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Short Communication

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Effectiveness of a permethrin-treated barrier and pour-on applications against *Culicoides* spp. (Diptera: Ceratopogonidae) and mosquitoes (Diptera: Culicidae) on a deer farm

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Culicoides biting midges (Diptera: Ceratopogonidae) and mosquitoes (Diptera: Culicidae) are important vectors of pathogens affecting ruminants. On deer farms, *Culicoides* species transmit bluetongue virus and epizootic hemorrhagic disease virus, while mosquitoes can cause chronic stress and even exsanguination. We evaluated the effectiveness of the insecticide InsectGuard (0.5% permethrin), applied as a barrier treatment and pour-on, to reduce mosquito and biting midge landings on deer in Martin County, Florida. Deer simulators baited with carbon dioxide and fitted with sticky cards were used to trap landing insects. A polyethylene fence barrier treated with InsectGuard (1.34 fl oz/m^2) and an untreated fence were tested against a no-barrier control. Separately, InsectGuard pour-on (1 fl oz per deer) was compared to an untreated control. The InsectGuard-treated barrier and pour-on applications reduced landings of three *Culicoides* species, including *Culicoides insignis* Lutz, a key bluetongue virus vector, by 175-fold and 7-fold, respectively. The InsectGuard-treated barrier also reduced mosquito landings: *Culex* spp. (15-fold), and *Psorophora* spp. (6-fold). While the InsectGuard pour-on caused a dramatic reduction of *C. insignis*, it had no measurable effect on *Culex* spp., *Psorophora* spp., or *Culicoides floridensis* Beck and appeared to attract *Culicoides pusillus* Lutz (8-fold increase). Our findings demonstrate that permethrin-treated barriers and pour-on applications can reduce the landing and, therefore, potential infectious bites of mosquitoes and biting midges. These interventions can be incorporated as part of an integrated vector management program for deer farms to enhance control outcomes, in combination with other strategies such as adulticide sprays, habitat management, and vaccination.

Keywords: livestock protection, Culicoides, mosquito, vector control, hemorrhagic disease

Introduction

Culicoides biting midges (Diptera: Ceratopogonidae) and mosquitoes (Diptera: Culicidae) are significant vectors of livestock pathogens. In the United States, *Culicoides* species transmit bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV) (Sedoreoviridae: *Orbivirus*), known collectively as hemorrhagic disease (HD) viruses (Mullen and Murphree 2019). Hemorrhagic disease causes up to 84% mortality in white-tailed deer (*Odocoileus virginianus* Zimmermann), resulting in an estimated 144 million USD in economic losses annually (Fox and Pelton 1973, Barua et al. 2024). Mosquitoes also transmit pathogens affecting ruminants, including Eastern equine encephalitis virus, St Louis encephalitis virus, and West Nile virus (Ayers et al. 2018, Curren et al. 2018, Madhav et al. 2024). Additionally, mosquito bites contribute to chronic stress and can cause livestock exsanguination under heavy infestation (Abbiti and Abbitt 1981, Addison and Ritchie 1993, Pagès and Cohnstaedt 2018, Cecco et al. 2022).

Vector control is critical for protecting farmed ruminants. In Florida deer farms, vector control relies on ultra-low volume space sprays of permethrin-based insecticides (Harmon et al., 2020, Cooper et al. 2025). However, no integrated vector management (IVM) programs exist for deer farms, and alternative control strategies remain poorly evaluated (Harmon et al.

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2020). As a comprehensive approach that combines multiple control methods, an IVM program could offer more effective, long-term solutions for mosquito and *Culicoides* biting midge control on deer farms.

Alternative vector control strategies include insecticide-treated barriers and pour-on applications. Pyrethroid-treated barriers have been widely used for preventing mosquito bites in humans (White et al. 2024), but their use in livestock settings is poorly documented. Barriers treated with DEET (*N*, *N*-diethyl-meta-toluamide) and cypermethrin have reduced *Culicoides* spp. attacks on livestock in Europe (Braverman et al. 1999, Page et al. 2009, Calvete et al. 2010). However, little is known about the efficacy of treated barriers against *Culicoides* species of veterinary importance in the United States (Carpenter et al. 2008, Harrup et al. 2016).

Pyrethroid pour-on applications have shown effectiveness against biting midges in Europe (Mehlhorn et al. 2008, Venail et al. 2011). A 3.6% permethrin pour-on formulation applied to sheep reduced *Culicoides* spp. captures in the Netherlands by 50% compared to untreated controls (Griffioen et al. 2011), and a 4.0% permethrin formulation applied to cattle and sheep hair clippings caused complete mortality in *Culicoides* spp. from Germany (Schmahl et al. 2009). However, most studies have been conducted in laboratory settings, and little is known about the efficacy of insecticide pour-on applications against North American *Culicoides* species (Pfannenstiel et al. 2015).

Given the need for alternative control strategies, this study evaluated a commercially available permethrin-based insecticide. Permethrin is known for its insecticidal properties but can also act as a repellent, especially when used to pre-treat clothing (EPA 2025). We tested its effectiveness when applied to a barrier and as a pour-on treatment, measuring its ability to reduce biting midge and mosquito landings on deer. By assessing both application methods, we aimed to identify alternative control tools that could be incorporated into an IVM program for deer farms.

Materials and Methods

The study was conducted at a privately owned deer farm in the eastern Florida flatwoods in Martin County, approximately 12 km west of Allapattah Flats Wildlife Management Area. The region is dominated by seasonally flooded wet prairies and cattle pastures. The farm houses penned white-tailed deer for breeding purposes.

Landing Rates

Landing rates were estimated using "deer simulators," intended to mimic the size and shape of an adult white-tailed deer. Each simulator consisted of a 1.5 m tall deer-shaped shooting target (FeraDyne Outdoors, Fond Du Lac, Wisconsin) (Fig. 1) made of foam and plastic, baited with carbon dioxide as respiration proxy, in the form of dry ice (barrier trials) or compressed gas (pour-on trial), based on availability. Six sticky cards (15 × 7.9 cm) (Biogents USA, Cary, North Carolina) were consistently placed on both sides of the deer simulator's neck, back, and legs to capture landing insects (Fig. 1C), based on preliminary observations of preferred landing areas (Cooper, unpublished data). Sticky cards were collected and replaced daily at 17:00 h.

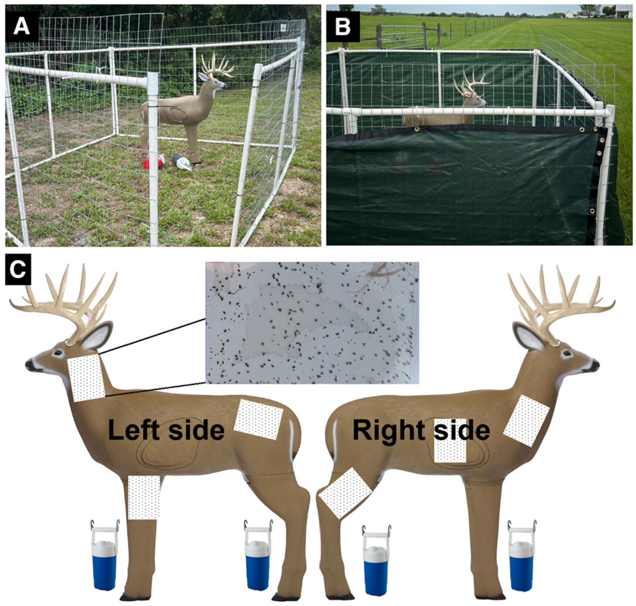

Fig. 1. Enclosures and deer simulators used to estimate landing rates of mosquitoes and *Culicoides* spp. A) enclosure with NB, B) enclosure with UB or TB, C) deer simulators showing placement of sticky cards. The beverage containers held 1 kg of dry ice each as an attractant.

Treated Barriers

Two small enclosures (2.5 m × 2.5 m × 1.2 m) simulating deer pens were constructed using 2.54 cm diameter PVC pipes and 14-gauge welded wire (5 cm × 10 cm openings) (Home Depot, Cobb County, Georgia) (Fig. 1A and B). Each enclosure housed 1 deer simulator baited with 2 insulated 1.89 liter containers (Igloo Products Corp., Katy, Texas, United States) with 1 kg of dry ice each (Fig. 1C). The barrier was a 1.21 m tall, polyethylene green privacy screen (Windscreen4less, Seattle, Washington), commonly used in deer pens for predator deterrence. The barrier covered all 4 sides of the enclosure, with the roof left open.

Two trials compared: (i) an untreated barrier (UB) versus no barrier (NB) over 6 days (10 to 16 September 2024), and (ii) a treated barrier (TB) versus NB over 12 d (12 to 20 July and 6 to 8 September 2024). Due to space constraints on the farm, only 2 treatments were tested simultaneously. The insecticide (InsectGuard, 0.5% permethrin; Thunder Mountain International LLC, Bellefonte, Pennsylvania) was applied 1 h before the 24-h sampling period began (17:00 h), using the sprayer bottle included with the product, at a rate of 1.34 fl oz/m^2 per label recommendations. Treatments were rotated every 3 d, with treated barriers discarded between rotations.

Pour-on Applications

Four deer simulators were placed across 2 farm locations selected at random from among available sites on the property. At each location, 1 simulator was treated with insecticide and 1 was left untreated, with the 2 positioned approximately 1 m apart to ensure comparable exposure to local insect populations. The 2 farm locations were separated by approximately 20 m to cover a large area of the farm. Sampling was conducted in late summer, over 4 d between 6 and 14 September 2024 (8 total replicates), with sticky cards collected daily at 17:00 h.

Each treated simulator received a daily application of 1 fl oz of insecticide along the deer backline in accordance with label recommendations, which was then spread onto the sides using nitrile-gloved hands. Simulators were baited with compressed carbon dioxide delivered through a gas regulator (Aquarzon, Australia) set to 75 kgf/cm^2, based on preliminary observations showing that this rate attracted biting insects (Cooper, unpublished data). Clear vinyl tubing was used as an extension, allowing the release of carbon dioxide to occur from the deer head.

Data Analysis

Biting midges and mosquitoes were counted and identified to genus or species using female morphology (Darsie and Ward 2004, Blosser et al. 2024). Statistical comparisons of total landings were made between treatment groups: UB versus NB, TB versus NB, and pour-on treatment versus untreated control. For the TB versus NB comparisons, Wilcoxon signed-rank tests were used due to non-normal data distributions. Comparisons between UB and NB were conducted using t-tests, as the data met assumptions of normality. The pour-on trial data were analyzed with *t*-tests for *Culicoides insignis* Lutz, *Culicoides floridensis* Beck, and *Culicoides pusillus* Lutz, and Wilcoxon signed-rank tests for all other species. All analyses were run using R studio (version 4.2.0, R Core Team). The following packages were used: “tidyr” for data manipulation, “ggplot2” for data visualization and base R functions for statistical testing.

Results

TB Versus NB

The TB treatment significantly reduced biting midge and mosquito landings on deer simulators compared to NB (Fig. 2A). *Culex* spp. were markedly lower in TB (1.1 per night) compared to NB (16.6 per night, $P = 0.012$). Similarly, *Psorophora* spp. landings were reduced 6-fold in TB (10.0 vs. 65.1 per night, $P = 0.029$). Substantial reductions in landings were

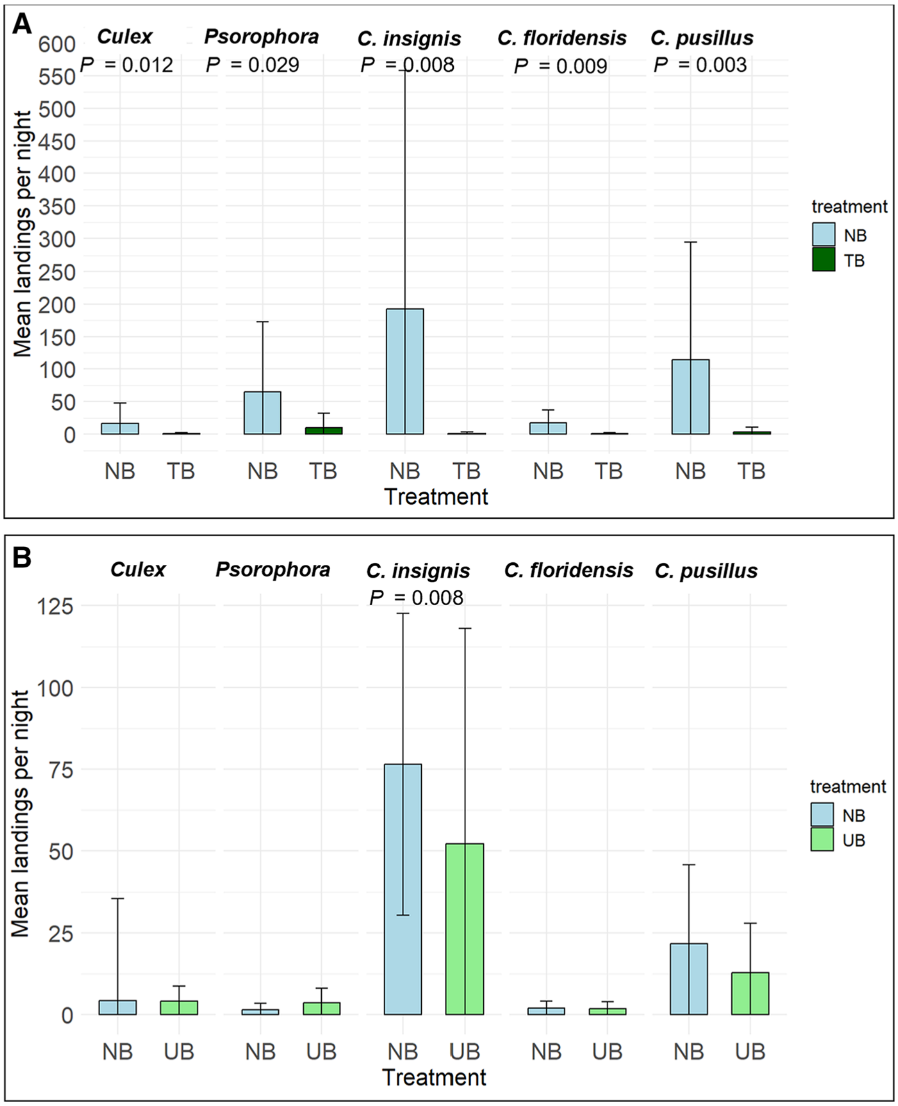

Fig. 2. Mean landings of mosquitoes and *Culicoides* biting midges in screen barrier trials. A) Comparison of the number of insects collected from NB versus UB, and B) comparison of the number of insects collected from NB versus TB sprayed with InsectGuard (0.5% permethrin). Whiskers represent the SD.

observed in the TB treatment among *Culicoides: C. insignis* landings were reduced 175-fold (1.1 vs. 192.7 per night, *P* = 0.008), *C. floridensis* by 34-fold (0.5 vs. 17.2 per night, *P* = 0.009), and *C. pusillus* by 30-fold (3.7 vs. 114.2 per night, *P* = 0.003) (Fig. 2A).

UB Versus NB

The UB treatment significantly reduced *C. insignis* landings compared to NB (52.1 vs. 76.5 per night, *P* = 0.045) (Fig. 2B). No significant reductions were observed for any other species. Landings of *Culex* spp. (4.2 vs. 4.3 per night, *P* = 0.968), *C. pusillus* (12.8 vs. 21.6 per night, *P* = 0.556), and *C. floridensis* (1.8 vs. 2.0 per night, *P* = 0.460) were slightly lower in UB than NB, though not significantly. In contrast, *Psorophora* spp. landings were slightly higher (but not significantly) in UB than NB (3.6 vs. 1.5 per night) (*P* = 0.384) (Fig. 2B).

Pour-on Treatment

The pour-on treatment reduced *C. insignis* landings by nearly 7-fold compared to the untreated control (90.3 vs. 623.4 per night, *P* = 0.007). Conversely, more *C. pusillus* were collected from the pour-on treatment than the untreated control (146.5 vs. 18.2 per night, *P* = 0.017) (Fig. 3). Although not statistically significant, landings were slightly lower in the pour-on treatment relative to the control for *C. floridensis* (3.0 vs. 9.7 per night, *P* = 0.090), *Culex* spp. (16.2 vs. 28.6 per night, *P* = 0.742), and *Psorophora* spp. (2.8 vs. 6.4 per night, *P* = 0.418) (Fig. 3).

Discussion

This study demonstrates the efficacy of InsectGuard, a permethrin-based insecticide, in reducing biting midge and mosquito landings on deer. To our knowledge, this is the first study showing efficacy of a permethrin-treated barrier and pour-on treatments against *C. insignis*, *C. floridensis*, and *C. pusillus*, as previous studies focused on European *Culicoides* species (Calvete et al. 2010, Del Río et al. 2014). InsectGuard significantly reduced *C. insignis* landings when applied to a barrier or as a pour-on and decreased *Culex* spp, *Psorophora* spp., *C. floridensis*, and *C. pusillus* when applied to a barrier.

Our results suggest that InsectGuard-treated barriers may help protect livestock from pathogen-vectors such as *C. insignis*, a primary BTV vector (Veggiani Aybar et al. 2016, Vigil et al. 2018, McGregor et al. 2022) and a weak EHDV vector whose bites can also cause allergic dermatitis to livestock (Mullens et al. 2005, Corrêa et al. 2007, Barbosa et al. 2024). These treated barriers may also provide substantial protection from *Psorophora* and *Culex* mosquitoes that cause chronic stress or even mortality. For instance, high densities of *Psorophora columbiae* (Dyar and Knab) in cattle ranches have resulted in livestock exsanguination (Cecco et al. 2022).

Pour-on treatments with InsectGuard may help protect fawns from biting midges. Fawns are the most susceptible age group to HD viruses. In Florida, fawns aged 3 to 6 mo have the highest proportion of HD virus-positive cases during mortality events, with up to 82% testing positive (Cottingham et al. 2021). While pour-on applications may help reduce livestock exposure to vectors, the impact of these applications on the vector population abundance and disease transmission risk is unclear and should be investigated.

Unexpectedly, while the TB treatment reduced *C. pusillus*, the pour-on appeared to attract them (Fig. 3). It is possible the TB treatment also attracted *C. pusillus*, but midges likely landed on the barrier and experienced mortality from insecticide exposure before flying over and reaching the sticky cards. The underlying cause of this pattern remains unclear. Volatile compounds in the insecticide may influence midge behavior, either by attracting them or altering their flight patterns. Similar phenomena have been observed in *Culicoides imicola* Kieffer, which was attracted to a mosquito and midge repellent (Mosi-guard, Citrefine, International Ltd, United Kingdom) formulated with oil of lemon eucalyptus (Braverman et al. 1999). However, other unknown factors could also explain this unexpected result. Although *C. pusillus* is not a primary vector in the United States, it is a putative BTV vector in South America and the Caribbean (Greiner et al. 1984, Caixeta et al. 2024). While logistical constraints prevented simultaneous testing of all 3 barrier treatments (NB, TB, and UB), the UB treatment only reduces landings of *C. insignis* (Fig. 2B). We suspect barriers alone only provide partial protection against mosquitoes and biting midges, which

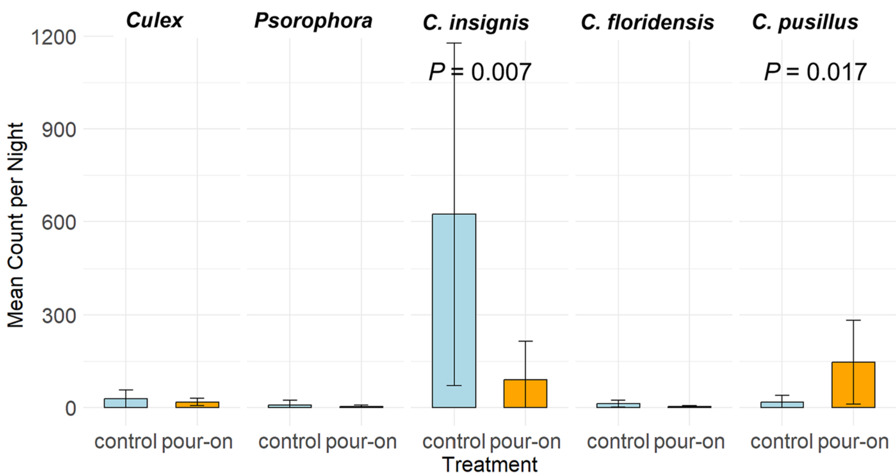

Fig. 3. Mean landings of mosquitoes and *Culicoides* biting midges on deer simulators exposed to pour-on treatment. Treatments include 2 deer simulators treated with InsectGuard (permethrin 0.5%) pour-on at 1 fl oz/deer and 2 untreated controls. Whiskers represent the SD. Only statistically significant. *P* values (*P* < 0.05) are reported.

are capable of flying above the 1.21 m barrier height. *Culicoides* spp. have been recorded at up to 200 m (Chapman et al. 2004, Sanders et al. 2011), and mosquitoes such as *Culex*, *Anopheles*, and *Aedes* can fly above 150 m (Yaro et al. 2022). For the TB treatment, insects may have initially been intercepted by the barrier and either perished or become moribund.

While InsectGuard demonstrated efficacy under experimental conditions, translating these results to deer farming operations may present challenges. The experimental enclosure (~7 m²) is far smaller than typical deer pens (at least 200 m²), where the ratio of treated to untreated surfaces would be reduced. Additionally, the product label recommends weekly reapplication for barriers and daily for pour-on, which may be impractical for farm operations. Future studies should examine the relationship between pen size (area) and the effectiveness of treated barriers to determine the point at which the protective effect is lost or diminished.

Overall, applying InsectGuard to barriers or directly to deer as a pour-on can reduce biting midge and mosquito landings. Both approaches have potential to decrease deer exposure to biting insects of veterinary importance. Incorporating these permethrin treatments into an IVM program for deer farms could improve vector control outcomes and reduce HD risk.

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Author Contributions

Vilma M. Cooper (Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing—original draft [lead]), Eva A. Buckner (Data curation [supporting], Methodology [supporting], Supervision [equal], Writing—original draft [supporting], Writing—review & editing [equal]), Samantha M. Wisely (Funding [lead], supervision [equal], Writing—review & editing [equal]), Juan M. Campos-Krauer (Funding acquisition [supporting], Supervision [equal]), and Nathan D. Burkett-Cadena (Data curation [supporting], Formal analysis [supporting], Funding acquisition [lead], Methodology [equal], Supervision [lead], Writing—original & draft [Equal], Writing—review & editing [lead])

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Conflicts of Interest

None declared.

References

Abbiti B, Abbitt L. 1981. Fatal exsanguination of cattle attributed to an attack of salt marsh mosquitoes (*Aedes sollicitans*). *J. Am. Vet. Med. Assoc.* 179:1397–1400.

Addison D, Ritchie S. 1993. *Cattle fatalities from prolonged exposure to Aedes taeniorhynchus in southwest Florida*. Florida Scientist. 65–69.

Ayers VB, Huang Y-JS, Lyons AC, et al. 2018. *Culex tarsalis* is a competent vector species for Cache Valley virus. *Parasit. Vectors*. 11:519. https://doi.org/10.1186/s13071-018-3103-2

Barbosa JD, Sodré MHS, Barbosa CC, et al. 2024. Allergic dermatitis in Pêga breed donkeys (*Equus asinus*) caused by *Culicoides* bites in the Amazon biome, Pará, Brazil. *Animals. (Basel)* 14:1330. https://doi.org/10.3390/ani14091330.

Barua S, Rana EA, Prodhan MA, et al. 2024. The global burden of emerging and re-emerging orbiviruses in livestock: an emphasis on bluetongue virus and epizootic hemorrhagic disease virus. *Viruses* 17:20. https://doi.org/10.3390/v17010020.

Blosser EM, McGregor BL, Burkett-Cadena ND. 2024. A photographic key to the adult female biting midges (Diptera: Ceratopogonidae: *Culicoides*) of Florida, USA. *Zootaxa* 5433:151–182.

Braverman Y, Chizov-Ginzburg A, Mullens BA. 1999. Mosquito repellent attracts *Culicoides imicola* (Diptera: Ceratopogonidae). *J. Med. Entomol.* 36:113–115. https://doi.org/10.1093/jmedent/36.1.113

Caixeta EA, Pinheiro MA, Lucchesi VS, et al. 2024. The study of bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV) circulation and vectors at the municipal parks and Zoobotanical Foundation of Belo Horizonte, Minas Gerais, Brazil. *Viruses* 16:293. https://doi.org/10.3390/v16020293

Cottingham SL, White ZS, Wisely SM, et al. 2021. A mortality-based description of EHDV and BTV prevalence in farmed white-tailed deer (*Odocoileus virginianus*) in Florida, USA. *Viruses* 13:1443.

Calvete C, Estrada R, Miranda MA, et al. 2010. Protection of livestock against bluetongue virus vector *Culicoides imicola* using insecticide-treated netting in open areas. *Med. Vet. Entomol.* 24:169–175. https://doi.org/10.1111/j.1365-2915.2009.00858.x

Carpenter S, Mellor PS, Torr SJ. 2008. Control techniques for *Culicoides* biting midges and their application in the U.K. and northwestern Palaearctic. *Med. Vet. Entomol.* 22:175–187. https://doi.org/10.1111/j.1365-2915.2008.00743.x

Cecco B, Sasaki E, Paulsen DB, et al. 2022. Livestock fatalities attributed to a massive attack of *Psorophora columbiae* following Hurricane Laura. *Bov. Pract.* 56:13–17. https://doi.org/10.21423/bovine-vol56no1p14-18

Chapman JW, Reynolds DR, Smith AD, et al. 2004. An aerial netting study of insects migrating at high altitude over England. *Bull. Entomol. Res.* 94:123–136. https://doi.org/10.1079/BER2004287

Cooper VM, Wisely SM, Campos-Krauer JM, et al. 2025. Toward sustainable and effective management of hemorrhagic disease vectors: a survey of Florida deer farmers. *J. Integr. Pest Manag* 16:28.

Corrêa TG, Ferreira JM, Riet-Correa G, et al. 2007. Seasonal allergic dermatitis in sheep in southern Brazil caused by *Culicoides insignis* (Diptera: Ceratopogonidae). *Vet. Parasitol.* 145:181–185. https://doi.org/10.1016/j.vetpar.2006.10.025

Curren EJ, Lindsey NP, Fischer M, et al. 2018. St Louis encephalitis virus disease in the United States, 2003–2017. *Am. J. Trop. Med. Hyg.* 99:1074–1079. https://doi.org/10.4269/ajtmh.18-0420.

Darsie R, Ward R. 2004. *Identification and geographical distribution of the mosquitoes of North America, North of Mexico*. University Press of Florida.

Del Río R, Barceló C, Paredes-Esquivel C, et al. 2014. Susceptibility of *Culicoides* species biting midges to deltamethrin-treated nets as determined under laboratory and field conditions in the Balearic Islands, Spain. *Med. Vet. Entomol.* 28:414–420. https://doi.org/10.1111/

EPA. 2025. Repellent-treated clothing [accessed 2025 June 6]. https://www.epa.gov/insect-repellents/repellent-treated-clothing

Fox J, Pelton M. 1973. Observations of a white-tailed deer die off in the Great Smoky Mountains National Park. *Proc. Ann. Conf. Southeastern Ass. Game Fish Commissions* 27:297–301.

Greiner EC, Garris GI, Rollo RT, et al. 1984. Preliminary studies on the spp. as potential vectors of bluetongue in the Caribbean region. *Prev. Vet. Med.* 2:389–399. https://doi.org/10.1016/0167-5877(84)90082-5

Griffioen K, van Gemst DBJ, Pieterse MC, et al. 2011. *Culicoides* species associated with sheep in The Netherlands and the effect of a

permethrin insecticide. *Vet. J*. 190:230–235. https://doi.org/10.1016/j.tvjl.2010.10.016.
Harmon LE, Sayler KA, Burkett-Cadena ND, et al. 2020. Management of plant and arthropod pests by deer farmers in Florida. *J. Integr. Pest Manag* 11:12. https://doi.org/10.1093/jipm/pmaa011
Harrup L, Miranda M, Carpenter S, et al. 2016. Advances in control techniques for *Culicoides* and future prospects. *Vet. Ital* 52:247–264. https://doi.org/10.12834/VetIt.741.3602.3
Madhav M, Blasdell KR, Trewin B, et al. 2024. *Culex*-transmitted diseases: mechanisms, impact, and future control strategies using *Wolbachia*. *Viruses* 16:1134. https://doi.org/10.3390/v16071134
McGregor BL, Shults PT, McDermott EG. 2022. A review of the vector status of North American *Culicoides* (Diptera: Ceratopogonidae) for bluetongue virus, epizootic hemorrhagic disease virus, and other arboviruses of concern. *Curr. Trop. Med. Rep*. 9:130–139. https://doi.org/10.1007/s40475-022-00263-8
Mehlhorn H, Schmahl G, D'Haese J, et al. 2008. Butox® 7.5 pour on: a deltamethrin treatment of sheep and cattle: pilot study of killing effects on *Culicoides* species (Ceratopogonidae). *Parasitol. Res*. 102:515–518. https://doi.org/10.1007/s00436-007-0841-z
Mullen G, Murphree S. 2019. Biting midges (Ceratopogonidae). In: Mullen G, Durden LA, editors. Medical and veterinary entomology. 3rd ed. Academic Press. p. 213–236.
Mullens BA, Owen JP, Heft DE, et al. 2005. *Culicoides* and other biting flies on the Palos Verdes Peninsula of Southern California, and their possible relationship to equine dermatitis. *J. Am. Mosq. Control Assoc*. 21:90–95. https://doi.org/10.2987/8756-971X(2005)21[90:CAOBFO] 2.0.CO; 2
Page PC, Labuschagne K, Nurton JP, et al. 2009. Duration of repellency of N, N-diethyl-3-methylbenzamide, citronella oil and cypermethrin against *Culicoides* species when applied to polyester mesh. *Vet. Parasitol*. 163:105–109. https://doi.org/10.1016/j.vetpar.2009.03.055
Pagès N, Cohnstaedt LW. 2018. Mosquito-borne diseases in the livestock industry. *Pests and vector-borne diseases in the livestock industry*. In: Garros C, Bouyer J, Takken W, Smallegange RC, editors. Wageningen Academic Publishers. p. 195–219. https://doi.org/10.3920/978-90-8686-863-6
Pfannenstiel RS, Mullens BA, Ruder MG, et al. 2015. Management of North American *Culicoides* biting midges: current knowledge and research needs. *Vector Borne Zoonotic Dis*. 15:374–384. https://doi.org/10.1089/vbz.2014.1705
Sanders CJ, Selby R, Carpenter S, et al. 2011. High-altitude flight of *Culicoides* biting midges. *Vet. Rec*. 169:208–208. https://doi.org/10.1136/vrd4245
Schmahl G, Klimpel S, Walldorf V, et al. 2009. Effects of permethrin (Flypor®) and fenvalerate (Acadrex®60, Arkofly®) on *Culicoides* species—the vector of bluetongue virus. *Parasitol. Res*. 104:815–820. https://doi.org/10.1007/s00436-008-1261-4
Veggiani Aybar CA, Díaz Gomez RA, Dantur Juri MJ, et al. 2016. Potential distribution map of *Culicoides insignis* (Diptera: Ceratopogonidae), vector of bluetongue virus, in Northwestern Argentina. *J. Insect Sci*. 16:65. https://doi.org/10.1093/jisesa/iew028
Venail R, Mathieu B, Setier-Rio M-L, et al. 2011. Laboratory and field-based tests of deltamethrin insecticides against adult *Culicoides* biting midges. *J. Med. Entomol*. 48:351–357. https://doi.org/10.1603/ME10178
Vigil SL, Ruder MG, Shaw D, et al. 2018. Apparent range expansion of *Culicoides insignis* (Hoffmania) (Diptera: Ceratopogonidae) in the Southeastern United States. *J. Med. Entomol*. 55:1043–1046. https://doi.org/10.1093/jme/tjy036
White AV, Knecht H, Richards SL. 2024. Assessment of barrier treatments impacting *Aedes albopictus* (Diptera: Culicidae) using lambda-cyhalothrin and pyriproxyfen in a suburban neighborhood in Eastern North Carolina, 2018. *Int. J. Environ. Health Res*. 34:991–1001. https://doi.org/10.1080/09603123.2023.2194613
Yaro AS, Linton Y-M, Dao A, et al. 2022. Diversity, composition, altitude, and seasonality of high-altitude windborne migrating mosquitoes in the Sahel: implications for disease transmission. *Front. Epidemiol*. 2:1001782. https://doi.org/10.3389/fepid.2022.1001782