**P O L I S H J O U R N A L O F E N T O M O L O G Y**
P O L S K I E P I S M O E N T O M O L O G I C Z N E

VOL. **87**: 191–197 Lublin 30 June 2018
DOI: 10.2478/pjen-2018-0014

# Observations of female and mixed sex swarming behaviour in *Culicoides* LATREILLE, 1809 (Diptera: Ceratopogonidae)

CARSTEN KIRKEBY*

Faunaphotonics, c/o Copenhagen Bioscience Park, Ole Maaloeesvej 3,
DK-2200 Copenhagen N, Denmark

**ABSTRACT**. Female swarming behaviour has rarely been described in *Culicoides*. Previous records of female swarms have only been described for females swarming in mixed swarms together with males. Two new observations of *Culicoides* swarms in Sweden are described here: a mixed swarm with females of *Culicoides obsoletus* / *gornostaevae* and males of *C. gornostaevae*, and a purely female swarm of *C. impunctatus*. Swarming behaviour can facilitate predator confusion. Swarming behaviour is therefore an evolutionary advantage that can explain mixed species swarms and purely female swarms.

**KEY WORDS**: *Culicoides gornostaevae*, *Culicoides obsoletus*, *Culicoides impunctatus*, mixed swarming, female swarming, biting midges.

## INTRODUCTION

Much research has focused on the flight behaviour and spatial distribution patterns of *Culicoides* LATREILLE, 1809 (Diptera: Ceratopogonidae) because of their ability to transmit diseases between animals and humans (e.g. MELLOR et al. 2000, CLAUSEN et al. 2009). A large range of other aspects, such as the indoor activity patterns of *Culicoides* (BALDET et al. 2006), preferred bloodmeal hosts (LASSEN et al. 2012) and descriptions of new *Culicoides* species (NIELSEN et al. 2015) have also been covered. However, some behavioural features of such species are still largely untouched, for instance, their swarming behaviour. Many species of Diptera form swarms for mating, especially males, but female

* Corresponding author: ckirkeby@gmail.com

swarming in *Culicoides* has rarely been described in the literature. In 1955, DOWNES reported observations of swarming behaviour in *C. nubeculosus* (MEIGEN, 1830), *C. riethi* (KIEFFER, 1914), *C. punctatus* (MEIGEN, 1804), *C. halophilus* (KIEFFER, 1924), *C. delta* (EDWARDS, 1839), *C. pulicaris* (LINNAEUS, 1758), *C. grisescens* (EDWARDS, 1830) and *C. pallidicornis* (KIEFFER, 1919). Downes also described a swarm of female *C. obsoletus* (MEIGEN, 1818) gathering near eaves but speculated that this behaviour was only seen in relation to females attacking a host. That author concluded that the function of swarming was purely sexual and that males formed swarms in order to attract females for mating. The same study also demonstrated that male swarms could be induced by placing dark objects against a light background such as a road: the males used the contrasts to help navigate their flight within the swarm. DZHAFAROV (1976) described male swarms as forming, before the appearance of females, in "aggregate flights" prior to attacking hosts. That author also mentioned that mixed swarms of males and females were often found near breeding sites, hosts or human buildings. GLUKHOVA & DUBROVSKAYA (1974) described swarms of male *Culicoides* that could comprise up to three different species. The male swarms were observed to attract females for mating. Swarming behaviour near conspicuous objects was also described for *C. brevitarsis* (KIEFFER, 1917) by CAMPBELL & KETTLE (1979). GLUKHOVA (1989) described mixed sex swarming and stated that swarms were found mostly near breeding sites and hosts. In a later study, BLACKWELL et al. (1992) described observations of male swarming behaviour in *C. impunctatus* GOETGHEBUER, 1920 and stated that no mixed swarms involving other species were found. MIRZAEVA (2000) described observations of swarms of *Culicoides* males that sometimes contained a few females. GONZALEZ et al. (2017) investigated 15 swarms of *Culicoides* in northern Spain but found only one female, engaged in copulation with a male.

In the present study, two observations of *Culicoides* swarming behaviour including females were made. Both purely female swarming and mixed swarming was observed; the findings are discussed in relation to previous observations.

## MATERIAL AND METHODS

**First swarm observation**

On 7 June 2014, from 21:00 to 21:30 hrs, I was walking along a roadside in Vivljunga, southern Sweden (GPS coordinates: N56.58501, E13.48143), when I noticed that the density of biting midges had suddenly increased dramatically in a very small area. A swarm of biting midges was hovering at a height of about 1 to 2 m above the ground over an area of about 3 x 3 m. The roadside vegetation consisted of diverse flowering plants, the most abundant of which were 10 to 30 cm tall grasses, lupin (*Lupinus* sp.) and umbellifers

(Apiaceae). The midges were swarming right next to a young, 3 m tall oak tree by the roadside, and about 100 m from a potential breeding site for *C. impunctatus* containing *Sphagnum* sp. There was no wind and the temperature was ca. 20 °C. The sky was cloudless and still sunlit, but the surrounding forest was blocking direct sunlight. By my estimate, the swarm comprised 200-300 individuals, most easily seen against the clear blue sky as I was lying on my back in the grass. I took a sample of the swarm with a pooter (both of flying specimens and of specimens that landed on my body). This was clearly swarming behaviour, because the density of *Culicoides* was a lot higher at that site than, for example, on the other side of the road, or on the same side just 10 m away. By leaving the site and coming back three times, I was able to establish that the swarm remained in the same place, independent of the human host, thus indicating that it consisted of a eurygamic species. I investigated the same site on the following evening at the same time under similar weather conditions, but found no swarm.

**Second swarm observation**

On 14 July 2017, I observed a swarm of *Culicoides* just below the eaves of a wooden house in Vivljunga, Sweden in the dusk at 21:30 hrs (GPS coordinates: N56.589330, E13.489836). The swarm had clearly formed before I (a potential host) had arrived, so could not have been induced by the presence of a host. The temperature was 15 °C and the swarm had formed in the shadow of the eaves. It presumably comprised a few hundred specimens gathered in a small volume of air with a spherical shape approximately 75 cm in diameter. The individual flight routes within the swarm were irregular, and my presence nearby did not affect the swarming behaviour. I took a sample from the swarm by quickly and repeatedly moving my wetted hand through the swarm. During this sampling procedure the swarm rapidly dispersed, but reformed after about 10 s. I visited the same location on subsequent evenings but observed no swarms. A video of this swarm observation is available on youtube (https://youtu.be/DT9Hy3xu9cE), or upon request from the author.

## RESULTS

The sample taken from the first swarm contained 28 female *C. obsoletus* and four male *C. gornostaevae* (MIRZAEVA, 1984) (See KIRKEBY & DOMINIAK 2014). The female specimens of *C. obsoletus* were identified based on the wing pattern, lack of interfacetal hairs (distinguishing them from *C. chiopterus* (MEIGEN, 1830)) and the shape of the maxillary palps (DELECOLLE 1985, NIELSEN & KRISTENSEN 2011). However, the identifications of the females of *C. obsoletus* are doubtful and cannot with certainty be distinguished from *C. gornostaevae* (KIRKEBY & DOMINIAK 2014). The female *C.*

*obsoletus* were host-seeking and thus bit the observer. No swarm was found in the same place on the following evening.

A total of 54 specimens were obtained in the sample from the second swarm. Specimens were identified by wing morphology using a Reicher microscope according to DELECOLLE (1985). All the specimens in the second swarm were female *C. impunctatus*.

## DISCUSSION

From the observations described here it appears that purely female swarms and swarms with both sexes can occur, independently of the presence of hosts. As shown by OLSON et al. (2013) using computer simulation models, predatory confusion created by swarming individuals is a clear evolutionary advantage that can cause selective pressure towards swarm formation. Swarming can therefore function as protection against predators, in which case it is also beneficial for different species, or even purely females, to swarm together. DOWNES (1955) described this predatory pressure for swarms of *Culicoides* where predaceous flies entered the swarms and caught single individuals. Furthermore, DOWNES (1955) found several females of "other species" in samples from mainly male *C. grisescens* swarms and concluded that they were probably hunting the observer. The observations described in the present study suggest that female swarming as well as mixed swarming with both different sexes and species can occur and thus DOWNES (1955) might actually have observed mixed species swarming.

Evolutionary selective pressure for swarming behaviour can also explain why swarms of purely females occur. Another explanation for purely female swarms could be the lack of males in an area. SULLIVAN (1981) briefly mentions female swarming behaviour, noting that: "female swarms resulted from a deficiency of males, so that swarming females competed for males and became less discriminating and more aggressive in initiating pair formation." It seems plausible that a local depletion of males could result in female swarms.

It is well known that males of mosquitoes and biting midges perform swarming flights (DOWNES 1969, ZIMMERMAN et al. 1982). However, swarms of females are rarely described. One of the reasons for this is perhaps that it is very difficult to make undisturbed observations of female *Culicoides* because many species will try to blood-feed on the observer, preventing unbiased observations. BLACKWELL et al. (1992) studied the swarming behaviour of *C. impunctatus* and found that the mean female:male ratio within the swarms was 1:9.5, and summarized previous findings of ratios of 1:77 for *C. brevitarsis* and 1:167 for *C. variipennis* (COQUILLETT, 1901). ZIMMERMAN et al. (1982) found this ratio for a swarm of *C. variipennis* to be 1:167. In the first *C. impunctatus* swarm described here this

ratio was 7:1, but likely with males of another species, *C. gornostaevae*. In the second swarm described here, no males at all were found.

During the sampling procedure of the second observed swarm described here, the swarm dispersed, but reformed after about 10 s, in agreement with BLACKWELL et al. (1992). This behavioural trait could indicate an evolutionary advantage for biting midges to be in a swarm, even though it is interrupted by a possible predator. In the second swarm observation described here, the flight patterns of the female *C. impunctatus* were similar to the patterns described by BLACKWELL et al. (1992). Neither of the two observed swarms described here were found again in the same location on the following evening, supporting previous observations where the abundance of *Culicoides* was spatially clustered in different locations on different nights (KIRKEBY et al. 2013). This volatile nature of swarming behaviour could be an evolutionary advantage, preventing predators from predicting swarming locations.

In order to discover more about the swarming behaviour of *Culicoides*, more observations like the ones described here are needed. The technique for inducing swarms as described by DOWNES (1955) is a suitable tool for obtaining more such observations.

## CONCLUSION

Two observations of *Culicoides* swarms are described, one with both sexes and one with only female specimens: they seemed to be independent of host presence and breeding sites.

## ACKNOWLEDGEMENTS

The author wishes to thank Patrycja DOMINIAK for her identification of the *C. gornostaevae* specimens, and also Andrey PRZHIBORO, Natalia BRODSKAYA, Serhii FILATOV and Magdalena LARSKA for their help with the references.

## REFERENCES

BALDET T., DELÉCOLLE J.C., CÊTRE-SOSSAH C., MATHIEU B., MEISWINKEL R., GERBIER G. 2008. Indoor activity of *Culicoides* associated with livestock in the bluetongue virus (BTV) affected region of northern France during autumn 2006. Preventive Veterinary Medicine **87**(1): 84–97.

BLACKWELL A., YOUNG M.R., MORDUE W. 1992. The swarming behaviour of the Scottish biting midge, *Culicoides impunctatus* (Diptera: Ceratopogonidae). Ecological Entomology **17**(4): 319–325.

CAMPBELL M.M., KETTLE D.S. 1979. Swarming of *Culicoides brevitarsis* KIEFFER (Diptera: Ceratopogonidae) with reference to markers, swarm size, proximity of cattle, and weather. Australian Journal of Zoology **27**(1): 17–30.

CLAUSEN P.H., STEPHAN A., BARTSCH S., JANDOWSKY A., HOFFMANN-KÖHLER P., SCHEIN E., MEHLITZ D., BAUER B. 2009. Seasonal dynamics of biting midges (Diptera: Ceratopogonidae, *Culicoides* spp.) on dairy farms of Central Germany during the 2007/2008 epidemic of bluetongue. Parasitology Research **105**(2): 381–386.

DELÉCOLLE J.C. 1985. Nouvelle contribution à l'étude systématique et iconographique des espèces du genre *Culicoides* (Diptera: Ceratopogonidae) du Nord-Est de la France. Thèse Université Louis Pasteur Strasbourg.

DOWNES J.A. 1955. Observations on the swarming flight and mating of *Culicoides* (Diptera: Ceratopogonidae). Ecological Entomology **106**(5): 213–236.

DOWNES J.A. 1969. The swarming and mating flight of Diptera. Annual Review of Entomology **14**(1): 271–298.

DZHAFAROV S.M. 1976. Biting midges (Diptera, Heleidae) of Transcaucasus (morphology, biology, ecology, geographical distribution, and harmfulness, control, fauna of the genera *Culicoides*, *Leptoconops* and *Lasiohelea*). Academy of Science of Azerbaijan, Baku.

GLUKHOVA V.M. 1989. Blood-sucking midges of the genera *Culicoides* and *Forcipomyia* (Ceratopogonidae). Nauka, Leningrad. (in Russian)

GLUKHOVA V.M., DUBROVSKAYA V.V. 1974. On the swarming flight and mating in bloodsucking biting midges (Diptera, Ceratopogonidae). Parasitologiya **8**(5): 432–437.

GONZALEZ M.A., ALARCÓN-ELBAL P.M., VENTER G.J., LÓPEZ S. 2017. Flight and swarming behaviour of Culicoides species (Diptera: Ceratopogonidae) on a livestock farm in Northern Spain. Veterinaria *Italiana* **53**(2): 157–166.

KIRKEBY C., BØDKER R., STOCKMARR A., LIND P. 2013. Spatial abundance and clustering of *Culicoides* (Diptera: Ceratopogonidae) on a local scale. Parasites & Vectors **6**(1): 43.

KIRKEBY C., DOMINIAK P. 2014. *Culicoides* (*Avaritia*) *gornostaevae* MIRZAEVA, 1984 (Diptera: Ceratopogonidae) – a possible vector species of the *Obsoletus* group new to the European fauna. Parasites & Vectors **7**(1): 445.

LASSEN S. B., NIELSEN S.A., KRISTENSEN M. 2012. Identity and diversity of blood meal hosts of biting midges (Diptera: Ceratopogonidae: *Culicoides* LATREILLE) in Denmark. Parasites & Vectors **5**(1): 143.

MELLOR P.S., BOORMAN J., BAYLIS M. 2000. *Culicoides* biting midges: their role as arbovirus vectors. Annual review of entomology **45**(1): 307–340.

MIRZAEVA A.G. 2000. Concerning Swarming of Males of Blood-Sucking *Culicoides* from Subgenus *Avaritia* (Ceratopogonidae). Sibirskii Ekologicheskii Zhurnal **4**(4): 419–423. (in Russian)

NIELSEN S.A., KRISTENSEN M. 2011. Morphological and molecular identification of species of the *Obsoletus* group (Diptera: Ceratopogonidae) in Scandinavia. Parasitology Research **109**(4): 1133–1141.

NIELSEN S.A., KRISTENSEN M., PAPE T. 2015. Three new Scandinavian species of *Culicoides* (Culicoides): *Culicoides boyi* sp. nov., *Culicoides selandicus* sp. nov. and *Culicoides kalix* sp. nov. (Diptera: Ceratopogonidae). Biodiversity Data Journal **3**: e5823.

OLSON R.S., HINTZE A., DYER F.C., KNOESTER D.B., ADAMI C. 2013. Predator confusion is sufficient to evolve swarming behaviour. Journal of The Royal Society Interface **10**(85): 20130305.

SULLIVAN R.T. 1981. Insect swarming and mating. The Florida Entomologist **64**(1): 44–65.

ZIMMERMAN R.H., BARKER S.J., TURNER JR E.C. 1982. Swarming and mating behavior of a natural population of *Culicoides variipennis* (Diptera: Ceratopogonidae). Journal of Medical Entomology **19**(2): 151–156.

Received: 4 January 2018
Accepted: 23 February 2018