serrated hair in *O. tigrina*. The presence of hooks is not only variable in *O. tigrina* : in the Netherlands, it was found that these hooks were sometimes present in *O. trilineata* as well. Specimens of *O. trilineata* bearing hooks cannot be identified accurately with the existing identification keys, but can still be recognised by the number of thickened setae on the ventral side of the penultimate abdominal segment and the shape of the spiracular plates.



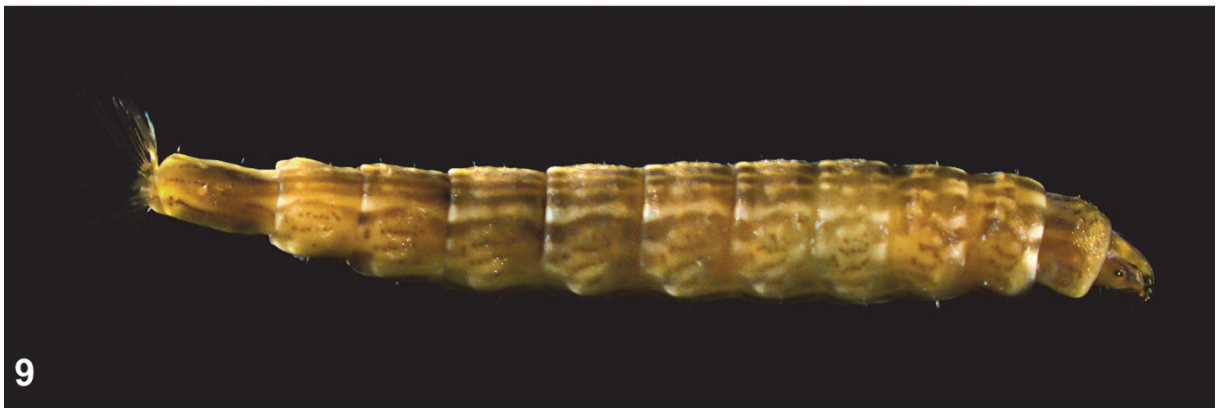


Fig. 6. Ventral side of the posterior end of the abdomen of *Odontomyia ornata* (Meigen, 1822) (photograph by Koen Lock).
Fig. 7. Ventral side of the posterior end of the abdomen of *Odontomyia tigrina* (Fabricius, 1775) (photograph by Koen Lock).
Fig. 8. Habitus of *Odontomyia ornata* (Meigen, 1822) (photograph by Koen Lock).
Fig. 9. Habitus of *Odontomyia tigrina* (Fabricius, 1775) (photograph by Koen Lock).

Fig. 10. Lateral side of the head of *Odontomyia ornata* (Meigen, 1822) with indication of the seta Lb2 (photograph by Koen Lock).

MEURISSE *et al.* (2011) identified the soldier flies sampled during the monitoring of the ecological water quality in Wallonia. They did not found *Microchrysa flavicornis*, *Odontomyia ornata*, *Oxycera meigenii*, *Pachygaster leachii*, *Sargus iridatus*, *Stratiomys potamida* and *Stratiomys singularior*, but instead, they recorded *Beris vallata* (Forster, 1771), *Oxycera leonina* (Panzer, 1798) and *Oxycera rara* (Scopoli, 1763). However, their records of *Sargus bipunctatus* (Scopoli, 1763) and *Odontomyia angulata* (Panzer, 1798) turned out to be misidentified specimens of *Chloromyia formosa* and *Oplodontha viridula*, respectively.

Acknowledgements

We would like to thank the Flemish Environment Agency for the opportunity to study their collections. For the help during the study of the collections, we would like to thank Rose SABLON, Yves SAMYN and Thierry BACKELJAU from the Royal Belgian Institute of Natural Sciences. We thank Cécile Herr for revising the French summary.

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