Biting midges (*Culicoides* spp.)

General Information

Figure 1: A biting midge, *Culicoides sonorensis*, collected from a southern California dairy. Photo by Xinmi Zhang, University of California Riverside (UCR).

Biting midges are a group of widely distributed, small biting flies in the genus *Culicoides* (Diptera: Ceratopogonidae) (Figure 1). They are also known as gnats, punkies, or no-see-ums. These flies can be a biting nuisance to humans and animals, and they can transmit several animal viruses of concern to cattle, sheep, deer, and horses. Biting midge species exhibit different host preferences. Many species bite large mammals, while others prefer small mammals, birds, or even reptiles. A few species are general or opportunistic feeders and will bite a wide range of animals. Despite their small size, these midges can give painful bites as they tear through host skin to feed on a pool of blood.

Identification and Life History

There are more than 1,400 biting midge species. Adult biting midges are 1-3 mm in size, and most species have wings with a pattern of dark and pale spots (Figure 2), though a few *Culicoides* lack this wing patterning and may be confused with closely related biting flies in the genus *Leptoconops*. However, *Culicoides* can be separated from *Leptoconops* by the presence of an R-M crossvein in the wing (Figure 2) and by having palps with five segments rather than four (Figure 3).

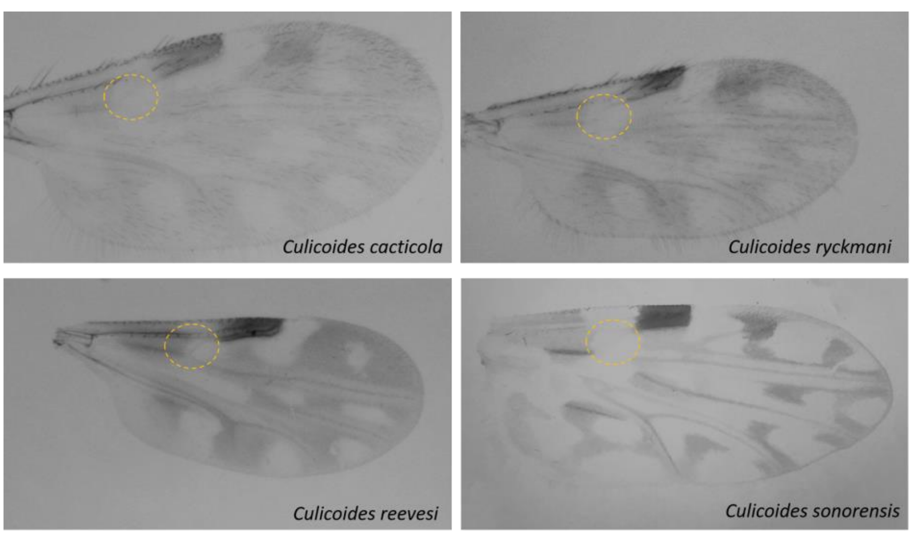

Figure 2: Wing patterns of four biting midge species that live in the southeastern desert region of California. Dashed circles indicate the R-M crossvein on the *Culicoides* wing. Photo by Xinmi Zhang, UCR.

Like all flies, biting midges undergo complete metamorphosis with egg, larva, pupa, and adult stages. The complete life cycle can take from 2-12 weeks depending upon midge species and the environmental temperature. Immature biting flies develop in a variety of organically enriched aquatic to wetted habitats including marshes, bogs, tree holes, rotting plants, manure ponds, piled animal manure, or wet soil. Larvae are vermiform and move with lateral undulation like snakes, including when swimming in open water. Biting midges graze on algae, detritus, yeasts, or may even prey on small organisms such as nematodes and protozoans. The pupal stage of biting midges does not eat. Pupae are 2-5 mm long, and range in color from pale yellow to dark brown. The pupal stage usually lasts for 2-3 days before the adult emerges.

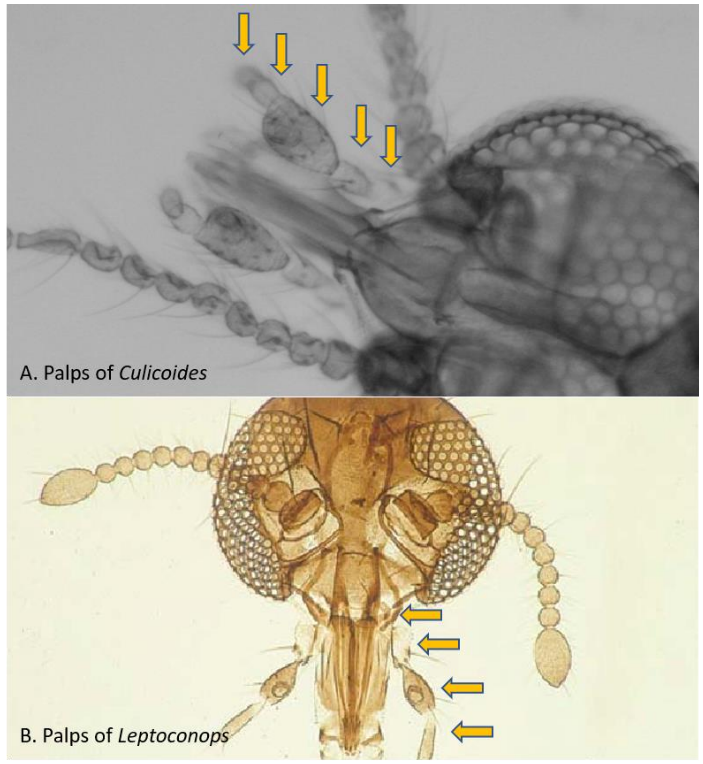

Figure 3: The palps of *Culicoides* (A) and *Leptoconops* (B). Arrows indicate the palp segments. A: photo by Xinmi Zhang, UCR. B: photo from Raspi *et al.* (2007).

Only adult females feed on blood, which is required for egg development. However, some biting midges can lay their first batch of eggs without a bloodmeal. These "autogenous" species store up enough nutrition during their immature stages to produce a single small batch of eggs, though bloodmeals are required for subsequent egg batches. The number of eggs produced in each egg batch varies among species but can be up to ≈250 eggs/batch for some species.

Most biting midges are active during warm seasons, with peak abundance and biting activity often occurring in summer or early fall. However, this pattern of biting activity can vary among midge species or with environmental conditions, and some species can remain active throughout the winter where temperatures are mild. Female biting midges generally seek animal hosts to bite near dusk and dawn, but weather conditions can result in a shift of biting activity to outside these crepuscular periods. Both sexes of adult biting midges feed on nectar and other sugar sources for flight energy.

Damage

In some geographic locations such as the Scottish Highlands and the U.S. Atlantic coast, enormous numbers of human-biting *Culicoides* are seasonally present. The irritating bites of these flies can greatly limit human enjoyment of the outdoors. Animals that are unable to escape biting *Culicoides* can develop a hypersensitivity reaction to the saliva of these biting flies. Hypersensitivity reactions can result in an itchy, atopic dermatitis with weeping sores or lesions that may become infected with bacteria if not treated. Horses are especially sensitive to *Culicoides* bites and can develop a severe hypersensitivity reaction called "sweet itch". This condition limits the use and value of the horse.

In addition to being a biting nuisance, *Culicoides* can transmit several viral pathogens of domestic and wild animals. These viruses include bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV) which can infect domestic and wild ruminants such as sheep, cattle, and deer. The species of biting midge responsible for transmission of these viruses varies with geographic region. In the United States, *Culicoides sonorensis* is the primary vector (transmitter) of BTV to cattle, while *Culicoides imicola* and species within the *Culicoides obsoletus* complex are the main vectors in Africa and Europe, respectively. The biting midge species responsible for transmitting EHDV are less well studied, as this virus primarily impacts deer, elk, and other wild ruminant animals. Ruminants infected with BTV or EHDV can show symptoms ranging from no symptoms to swelling of lips, tongue, and gums, lameness, abortion, and even death, dependent upon the type of infecting virus and on the species of animal infected.

Another important *Culicoides*-transmitted virus is African horse sickness virus (AHSV). This virus causes fever, heart and respiratory problems in horses and mules, often leading to death. Zebra and donkeys infected with the virus usually are asymptomatic and are natural reservoirs of the virus. Thus far, AHSV is largely limited to sub-Saharan Africa, but is of great concern worldwide as biting midges in other parts of the world have been shown in laboratory studies to be capable of transmitting this virus.

Due to their potential hazards and the impact they may cause to international trade, the *Culicoides*-transmitted viruses discussed above (BTV, EHDV, and AHSV) are included on the World Organization for Animal Health (OIE) list of reportable diseases (https://www.oie.int/en/animal-health-in-the-world/oie-listed-diseases-2020/).

Integrated Pest Management

Monitoring

Surveillance for biting midges is important to identify the *Culicoides* species that are present in a geographic region, as species vary in their ability to transmit viruses or to cause animal hypersensitivity reactions. Routine monitoring of biting adults can provide information on seasonal abundance and daily biting activity of local *Culicoides* species, and when coupled with virus detection in captured midges allows for estimation of virus transmission risk. Monitoring outcomes drive the need for and timing of control efforts.

Figure 4: CDC miniature suction trap baited with dry ice (CO_2) to collect biting midges on a dairy farm. Photo by Xinmi Zhang, UCR, USA.

Given the challenges of collecting small biting midges directly from their animal hosts, non-animal traps are commonly used to monitor biting midge activity. These traps use animal odors (e.g., CO_2, octenol) and/or UV light to attract and capture biting midges (Figure 4). For reasons that we do not currently understand, some *Culicoides* species are poorly collected in traps baited with animal odors and surveillance of these species relies instead on their attraction to UV light. However, traps with UV light will attract many kinds of insects and often require laborious separation of the small biting midges from other captured insects. This can be remedied by placing a screen on the trap so that larger insects (moths, mosquitoes, beetles) are excluded from the trap.

Captured *Culicoides* should be separated by species since each species varies in the capacity to cause damage, including virus transmission. Separation by species is usually performed by examining the wing patterning (Figure 3). However, there are important species complexes with closely related species that cannot be reliably distinguished in this way. These species may be best identified using molecular tools to sequence gene segments for comparison to species sequences published in GenBank or similar databases. Unfortunately, many less abundant or geographically limited species are not included in these databases, so many species cannot be confidently identified at the current time.

Figure 5: *Culicoides imicola* showing parous (right two) and nulliparous (left two). Parous females have red to brown pigment in their abdomen. Photo by Alan R Walker.

Virus detection in captured midges is usually performed using molecular methods (polymerase chain reaction or PCR) to amplify virus gene fragments. In areas where *Culicoides* species are not well studied, virus detection in biting midge species is important for incriminating a species as a vector of the virus. For greater efficiency of virus detection, captured female biting midges can often be separated by their parity status (nulliparous or parous). Nulliparous midges are those that have not previously taken a bloodmeal to develop eggs, while parous midges have fed on an animal host and subsequently deposited eggs at least once. In many *Culicoides* species, the abdomen of the adult female will acquire a red pigmentation after taking a bloodmeal and subsequently developing a batch of eggs (Figure 5). Generally, biting midges can acquire virus only from feeding on an infected animal host, so only parous midges need to be tested for the presence of virus.

Management

Only a few biting midge species have been well studied in the field or in the laboratory. Most species are very difficult to colonize in the laboratory and in the field it can be difficult to determine which biting midge species are responsible for virus transmission. Therefore, the general methods discussed below to control *Culicoides* may not be effective for all species.

Reducing Immature Development: Since immature biting midges require development sites that are moist to semi-aquatic, simply drying out known development sites can limit immature development and adult production. For some well-studied species, such modification of immature development sites has been shown to be an effective strategy for their control. For example, one of the most widespread biting midges in the U.S. (*Culicoides sonorensis*) develops in the mud-water interface at the edge of dairy ponds (Figure 6), and rapidly lowering the water level on a dairy pond can strand the immatures in the mud above water line resulting in death of the immature midge as this mud dries. The application of insecticides to biting midge development sites has not been well studied.

Figure 6: A typical biting midge (*Culicoides sonorensis*) larvae development site at the edge of a manure-polluted pond on a southern California dairy. Photo by Xinmi Zhang, UCR.

Reducing Adult Biting Rate: Given the challenge of locating immature habitat for most biting midge species, and the lack of methods to control immature midges even if this habitat is known, control efforts often aim to reduce biting of adult midges by protecting the host using screens and barriers or by use of repellents applied to the host.

Screens and meshes can be used to prevent biting midges from entering housing or stabling areas, but the mesh size must be less than 1.6 mm^2 to be effective. Common window screens will not exclude these flies! Screens can also be treated with insecticides to kill flies landing on the screen as biting midges try to reach the protected host. Hosts can also be protected through temporal separation by moving hosts into indoor environments near dusk and dawn when adult biting midges are most active. Some biting midge species are very reluctant to enter enclosed structures even when not excluded by screens. For example, in Africa simply moving horses into stables at night can reduce bites by the primary vector of AHSV (*Culicoides imicola*).

The most widely used repellents to protect humans from biting midges are *N, N*-Diethyl-*meta*-toluamide (DEET) and oil of lemon eucalyptus (OLE). These repellents will also repel other biting arthropods such as mosquitoes and ticks. In general, the repellent effect only lasts for a few hours, so regular reapplication is necessary. DEET is not safe for use on some animals (e.g. horses), so careful attention must be paid to the product label. In rural India, farmers burn neem leaves in livestock housings to repel *Culicoides* and other biting insects. Neem has showed anti-landing and anti-feeding effects for some biting midge species tested in the laboratory.

Synthetic pyrethroid insecticides (e.g., permethrin, deltamethrin, and α-cypermethrin) can be applied topically to animals to reduce *Culicoides* bites, though the effectiveness of these applications to reduce virus transmission is not clear. Nevertheless, insecticide treatment of animals may be useful when moving potentially infected animals through quarantine zones as the insecticides will kill insects that bite these animals preventing spread of any pathogen from the transported animal.

Where host protection is not an achievable approach, insecticides to kill adult biting midges may be applied over large geographic areas as ultra-low volume (ULV) sprays. For example, the U.S. Air Force Aerial Spray unit out of Youngstown Air Base applies ULV insecticides by aircraft to areas of the U.S. where biting midges are a severe nuisance to area residents. However, this form of insecticide application typically provides only temporary relief since immature flies are not killed and will soon emerge as hungry adult flies.

References for more information

Blanton, F.S. and Wirth, W.W., 1979. sand flies (*Culicoides*) of Florida.

Mellor, P.S., Boorman, J. and Baylis, M., 2000. *Culicoides* biting midges: their role as arbovirus vectors. *Annual review of entomology*, *45*(1), pp.307-340.

Harrup, L.E., Miranda, M.A. and Carpenter, S., 2016. Advances in control techniques for *Culicoides* and future prospects. *Veterinaria Italiana*, *52*(3-4), pp.247-64.

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