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Understanding rabbit owners' willingness to engage in disease prevention behaviors

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ABSTRACT

Rabbit hemorrhagic disease virus 2 (RHDV2) is a fatal, highly contagious pathogen that infects wild and domestic lagomorphs (rabbits and hares). RHDV2 is an important cause of disease in pet and companion rabbits, and has caused declines of wild lagomorph populations. It is essential for domestic rabbit owners to engage in appropriate actions (e.g., using effective disinfectants, creating secure barriers between domestic and wild rabbits) to protect the health and welfare of their rabbits and reduce the risk of human-mediated spread of RHDV2. Thus, we investigated rabbit owners' stated willingness to engage in nine commonly recommended biosecurity practices and their support for seven potential government-implemented management actions. We administered an online survey to 1790 rabbit owners in the United States between April and August 2021. Respondents were likely to engage in all biosecurity measures and were supportive of most management actions that could be implemented by government agencies. Respondents' willingness to engage in and support biosecurity measures was positively correlated with their perceptions of the importance of biosecurity, risk perceptions pertaining to the impact of RHDV2 on lagomorphs and rabbit-related industries, knowledge of RHDV2, and trust in government to manage RHDV2. Respondents' motivations for owning rabbits, husbandry behaviors, and demographic characteristics also influenced their willingness to engage in or support biosecurity measures. Engaging domestic rabbit owners in collaborative biosecurity measures is critical for protecting domestic rabbit health and preventing potential spillover between domestic and free-roaming lagomorphs, as there are still many uncertainties about how RHDV2 is spreading across the United States and the world. Implementing outreach strategies that communicate the importance and effectiveness of biosecurity practices in protecting rabbit welfare, rabbit-related activities, and wild lagomorph populations may increase the likelihood of rabbit owners adopting biosecurity measures.

1. Introduction

Rabbit hemorrhagic disease virus 2 (GI.2/RHDV2/b; [Le Pendu et al., 2017](#)) is a highly contagious pathogen (genus *Lagovirus*, family *Caliciviridae*) that causes rabbit hemorrhagic disease (RHD) in wild and domestic lagomorphs ([Asin et al., 2021](#)). Rabbit hemorrhagic disease virus 2 (hereafter, RHDV2) causes disease within 2–4 days of infection (with mortality rates of up to 80%), but infected lagomorphs often show no visible signs of disease before death ([Le Gall-Reculé et al., 2013](#)). The virus was first detected in France in 2010 and has since spread outside Europe to Africa, Asia, Australia, and North America ([Rouco et al., 2019](#);

[Katayama et al., 2021](#)). The spread of RHDV2 was likely exacerbated by the human-mediated movement of lagomorphs, as the virus is hardy (surviving up to 15 weeks in dry conditions and more than 90 days in decaying animal tissue outdoors) and can be transmitted through multiple pathways (contact with infected lagomorphs, fomites, mechanical transmission by insects, and other animal vectors; [Marschang et al., 2018](#); [Rouco et al., 2019](#)). In Europe, RHDV2 is an important cause of disease in pet rabbits, with one study finding that 37.4% of samples collected from domestic rabbits submitted by veterinarians and owners throughout Europe were positive for RHDV2 ([Marschang et al., 2018](#)). RHDV2 has also caused population declines of wild lagomorphs and

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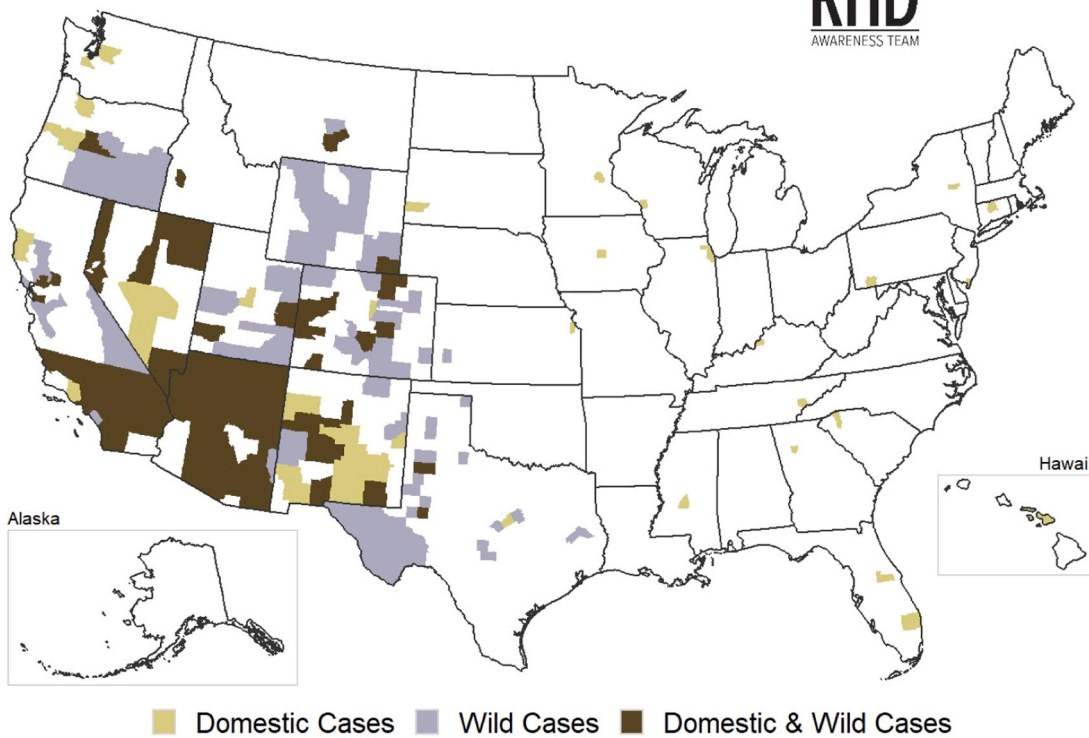
lagomorph predators, with one study finding a 60–70% decline in lagomorph populations, followed by fecundity decreases of 65.7% in Iberian lynx (*Lynx pardinus*) and 45.5% in Spanish Imperial eagles (*Aquila adalberti*; Monterroso et al., 2016). RHDV2 has resulted in economic losses for the lagomorph hunting and commercial rabbit industries (Campagnolo et al., 2003; Rouco et al., 2019).

In the United States (U.S.), RHDV2 is classified as a foreign animal disease and is reportable to the World Organization for Animal Health (OIE). In March 2020, an outbreak of RHDV2 was confirmed in domestic and wild lagomorphs in New Mexico (U.S. Department of Agriculture, 2022). As of August 2023, RHDV2 has been detected in wild lagomorphs, domestic rabbits and/or feral rabbits in 29 states (Fig. 1). This virus has the potential to impact a diverse array of rabbit-owning stakeholders, including people who own rabbits as pets or companion animals, volunteer or work at animal rescues and shelters, breed rabbits, raise rabbits for meat or fur, and show rabbits at exhibitions. The estimated worth of the domestic rabbit trade is \$2.2 to \$2.3 billion (Grannis, 2002), and in 2017, almost 500,000 rabbits were sold for commercial

use (U.S. Department of Agriculture, 2019). Americans own over two million rabbits as pets or companion animals (American Veterinary Medical Association, 2018). However, despite the popularity of rabbits as pets or companion animals and the significant value of the domestic rabbit trade, rabbit owner disease preventive behaviors and the movement of rabbits across the U.S. are poorly documented. This lack of data makes it difficult to monitor, track, and prevent RHDV2 spread, unless stakeholders who own or interact with rabbits voluntarily report RHDV2 detections or suspicious rabbit deaths to veterinarians or relevant government agencies (e.g., state agricultural agencies).

In response to the risks posed by RHDV2, state animal health officials and veterinarians recommended that rabbit owners develop customized biosecurity plans, establish best practices to prevent RHDV2 transmission, and consider available tools for disease mitigation and control (e.g., vaccines; National Assembly of State Animal Health Officials RHDV2 Subcommittee 2020a, 2020b). Animal health experts specifically recommended that rabbit owners should prevent domestic rabbits from interacting with wild lagomorphs, feral rabbits, and contaminated

RHDV2 August 2023



Data provided by USDA APHIS. Supplemental data reports (e.g., Press Releases) have been collated by Rabbits Rescue Society and WildRescue Inc. since the last USDA reporting period (every 3 months).

See [RHDV2.org/resources](https://rhdv2.org/resources) for USDA data disclaimer.
 Domestic cases include both domestic and feral rabbit cases.
 Map Credit: Dr. Michel Kohl, RHD Awareness Team, University of Georgia.
 Data last updated August 1 2023

Fig. 1. Detections of rabbit hemorrhagic disease virus 2 (RHDV2) in wild and domestic lagomorphs in the United States from March 2020 through August 2023. Shaded counties represent detections of RHDV2 reported to, and/or confirmed by, the US Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS). Detections are primarily the result of investigation of mortality events involving wild and domestic lagomorphs by state or federal wildlife agencies, state agricultural agencies, the USDA, or clinical veterinarians. The map represents the known distribution of RHDV2 in the US since March 2020. The number of impacted lagomorphs in a shaded county is not publicly available. Map last updated on August 1, 2023. Data Source: USDA-APHIS. Supplemental data reports that have been verified using press releases were used to update the map between USDA reporting periods. Domestic cases include both domestic and feral rabbit (*Lagomorpha*) cases. Map credit: M.T. Kohl. Map publicly available at rhdv2.org.

environments (e.g., keeping rabbits indoors or on man-made surfaces, creating a secure barrier between domestic rabbits and wild lagomorphs; [National Assembly of State Animal Health Officials RHDV2 Subcommittee, 2020a](#)). Additionally, state animal health officials developed guidelines for rabbit shows and exhibitions, including limiting interactions with domestic rabbits and other rabbit owners, isolating rabbits on return from shows, and following rules pertaining to the interstate movement of domestic rabbits ([National Assembly of State Animal Health Officials RHDV2 Subcommittee, 2020b](#)). Some states created or temporarily adopted rules and regulations to slow or prevent potential human-mediated spread of RHDV2 (e.g., reducing the length of time that a certificate of veterinary inspection is considered valid, canceling rabbit shows); however, the implementation and enforcement of these measures varies greatly between states ([Shapiro et al., 2022a](#)). Thus, many agencies rely on people who own or interact with domestic rabbits to report suspicious rabbit mortalities and engage in voluntary biosecurity actions.

In 2021, we surveyed rabbit owners in the U.S. to ascertain whether rabbit owners are willing to adopt recommended biosecurity actions or support potential government-mandated biosecurity measures. Consistent with social science studies of other wildlife diseases, we posited that rabbit owners would be more likely to engage in or support biosecurity measures if they believe biosecurity measures are important, perceive the economic, ecological or animal welfare risks associated with RHDV2 spread ([Hanisch-Kirkbride et al., 2013](#); [Triezenberg et al., 2014](#); [Wiethoelter et al., 2017](#); [Pienaar et al., 2022](#)), trust the government to manage RHDV2 ([Siegrist and Cvetkovich, 2000](#); [Hanisch-Kirkbride et al., 2014](#); [Wright et al., 2018](#)), and are knowledgeable about RHDV2. We also posited that rabbit owners' motivations for owning domestic rabbits (e.g., as companion animals, for exhibition, for sale), rabbit husbandry ([Rooney et al., 2014](#); [Welch et al., 2017](#)), and demographic characteristics ([Wiethoelter et al., 2017](#); [Wright et al., 2018](#)) would influence their willingness to engage in or support biosecurity measures.

This study builds on our recent finding that rabbit owners in the U.S. agreed that individuals who own or interact with domestic rabbits must engage in biosecurity measures to prevent the spread of RHDV2 to new areas, regardless of access to vaccinations or the RHDV2 status of their state ([Shapiro et al., 2022b](#)). Survey respondents had high awareness and knowledge of RHDV2, believed RHDV2 poses a large risk to rabbit-related industries, and were concerned about the economic and ecological impacts of RHDV2 ([Shapiro et al., 2022b](#)). In this paper, we build on our previous analysis by 1) examining rabbit owners' stated willingness to engage in specific, voluntary biosecurity practices and support potential government-implemented disease management actions, and 2) identifying determinants of rabbit owners' willingness to engage in or support biosecurity actions.

2. Methods

2.1. Survey design

We created and distributed online surveys to examine respondents' willingness (very unlikely=1; unlikely=2; neither likely nor unlikely=3; likely=4; very likely=5) to engage in nine voluntary biosecurity actions, specifically: 1) reporting suspicious rabbit deaths to their state agricultural agency; 2) keeping rabbits inside; 3) creating a secure barrier between areas used by domestic rabbits and wild lagomorphs; 4) using USDA-recommended disinfectants to clean rabbit enclosures; 5) having separate shoes and clothes for inside and outside rabbit enclosures; 6) preventing other rabbit owners from interacting with their rabbits; 7) isolating new rabbits from other rabbits for at least 30 days; 8) acquiring a certificate of veterinary inspection (CVI) before transporting rabbits between states; and 9) vaccinating rabbits if/when the RHDV2 vaccine became available ([National Assembly of State Animal Health Officials RHDV2 Subcommittee, 2020a, 2020b](#)). It is important to note that

during data collection, RHDV2 vaccines could only be imported from Europe by states with confirmed RHDV2 mortalities ([Shapiro et al., 2022a](#)). A vaccine developed and produced in the U.S. received emergency use authorization from the USDA in September 2021 ([Bosco-Lauth et al., 2022](#)), and most states have approved its use as of April 2023. Respondents could indicate which biosecurity measures were not applicable to their situation. We also asked respondents about their support for or opposition to seven potential government measures to prevent the spread of RHDV2 (strongly oppose=1, oppose=2, neither oppose nor support=3, support=4, strongly support=5), namely: 1) relocating rabbit shows/exhibitions at least 150 miles (241.40 km) from counties with RHDV2; 2) requiring rabbit owners to obtain a CVI before attending any events with live rabbits; 3) penalizing rabbit transporters who do not obtain a CVI for the rabbits they transport; 4) requiring rescued rabbits to be inspected by a veterinarian before being moved by rabbit rescues or animal shelters over state borders; 5) banning rabbit rescues from acquiring rabbits from states with RHDV2; 6) banning the trade of rabbits (alive and dead) that come from states with confirmed RHDV2 cases; and 7) banning the trade of all rabbits (alive and dead) until the U.S. produces and distributes a domestic RHDV2 vaccine.

As part of this research effort, we asked respondents to provide us with information about: their rabbit husbandry behaviors; prior awareness and knowledge of RHDV2; perceptions of the level of risk that RHDV2 poses to the commercial rabbit trade and lagomorph hunting (a measure of risk susceptibility); level of concern about the impact of RHDV2 on the commercial rabbit trade, lagomorph hunting, the health of domestic rabbits and wild lagomorphs in their state, and biodiversity (a measure of risk sensitivity); perceptions of the importance of biosecurity measures; trust in state government to manage RHDV2; and demographics (gender, age, and education level). Responses to these survey questions are published in [Shapiro et al. \(2022b\)](#). See also the [Supporting Information](#).

Veterinary medicine and animal disease specialists, human dimensions experts, and wildlife biologists reviewed the survey instrument prior to implementation. We also pre-tested the survey using cognitive testing with members of key stakeholder groups who interact with lagomorphs, including high-level members of rabbit rescue and rabbit breeder groups. Our study was reviewed by the University of Georgia's Institutional Review Board and classified as not human subjects research.

2.2. Survey implementation

We distributed online surveys from April to August 2021. Individuals were eligible to participate in this study if they were adults (≥ 18 years of age), and owned or interacted with domestic rabbits at the time of the study (i.e., participants bred rabbits, worked or volunteered at rabbit rescues, and/or owned rabbits as companion animals). We conducted an online search of rabbit breeders across the U.S. and sent 3696 rabbit breeders an online invitation to participate in this research. We also paid Qualtrics Research Services to survey 220 people who owned rabbits as pets or companion animals. The House Rabbit Society emailed the survey information and link to 8363 email subscribers and educators. The American Rabbit Breeders Association posted the survey link on the RHDV2 page of their website. Potential participants who were emailed an online invitation to take the survey were sent one to three reminders to participate in the research if they had not responded to the survey. The survey remained open for three months after dissemination.

2.3. Statistical analysis

We used SPSS 28.0 (SPSS Statistics for Windows, Version 28.0, Armonk, NY: IBM Corp.) to run descriptive analyses and principal factor analysis. We used principal factor analysis, with varimax rotation, and Cronbach's alpha (Cronbach, 1951) to test whether survey items could be combined to generate composite variables (e.g., respondents'

susceptibility and sensitivity to risk). We generated composite variables by averaging responses to survey items that loaded onto factors with an eigenvalue ≥ 1 and Cronbach's alpha ≥ 0.7 (Gliem and Gliem, 2003).

We used ordinal logistic regression models to analyze respondents' willingness to engage in each biosecurity measure and their support for government strategies to prevent the spread of RHDV2. We included respondents' sociodemographic variables, rabbit ownership, husbandry behaviors, awareness of RHDV2 and composite measures of their knowledge of RHDV2, risk sensitivity, risk susceptibility, perceptions of the importance of engaging in biosecurity, and trust in government to manage RHDV2 as explanatory variables in the regression models. We also included interaction effects in the regression models to test whether the influence of respondents' socio-psychological characteristics on their willingness to engage in or support biosecurity measures was influenced by whether or not they breed rabbits. We used the polr package in R 4.1.2 (R Core Team, 2021) to estimate the ordinal logistic regression models. We used the Akaike Information Criterion (AIC) to identify best-fit models (Burnham and Anderson, 2004) after comparing all possible models using the MuMIn package. We averaged models that were within $AIC \leq 2$ of the model with the lowest AIC. We considered a coefficient to be statistically significant at $p \leq 0.05$.

3. Results

We collected a total of 1790 completed surveys from rabbit owners, breeders, and rescue volunteers and staff. The response rate for the surveys sent by the House Rabbit Society was 12.3% and the response rate for the surveys we sent to an online list of rabbit breeders was 5.9%. We could not calculate response rates for surveys administered by Qualtrics Research Services or collected from the online link posted on the American Rabbit Breeders Association website because we do not know how many individuals received or saw the invitation to participate in this study.

Most respondents were female (80.0%) and had completed a university degree (63.5%). The median age range of respondents was 35–44 years, and the median number of rabbits owned by respondents was 2–5 animals. Most respondents owned pet or companion rabbits ($n = 1311$; 73.2%), but respondents also bred rabbits ($n = 560$; 31.3%) or volunteered or worked at a rabbit rescue or animal shelter ($n = 322$; 18.0%).

Most respondents were likely or very likely to engage in all voluntary biosecurity actions, with respondents expressing greatest willingness to report suspicious rabbit deaths and least willingness to acquire a CVI before transporting rabbits between states (Table 1). On average,

Table 1

Respondents' willingness to engage in voluntary biosecurity actions to prevent the spread of RHDV2 ($n = 1790$). Respondents answered the question "How likely are you to engage in the following behaviors?"

Biosecurity action	Median response	Percent of respondents who provided response					
		Very unlikely ^a	Unlikely	Neither likely nor unlikely	Likely	Very likely	Not applicable
Report suspicious rabbit deaths	Very likely	2.7	1.5	3.0	17.7	73.7	1.5
Keep your rabbit(s) inside	Very likely	5.1	5.8	4.7	9.4	72.6	2.4
Use USDA-recommended disinfectants to clean rabbit housing areas	Very likely	3.1	6.4	9.4	23.2	55.6	2.1
Prevent other rabbit owners from interacting with your rabbit(s)	Very likely	1.6	5.1	10.9	21.5	58.4	2.5
Have separate clothes and shoes for inside and outside your rabbit enclosure area	Likely	6.1	15.2	14.1	20.1	41.0	3.4
Create a secure barrier between areas used by domestic and wild rabbits	Very likely	3.0	4.8	7.6	15.1	49.6	19.9
Acquire a Certificate of Veterinary Inspection (CVI) before transporting rabbits between states	Likely	9.2	9.0	13.9	13.9	27.7	26.5
Isolate new rabbit(s) from your other rabbit(s) for at least 30 days	Very likely	1.7	3.2	5.1	16.7	58.3	15.0
Vaccinate your rabbit(s) if/when the RHDV2 vaccine becomes available	Very likely	3.7	4.5	8.5	14.6	66.9	1.7

^a Very unlikely = 1, unlikely = 2, neither likely nor unlikely = 3, likely = 4, very likely = 5

respondents expressed support for most agency actions to prevent RHDV2 spread, with the exception of banning rabbit rescues from acquiring rabbits from states with RHDV2 and banning the trade of rabbits until the U.S. started producing and distributing a RHDV2 vaccine (Table 2).

Most respondents had heard of RHDV2 (90.0%), and these respondents had high levels of RHDV2 knowledge (median = 0.87; 0.81 ± 0.20 ; range = 0–1; Shapiro et al., 2022b). We used principal factor analysis to combine survey items and generate five variables (see Supporting Information). Respondents were concerned about the impacts of RHDV2 on lagomorphs (variable name: risk sensitivity to lagomorph deaths; median = 4.50; 4.31 ± 0.82 ; range = 1–5; Table S1). Respondents expressed less concern about the impacts of RHDV2 on rabbit-related industries (variable name: risk sensitivity to the economic impacts of RHDV2; median = 3.75; 3.59 ± 1.12 ; range = 1–5; Table S1). Respondents believed that RHDV2 poses a risk to rabbit-related industries (variable name: risk susceptibility to the economic impacts of RHDV2, median = 3.60; 3.49 ± 0.53 ; range = 1–4; Table S2). Respondents recognized the necessity of biosecurity measures (variable name: perceived importance of biosecurity, median = 4.60; 4.47 ± 0.58 ; range = 1–5; Table S3). Finally, respondents expressed neither trust nor distrust in their state government's management of RHDV2 (variable name: trust in government, median = 3.00; 2.91 ± 0.80 ; range = 1–5; Table S4).

3.1. Ordinal logistic regression analysis of rabbit owners' willingness to engage in or support biosecurity actions

3.1.1. Engagement in rabbit-related activities

Rabbit breeders ($p = 0.003$) and rescue staff ($p = 0.001$) were more likely to use USDA-recommended disinfectants to clean rabbit enclosures (Table 3). Breeders were more likely to isolate new rabbits before introducing them into the rabbit herd ($p = 0.014$; Table 3) and support a government ban on rabbit rescues obtaining rabbits from states with RHDV2 ($p < 0.001$; Table 4). Breeders were less likely to keep their rabbits inside ($p < 0.001$) and vaccinate their rabbits ($p < 0.001$). Breeders were less likely to support mandated CVIs for events with live rabbits ($p < 0.001$), penalties for individuals who transport rabbits without CVIs ($p < 0.001$), or rabbit trade bans ($p < 0.001$), whereas rescue staff were more likely to support these measures ($p \leq 0.04$). Breeders were also less likely to support rules requiring rescued rabbits to be inspected by a veterinarian before being moved between states ($p = 0.005$). Rescue staff were more likely to report suspicious rabbit deaths ($p = 0.013$), have separate clothes for rabbit enclosures ($p = 0.034$), and vaccinate rabbits ($p = 0.014$), but they were less likely

Table 2

Respondents' support for agency actions to prevent the spread of RHDV2 in the U.S. (n = 1790) Respondents answered the question "Please indicate if you oppose or support the following potential regulations designed to prevent the spread of RHDV2."

Agency-mandated biosecurity measures	Median response	Percent of respondents who provided response				
		Strongly oppose ^a	Oppose	Neither oppose nor support	Support	Strongly support
Relocate rabbit shows/exhibitions at least 150 miles from counties with RHDV2	Support	2.7	3.9	19.5	32.3	41.7
Require rabbit owners to obtain a Certificate of Veterinary Inspection before attending events with live rabbits	Support	10.3	8.4	12.8	23.4	45.1
Penalize rabbit owners who do not obtain a Certificate of Veterinary Inspection for the rabbits they carry	Support	7.2	7.2	18.2	25.8	41.7
Require rescued rabbits to be inspected by a veterinarian before being moved by rescues over state borders	Support	2.5	3.5	10.2	35.9	47.9
Ban rabbit rescues from acquiring rabbits from states with RHDV2	Neither oppose nor support	10.7	20.9	27.9	16.8	23.6
Trade ban on rabbits that come from states with confirmed RHDV2 cases	Support	6.9	11.9	23.5	22.0	35.8
Trade ban on all rabbits until the U.S. starts producing and distributing a RHDV2 vaccine	Neither oppose nor support	14.5	13.7	22.1	19.4	30.2

^a Strongly oppose= 1, oppose= 2, neither oppose nor support= 3, support= 4, strongly support= 5.

to prevent interactions between their rabbits and other rabbit owners (p = 0.003). Rescue staff were more likely to support the relocation of rabbit shows (p = 0.013).

3.1.2. Rabbit husbandry and respondent demographics

Respondents who housed their rabbits outside were less likely to move their rabbits indoors (p < 0.001), have separate clothing for their rabbit enclosures (p = 0.019), create secure barriers between their rabbits and wild lagomorphs (p < 0.001), or vaccinate their rabbits (p = 0.017). Respondents who traveled across state lines with their rabbits were more likely to disinfect enclosures (p = 0.016) but were less likely to acquire CVIs (p = 0.028). They were also more likely to support relocation of rabbit shows (p = 0.048) and bans on the movement of rescued rabbits from states with RHDV2 (p = 0.003) but were less likely to support CVI requirements for transporters and rabbit shows (p < 0.001). Respondents from states with RHDV2 were more likely to obtain CVIs (p = 0.004) but were less likely to support relocation of rabbit shows (p < 0.001), CVI requirements (p = 0.031), and bans on the transport of rabbits out of states with RHDV2 (p < 0.001). The number of rabbits owned by respondents and respondents' sociodemographic characteristics (age, gender, education) influenced their willingness to engage in and support biosecurity measures. These effects were often small, but we note that female respondents were more likely to prevent other owners interacting with their rabbits (p = 0.018), to acquire CVIs before transporting rabbits (p = 0.002), and to isolate new rabbits for 30 days (p = 0.016).

3.1.3. Knowledge of RHDV2

Respondents who were previously aware of RHDV2 were less likely to change clothes after exiting rabbit enclosures (p < 0.001), even if they had high knowledge of RHDV2 (p = 0.009). Respondents who were aware of RHDV2 were also less likely to acquire CVIs (p = 0.042). Respondents with greater knowledge of RHDV2 were more likely to report suspicious rabbit deaths (p = 0.003) and isolate new rabbits from the herd for 30 days (p = 0.039), but they were less likely to support CVI requirements for rabbit-based events (p < 0.001) and bans on the movement of rescued rabbits (p < 0.001) or the rabbit trade (p ≤ 0.047).

3.1.4. Perceived importance of biosecurity, risk perceptions, and trust in government

Respondents who perceived the importance of biosecurity were more likely to engage in all voluntary biosecurity actions and to support government-mandated biosecurity measures (p ≤ 0.002). Respondents who trusted state government to manage RHDV2 were more likely to

keep their rabbits inside (p = 0.007), change clothes after exiting rabbit enclosures (p = 0.011), create secure barriers between domestic and wild rabbits (p = 0.023), acquire CVIs (p < 0.001), vaccinate their rabbits (p = 0.006), and support a ban on rabbit rescues acquiring rabbits from states with RHDV2 (p < 0.001). Breeders who trusted the state government to manage RHDV2 were more likely to support the relocation of rabbit shows (p = 0.005), CVI requirements for rabbit shows (p < 0.001), and trade bans until a domestic vaccine was produced (p = 0.005).

Respondents who expressed high susceptibility to the economic risks of RHDV2 (i.e., they believed RHDV2 poses substantial risks to rabbit-based activities and industries) were more likely to engage in or support biosecurity measures (p ≤ 0.002), with the exception of keeping rabbits inside and requiring veterinary inspection of rescued rabbits. Respondents who expressed greater concerns about the economic impacts of RHDV2 (i.e., high risk sensitivity) were more likely to disinfect rabbit enclosures (p < 0.001), have separate clothing for enclosures (p = 0.043), prevent other rabbit owners from interacting with their rabbits (p = 0.002), and acquire a CVI (p < 0.001). These individuals were more likely to support mandatory veterinary inspections of rescued rabbits (p = 0.017) and bans on interstate movement of rescued rabbits (p < 0.001) but were less likely to support rabbit trade bans (p ≤ 0.038). Respondents who were concerned about the impact of RHDV2 on rabbit rescues were more likely to vaccinate rabbits (p < 0.001), have separate clothing for rabbit enclosures (p = 0.031), keep rabbits inside (p = 0.001), support CVI requirements for rabbit-based events (p = 0.037), support veterinary inspections of rescued rabbits (p = 0.013), and support a ban on rabbit trade until a vaccine was produced (p = 0.002). These individuals were less likely to support bans on rescues acquiring rabbits from states with RHDV2 (p < 0.001). Rabbit breeders who were concerned about the impact of RHDV2 on rescues were more likely to acquire CVIs before transporting rabbits between states (p = 0.002) and to support penalties for transporters who did not acquire CVIs (p = 0.002). Respondents who expressed risk sensitivity to RHDV2-related lagomorph deaths were more likely to report suspicious rabbit deaths (p < 0.001), have separate clothes for rabbit enclosures (p = 0.016), acquire CVIs (p = 0.029), and vaccinate rabbits (p < 0.001). These individuals were more likely to support all government-mandated biosecurity measures (p ≤ 0.036), with the exception of banning rabbit rescues from acquiring rabbits from states with RHDV2.

There are, however, caveats to these findings based on whether respondents were rabbit breeders. For example, rabbit breeders who expressed susceptibility to the economic impacts of RHDV2 were less likely to report suspicious rabbit deaths (p = 0.009), unless they were

Table 3

Ordinal logistic regression analysis of respondents' willingness to engage in biosecurity measures to prevent the spread of RHDV2 in the U.S. Coefficient estimates with p values provided in parentheses.

	Report suspicious rabbit deaths	Keep your rabbit(s) inside	Use USDA-recommended disinfectants to clean rabbit housing areas	Prevent other rabbit owners from interacting with your rabbit(s)	Have separate clothes and shoes for inside and outside your rabbit enclosure area	Create a secure barrier between areas used by domestic and wild rabbits	Acquire a Certificate of Veterinary Inspection (CVI) before transporting rabbits between states	Isolate new rabbit (s) from your other rabbit(s) for at least 30 days	Vaccinate your rabbit (s) if/when the RHDV2 vaccine becomes available
Perceived importance of biosecurity	0.654 (<0.001)	0.448 (<0.001)	0.550 (<0.001)	0.815 (<0.001)	0.698 (<0.001)	0.718 (<0.001)	0.485 (<0.001)	1.016 (<0.001)	0.584 (<0.001)
× rabbit breeder	0.479 (0.017)								-0.471 (0.017)
Risk sensitivity to lagomorph deaths	0.354 (<0.001)	0.214 (0.062)	0.057 (0.388)	0.086 (0.192)	0.203 (0.016)	0.126 (0.068)	0.189 (0.029)	0.130 (0.093)	0.542 (<0.001)
× rabbit breeder		-0.228 (0.132)			-0.224 (0.069)		-0.138 (0.304)		
Risk sensitivity to economic impacts of RHDV2	-0.021 (0.767)		0.206 (<0.001)	0.156 (0.002)	0.095 (0.043)		0.282 (<0.001)		0.123 (0.100)
× rabbit breeder	0.398 (0.012)		-0.166 (0.215)				-0.402 (0.006)		
Concern about the impact of RHDV2 on rabbit rescues		0.363 (0.001)			0.123 (0.031)		-0.160 (0.114)	0.116 (0.089)	0.225 (<0.001)
× rabbit breeder		-0.505 (<0.001)					0.438 (0.002)		
Risk susceptibility to economic impacts of RHDV2	0.504 (<0.001)	0.220 (0.082)	0.392 (<0.001)	0.513 (<0.001)	0.521 (<0.001)	0.627 (<0.001)	0.378 (0.002)	0.522 (<0.001)	0.406 (0.002)
× rabbit breeder	-0.661 (0.009)				-0.311 (0.106)	-0.441 (0.028)			
Trust in government to manage RHDV2		0.211 (0.007)	0.105 (0.100)		0.151 (0.011)	0.155 (0.023)	0.429 (<0.001)	0.143 (0.097)	0.209 (0.006)
× rabbit breeder							-0.204 (0.127)	-0.167 (0.262)	
Prior awareness of RHDV2	0.372 (0.184)		-0.205 (0.235)		-0.931 (<0.001)		-0.524 (0.042)	-0.530 (0.069)	
Knowledge of RHDV2	0.856 (0.003)				0.665 (0.009)		0.360 (0.243)	0.716 (0.039)	0.436 (0.056)
RHDV2 status of respondents' state of residence		0.243 (0.053)		0.146 (0.143)	0.155 (0.089)		0.315 (0.004)	0.182 (0.121)	0.229 (0.061)
Number of rabbits owned ^a		0.003 (0.048)	0.004 (0.002)	0.002 (0.065)	0.002 (0.011)	0.001 (0.182)			-0.001 (0.189)
House rabbits outside		-2.656 (<0.001)	-0.142 (0.257)	-0.161 (0.213)	-0.264 (0.019)	-0.560 (<0.001)			-0.309 (0.023)
Travel out of state with rabbits		0.279 (0.056)	0.282 (0.016)	-0.205 (0.083)	0.192 (0.073)		-0.254 (0.028)		
Rabbit breeder	-0.105 (0.536)	-0.646 (<0.001)	0.425 (0.003)	0.234 (0.106)	-0.131 (0.331)	-0.234 (0.074)	-0.083 (0.607)	0.357 (0.014)	-1.251 (<0.001)
Rescue volunteer	0.473 (0.013)	0.322 (0.130)	0.443 (0.001)	-0.414 (0.003)	0.270 (0.039)			0.293 (0.097)	0.579 (0.014)
Age ^b		0.007 (0.123)	-0.007 (0.029)	0.007 (0.036)		-0.012 (0.002)	-0.010 (0.005)	-0.010 (0.017)	-0.013 (0.003)
Gender ^c				0.152 (0.018)		0.076 (0.270)	0.205 (0.002)	0.171 (0.016)	0.113 (0.127)
Education ^d			-0.083 (0.002)	-0.046 (0.089)		0.042 (0.147)			

Intercepts:

(continued on next page)

Table 3 (continued)

	Report suspicious rabbit deaths	Keep your rabbit(s) inside	Use USDA-recommended disinfectants to clean rabbit housing areas	Prevent other rabbit owners from interacting with your rabbit(s)	Have separate clothes and shoes for inside and outside your rabbit enclosure area	Create a secure barrier between areas used by domestic and wild rabbits	Acquire a Certificate of Veterinary Inspection (CVI) before transporting rabbits between states	Isolate new rabbit (s) from your other rabbit(s) for at least 30 days	Vaccinate your rabbit (s) if/when the RHDV2 vaccine becomes available
β_1	-3.256 (<0.001)	-4.188 (<0.001)	-4.969 (<0.001)	-4.461 (<0.001)	-3.147 (<0.001)	-3.910 (<0.001)	-3.024 (<0.001)	-4.330 (<0.001)	-4.537 (<0.001)
β_2	-2.771 (<0.001)	-3.166 (<0.001)	-3.755 (<0.001)	-2.964 (<0.001)	-1.607 (<0.001)	-2.843 (<0.001)	-2.116 (<0.001)	-3.170 (<0.001)	-3.617 (<0.001)
β_3	-2.149 (<0.001)	-2.546 (<0.001)	-2.908 (<0.001)	-1.785 (<0.001)	-0.804 (<0.001)	-1.993 (<0.001)	-1.141 (<0.001)	-2.304 (<0.001)	-2.603 (<0.001)
β_4	-0.407 (0.009)	-1.617 (<0.001)	-1.649 (<0.001)	-0.537 (0.253)	0.155 (0.332)	-0.934 (0.049)	-0.227 (0.292)	-0.874 (<0.001)	-1.576 (<0.001)
N	1763	1747	1752	1746	1729	1433	1316	1522	1760
Log likelihood ^c	-1236.85	-1256.13	-1965.21	-1790.06	-2353.94	-1524.45	-1723.36	-1317.85	-1318.37
AIC ^c	2497.70	2548.26	3958.42	3608.12	4745.88	3072.89	3482.72	2667.70	2672.73

^a Coded as 1 rabbit = 1; 2–5 rabbits = 4; 6–10 rabbits = 8; 11–20 rabbits = 15; 21–50 rabbits = 35; 51–100 rabbits = 75; 101–500 rabbits = 300.

^b Coded as male = -1; prefer not to answer = 0, female = 1.

^c Coded as 18–24 years old = 21, 25–34 = 30; 35–44 = 40; 45–54 = 50; 55–64 = 60; 65–74 = 70; 75 years old and over = 75.

^d Coded as less than 12th grade = 10; high school graduate = 12; some college or an associate degree = 14; Bachelor's degree = 16; graduate degree = 18.

^e The MuMIn package in R identifies all models that are within 2 AIC of the model with the lowest AIC value, and then averages the estimated coefficients (β) across these models. The estimated coefficients provided in the table are averages of the estimated coefficients across the different models that were good fits of the data. The AIC and log likelihood pertain to the best-fit model (i.e., the model with the lowest AIC).

also concerned about the economic impacts of RHDV2 (i.e., they expressed sensitivity to economic risks; $p = 0.012$). Breeders who were concerned about the economic impacts of RHDV2 were less likely to acquire CVIs ($p = 0.006$), and breeders who trusted the government to manage RHDV2 were less likely to support bans on rabbit rescues acquiring rabbits from states with RHDV2 ($p < 0.001$).

4. Discussion

Rabbit owners' voluntary engagement in RHDV2 biosecurity behaviors and support for management actions to reduce the risk of human-mediated RHDV2 spread are essential for protecting domestic rabbit health. It is therefore encouraging that most respondents stated that they were likely to engage in appropriate biosecurity measures, in particular keeping their rabbits inside, thereby decreasing the risk of RHDV2 transmission between domestic rabbits, free-roaming lagomorphs, and contaminated environments. Respondents also supported most potential management actions designed to prevent the human mediated spread of RHDV2, with the exception of banning rabbit rescues from acquiring rabbits from states with RHDV2 and banning rabbit trade until the U.S. started producing and distributing a RHDV2 vaccine. Although these findings are encouraging, it is important to note that because of limited records on rabbit ownership in the U.S., we sampled a small proportion of rabbit-owning stakeholders, many of whom were recruited by rabbit-specialist groups. It is unlikely that our sample is representative of the population of rabbit owners in the U.S., and thus our results cannot be generalized. Agencies should identify and engage with rabbit owners in their state to determine if our results are representative of the larger rabbit-owning population.

Top-down RHDV2 management strategies, particularly bans on the interstate movement of rabbits, will be ineffective if they are not consistent across states and rigorously enforced. Unfortunately, many state agricultural agencies in the U.S. do not have jurisdiction over domestic rabbits or lack the resources to institute or enforce domestic rabbit movement controls (Shapiro et al., 2022a). Thus, we recommend that government agencies, veterinarians, and rabbit specialist groups focus their efforts on increasing rabbit owners' adoption of voluntary biosecurity behaviors by addressing motivations that are important to rabbit owners. For example, educational materials should highlight the

importance of engaging in biosecurity measures to protect domestic rabbits and prevent the spread of RHDV2. Consistent with other studies of pet and livestock owners, we found that respondents were more likely to adopt or support biosecurity measures if they recognize the importance of engaging in biosecurity or considered them effective (Schemann et al., 2012; Brennan and Christley, 2013; Damiaans et al., 2018). In written comments at the end of our survey, respondents suggested that some recommended practices are ineffective, impractical, or unnecessary. Several respondents argued that CVIs are ineffective in detecting and preventing the spread of RHDV2 because unvaccinated rabbits infected with RHDV2 often die quickly and without obvious signs of illness. Traditional CVIs, which require veterinary inspection 30 days before travel, are unlikely to assist in RHDV2 detection before rabbits are transported across state borders. Some states have tried to address this issue by shortening the CVI time (e.g., 72 h before travel) to increase the likelihood of RHDV2 detection. However, CVIs for rabbits remain poorly enforced, and agencies do not have a system in place to monitor pathogen spread through the domestic rabbit trade (Shapiro et al., 2022a).

Since it is unlikely that effective monitoring of the rabbit trade (in particular, the pet trade) will be implemented in the immediate future, improved outreach and communication about how rabbit owners can protect their rabbits and may prevent the spread of RHDV2 is important. Educational efforts should provide clear and consistent information about RHDV2 and how it is spread. Although we found that respondents' risk perceptions were stronger determinants of their stated support for biosecurity than knowledge of RHDV2, this is likely attributable to the fact that most respondents were knowledgeable about RHDV2. Our respondents may have been more knowledgeable about RHDV2 than the general population of rabbit owners because we partnered with rabbit-specialist groups that have actively engaged in RHDV2 outreach. Nonetheless, previous research suggests that education on the health and welfare of rabbits by trusted sources is an important determinant of rabbit husbandry and health (Edgar and Mullan, 2011; Welch et al., 2017; Rioja-Lang et al., 2019), which reinforces our suggestion that messaging may increase rabbit owners' adoption of biosecurity.

Based on our findings, educational messaging or programs should also communicate the scientific reasoning behind recommended biosecurity measures and highlight the effectiveness of these measures in

Table 4

Ordinal logistic regression analysis of respondents' support for government-mandated biosecurity measures to prevent the spread of RHDV2 in the U.S. Coefficient estimates with p values provided in parentheses.

	Relocate rabbit shows/ exhibitions at least 150 miles from counties with RHDV2	Require rabbit owners to obtain a CVI before attending events with live rabbits	Penalize rabbit transporters who do not obtain a CVI for the rabbits they carry	Require rescued rabbits to be inspected by a veterinarian before being moved by rescues over state borders	Ban rabbit rescues from acquiring rabbits from states with RHDV2	Trade ban on rabbits that come from states with confirmed RHDV2 cases	Trade ban on all rabbits until the U. S. starts producing and distributing a RHDV2 vaccine
Perceived importance of biosecurity	1.015 (<0.001)	1.072 (<0.001)	1.016 (<0.001)	0.789 (<0.001)	0.295 (0.002)	0.504 (<0.001)	0.555 (<0.001)
× rabbit breeder	0.258 (0.134)			0.510 (0.008)	0.151 (0.353)	0.338 (0.056)	
Risk sensitivity to lagomorph deaths	0.235 (<0.001)	0.237 (0.007)	0.251 (0.002)	0.190 (0.027)	0.048 (0.428)	0.168 (0.036)	0.171 (0.026)
× rabbit breeder		-0.317 (0.016)	-0.377 (0.004)	-0.245 (0.058)	-0.043 (0.648)	-0.251 (0.036)	-0.160 (0.175)
Risk sensitivity to economic impacts of RHDV2		-0.101 (0.058)	0.052 (0.297)	0.122 (0.017)	0.197 (<0.001)	-0.130 (0.007)	-0.098 (0.038)
× rabbit breeder			-0.290 (0.053)	-0.361 (0.018)			
Concern about the impact of RHDV2 on rabbit rescues		0.183 (0.037)	0.107 (0.197)	0.159 (0.013)	-0.203 (<0.001)	0.097 (0.089)	0.182 (0.002)
× rabbit breeder		0.251 (0.040)	0.367 (0.002)				
Risk susceptibility to the economic impacts of RHDV2	0.652 (<0.001)	0.549 (<0.001)	0.449 (<0.001)	0.196 (0.059)	0.345 (<0.001)	0.549 (<0.001)	0.489 (<0.001)
× rabbit breeder		-0.335 (0.111)					
Trust in government to manage RHDV2	-0.049 (0.501)	-0.034 (0.676)	-0.051 (0.495)		0.311 (<0.001)	0.101 (0.086)	0.064 (0.383)
× rabbit breeder	0.288 (0.005)	0.464 (<0.001)	0.179 (0.080)		-0.423 (<0.001)		0.295 (0.005)
Prior awareness of RHDV2				0.287 (0.284)			
Knowledge of RHDV2	0.107 (0.510)	-0.592 (0.001)		-0.302 (0.277)	-0.538 (<0.001)	-0.337 (0.047)	-0.433 (0.010)
RHDV2 status of respondents' state of residence	-0.519 (<0.001)	-0.210 (0.031)	-0.175 (0.056)		-0.531 (<0.001)	-0.667 (<0.001)	
Number of rabbits owned ^a		-0.004 (<0.001)			0.004 (<0.001)	-0.001 (0.091)	-0.003 (0.002)
House rabbits outside							-0.188 (0.103)
Travel out of state with rabbits	0.208 (0.048)	-0.443 (<0.001)	-0.407 (<0.001)		0.312 (0.003)		
Rabbit breeder	-0.125 (0.270)	-1.760 (<0.001)	-0.962 (<0.001)	-0.420 (0.005)	0.714 (<0.001)	-0.804 (<0.001)	-1.556 (<0.001)
Rescue volunteer	0.319 (0.013)	0.624 (<0.001)	0.273 (0.040)			0.446 (<0.001)	0.352 (0.005)
Age ^b	0.009 (0.005)		0.009 (0.004)		0.020 (<0.001)	0.012 (<0.001)	0.011 (<0.001)
Gender ^c							0.058 (0.323)
Education ^d				-0.064 (0.010)	-0.039 (0.098)		-0.038 (0.113)
Intercepts:							
β ₁	-3.919 (<0.001)	-4.571 (<0.001)	-3.388 (<0.001)	-5.204 (<0.001)	-2.162 (<0.001)	-3.236 (<0.001)	-3.003 (<0.001)
β ₂	-2.885 (<0.001)	-3.463 (<0.001)	-2.424 (<0.001)	-4.223 (<0.001)	-0.688 (0.092)	-1.944 (<0.001)	-1.883 (<0.001)

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Table 4 (continued)

	Relocate rabbit shows/ exhibitions at least 150 miles from counties with RHDV2	Require rabbit owners to obtain a CVI before attending events with live rabbits	Penalize rabbit transporters who do not obtain a CVI for the rabbits they carry	Require rescued rabbits to be inspected by a veterinarian before being moved by rescues over state borders	Ban rabbit rescues from acquiring rabbits from states with RHDV2	Trade ban on rabbits that come from states with confirmed RHDV2 cases	Trade ban on all rabbits until the U. S. starts producing and distributing a RHDV2 vaccine
β_3	-1.047 (<0.001)	-2.284 (<0.001)	-1.032 (<0.001)	-3.018 (<0.001)	0.660 (0.106)	-0.607 (<0.001)	-0.614 (0.128)
β_4	0.601 (<0.001)	-0.754 (<0.001)	0.351 (0.029)	-1.063 (0.006)	1.578 (<0.001)	0.442 (0.013)	0.432 (0.285)
N	1790	1790	1790	1790	1790	1790	1790
Log likelihood ^c	-2061.38	-1967.94	-2187.64	-1939.19	-2614.86	-2439.91	-2453.66
AIC ^e	4148.76	3973.88	4407.28	3906.38	5263.72	4915.82	4941.31

^a Coded as 1 rabbit = 1; 2–5 rabbits = 4; 6–10 rabbits = 8; 11–20 rabbits = 15; 21–50 rabbits = 35; 51–100 rabbits = 75; 101–500 rabbits = 300.

^b Coded as male = -1; prefer not to answer = 0, female = 1.

^c Coded as 18–24 years old = 21, 25–34 = 30; 35–44 = 40; 45–54 = 50; 55–64 = 60; 65–74 = 70; 75 years old and over = 75.

^d Coded as less than 12th grade = 10; high school graduate = 12; some college or an associate degree = 14; Bachelor's degree = 16; graduate degree = 18.

^e The MuMIn package in R identifies all models that are within 2 AIC of the model with the lowest AIC value, and then averages the estimated coefficients (β) across these models. The estimated coefficients provided in the table are averages of the estimated coefficients across the different models that were good fits of the data. The AIC and log likelihood pertain to the best-fit model (i.e., the model with the lowest AIC).

protecting rabbit-based industries, wild lagomorphs, and the health and welfare of domestic rabbits to increase the likelihood of rabbit owners voluntarily adopting biosecurity measures (see related findings by Gramza et al., 2016; Robin et al., 2017; Slunge and Boman, 2018; Steele and Pienaar, 2021; Shapiro et al., 2023). Communication efforts by trusted sources (e.g., veterinarians, state animal health officials) should highlight the negative impacts of RHDV2 on the welfare of rabbits and how engaging in biosecurity measures lowers the risk of RHDV2 transmission (Edgar and Mullan, 2011; Welch et al., 2017; McMahon and Wigham, 2020). These efforts should also note how economically important industries (e.g., pet trade) and socially important rabbit-based activities (e.g., showing rabbits) could be affected by RHDV2.

However, we recognize that risk perceptions pertaining to the impacts of RHDV2 on lagomorphs and rabbit-based industries and activities did not always translate into increased willingness to engage in or support biosecurity measures. We found that rabbit rescue volunteers or staff and breeders differed in their willingness to engage in and support multiple biosecurity actions, even if they expressed concern about the economic and ecological impacts of RHDV2. Although both these groups agreed that transporting rabbits increases the risk of RHDV2 spread and that biosecurity is important, rescue staff or rabbit breeders may still engage in higher-risk behaviors (Shapiro et al., 2022b). For example, rescue volunteers or staff were less likely to disallow interaction between their rabbits and other rabbit owners, as this behavior is central to rescue operations. Rabbit breeders were less likely to engage in costly biosecurity measures (e.g., vaccinating their rabbits) owing to how these measures would impact their profits (Shapiro et al., 2022b). Rabbits owned by stakeholders who interact with numerous rabbits and/or travel with their rabbits are at a higher risk of becoming infected with RHDV2 and these stakeholders are at a higher risk of spreading RHDV2. As such, state animal health officials, veterinarians, and rabbit specialist groups should identify stakeholder-specific barriers to engaging in biosecurity and work with rabbit owners to overcome these barriers. Reducing the cost of CVIs and vaccines and making vaccines widely available for both rabbit owners and veterinarians will likely be necessary to increase rabbit owners' adoption of these practices. Equally importantly, veterinarians and state animal health officials should customize educational strategies based on the specific goals and constraints of breeders, rescues, and pet owners. Understanding different stakeholders' beliefs, attitudes, motivations for engaging in the rabbit trade or rabbit-based activities, and constraints to engaging in biosecurity will be crucial to improve adoption of and support for biosecurity. Animal health officials and private veterinarians will likely play an essential role in this process, as both groups have been shown to

be important, trusted sources of information capable of increasing animal owners' adoption of biosecurity measures (Wiethoelter et al., 2007; Welch et al., 2017).

In addition to outreach and education, we recommend that agencies partner with rabbit specialist and enthusiast groups to prevent the spread of RHDV2 through collaborative actions. We note that respondents' trust in their state government was positively correlated with their likelihood of engaging in biosecurity, but most respondents did not have an opinion or did not know about their state government's efforts to manage RHDV2. This is not surprising, as many state agricultural agencies did not have any established relationships or communication with rabbit stakeholder groups prior to the RHDV2 outbreak (Shapiro et al., 2022a). However, some state agricultural agencies have worked with rabbit-specialist groups to disseminate RHDV2 information and move rabbit-based events away from counties with RHDV2 cases (Shapiro et al., 2022a), which are important first steps towards collaborative RHDV2 management.

Ethics Approval

The University of Georgia's Institutional Review Board determined that this project did not constitute research with human subjects and that full IRB review/approval was not required.

CRedit authorship contribution statement

Shapiro, Ruder and Pienaar conceptualized this research. Shapiro and Pienaar were responsible for the design of the methodology, investigation, and writing the original draft of the manuscript. Shapiro and Nimlos conducted formal analysis. Nimlos and Ruder reviewed and edited the manuscript. Pienaar and Ruder were responsible for funding acquisition. Pienaar supervised the project and was responsible for project administration.

Declaration of Competing Interest

None.

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Data and Model Availability Statement

None of the data were deposited in an official repository. Data can be made available via request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2023.106018.

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