Journal of Integrated Pest Management, (2025) 16(1): 28; pmaf025
https://doi.org/10.1093/jipm/pmaf025
Surveys and Needs Assessments

Toward sustainable and effective management of hemorrhagic disease vectors: a survey of Florida deer farmers

Vilma M. Cooper[1,*], Samantha M. Wisely[2], Juan M. Campos-Krauer[3], and Nathan D. Burkett-Cadena[1]

[1]Florida Medical Entomology Laboratory, Department of Entomology and Nematology, Institute of Food and Agricultural Sciences, University of Florida, Vero Beach, FL, USA
[2]Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL, USA
[3]Department of Large Animal Clinical Sciences, University of Florida, Gainesville, FL, USA

[*]Corresponding author. Florida Medical Entomology Laboratory, UF/IFAS 200 9th Street SE, Vero Beach, FL 32962, USA (Email: vilma.montenegro@ufl.edu; vilmamcooper@gmail.com).

Subject Editor: Stephen Vantassel

Received on 7 April 2025; revised on 11 May 2025; accepted on 1 June 2025

Deer farming is a robust industry in the United States, with farmed and wild cervids vulnerable to vector-borne diseases such as hemorrhagic disease, caused by bluetongue virus and epizootic hemorrhagic disease virus. These viruses are transmitted by biting midges (Diptera: Ceratopogonidae: *Culicoides*), highlighting the importance of vector control in safeguarding deer health on deer farms. Despite the role of biting midges as pathogen vectors, effective control programs for managing biting midges remain underdeveloped. To address this gap, a comprehensive evaluation of current pest and vector management practices on deer farms is essential for designing successful control strategies against hemorrhagic disease vectors. We conducted a Knowledge, Attitudes, and Practices (KAP) survey among Florida trophy-deer farmers using an online questionnaire to gather data related to pest and vector control. Thirty-three survey responses were collected out of a pool of 60 farmers. Sixty-six percent of the respondents used insecticides to control pests and vectors, including biting midges, with nearly 70% of these applications using permethrin-based products, with applications taking place as often as daily. Over 82% of the respondents believe that insecticides are the most effective way to control pests, yet most (66%) do not rotate insecticides, raising concerns about the development of insecticide resistance. Our findings underscore the need for educational programs to enhance deer farmers' understanding of safe and sustainable pest and vector management practices. These efforts could improve pest and vector control efficacy while mitigating the risk of insecticide resistance, ultimately promoting long-term health and productivity in trophy-deer farming.

Keywords: needs assessment, KAP survey, pest control, permethrin, vector control

Introduction

Deer farming is an economically important industry in the United States, with over 3,000 operations of captive deer according to the 2022 Census of Agriculture. The deer farming industry contributes an estimated USD 2.6 billion annually to the US economy each year and supports over 56,000 jobs (Anderson et al. 2017). In Florida, more than 300 deer farms are registered, primarily producing white-tailed deer (*Odocoileus virginianus*), but also other cervids and bovids for hunting (McGregor et al. 2019, Wisely 2021). Combining the deer farming industry with the hunting component, the total impact of this industry to the US economy is USD 7.9 billion annually. Deer farming supports both economic activity and conservation efforts, serving an important role in rural development and the hunting tourism sector. Deer farms often manage large tracts of land, which are maintained as suitable habitat not only for deer but also for other native wildlife, helping preserve local biodiversity and natural landscapes.

Farmed and wild cervids are susceptible to a variety of vector-borne diseases, with the transmission of pathogens between captive and wild deer being a significant concern for deer farmers and natural resource management agencies (Cauvin et al., 2020). In the United States, deer health is particularly affected by hemorrhagic disease (HD), caused by bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV) (Reoviridae: *Orbivirus*). These are the most critical viral diseases impacting farmed and wild white-tailed deer in North America, causing substantial morbidity and mortality, and substantial economic losses (Cottingham et al. 2021). For instance, in Florida, an HD outbreak in 2012 led to losses of up to USD 32 million for deer farmers (Wisely 2020).

HD viruses are transmitted by some species of *Culicoides* biting midges (Diptera: Ceratopogonidae). To mitigate the spread of these viruses, deer farmers manage biting midge populations using insecticides targeting adults (Venail et al. 2015). A 2018 survey of Florida deer farmers (32 respondents) found that 94% of respondents applied chemicals on their property: 53% targeted both unwanted plants and arthropod pests, 38% focused solely on arthropods, and 3% dealt only with unwanted plants (Harmon et al. 2020). Nearly all deer farmers applied insecticides aimed at controlling biting midges, with some performing daily applications during the HD transmission season (Harmon et al. 2020). This frequent use of insecticides has raised concerns about the development of insecticide resistance and the potential for non-target effects on other species.

Insecticide resistance has been extensively studied in various insect groups, including many species of nuisance and vector mosquitoes (Vontas et al. 2020), pests like house flies (Freeman et al. 2019), and insects of veterinary importance such as horn flies (Guerrero et al. 1997). Knowledge on insecticide resistance in biting midges in the United States remains limited, which poses challenges for vector control efforts among Florida deer farmers, particularly given their reliance on insecticides to manage vectors (Harmon et al. 2020).

While insecticide susceptibility studies have been conducted in other parts of the world, results are often inconsistent. For instance, no evidence of resistance was found in *Culicoides nubeculosus* Meigen, *Culicoides obsoletus* Meigen, and *Culicoides imicola* Kieffer from France, Spain, Senegal, and South Africa when tested against six organophosphates and synthetic pyrethroids, including permethrin (Venail et al. 2015). In China, wild-collected *Culicoides oxystoma* Kieffer exhibited incomplete mortality even 24 h after exposure to pyrethroids (deltamethrin and beta-cypermethrin), an organophosphate (chlorpyrifos), and an avermectin (DDVP) (Min et al. 2017). The differing results of these studies underscore the complexity of assessing insecticide resistance in biting midges, due to factors such as the lack of colonized species of biting midges for comparative studies. This scarcity makes it difficult to develop comprehensive resistance management strategies, particularly for field-collected individuals. Notably, there are limited published insecticide susceptibility studies on confirmed or putative HD vectors in the United States (Cooper et al. 2025, Cooper et al. *In Press*), highlighting a critical gap in our understanding of their resistance status.

Integrated vector management (IVM) should be considered as a strategy to address the growing concern of insecticide resistance in Florida deer farms. IVM is a comprehensive, sustainable approach to vector control that integrates both chemical and non-chemical approaches for effective and environmentally responsible management (Manikandan et al. 2022). By combining these methods, IVM aims to reduce reliance on insecticides alone, thereby minimizing the risk of resistance development. Despite the potential benefits, an IVM program designed for the control of biting midges in Florida deer farms has not been developed (Harmon et al. 2020). The lack of such program is likely due to the limited understanding of the ecology of North American biting midges and the general absence of effective control strategies tailored to their biology and behavior (Mullens et al. 2015, Pfannenstiel et al. 2015).

A detailed assessment of current pest and vector management practices among deer farmers is essential for developing IVM practices against HD vectors. Knowledge, Attitudes, and Practices (KAP) surveys are valuable research tools for identifying knowledge gaps and assessing behaviors (Zarei et al. 2024), which can inform the design of future extension initiatives (Anderson and Feder 2007). By understanding current insecticide use and management practices, researchers can tailor IVM programs to the specific needs of Florida deer farms and identify gaps where education may be beneficial. The purpose of this research was to (i) collect information about current insecticides in Florida trophy-deer farms; (ii) determine the timing and methods of these insecticide applications; and (iii) assess the perspectives and knowledge of trophy-deer farmers about pest and vector control to identify potential educational opportunities. This assessment is vital for informing the development of IVM programs that effectively control HD vectors while reducing the risk of insecticide resistance.

Materials and Methods

The survey was distributed to Florida deer farmers over the age of 18, who were members of the Southeast Trophy-deer Association (SeTDA) at the time of the data collection. This group was chosen because they represent key stakeholders who have partnered with the University of Florida, the Institute for Food and Agricultural Science, Cervidae Health Research Initiative (CHeRI) to support research related to deer health. Demographic information such as gender, age, race, and ethnicity was not collected. The survey protocol was reviewed by the University of Florida Institutional Review Board (UF IRB) and was deemed exempt using the automated determination tool for nonhuman and exempt research (ID 16846).

The survey was created and delivered using the online survey platform Qualtrics. The survey consisted of six blocks, including survey introduction, general information questions, deer health-related questions, insect management questions, questions related to perspectives on the use of insecticides, and general information about CHeRI. The survey included a maximum of 38 questions (Table 1), with multiple choice, yes or no, ranking, and agree or disagree questions. The survey was reviewed for content validity by experts consisting of faculty and extension specialists from the University of Florida Entomology and Nematology Department, and from CHeRI. The reading levels of the survey were reviewed to ensure the appropriateness for the targeted audience. Scientific terms, including the term 'insecticide' were defined to the respondents in the survey. In this case, we used the term 'insecticide' to refer to any chemical being used to kill an arthropod.

Survey data were collected during the SeTDA Spring Fling, the organization's largest annual gathering, held in Orlando, FL, on April 21–22, 2023. Attending deer farmers (SeTDA members) were invited to participate by scanning a QR code that directed them to an anonymous link to complete the survey on their phones or using the tablets that we provided. This survey builds upon a prior survey conducted by Harmon et al. in 2018, which targeted the same population (Harmon et al. 2020). However, our survey differed in several key aspects. Firstly, our survey was shorter to encourage higher completion rates. Our survey centered specifically on insecticide use for managing insects of veterinary importance in deer farms,

Table 1. List of questions distributed in the survey of deer farmers in Florida in 2023. Some questions have been shortened for brevity. The response rate is calculated based on the total number of respondents ($n = 33$).

Question	Answer type	No. of responses	Response rate (%)
General Information			
In what county is your deer farm located?	Heat map	31	93.9
How many white-tailed deer are present in your farm?	Multiple choice	33	100
Where are most of your bucks housed?	Multiple choice	33	100
Where are your most of your does housed?	Multiple choice	33	100
Where are most of your fawns housed?	Multiple choice	33	100
Are cattle present on or within 1 mile of your deer farm?	Yes/No	33	100
Have you vaccinated your deer against any infectious diseases in the past two years?	Yes/No	33	100
Which vaccines have your deer received in the past 2 years?	Multiple choice	26	78.8
How many cases of hemorrhagic disease (epizootic hemorrhagic disease or bluetongue) occurred in your farm in 2022?	Multiple choice	31	93.9
Did you report all of your white-tailed deer with hemorrhagic disease to CHeRI (Cervidae Health Research Initiative)?	Yes/No	16	48.5
Insect Management			
In 2022, which methods did you use to control unwanted insects or other arthropods such as ticks, mosquitoes, biting midges (no-see-ums) stable flies, horn flies, etc.? *Select all that apply*	Multiple choice	33	100
Do you apply insecticides specifically to control biting insects and/or other arthropods that may affect your deer's health?	Yes/No	31	93.9
What biting insects/arthropods do you attempt to control on your farm? *Select all that apply.*	Multiple choice	22	66.7
Rank the following methods of insecticide application based on your preferences. Rank from most preferred to least preferred.	Rank order	21	63.6
What application method do you use the most to apply insecticides against biting midges (no-see-ums)?	Multiple choice	21	63.6
How much money did you spend on insecticide applications in 2022?	Multiple choice	22	66.6
What insecticides do you apply through ULV applications?	Multiple choice	13	39.4
At what rate are you applying this insecticide?	Multiple choice	9	27.3
During peak hemorrhagic disease (HD) season (summer and fall), how often do you apply insecticides?	Multiple choice	21	63.6
During what time of the day do you apply insecticides to specifically control biting midges (no-see-ums)?	Multiple choice	22	66.6
In your farm, do you apply insecticides for any of these reasons? Select all that apply	Multiple choice	33	100
Perspectives			
How do you determine that you need to apply insecticides to control biting midges (no-see-ums)? Rank from most used to least used.	Rank order	30	90.9
If you needed to apply insecticides, how would you decide at what rate to apply an insecticide? *Select all that apply.*	Multiple choice	30	90.9
Are you worried about any of these negative effects of insecticide over-use? *Select all that apply*	Multiple choice	33	100
Do you rotate insecticides?	Yes/No	30	90.9
Statements			
Insecticides are the best solution to control pests in my deer farm	Agree/ Disagree	29	87.9
It is important to read the insecticide label before using it	Agree/ Disagree	33	100
If I have unvaccinated deer within the next year, I will likely vaccinate them against EHD (epizootic hemorrhagic disease)	Agree/ Disagree	31	93.9
This year, I will report to CHeRI all of the HD cases that occur in my farm.	Agree/ Disagree	31	93.9

as opposed to addressing plant and arthropod pest control more broadly. Additionally, our questionnaire included questions aimed at elucidating deer farmers' perspectives and knowledge regarding chemical pest control methods, which would allow us to develop an educational program for deer farmers.

All responses were combined in Qualtrics. Descriptive summary statistics were used to present the results and data were presented in tables and graphs for ease of visualization and comparison between responses (Potter et al. 2016). Response rates were calculated for each of the questions asked. Minimum, maximum, and average were calculated for the number of white-tailed deer kept in the deer farms. Percentages were calculated to represent the responses whenever possible. Chi-square tests of goodness of fit were used to determine whether there were significant differences between observed and expected frequencies in categorical data. For instance, we tested the hypothesis that there was an equal interest in controlling biting midges, mosquitoes, deer flies, horn flies, and stable flies.

Results and Discussion

Survey Data

A total of 33 trophy-deer farmers in the state of Florida responded to the survey, out of a pool of 58 SeTDA members from Florida registered at the time of the survey. This met our expectations, as the previous survey of the same demographic in 2018 received a total of 32 responses (Harmon et al. 2020). Our survey assessed trophy-deer farmers from approximately one third ($n = 22$) of Florida's 67 counties, distributed throughout the state (Fig. 1) indicating that

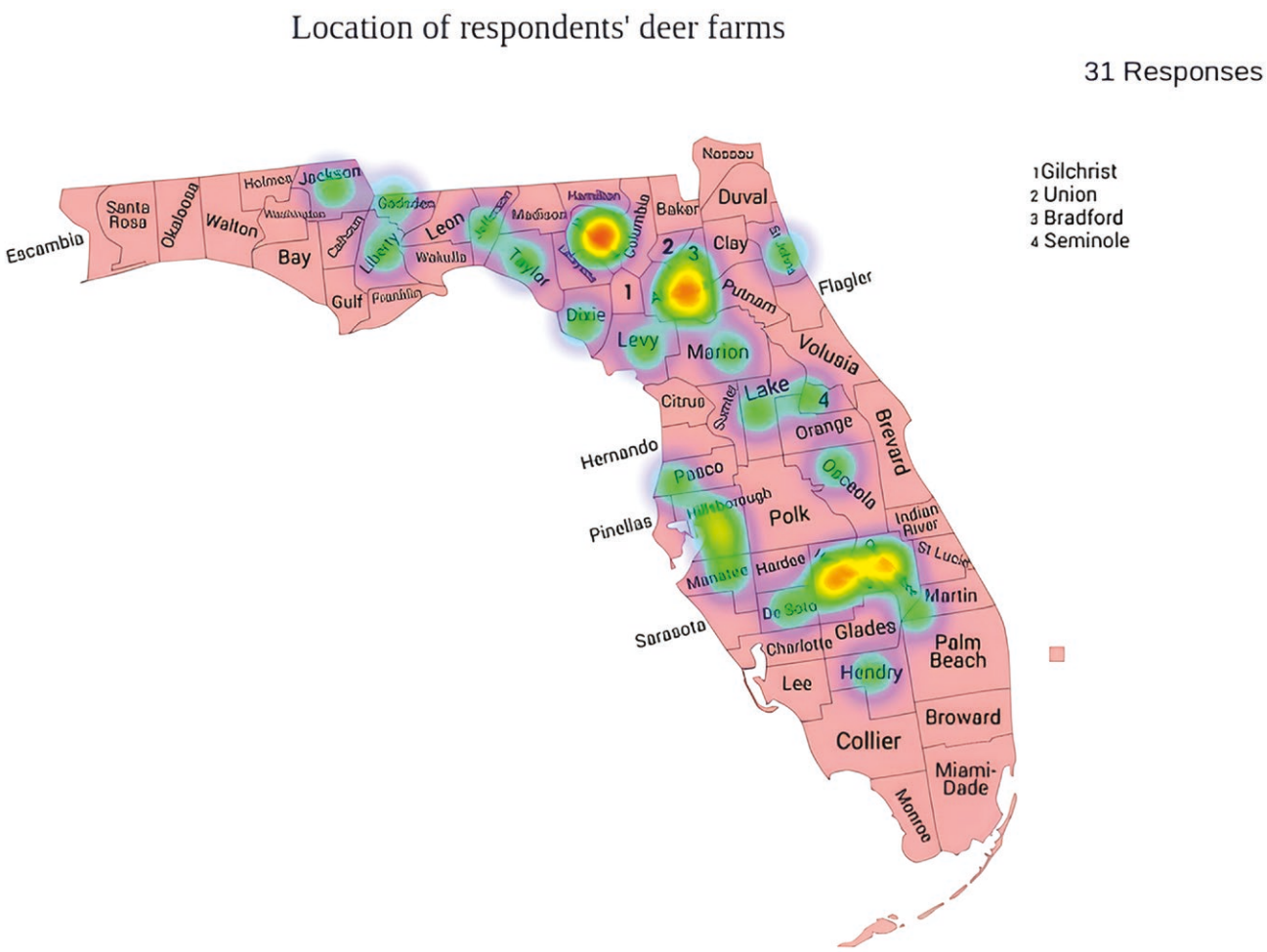

Fig. 1. Heat map depicting the 22 counties where the respondents to our 2023 survey of deer farmers own deer farms across the state of Florida.

we included deer farmers from diverse ecoregions that potentially experience diverse pest and HD pressures. For example, the main vector of BTV, *Culicoides insignis* Lutz is more commonly found in southern Florida, whereas species that have been incriminated in the transmission of EHDV, such as *Culicoides stellifer* (Coquillett), *Culicoides venustus* Hoffman, and *Culicoides debilipalpis* (Lutz) are common in northern Florida, and they have been extensively documented in the Florida panhandle (McGregor et al. 2019, 2020, Quaglia et al. 2020, Sloyer et al. 2023).

We followed recommendations by Harmon and co-authors (2020), who suggested that improvements could be made to increase the survey response rates. In response, we developed a shorter survey that could be completed within 10 min, up to 10 min faster than the 15- to 20-min survey conducted by Harmon et al. (2020). Not all questions were answered, since the respondents had the option to skip questions and stop the survey at any time (Table 1), a strategy to encourage participation and minimize survey abandonment. Some of the skipped questions were related to topics that may be perceived as sensitive, such as vaccination practices, which may have influenced the response rate despite the survey being anonymous. Additionally, Harmon et al. (2020) suggested that providing a clear explanation of the purpose of the survey could increase participant engagement. Delivering the survey during this in-person event allowed us to directly engage with deer farmers and emphasize the significance of their participation, explaining how their responses would contribute to the development of an IVM program targeting biting midges that vector HD viruses.

Deer Farms

Our survey revealed considerable diversity in the operations of trophy-deer farms in Florida. Farm sizes, measured by the number of deer per farm, ranged from 0 to 50 deer (51.5%), 50 to 100 deer (30.3%), to more than 100 deer (18.2%). Most respondents reported housing their deer, including bucks, does, and fawns, in outdoor pens. Outdoor pens were typically smaller, enclosed areas designed to house animals in a more controlled environment. Specifically, 72.7% of respondents indicated housing their bucks in outdoor pens, while 21.2% housed them in fenced preserves, which were larger, more natural enclosures that mimic wild habitats. Additionally, only 18.2% of does and 12.2% of fawns were housed in fenced preserves. Although our survey did not investigate the factors driving these variations in housing type and farm size, we believe these differences were likely influenced by property size.

Dear Health

We asked the respondents about the occurrence of HD on their farms and their vaccination practices. We determined that 54.5% of respondents had vaccinated their deer against infectious diseases in the past 2 yr (2020 to 2022). The majority of vaccines (34.6%) were aimed at preventing clostridial diseases, such as tetanus, blackleg, and pulpy kidney (Fig. 2). Other vaccines administered included those for EHDV (26.9%), and for preventing bacterial infections like leptospirosis, brucellosis, and pasteurellosis (23.1%) (Fig. 2).

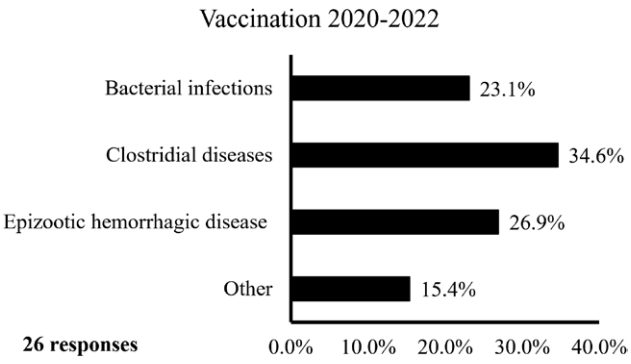

Fig. 2. Vaccines administered to deer in Florida trophy-deer farms between 2020 and 2022. Responses are based on our 2023 survey of deer farmers in Florida.

The remaining 15.4% mentioned using 'other vaccines', and specified poliovirus type 2.

Despite the occurrence of HD on Florida trophy-deer farms, 51.6% of respondents indicated that they had no intentions of vaccinating their deer against EHDV in 2024. This hesitation may be due to the limitations of the experimental vaccine available in Florida, which protects only against two of the serotypes circulating in the state (EHDV-2 and EHDV-6). Additionally, logistical challenges such as the need for two doses administered at specific intervals, associated costs, and the difficulty of vaccinating wild, semi-wild, or free-ranging deer may play significant roles in this reluctance to vaccinate (Orange et al. 2021).

Just over half (52.0%) of the respondents reported having cases of HD on their farms in 2022. The reported number of HD cases ranged from 1 to 5 cases (38.7%), 5 to 10 cases (6.4%), to more than 10 cases (6.4%). These findings highlight the critical need for effective control of HD vectors on deer farms to mitigate economic losses. The financial impact is significant, as the loss of a single animal can cost deer farmers thousands of dollars. For instance, the average annual income from breeding stock is USD 1,525 per fawn, USD 9,225 per bred doe, and USD 11,431 per breeder buck (Anderson et al. 2017).

Pest and Vector Control

The respondents reported using a variety of methods to control unwanted insects on their farms. We found that insecticide applications were the most popular approach for insect control (48.8%), followed by the use of barriers and screens (18.6%) (Fig. 3a). Most respondents (81.8%) spent less than USD 1000 on insecticide applications in 2022, while the remaining 18.2% spent between USD 1000 and 5000. Other control methods included preventive tactics such as removing breeding sites (7.0%), and biological control (4.7%) (Fig. 3a). Two percent of respondents reported using alternative tactics, including insect trapping, mosquito dunks, and applications of apple cider vinegar. Eighteen percent of the respondents indicated that they did not use any control methods on their farm in 2022 (Fig. 3a).

Sixty-six percent of the respondents reported applying insecticides specifically to control insects that impact deer health. The insects targeted during insecticide applications included biting midges (25.8%), mosquitoes (25.8%), deer flies (20.9%), horn flies (6.4%), and stable flies (4.8%) (Fig. 3c). Other arthropods like ticks are also targeted during these applications (16.1%). Deer farmers showed greater focus on controlling biting midges and mosquitoes, in comparison to the other flies listed in the survey ($\chi^2 = 3.161$, df = 1, $P = 0.038$).

In the survey conducted in 2018, Harmon and co-authors (2020) found that nearly 100% of deer farmers targeted biting midges for control, with about 80% targeting mosquitoes. Our survey, however, showed equal interest in controlling both biting midges and mosquitoes. While it is unclear if there has been a shift in focus toward mosquito control, our survey suggests that deer farmers are interested in managing mosquitoes as well as biting midges. This may be because mosquito bites can stress animals, negatively affecting their fitness, weight gain, and overall welfare (Pagès and Cohnstaedt 2018).

Ultra-low volume (ULV) applications remain the preferred method for insecticide application, consistent with the findings of Harmon et al. (2020). In our survey, 61.9% of respondents ranked ULV applications as their preferred method. We observed a notable preference for timing insecticide applications against biting midges, with most respondents applying at dusk (40.9%) compared to other times ($\chi^2 = 10.385$, df = 4, $P = 0.017$) (Fig. 3b). An equal proportion of respondents reported applying insecticides at dawn or during the daytime (18.2% each). Additionally, 18.2% of respondents indicated that they applied insecticides whenever they were available, regardless of timing, while a small number (4.5%) indicated applying at other times not listed in the answer options, without providing details. Given that the timing of adulticide applications should coincide with the period when these insects are most active (Wilke et al. 2023), additional studies on the patterns of circadian flight activity of HD vectors in Florida are needed to optimize insecticide application timings for effective control.

Permethrin Use

Among respondents who applied insecticides against biting midges, 69.2% (13 out of 24), reported using permethrin-based products. Others used malathion (organophosphate) (15.4%), or were uncertain of the product they applied (15.4%) (Fig. 3d). None of the respondents indicated using insect growth regulators, or other insecticides (Fig. 3d). Of those using permethrin-based products, 55.6% applied it at the maximum label rate, 22.2% applied it at a lower rate, and 22.2% were unsure of the rate they use. In comparison, Harmon et al. (2020), found that 62.5% (out of 32 respondents) used permethrin-based insecticides. They also reported that 53.1% of respondents applied chemicals for both plant and insect pests, while 37.5% targeted only insect pests. In our survey ($n = 37$), 48.9% of respondents reported using insecticides. Due to the nature of the questions and data reporting, statistical comparisons with the previous survey were not possible. However, we suspect that the slight reduction in permethrin use could be a result of the 15.4% of respondents who were uncertain of the insecticide they were applying.

Insecticide Resistance

Current pest control strategies among Florida trophy-deer farmers may pose risks for insecticide resistance and non-target effects on beneficial insects. Our data indicated that the vast majority of respondents perceived insecticides as the most effective method for pest control. During the peak HD season in Florida (summer and fall), the frequency of insecticide application varied, with 28.6% of respondents applying insecticides three to four times per week, 19.0% weekly, and 14.3% applying twice per week, every other week (14.2%), or once a month (19.0%). Daily applications were reported by 4.8% of respondents, suggesting potential overuse of insecticides. Although the specific products used by the respondents are unknown, Cooper et al., (2025) reported that some of the permethrin-based products used in Florida trophy-deer farms include PermaSease 4-4, Pursuit 4-4, Perm-X UL 4-4, and Permanone 30-30.

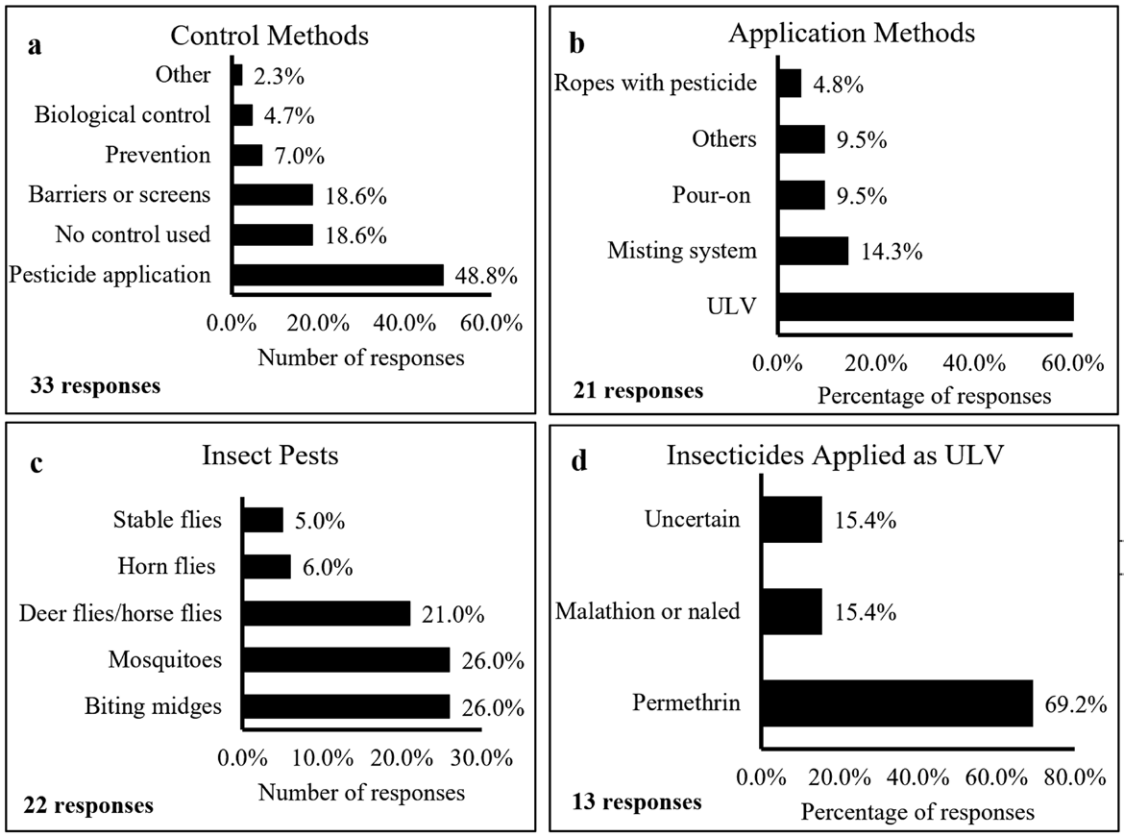

Fig. 3. Responses to insecticide use-related questions in our 2023 survey of deer farmers in Florida: a) Methods used to control unwanted insects; b) Most used methods of application against biting midges (no-see-ums); c) Insect pests that deer farmers attempt to control; d) Insecticides applied through ultra-low volume (ULV) applications.

These product labels generally recommend waiting at least three days before reapplication, and a limit of permethrin per acre applied by season is generally provided. No significant differences were observed in the timing of applications ($\chi^2 = 3.5$, df = 5, $P = 0.312$). These results suggested that deer farmers were applying insecticides frequently and may benefit from vector surveillance, guidance on timing applications to maximize efficacy, and other aspects of IVM. Implementing a range of control strategies as part of an IVM program could help minimize the development of insecticide resistance and better protect deer health in the long term.

In addition to insecticide applications for the control of biting insects, some trophy-deer farmers also attempted to control crop and structural pests. Forty-four percent of the respondents reported using insecticides exclusively for managing biting arthropods such as biting midges, while 26.5% indicated using insecticides to control structural pests such as cockroaches, termites, and ants, and 26.5% did not use insecticides at all. Only 2.9% of the respondents indicated using insecticides to control crop pests on their property. Despite these applications not targeting biting midges or mosquitoes directly, their indirect exposure to these chemicals could contribute to the development of insecticide resistance. Studies have shown that exposure of non-target species to insecticide residues can increase the likelihood of resistance development (Khan 2022). Additionally, more than half of Florida deer farmers did not rotate insecticides (Table 2), relying predominantly on permethrin as the main active ingredient to control biting midges. Implementing insecticide rotation is challenging on deer farms, as other insecticide classes such as organophosphates, carbamates, and neonicotinoids are often considered less safe for livestock due to potential residues in meat, or risks to animal health through dermal or oral exposure (Craddock et al. 2019). This constraint highlights the need for further research into safe and effective alternative chemistries and non-chemical vector control tools compatible with deer farming systems.

Knowledge and Attitudes

The knowledge and attitudes section of our survey revealed varying perspectives and levels of understanding among trophy-deer farmers regarding vector control on their farms. When asked to rank their strategies for timing insecticide applications to control biting midges, the most common approach was to apply insecticides when deer started to die on their farms, followed by when deer mortality occurred in other Florida farms, and in response to deer deaths reported on other farms in Florida. Trophy-deer farmers should consider preventative control of biting midges, rather than attempting to control biting midges during outbreaks, when infected biting midges may already have transmitted HD viruses to multiple animals in the farm. A preventative vector control program may consist of multiple control strategies, such as habitat management to reduce breeding sites, use of topical adulticides to prevent insect bites, use of insecticide-treated barriers, and vaccination when possible. Improving communication and education efforts could enhance the use of available resources and support better management of HD in Florida deer farms (Anderson and Feder 2007).

All respondents (100%) acknowledged the importance of reading the label before using a product (Table 2). While the majority 66.7% reported using the label to guide their application rates, nearly one-third of deer farmers still did not rely on product labels

Table 2. Responses to questions related to deer farmers' attitudes in our 2023 survey of deer farmers in Florida.

Statements/ Questions	Agree/ Yes	Disagree/ No
Insecticides are the best solution to control pests in my farm	82.8%	17.2%
It is important to read the insecticide label before using it	100%	0%
Do you rotate insecticides?	33.3%	66.7%
If I have unvaccinated deer within the next year, I will likely vaccinate them against EHD	48.4%	51.6%

for this purpose. Other respondents indicated that they based their decisions on recommendations from friends or colleagues (18.2%), information obtained through web searches (12.1%), or advice from pest control companies (3.0%). This variation in knowledge acquisition highlights a need for better education on the importance of adhering to insecticide label instructions for the effective and safe use of insecticides.

Conclusion

Our survey identified areas where trophy-deer farmers from Florida could benefit from additional information on safe and sustainable pest control practices. The information we collected in this survey will be used to create an educational program for deer farmers in Florida, focusing on IVM topics that could prove beneficial for herd health and production. We believe that deer farmers would benefit from learning details concerning HD vectors, the significance of comprehensively reviewing insecticide labels, strategies for mitigating insecticide resistance, and the potential adverse impacts on non-target organisms resulting from insecticide overuse.

We found that trophy-deer farmers from Florida predominantly rely on insecticide applications, particularly permethrin delivered through ULV machines, to control biting insects. This underscores the need for research evaluating the effectiveness of ULV permethrin applications against HD vectors and identifying potential improvements, such studies are already underway (Cooper et al., In Press). Additionally, generating information on the circadian flight activity of HD vectors will be crucial to ensure that insecticide applications are timed to coincide with periods of vector activity which would more effectively reduce the risk of infectious bites.

The insights from this survey will guide the development of an IVM program tailored to HD vectors in Florida that aligns with the needs of trophy-deer farmers. Implementing IVM will offer a comprehensive approach to pest and vector control, enhancing the long-term effectiveness of control measures while reducing the risk of insecticide resistance.

Acknowledgments

We would like to thank the Florida deer farmers for taking our survey. We thank the Southeast Trophy-deer Association for allowing us to provide the survey at their event. Thanks to Eva Buckner for providing valuable insights about the methodology of this study. We thank Laura Harmon and Emma Weeks for their valuable feedback in the development of the survey. Thanks to the students, faculty, and staff working at the University of Florida, Entomology Department, and the Institute of Food and Agricultural Sciences (UF/IFAS) Cervidae Health Research Initiative (CHeRI) for their contribution in preparing the survey. We thank our funding sources, UF/IFAS CHeRI as well as the University of Florida College of Agricultural and Life Sciences for contributing to funding the stipend of V.M.C.

Author contributions

Vilma Cooper (Conceptualization [Lead], Investigation [Lead], Methodology [Lead], Project administration [Lead], Resources [Lead], Visualization [Lead], Writing - original draft [Lead]), Samantha Wisely (Funding acquisition [Lead], Methodology [Supporting], Supervision [Supporting], Writing - review & editing [Equal]), Juan M. Campos-Krauer (Funding acquisition [Lead], Methodology [Supporting], Supervision [Supporting], Writing - review & editing [Equal]), and Nathan Burkett-Cadena (Conceptualization [Supporting], Funding acquisition [Lead], Methodology [Supporting], Project administration [Equal], Resources [Supporting], Supervision [Supporting], Visualization [Supporting], Writing - review & editing [Equal])

Conflicts of interest. The authors do not have any conflicts of interest.

References

Anderson, J.R., Feder, G. 2007. Chapter 44 agricultural extension. In: Evenson R, Pingali P, **editors.** Handbook of agricultural economics. Texas A&M University, Agricultural and Food Policy Center. Elsevier. 3, p. 2343–2378.

Anderson DP, Outlaw JL, Earley M, et al. 2017. Economic impact of U.S. deer breeding and hunting operations. Research Report 17–4. Agricultural and Food Policy Center Department of Agricultural Economics; pp. 1–20.

Cauvin A, Dinh ETN, Orange JP, et al. 2020. Antibodies to epizootic hemorrhagic disease virus (EHDV) in farmed and wild Florida white-tailed deer (*Odocoileus virginianus*). J. Wildl. Dis. 56:208–213.

Cooper VM, Buckner EA, Jiang Y, et al. 2025. Laboratory and field assays indicate that a widespread no-see-um, *Culicoides furens* (Poey) is susceptible to permethrin. Sci. Rep. 15:4698. https://doi.org/10.1038/s41598-025-89520-0

Cooper VM, Buckner EA, Campos-Krauer JM, et al. In press. Laboratory and semi-field data indicate that vector culicoides spp. in Florida are susceptible to permethrin. J. Med. Entomol 62:496.

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. https://doi.org/10.3390/v13081443

Craddock HA, Huang D, Turner PC, et al. 2019. Trends in neonicotinoid pesticide residues in food and water in the United States, 1999–2015. Environ. Health 18:1–6.

Freeman JC, Ross DH, Scott JG. 2019. Insecticide resistance monitoring of house fly populations from the United States. Pestic. Biochem. Physiol. 158:61–68. https://doi.org/10.1016/j.pestbp.2019.04.006

Guerrero FD, Jamroz RC, Kammlah D, et al. 1997. Toxicological and molecular characterization of pyrethroid-resistant horn flies, *Haematobia irritans*: identification of kdr and super-kdr point mutations. Insect. Biochem. Mol. Biol. 27:745–755. https://doi.org/10.1016/s0965-1748(97)00057-x

Harmon LE, Sayler KA, Burkett-Cadena ND, et al. 2020. Management of plant and arthropod pests by deer farmers in Florida. Gouge D, editor. J Integr Pest Manag 11:12.

Khan HAA. 2022. An impact assessment of insecticides application on the non-targeted mosquito *Aedes albopictus* (Skuse) in Punjab rice fields, Pakistan. PeerJ 10:e13697. https://doi.org/10.7717/peerj.13697

Manikandan S, Mathivanan A, Bora B, et al. 2022. A review on vector borne disease transmission: current strategies of mosquito vector control. China CDC Weekly 6:1–11.

McGregor BL, Blackburn JK, Wisely SM, et al. 2020. *Culicoides* (Diptera: Ceratopogonidae) communities differ between a game preserve and nearby natural areas in northern Florida. J. Med. Entomol. 58:450–457.

McGregor BL, Sloyer KE, Sayler KA, et al. 2019. Field data implicating *Culicoides stellifer* and *Culicoides venustus* (Diptera: Ceratopogonidae) as vectors of epizootic hemorrhagic disease virus. Parasites Vectors 12:258.

Min C, Feipeng W, Xiangzhu H, et al. 2017. Toxicity of five insecticides to *Culicoides oxystoma* Kieffer (Diptera: Ceratopogonidae). Plant Dis. 8:1.

Mullens B, McDermott E, Alec CG. 2015. Progress and knowledge gaps in Culicoides ecology and control. Veterinaria Italiana 201. https://doi.org/10.12834/VetIt.560.2675.1

Orange JP, Dinh ETN, Goodfriend O, et al. 2021. Evidence of epizootic hemorrhagic disease virus and bluetongue virus exposure in nonnative ruminant species in northern Florida. JZWM 51:745.

Pagès, N., Cohnstaedt, L.W. 2018. Mosquito-borne diseases in the livestock industry. In Garros C, Bouyer J, Takken W, Smallegange RC, **Editors.** Pests and vector-borne diseases in the livestock industry. Brill | Wageningen Academic. p. 195–219.

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

Potter A, Jardine A, Neville PJ. 2016. A Survey of knowledge, attitudes, and practices in relation to mosquitoes and mosquito-borne disease in Western Australia. Front. Public Health 29.

Quaglia AI, Blosser EM, McGregor BL, et al. 2020. Tracking community timing: pattern and determinants of seasonality in *Culicoides* (Diptera: Ceratopogonidae) in Northern Florida. Viruses 12:931. https://doi.org/10.3390/v12090931

Sloyer KE, Acevedo C, Wisely SM, et al. 2023. Host associations of biting midges (Diptera: Ceratopogonidae: *Culicoides*) at deer farms in Florida, USA. J. Med. Entomol. 60:518–526. https://doi.org/10.1093/jme/tjad036

Venail R, Lhoir J, Fall M, et al. 2015. How do species, population and active ingredient influence insecticide susceptibility in *Culicoides* biting midges (Diptera: Ceratopogonidae) of veterinary importance? Parasites Vectors 8:439.

Vontas J, Katsavou E, Mavridis K. 2020. Cytochrome P450-based metabolic insecticide resistance in *Anopheles* and *Aedes* mosquito vectors: muddying the waters. Pestic. Biochem. Physiol. 170:104666. https://doi.org/10.1016/j.pestbp.2020.104666

Wilke ABB, Mhlanga A, Kummer AG, et al. 2023. Diel activity patterns of vector mosquito species in the urban environment: implications for vector control strategies. Rasic G, editor. PLoS Negl.Trop. Dis. 17:e0011074. https://doi.org/10.1371/journal.pntd.0011074

Wisely, S.M. 2020. UF/IFAS is working closely with deer farmers in Northwest Florida. University of Florida UF IFAS Extension. Available from https://nwdistrict.ifas.ufl.edu/phag/2020/05/08/uf-ifas-is-helping-deer-farms-in-northwest-florida/. Accessed on 11/01/2024.

Wisely, S.M. 2021. Trophy-deer farming in Florida. AskIFAS. Available from https://edis.ifas.ufl.edu/entity/topic/trophy-deer-farming-in-florida. Accessed on 11/01/2024.

Zarei F, et al. 2024. ChecKAP: a checklist for reporting a knowledge, attitude, and practice (KAP) study. APJCP 25:2573.