Acta entomologica serbica, Supplement, 2006, 131-140

UDC 595.77 : 595.771 (4)

NEW RESULTS ON DIPTERA PREDATORS IN THE BLACKFLY PLAGUE AREAS OF CENTRAL EUROPE AND THE CAUCASUS

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ABSTRACT – Between 2002 and 2006, studies were made of the population dynamics and behavior of *Simulium* pest species (Simuliidae) and of the activity and behavior of their natural predators at habitats in Germany, Poland, Serbia, and Armenia. In addition to the Araneae, Hemiptera, Odonata, and Trichoptera, it is principally predaceous species of the Diptera that are able to affect blackfly populations, as larvae, adults, or both. The most important families of predaceous Diptera together with their relevant species are discussed.

KEY WORDS: Diptera, Simuliidae, Europe, predation, predator, prey, natural enemies

INTRODUCTION

The mass emergence of swarming, biting blackflies is a perennial problem in many parts of the world. Attempts at control have included water management (e.g., the damming of large rivers) and the application of chemical and bacterial larvicides. The favored method now is to apply the bacterial larvicide *Bacillus thuringiensis* ssp. *israelensis*, or B.t.i. Questions regarding the development of resistance among the target organisms as well as the effects of B.t.i. on non-target organisms and the food chain have not yet been definitively resolved. So far, the role of the natural predators in the ecosystem has been largely ignored, and for this reason we have focussed our attention on the Diptera predators.

Like all Diptera, Simuliidae have a holometabolous developmental cycle, with egg, larva with 6-9 instars, pupa, and adult (imago). The preimaginal stages are entirely aquatic. Water conditions

which, from a human point-of-view, are unfavorable can lead to a rapid build-up of massive populations and often to a synchronous mass emergence of the adults. This is especially a problem around some of the large lowland rivers in Europe such as the Oder, Wartha, Elbe, and Danube.

Study Area

The work reported here was carried out on a number of lowland rivers in various regions of Armenia, Germany, Poland and Serbia. Several localities in blackfly plague areas were studied. The countries and rivers are listed below:

ARMENIA:

Aragatsotn: Apnaget and Kasakh Rivers Ararat: Argavand Gegharkunik: Argichi and Gavaraget Rivers Kotayk: Hrazdan, Azat, and Marmarik Rivers Vayots Dzor: Arpa River Yerevan: Hrazdan and Jrvezh Rivers

GERMANY: Brandenburg: Oder, Spree, and Neiße Rivers Sachsen-Anhalt: Elbe and Bode Rivers Baden-Württemberg: Danube River

POLAND: Zachodniopomorskie: Oder River Lubuskie: Warta, Oder, and Notec Rivers Dolnośląskie: Warta, Oder, and Notec Rivers

SERBIA: Novi Sad: Danube River Bačka Palanka: Danube River

MATERIAL

The material of predators and their prey was collected and pinned or, depending on the lifestage or the state of preservation, stored in 75% alcohol. It is deposited mainly in the Museum für Naturkunde, Humboldt-Universität zu Berlin, Berlin, Germany.

RESULTS AND DISCUSSION

Blackflies are attacked by a wide variety of organisms, ranging from birds, fishes and mammals at one end of the scale to the tiniest protozoans and nematodes at the other. We must distinguish between predators, which kill their prey for food, and parasites, which only weaken their host indirectly, but generally prevent it from reproducing. All life stages (eggs, larvae, pupae, and adults) are attacked. The most important and effective parasites of blackflies are protozoans, fungi, and

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nematodes, but the predators too may play a significant role in the regulation of populations.

One previously completely overlooked group of predators, but one which may be of some importance, is the Araneae group of the Arachnida. Many spiders are found along watercourses and spin webs across streams and brooks that trap adult black flies. A separate report on this topic is currently being prepared.

Insects from at least nine orders are known to feed on black flies. The most important of these are undoubtedly the caddis flies (Trichoptera). Other orders that have been largely overlooked in this context are the Odonata and the Hemiptera, but in many biotopes these two orders develop large populations that may be able to affect significantly the developmental stages of blackflies. For example, adults of the water measurer Hydrometra stagnorum (Linnaeus, 1758) (Hemiptera: Hydrometridae) seize ovipositing blackfly females and carry them to sheltered spots on the river bank, where they suck them dry undisturbed. Another predaceous bug, Orius minutus (Linnaeus, 1758) (Hemiptera: Anthocoridae), is frequently found in stands of reeds, where it hunts for softbodied insects such as plant lice. It was often observed to seize freshly emerged adults of blackflies as prey, especially Simulium equinum (Linnaeus, 1758). Demonstrating predation by the Odonata on Simuliidae is proving to be extremely difficult. The club-tailed dragonfly Gomphus vulgatissimus (Linnaeus, 1758) (Odonata: Gomphidae) is the only species of the Gomphidae with a flight period in April and May that coincides with the mass occurrence of many blackfly species. At present it is close to extinction in Central Europe (BELLMANN, 1987), but we have been able to show that the nymphs as well as the adults are able to take advantage of the mass occurrence of simuliids as a food resource.

Equally as important as other groups of predators, but under-estimated and certainly underinvestigated, are the Diptera, many of which are obligate predators as larvae, adults or both. In the course of our fieldwork in Europe during the last two years, we have been able to increase the number of Diptera that are known to prey on blackflies to at least 102 species in 14 families, and we have much new information on Muscidae, Anthomyiidae, Empididae, and Dolichopodidae, some examples of which are discussed here.

Muscidae

Within the family Muscidae, the subfamily Coenosiinae is characterized by the fact that all the adults live as predators. The subfamily is divided into two tribes, the Coenosiini and the Limnophorini, and our attention has focussed on the limnophorine genera *Limnophora* Robineau-Desvoidy, *Spilogona* Schnabl, and *Lispe* Latreille. The larvae of many if not all the species in these genera live in aquatic or semi-aquatic habitats, in the same breeding habitats as simuliid larvae, and are also predaceous, attacking the populations of blackfly larvae.

In Armenia we were able to find species of *Limnophora* and *Lispe* at all the simuliid breeding sites that we visited. However, the genus *Spilogona*, which occurs predominantly in more northern or upland latitudes, was not found. *Limnophora patellifera* (Villeneuve, 1911) and *Lispe tentaculata* (De Geer, 1776) were the dominant species, but other species of these genera were also recorded. During our fieldwork in Armenia, the principal predators of the pest species *Simulium equinum* (Linnaeus, 1758) and *Simulium caucasicum* (Rubtsov, 1940) were Muscidae.

In Europe, the widely distributed *Limnophora riparia* (Fallén, 1824) is the most important antagonist of blackfly larvae and adults in numerous biotopes. As we have recently shown (WERN-

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ER AND PONT, 2006), we have been able to clarify many of the ecological requirements of this species, its mating and hunting strategies, and its adaptations to the occurrence of simuliid populations.

In the course of our work in Armenia, we found another active predator in the same group as *Limnophora riparia*, namely *Limnophora patellifera* (Villeneuve, 1911) (Fig. 1). This is an extremely little-known species, with no information available on its habitat requirements and biology. Its hunting behavior and feeding patterns resemble those of *Limnophora riparia*, and at one site we found it to be a vigorous predator of exposed pupae of *Simulium caucasicum*.



Fig. 1. *Limnophora patellifera* (Villeneuve), male and female feeding on a larva of *Obuchovia popowae* (Rubtsov) (Photo: WERNER 6/ 2005).

Among the species of the genus *Lispe* that we have studied, *Lispe consanguinea* Loew, 1858 is an abundant species along the Oder River in Germany. Here too we were able to study its predatory relationship with the simuliid populations and also to record previously unknown details on mating behaviour, oviposition and immature stages (WERNER AND PONT, 2006).

In the areas where we have been working, the following 13 species of the Limnophorini have now been found to be active predators of black flies:

Limnophora maculosa (Meigen, 1826) Limnophora pandellei Séguy, 1923 Limnophora patellifera (Villeneuve, 1911) Limnophora pollinifrons Stein, 1916 Limnophora riparia (Fallén, 1824) Limnophora tigrina (Am Stein, 1860) Limnophora triangula (Fallén, 1825) Lispe consanguinea Loew, 1858 Lispe pygmaea Fallén, 1825 Lispe tentaculata (De Geer, 1776) Spilogona falleni Pont, 1984 Spilogona solitariana (Collin, 1921) Spilogona surda (Zetterstedt, 1845)

These species are particularly abundant in those habitats where the mass development of blackflies takes place, and their own development and immature stages take place within these same habitats. *Limnophora* species require accumulations of moss and algae on the stream bed for oviposition, whereas *Lispe* species require pebbly or muddy sand along rivers or stream margins.

Anthomyiidae

In our review of the Diptera predators of blackflies (WERNER AND PONT, 2003), we were not able to establish any connection between predaceous species of Anthomyiidae and blackfly populations. Since then we have found four species of this family as active and abundant predators of simuliids:

Alliopsis new species *Hydrophoria annulata* (Pandellé, 1899) *Hydrophoria lancifer* (Harris, 1780) *Zaphne divisa* (Meigen, 1826)

Particularly interesting was the discovery of a new species of the predaceous genus Alliopsis Schnabl and Dziedzicki in Armenia, which we were able to observe in huge numbers attacking larvae of Prosimulium petrosum Rubtsov, 1955 (ACKLAND AND WERNER, in press). One fascinating aspect of this was the "co-operative" hunting strategy of the flies. With Limnophora, for example, it is individual flies that overpower and capture the blackfly larvae or adults. It happens occasionally that a second male or female will approach the feeding fly and sometimes be tolerated, but more usually driven away. Anthomyids of the genera Zaphne Robineau-Desvoidy and Hydrophoria Robineau-Desvoidy follow this pattern of behaviour. With the new Alliopsis (Fig. 2), on the other hand, it is usually the case that several flies will together detach a simuliid larva and then transport it to a spot away from the splash zone. We observed them to capture the preimaginal stages of Simuliidae and Chironomidae found in the main current of the Arpa River, on large rocks and on boulders that had fallen from the adjacent cliffs. Of the Simuliidae, there were large populations of Prosimulium petrosum and larvae of the Simulium (Wilhelmia) group. Unlike the situation in other rivers and among other species, the larvae and pupae were found in the splash zone and in areas of river turbulance, attached to rocks and boulders that lay facing away from the main current. Larvae and pupae covered the surface of the rocks in these zones like a carpet. Males and females of the new Alliopsis were observed catching and sucking on living larvae of Simuliidae. The predatory flies were abundant and in large numbers on most of the boulders and stones, and it is surprising that feeding by adult anthomyids on living simuliid prey has never been observed previously. The Alliopsis walk around on the rocks and down towards the water, to the splash zone and the water surface, or run around on the rocks to which Prosimulium larvae are attached and pull larvae out of the deeper splash zone and out of the water. Even when the larva struggles violently, they all begin to feed together from different places. The adult *Alliopsis* pierce the body of the larva with their mouthparts, thrust their proboscis into the larval body and suck out the contents in the company of other intruding flies of the same species, as is known to take place in species of Muscidae such as Limnophora riparia (Fallén, 1824) or Lispe tentaculata (De Geer, 1776) (WERNER AND PONT, 2006).

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Fig. 2. *Alliopsis* spec. nov., females feeding on a larva of *Prosimulium petrosum* Rubtsov (Photo: WERNER 6/2005).

Empididae

The number of 29 species of Empididae that are active predators of blackflies has been substantially increased by our collections in 2005 and 2006. Some brief results are given here of studies on species that are associated with blackfly populations in Central Europe. All adult Empididae are predaceous, and in the huge genera *Empis* Linnaeus, *Rhamphomyia* Meigen, and *Hilara* Meigen, the male captures and presents a "wedding gift" to the female which consumes it during copulation.

The two most abundant species during our investigations were *Rhamphomyia crassirostris* (Fallén, 1816) and *Hilara maura* (Fabricius, 1776). They were present at all localities and sometimes formed up to 98% of the individuals caught with simuliid prey. Because of this association with the mass occurrence of simuliid populations, we were once again able to clarify many details in their behavior and biology.

Other species of *Hilara* were observed, about which no biological information was known. Females and males of these species swarm together in shaded habitats beneath alder bushes. It is known that the males of many species of *Hilara* gather debris off the water surface for their wedding gifts. At our study site in Germany, however, some *Hilara* species captured only live prey. In this case, the prey species was *Simulium equinum* (Linnaeus, 1758).

Many species of Simuliidae also swarm and copulate beneath or alongside the river bank. Their favourite markers are willows. The males of *Rhamphomyia crassirostris* catch their prey while swarming under willow trees on the river bank and immediately present it to a female that is ready to mate. They only mate in flight, and do not settle on vegetation as do other Empididae. At some sites, Simuliidae formed 100% of the prey that we recorded, although Chironomidae, other Empididae, Muscidae, and also Ephemeroptera were swarming in the same habitat.

Diptera predators in Central Europe and the Caucasus



Fig. 3. *Wiedemannia* spec., female feeding on a larva of *Simulium caucasicum* Rubtsov (Photo: WERNER 6/2005).

In 2004 we made the observation that certain species of the subfamily Clinocerinae are commonly found on masses of simuliid eggs. We now know that these species, mainly belonging to the genus *Wiedemannia* Zetterstedt (Fig. 3), target blackfly eggs and early larval instars for their prey. We have been able to demonstrate this in Europe and in Armenia.

Dolichopodidae

We have found 15 species of Dolichopodidae belonging to the following seven genera to be active as predators of Simuliidae:

Argyra Macquart Dolichopus Latreille Gymnopternus Loew Liancalus Loew Nodicornis Rondani Rhaphium Meigen Sybistroma Meigen

The adults all follow the same pattern of behavior: they run around in the splash zone where they suck out the eggs. They often also capture larvae (Fig. 4) and take them outside the splash zone to suck. We found the species *Liancalus virens* (SCOPOLI, 1763) commonly associated with black-fly populations in both England and Armenia.

Scathophagidae

When we have referred to "feeding", we mean in every case that strong teeth at the tip of the fly's proboscis puncture the victim's cuticle, the proboscis is then inserted into the body and the

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Fig. 4. Argyra spec., female feeding on a larva of Simulium variegatum Meigen (Photo: WERNER 6/2004)

internal contents of the victim are liquified and ingested. The feeding strategy of the European scathophagid *Hydromyza livens* (Fabricius, 1794), which completely dismembers its simuliid prey, is quite different from this and is unique among Diptera predators. WERNER, MANN AND PONT (2006) have given a detailed account of the prey capture and feeding behavior of this species. The typical breeding habitats of *Hydromyza livens* are rivers with moderate flow velocity and margins lined with water lilies. The flies run around on the leaves of these plants and seize freshly emerged simuliid adults that gather there to harden.

CONCLUSIONS

These tabular overviews show that our work so far has added more than 50 species to the list of known Diptera predators of blackfly populations. Further investigations are planned and are necessary in order to draw detailed conclusions about the influence of predators on blackfly populations and to evaluate their potential role as biological antagonists within possible integrated biocontrol programs.

ACKNOWLEDGEMENTS

We would like to thank the many dipterists and specialists without whose generous collaboration our work would not have been able to progress: D. M. Ackland (Bridport, UK), Professor P. H. Adler (Clemson, USA), D. J. Henshaw (Waltham Abbey, UK), Dr M. Pollet (Brussels, Belgium), Dr B. J. Sinclair (Bonn, Germany), and Dr H. Ulrich (Bonn, Germany).

Tab. 1. Observations on Dipteran predators of Simuliidae (numbers in parentheses indicate new records, some of which are still unpublished). PA = Palaearctic, AF = Afrotropical, OR = Oriental, AU = Australasian/Oceanian, NE = Nearctic, NO = Neotropical.

Diptera	Number of observations per zoogeographic region								
family									
	PA	AF	OR	AU	NE	NO	total		
Nematocera:									
Chaoboridae	1	0	0	0	1	0	2		
Chironomidae	12 (2)	3	0	3	6	2	28		
Limoniidae	(17)	0	0	0	0	0	17		
Ceratopogonidae	1	0	0	0	0	1	2		
Brachycera: Orthorrhapha									
Asilidae	7 (10)	0	0	0	23	8	48		
Empididae	18 (306)	1	0	1	29	2	357		
Hybotidae	0	0	0	0	3 (1)	0	4		
Dolichopodidae	2 (90)	0	0	0	5	0	97		
Brachycera: Cyclorrhapha									
Phoridae	1 (2)	0	1	0	0	0	4		
Ephydridae	(9)	2	0	0	1	0	12		
Drosophilidae	0	7	0	0	0	0	7		
Scathophagidae	4 (41)	0(1)	0	0	0	0	46		
Anthomyiidae	0 (25)	0	0	0	0	0	25		
Muscidae	7 (221)	12(1)	0	0	0	0	241		

Tab. 2. Numbers of Diptera species that predate on Simuliidae (numbers in parentheses indicate new records, some of which are still unpublished). PA = Palaearctic, AF = Afrotropical, OR = Oriental, AU = Australasian/Oceanian, NE = Nearctic, NO = Neotropical.

Diptera	Number of predator species per zoogeographic region							
family								
	PA	AF	OR	AU	NE	NO	total	
Nematocera:								
Chaoboridae	1	0	0	0	1	0	2	
Chironomidae	7(1)	2	0	1	4	1	16	
Limoniidae	(1)	0	0	0	0	0	1	
Ceratopogonidae	1	0	0	0	0	1	2	
Brachycera: Orthorrhapha								
Asilidae	4(1)	0	0	0	13	4	22	
Empididae	15 (12)	1	0	1	15	1	45	
Hybotidae	0	0	0	0	3 (1)	0	4	
Dolichopodidae	2 (16)	0	0	0	4	0	22	
Brachycera: Cyclorrhapha								
Phoridae	1 (2)	0	1	0	0	0	4	
Ephydridae	(1)	1	0	0	1	0	3	
Drosophilidae	0	4	0	0	0	0	4	
Scathophagidae	3 (1)	0(1)	0	0	0	0	5	
Anthomyiidae	0 (4)	0	0	0	0	0	4	
Muscidae	2 (8)	3 (1)	0	0	0	0	14	

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