

# Falconer perceptions of, and support for, rabbit hemorrhagic disease biosecurity actions

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**Abstract:** Rabbit hemorrhagic disease virus 2 (RHDV2) is a highly contagious virus that primarily infects wild and domestic rabbits and hares (lagomorphs). In the United States, state wildlife agencies rely on stakeholders to report RHDV2-related mortalities and engage in voluntary biosecurity actions to prevent the spread of RHDV2. However, stakeholder perceptions of RHDV2 and relevant biosecurity actions have not been evaluated. We conducted the first study in the United States on how falconers' risk perceptions, knowledge, trust in state wildlife agencies to manage RHDV2, hunting behaviors, and demographic characteristics influenced their willingness to engage in voluntary biosecurity actions and support potential government-mandated biosecurity measures. To complete our study, we surveyed 480 falconers in 45 states using an online questionnaire from April 2021 to March 2022. Most respondents were aware of RHDV2 but did not know about the multiple vectors for RHDV2 transmission or that infected lagomorphs are unlikely to show signs of disease. Most respondents were willing to engage in all voluntary biosecurity actions (52.9–89.8%) and supported 3 of the 4 RHDV2 management strategies (56.0–62.5%). Respondents' willingness to engage in or support biosecurity measures depended on the importance they placed on biosecurity, their risk perceptions, and their trust in state wildlife agencies to manage RHDV2. Consistent, up-to-date outreach efforts should communicate the economic and hunting risks associated with RHDV2 and how falconer adoption of biosecurity behaviors may lower the risk of human-mediated RHDV2 spread. State wildlife agencies may build trust with falconry groups by actively engaging falconers in lagomorph and RHDV2 monitoring efforts and working with falconers to implement biosecurity measures that are safe for raptors while also lowering the risk of human-mediated RHDV2 spread.

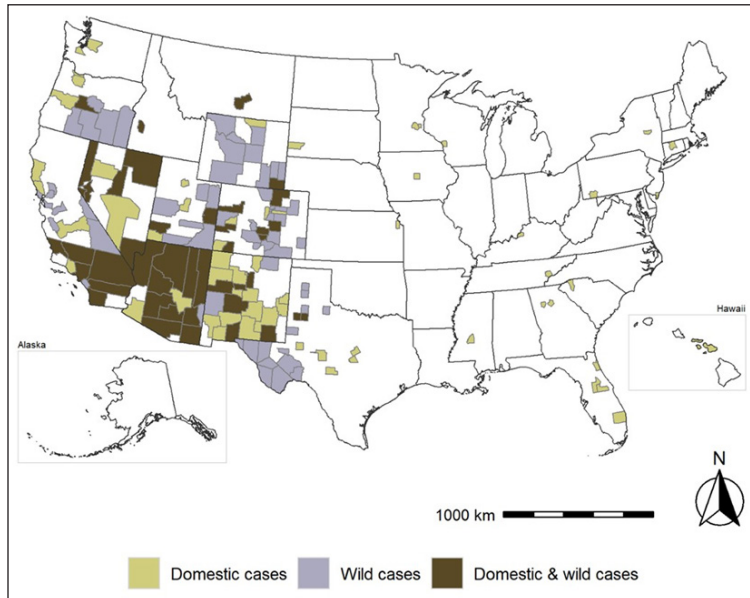
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**MANAGING PATHOGEN SPILLOVER** at the wildlife-domestic animal interface is a growing conservation and economic concern (Miller et al. 2013, Meurens et al. 2021). The introduction of foreign animal pathogens into naïve animal populations (i.e., animal populations that have not been previously exposed to these pathogens) has resulted in wildlife population declines, substantial financial losses to agricultural and commercial animal trades, and costly control efforts (Siembieda et al. 2011, Pepin et al. 2014, Wiethoelter et al. 2015, Kao et al. 2018). Foreign animal pathogens are transboundary animal pathogens that are not known to exist in a region's existing animal population. Once introduced to a region, foreign animal pathogens may change in pathogenicity, communicability, or zoonotic potential to become a threat to animals or humans in that

region. National and international health and conservation organizations have highlighted the critical need to develop and implement biosecurity measures that prevent the introduction and spread of foreign animal pathogens into new regions (Ryser-Degiorgis 2013, Portier et al. 2019, Stephen et al. 2019).

In this paper, we focus on the rapid spread of a foreign animal pathogen, rabbit hemorrhagic disease virus 2 (RHDV2), in the United States. RHDV2 is a highly contagious virus that causes rabbit hemorrhagic disease (RHD) in wild and domestic rabbits and hares (lagomorphs; family Leporidae, order Lagomorpha). RHDV2 was first detected in France in 2010 and has since spread to 5 continents (Katayama et al. 2021, Rouco et al. 2019, Ramsey et al. 2020).

The virus typically has a short incubation pe-



**Figure 1.** Rabbit (Leporidae) hemorrhagic disease virus 2 (RHDV2) occurrence in the United States. Map last updated on October 31, 2022. Data source: U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service. 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. Kohl, University of Georgia. Map publicly available at [rhv2.org](http://rhv2.org).

riod and can cause fatal disease within 2–4 days of infection (Marcato et al. 1991, Le Gall-Reculé et al. 2013). Infected lagomorphs often show no obvious signs of disease before death (Williams et al. 2021), and mortality rates may be as high as 80% (Le Gall-Reculé et al. 2013, Mutze et al. 2018). RHDV2 spreads through direct or indirect (i.e., oculonasal secretions, urine, feces, blood) contact with infected lagomorphs, lagomorph carcasses or carcass parts, insect vectors, and environments or materials contaminated by infected lagomorphs (e.g., clothing, forage). The virus may remain viable up to 15 weeks in dry conditions and >90 days in decaying animal tissue outdoors (Henning et al. 2005).

In the United States, RHDV2 was first detected in domestic rabbits in Ohio in 2018 (Williams et al. 2021). In March 2020, an outbreak of RHDV2 was confirmed in domestic and wild lagomorphs in New Mexico (U.S. Department of Agriculture [USDA] 2022). As of December 2022, RHDV2 has been detected in wild and/or domestic lagomorphs in 28 states (Figure 1). RHDV2 has infected 8 wild lagomorph species, including the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*), and poses a risk

to all 15 native lagomorph species in the United States. RHDV2 is likely to place additional strain on imperiled (e.g., white-tailed jack rabbits [*Lepus townsendii*]; Brown et al. 2020) and once common lagomorph species whose populations have been declining due to habitat loss (Bosch et al. 2016), increasing predator populations (Kays and DeWan 2004), climate change (Diefenbach et al. 2016), and species invasions (McCleery et al. 2015).

The impact of RHDV2 on lagomorph populations in the United States is currently unknown (Shapiro et al. 2022). However, in Europe, RHDV2 resulted in population declines (60–70%) of wild lagomorphs, triggering ecological disruptions

and declines of rabbit-specialist predators (e.g., the Iberian lynx [*Lynx pardinus*] and the Spanish Imperial eagle [*Aquila adalberti*]; Monterroso et al. 2016), and resulted in substantial economic losses for hunting in Europe (Rouco et al. 2019). A decline in wild lagomorph populations may negatively affect small game hunting and falconry in the United States, where lagomorphs are the fourth most popular game animal (~1.3 million individuals hunt lagomorphs every year; U.S. Fish and Wildlife Service and U.S. Census Bureau 2018).

To control RHDV2, state wildlife agencies have implemented temporary management or rule changes (e.g., prohibitions on the movement of wild lagomorph carcasses from RHDV2 positive areas into the state or take of lagomorphs for research; Pennsylvania Game Commission 2021, California Department of Food and Agriculture 2022, Shapiro et al. 2022). State wildlife agencies rely on the public, hunters, and falconers to report suspicious rabbit deaths (e.g., passive disease surveillance) and to assist in disease management (Shapiro et al. 2022). Accordingly, many wildlife agencies have created educational and outreach materials to inform the public,

hunters, and falconers about RHDV2 and the variety of ways they can help prevent its spread into new areas (Shapiro et al. 2022).

In addition to emphasizing the need for people to report suspicious rabbit deaths, wildlife agencies recommend that key stakeholders engage in appropriate biosecurity behaviors (e.g., removing all lagomorph remains from the environment and disposing of them in the trash, sanitizing all hunting equipment and clothing). However, to date, falconers' willingness to engage in biosecurity actions or support management strategies have not been examined. Falconry is defined as the taking of wild quarry (e.g., game birds [Galliformes], waterfowl [Anseriformes], lagomorphs, squirrels [Sciuridae]) in their natural state and habitat by means of a trained raptor (Wallen and Bickford 2020, North American Falconers Association 2022). There are approximately 3,000–5,000 licensed falconers in the United States (Hay 2014). Falconers are an important group to consider in lagomorph and RHDV2 management, as they are well-positioned to observe changes in prey populations (Wallen and Bickford 2020). Currently, there is no evidence that RHDV2 transmits to humans or raptors. However, RHDV2 has been detected in Eurasian badgers (*Meles meles*) in Portugal (Abade dos Santos et al. 2022), which raises the possibility that RHDV2 might transmit to other species.

Previous studies on public and hunter support for wildlife disease management applied cognitive approaches to investigate determinants (e.g., knowledge, risk perceptions, trust in government) of stakeholders' stated willingness to engage in voluntary biosecurity actions and support agency interventions (e.g., Pienaar et al. 2022, Shapiro et al. 2023). Risk perceptions are subjective judgments about the characteristics and severity of risks. Risk perceptions are commonly measured in terms of severity (i.e., perceptions of how serious the risk is), susceptibility (i.e., the perceived likelihood of risk), and dread (i.e., degree of worry or fear about the risk; Gore et al. 2009, Hanisch-Kirkbride et al. 2013, Harper et al. 2015, Needham et al. 2017). Previous studies suggest that type of hazard (e.g., adverse ecological and economic impacts of pathogen transmission), susceptibility to risk, and sensitivity to risk influence people's support for biosecurity (Pienaar et al. 2022, Sha-

piro et al. 2023). Women and older individuals tend to have higher risk perceptions related to pathogens, whereas more educated individuals may have lower risk perceptions, which in turn influences support for, or engagement in, biosecurity actions (Hanisch-Kirkbride et al. 2013, Needham et al. 2017, Pienaar et al. 2022).

Trust in state agencies includes people's perceptions of whether their state agencies have the necessary expertise and resources to effectively manage disease risks (Siegrist and Cvetkovich 2000, Siegrist et al. 2005, Hanisch-Kirkbride et al. 2014, Harper et al. 2015, Vaske and Miller 2018). Trust in state agencies to manage disease risks may play an important role in risk perceptions when individuals lack knowledge about a hazard such as the spread of a pathogen (Vaske et al. 2004, Siegrist et al. 2005). Previous studies show that hunters' intention to continue hunting in areas with chronic wasting disease (CWD) and to support agency management of game populations and CWD were positively correlated with their trust in state wildlife agencies to manage CWD (Vaske et al. 2004, Brown et al. 2006, Stafford et al. 2007, Needham and Vaske 2008, Manfredo et al. 2009, Harper et al. 2015, Meeks et al. 2021). Finally, hunting specialization (e.g., hunters' skills and experience, their financial investment in hunting, the number of species they target) may influence hunters' response to wildlife disease (e.g., CWD; Needham et al. 2007), including their willingness to engage in or support biosecurity actions.

Consistent with other studies on public and hunter support for wildlife disease management, we applied cognitive approaches to investigate falconers' stated willingness to engage in voluntary biosecurity actions and their support for agency interventions to prevent the spread of RHDV2. We posited that falconers' support for RHDV2 prevention and willingness to engage in biosecurity actions would be positively correlated with their knowledge of RHDV2, risk perceptions pertaining to RHDV2 (Hanisch-Kirkbride et al. 2013, Triezenberg et al. 2014), trust in state wildlife agencies to manage RHDV2 (Hanisch-Kirkbride et al. 2014, Harper et al. 2015, Vaske and Miller 2018), and subjective assessment of the importance of biosecurity measures (Shapiro et al. 2023). We also predicted that falconers' demographics and hunting specialization (Needham et al. 2007)

would influence their willingness to engage in biosecurity actions and support RHDV2 management by agencies.

## Methods

### Sampling

We conducted online surveys from April 2021 to March 2022 using University of Georgia's Qualtrics license (Qualtrics.com). We recruited research participants by asking the North American Falconers Association (NAFA) and state falconry associations to send the invitation to their members and by cooperating with state wildlife agencies to send the invitation to licensed falconers in their state. Falconers received 1 reminder to participate in the research 2 weeks after the initial invitation if they were recruited by a falconry club or a state wildlife agency. In those instances where state wildlife agencies provided us with their list of falconers, we sent 3 reminders at weekly intervals. The survey link remained active for 1 month after the final reminder. On average, it took respondents 10–15 minutes to complete the survey.

### Survey design

We designed the online questionnaire to elicit determinants of falconers' stated willingness to engage in voluntary biosecurity actions and their support for state government actions to manage RHDV2 (supplemental material). We measured falconers' willingness to engage in voluntary biosecurity actions by asking them the likelihood they would engage in 6 commonly recommended behaviors to control or prevent the spread of RHDV2, namely: (1) reporting suspicious lagomorph deaths to their state wildlife agency; (2) wearing disposable gloves when handling lagomorph carcasses; (3) placing the remains of cleaned lagomorphs in a bag, sanitizing the bag, and either burying the bag or disposing of it in the trash; (4) waiting to clean lagomorph carcasses until they had returned home, rather than cleaning lagomorphs in the field; (5) cooking lagomorphs to an internal temperature of 165°F (73.89°C); and (6) sanitizing all tools, equipment, or other items used to hunt or clean lagomorphs before and after contact with wild lagomorphs (Association of Fish and Wildlife Agencies 2020, National Assembly of State Animal Health Officials 2020). Respondents had the option to indicate if any of these

biosecurity actions were not applicable to them (for example, they do not cook and eat wild lagomorphs). We also asked falconers whether they supported or opposed 4 potential RHDV2 management actions that could be implemented by state agencies, namely: (1) relocating field trials that use lagomorphs at least 150 mi (241.40 km) from counties with confirmed RHDV2 cases, (2) restricting lagomorph hunting in areas with lagomorphs that are threatened or endangered, (3) banning the transport of lagomorphs (alive and dead) that come from states with confirmed RHDV2 cases (Pennsylvania Game Commission 2021, California Department of Food and Agriculture 2022), and (4) banning the transport of lagomorphs (alive and dead) between states until a domestic RHDV2 vaccine was produced.

Before asking respondents their opinions on biosecurity measures, we first asked them to provide us with information on their hunting behaviors (i.e., game species hunted, whether they hunt with dogs [*Canis lupus familiaris*], whether they travel out of state to hunt) as a measure of hunting specialization. We then measured respondents' prior awareness of RHDV2 (binary variable coded as 1 if the respondent had previously heard of the virus) and their prior knowledge of RHDV2 (i.e., which lagomorphs are susceptible to RHDV2, the RHDV2 status of their state, the vectors for pathogen transmission, the likelihood that lagomorphs show signs of infection before death). After answering these knowledge questions, respondents were presented with the correct answers and additional information on RHDV2 mortality rates, vulnerable species, and treatments and available vaccines to ensure that each individual responded to subsequent questions based on accurate information.

We measured respondents' risk susceptibility by asking them how much risk they believed RHDV2 poses to the domestic rabbit trade and lagomorph hunting. We measured respondents' risk sensitivity by asking them whether they were concerned about the impact of RHDV2 on the domestic rabbit trade, lagomorph hunting, the health of domestic and wild lagomorphs in their state, and biodiversity. In conjunction with these risk perceptions, we asked respondents to indicate whether they considered biosecurity to be important. Specifically, we asked whether they agreed that transporting lagomorphs increases the probability of RHDV2 transmission, hunters

should engage in measures to prevent RHDV2 spreading, and that disease prevention measures are important in states with and without RHDV2 cases. We measured trust in state agencies to manage RHDV2 by asking respondents whether they agreed that their state government has the knowledge, resources, and sufficiently skilled people to manage RHDV2, and has been effective in managing RHDV2. Finally, we elicited respondents' gender, age, and education levels.

We conducted an expert review of the survey instrument with 5 veterinary medicine and animal disease specialists, 2 wildlife biologists, and 3 human dimensions experts. We used cognitive testing to pre-test the survey instrument with 10 members of key stakeholder groups who interact with wild lagomorphs and/or domestic rabbits, which included high-level NAFA members. We adjusted the survey based on expert review and pre-tests to ensure that the RHDV2 and hunting information we presented in the survey was factually accurate, and we had minimized any potential response bias in the survey (i.e., our questions were appropriately designed and framed to ensure that respondents provided accurate, thoughtful responses that reflected their true opinions and behavioral intentions).

The University of Georgia's Institutional Review Board reviewed all research materials and protocols and characterized our study as non human subjects research because we elicited no identifiable or sensitive private information from research participants. We informed all research participants in writing that they were not obligated to participate in this study, and that they could stop taking the survey at any time without penalty.

### Data analysis

We used the statistical analysis software SPSS 27.0 (SPSS Statistics for Windows, Version 27.0, IBM Corp., Armonk, New York, USA) to run descriptive analyses and conduct principal factor analysis. We used principal factor analysis to test whether ordinal survey items could be combined to generate composite variables (e.g., by averaging individual items to generate unweighted scores that measured respondents' risk perceptions, trust in state agencies to manage RHDV2, and the importance they placed on engaging in biosecurity measures). We used Cronbach's alpha (Cronbach 1951) to measure

the inter-item reliability of items used to generate these constructs (scores). We combined survey items that loaded onto factors with an eigenvalue  $\geq 1$  and Cronbach's alpha  $\geq 0.7$  (Gliem and Gliem 2003) to generate composite variables. We generated a RHDV2 knowledge score (no correct responses = 0; all correct responses = 15) by summing the number of correct responses respondents provided to the knowledge questions. We converted this score into a proportion by dividing the total number of correct responses by 15 (i.e., the knowledge score ranged from 0 to 1). Respondents who were not aware of RHDV2 prior to taking the survey received a 0 for their knowledge score.

We used ordinal logistic regression models to analyze respondents' willingness to engage in voluntary biosecurity actions and their support for government measures to manage RHDV2. We included risk sensitivity, risk susceptibility, trust in state agencies to manage RHDV2, the perceived importance of engaging in biosecurity measures, prior awareness of RHDV2, prior knowledge of RHDV2, hunting behaviors, and sociodemographic variables in the full models. We used the "polr" package in R 4.1.2 (Ripley 2015) to estimate the ordinal logistic regression models. We conducted both stepwise reduction and comparison of all possible models using the "MuMIn" package to determine the best-fit models (Barton and Barton 2015). We identified the best-fit models based on the Akaike Information Criterion (AIC; Burnham and Anderson 2004), whereby the best-fit model had the lowest AIC. We conducted model averaging when there were multiple models that were within  $AIC \leq 2$  of the lowest AIC (Burnham and Anderson 2004). We considered a coefficient to be statistically significant at  $P \leq 0.05$ .

### Results

We received 521 surveys from falconers in 45 states. We removed incomplete responses and responses by people who indicated they were  $< 18$  years old, leaving 480 completed responses. Most respondents ( $n = 361$ ; 75.2%) were male. The median age range for respondents was 55–64 years, and the median education level was a bachelor's degree. Less than half of respondents also used dogs when hunting lagomorphs ( $n = 209$ ; 43.5%) and traveled to other states to hunt lagomorphs ( $n = 168$ ; 35.0%). On average, respondents hunt-

**Table 1.** Falconers' (*n* = 480) willingness to engage in voluntary biosecurity measures to prevent the spread of rabbit (*Leporidae*) hemorrhagic disease virus 2 (RHDV2), April 2021 to March 2022, USA. Respondents answered the question "How likely are you to engage in the following behaviors?"

Biosecurity actions	Median	Very unlikely	Unlikely	Neither likely nor unlikely	Likely	Very likely	Not applicable
Report suspicious rabbit deaths to your state wildlife agency	Very likely <sup>a</sup>	18 (3.8%)	10 (2.1%)	17 (3.5%)	95 (19.8%)	336 (70.0%)	4 (0.8%)
Wear disposable gloves when handling rabbit carcasses	Likely	30 (6.3%)	79 (16.5%)	37 (7.7%)	112 (23.3%)	219 (45.6%)	3 (0.6%)
Place remains of cleaned rabbits in a bag, sanitize the bag, and either bury the bag or dispose of it in the trash	Very likely	23 (4.8%)	38 (7.9%)	22 (4.6%)	111 (23.1%)	279 (58.1%)	7 (1.5%)
Wait to clean rabbit carcasses until you have returned home	Likely	48 (10.0%)	61 (12.7%)	33 (6.9%)	111 (23.1%)	219 (45.6%)	8 (1.7%)
Cook rabbits to an internal temperature of 165°F (73.89°C)	Very likely	33 (6.9%)	15 (3.1%)	18 (3.8%)	53 (11.0%)	201 (41.9%)	160 (33.3%)
Sanitize all tools, equipment, or other items used to hunt/clean rabbits before and after contact with wild rabbits	Very likely	18 (3.8%)	36 (7.5%)	31 (6.5%)	110 (22.9%)	274 (57.1%)	11 (2.3%)

<sup>a</sup> Very unlikely = 1; unlikely = 2; neither likely nor unlikely = 3; likely = 4; very likely = 5

**Table 2.** Falconers' (*n* = 480) support for agency actions to mitigate the spread of rabbit (*Leporidae*) hemorrhagic disease virus 2 (RHDV2), April 2021 to March 2022, USA. Respondents answered the question "Please indicate if you oppose or support the following potential regulations designed to prevent the spread of RHDV2."

Potential regulation	Median	Strongly oppose	Oppose	Neither oppose nor support	Support	Strongly support
Relocate field trials that use rabbits at least 150 mi (241.2 km) from counties with RHDV2	Support <sup>a</sup>	10 (2.1%)	32 (6.7%)	138 (28.7%)	182 (37.9%)	118 (24.6%)
Restrict rabbit hunting in areas with rabbits that are threatened or endangered	Support	41 (8.5%)	52 (10.8%)	95 (19.8%)	181 (37.7%)	111 (23.1%)
Ban the transport of rabbits (alive and dead) that come from states with confirmed RHDV2 cases	Support	31 (6.5%)	66 (13.8%)	114 (23.8%)	149 (31.0%)	120 (25.0%)
Ban transport of rabbits (alive and dead) between states until domestic RHDV2 vaccine <sup>b</sup> is produced and distributed	Neither oppose nor support	46 (9.6%)	62 (12.9%)	147 (30.6%)	134 (27.9%)	91 (19.0%)

<sup>a</sup> Strongly oppose = 1; oppose = 2; neither oppose nor support = 3; support = 4; strongly support = 5.

<sup>b</sup> A domestic vaccine was not produced until October 2021.

ed 3 game species in the past 5 years, primarily lagomorphs (all respondents), squirrels ( $n = 325$ ; 67.7%), and game birds ( $n = 280$ ; 58.3%). Most respondents indicated they hunted for rabbits >5 times a season ( $n = 374$ ; 77.9%), with multiple respondents indicating they hunt for rabbits at least 50 times a year. Approximately half of respondents lived in a state that had confirmed RHDV2 cases ( $n = 238$ ; 49.6%).

### Biosecurity measures

Most respondents were likely or very likely to engage in all recommended biosecurity behaviors (Table 1). On average, respondents also expressed support for potential agency actions to prevent or control RHDV2 spread by relocating field trials, banning the transport of lagomorphs from areas with RHDV2, and restricting hunting in areas with imperiled lagomorphs (Table 2).

### Awareness and knowledge of RHDV2

Most respondents had heard of RHDV2 before taking the survey ( $n = 395$ ; 82.3%). Respondents who had heard of RHDV2 were moderately knowledgeable about RHDV2 (median = 0.67;  $0.63 \pm 0.25$ ; range = 0–1; Table 3), but few respondents ( $n = 52$ ; 13.2%) knew that lagomorphs infected with RHDV2 are unlikely to show signs of the disease before they die.

### RHDV2 risk perceptions

Respondents expressed high risk sensitivity to lagomorph deaths caused by RHDV2, with most respondents expressing concern about the negative impacts of RHDV2 on domestic rabbits (70.6%), wild lagomorphs (87.7%), and biodiversity loss from the disease-related deaths of native lagomorphs (82.9%). Respondents' concerns about the impact of RHDV2 on domestic rabbits, wild lagomorphs, and biodiversity represented a single construct "risk sensitivity to lagomorph deaths" (eigenvalue = 2.14; Cronbach's alpha = 0.80; Table 4). Respondents' risk sensitivity to lagomorph deaths skewed left (median = 4.33;  $4.20 \pm 0.79$ ; range = 1–5), which reflected that respondents tended toward high levels of concern about RHDV2-related lagomorph deaths.

Respondents were most concerned about the impact of RHDV2 on the sport of rabbit hunting (92.3% were concerned or very concerned). Respondents demonstrated lower risk sensitivity to the impacts of RHDV2 on the rabbit pet

trade (49.0% were concerned or very concerned), rabbit exhibitions (49.2%), rabbit rescues and animal shelters (55.8%), and the rabbit meat market (54.8%). Respondents' concern about the impacts of RHDV2 on the rabbit trade and rabbit rescues represented a single construct, "sensitivity to the economic impacts of RHDV2" (median = 3.5;  $3.56 \pm 0.95$ ; range = 1–5; eigenvalue = 3.47; Cronbach's alpha = 0.95; Table 4).

Most respondents believed that RHDV2 poses a risk to the rabbit pet trade (81.9% considered RHDV2 a moderate or high risk), rabbit rescues (87.7%), rabbit shows (83.4%), the rabbit meat market (81.5%), and the sport of rabbit hunting (92.8%). Respondents' assessment of the risk of RHDV2 to the domestic rabbit trade and hunting represented a single construct, "risk susceptibility to the economic impacts of RHDV2" (median = 3.40;  $3.33 \pm 0.58$ ; range = 1–4; eigenvalue = 3.30; Cronbach's alpha = 0.87; Table 4).

### Perceived importance of biosecurity actions

Most respondents strongly agreed on the importance of engaging in disease prevention measures, recognizing that RHDV2 may be spread through the transport of rabbits between states (52.7% strongly agreed), hunters should practice disease prevention measures to prevent RHDV2 spread (60.2%), and that disease prevention measures are important in states with no RHDV2 cases (53.5%) and in states with RHDV2 cases (69.0%). The items used to measure the perceived importance of biosecurity loaded onto a single factor (eigenvalue = 2.85; Cronbach's alpha = 0.85; Table 4). Respondents' perceptions of the importance of engaging in biosecurity actions skewed left (median = 4.75;  $4.48 \pm 0.60$ ; range = 1–5).

### Trust in state agencies to manage RHDV2

The largest share of respondents neither agreed nor disagreed that (or did not know whether) their respective state agency had the knowledge (46.5%), resources (48.3%), or skilled employees (46.0%) to prevent RHDV2 transmission, or had been effective (68.3%) in preventing or controlling the spread of RHDV2. The 4 items used to measure respondents' "trust in state agencies to manage RHDV2" loaded onto a single factor (eigenvalue=2.68; Cronbach's alpha = 0.83; median = 3.00;  $3.11 \pm 0.74$ ; range = 1–5; Table 4), indicating that respondents were neutral

**Table 3.** Falconers' prior knowledge of rabbit (Leporidae) hemorrhagic disease virus 2 (RHDV2), April 2021 to March 2022, USA. This table only contains responses from individuals who stated they had heard about RHDV2 prior to taking the survey ( $n = 395$ ; 82.3%).

Knowledge question	Number	Percent	Knowledge score <sup>a</sup>
Respondents knew that RHDV2 infects <sup>b</sup>			
Wild lagomorphs	390	98.7	1
Domestic rabbits	336	85.1	1
Respondents who correctly identified that RHDV2 had been confirmed in their state <sup>c</sup>	251	63.5	1
How likely is it that rabbits infected with RHDV2 show signs of the disease before they die?			
Very unlikely <sup>d</sup>	8	2.0	1
Unlikely	44	11.1	1
Neither likely nor unlikely	33	8.4	0
Likely	117	29.6	0
Very likely	31	7.8	0
I don't know	162	41.0	0
To the best of your knowledge, who or what can spread RHDV2?			
Domestic rabbits	332	84.1	1
Wild lagomorphs	351	88.9	1
Other domestic animals (e.g., dogs [ <i>Canis lupus familiaris</i> ])	155	39.2	1
People	157	39.7	1
Animals that eat rabbits	216	54.7	1
Insects	81	20.5	1
Other	18	4.6	0
I don't know	39	9.9	0
To the best of your knowledge, how does RHDV2 spread?			
Contact with infected rabbits that are still alive	313	79.2	1
Contact with rabbits that have died from RHDV2	295	74.7	1
Contact with the meat/fur of infected rabbits	256	64.8	1
Contact with the urine, feces, and/or saliva of infected rabbits	291	73.7	1
Contact with items that infect rabbits have used (e.g., food forage, bedding)	232	58.7	1
Other	7	1.8	0
I don't know	58	14.7	0

<sup>a</sup> Correct responses were assigned a score of 1 if the respondent selected these answers. Each of the 15 possible correct answers to the knowledge questions were summed and then divided by 15 to generate a score between 0 and 1.

<sup>b</sup> No = 0; yes = 1.

<sup>c</sup> No = 0; yes = 1; I don't know = 0.

<sup>d</sup> Very unlikely = 1; unlikely = 1; neither likely nor unlikely = 0; likely = 0; very likely = 0; I don't know = 0.

**Table 4.** Factor analysis of statements used to measure falconers' risk perceptions pertaining to rabbit (Leporidae) hemorrhagic disease virus 2 (RHDV2), the importance they placed on biosecurity measures, and their trust in state agencies to manage RHDV2 ( $n = 480$ ), April 2021 to March 2022, USA.

Construct	Survey item	Factor loading
Risk perceptions: sensitivity to lagomorph deaths	I am concerned that RHDV2 will negatively affect/cause a loss of: <sup>a</sup>	
	Domestic rabbits	0.60
	Wild lagomorphs	0.85
	Biodiversity from the disease-related deaths of native lagomorphs	0.81
Risk perceptions: sensitivity to the economic impacts of RHDV2	I am concerned about the impact of RHDV2 on the: <sup>a</sup>	
	Pet trade	0.94
	Rabbit rescues/animal shelters	0.91
	Rabbit shows/exhibitions	0.95
	Rabbit meat market	0.84
	Sport of rabbit hunting <sup>b</sup>	0.24
Risk perceptions: susceptibility to the economic impacts of RHDV2	How much risk do you think RHDV2 poses to the following activities? <sup>c</sup>	
	Pet trade	0.87
	Rabbit rescues/animal shelters	0.84
	Rabbit shows/exhibitions	0.88
	Rabbit meat market	0.73
	Sport of rabbit hunting	0.44
Perceived importance of biosecurity actions	Transporting rabbits (alive or dead) between states increases the chance of RHDV2 spreading <sup>a</sup>	0.60
	Hunters must practice disease prevention measures to prevent RHDV2 spreading to areas without the disease	0.88
	Engaging in disease prevention measures is important in states with no RHDV2 cases	0.84
	Engaging in disease prevention measures is important in states with confirmed RHDV2 cases	0.82
Trust in state agencies to manage RHDV2	Please indicate your agreement or disagreement with the following statements: Your state government has: <sup>a</sup>	
	The knowledge to effectively manage RHDV2	0.75
	The resources to effectively manage RHDV2	0.81
	Sufficiently skilled people to effectively manage RHDV2	0.78
	Been effective in managing RHDV2	0.66

<sup>a</sup> Response options measured as strongly disagree = 1; disagree = 2; neither agree nor disagree = 3; agree = 4; strongly agree = 5.

<sup>b</sup> Owing to the low factor loading for this item, it was not included in the construct "sensitivity to the economic impacts of RHDV2."

<sup>c</sup> Response options measured as no risk = 1; low risk = 2; moderate risk = 3; high risk = 4.

in their assessment or unsure of state agencies' ability and effectiveness in managing RHDV2.

### Ordinal logistic regression models

Respondents who considered biosecurity measures important to prevent the spread of RHDV2 were more likely to engage in voluntary biosecurity actions or support agency-mandated biosecurity measures (with the exception of waiting to clean rabbit carcasses until returning home; Tables 5 and 6). Respondents who expressed susceptibility to the economic impacts of RHDV2 were also more likely to engage in or support biosecurity actions (with the exception of sanitizing hunting tools and equipment). Respondents who were concerned about the impact of RHDV2 on hunting were less likely to wear disposable gloves when handling rabbit carcasses, but were more likely to support both the relocation of field trials and bans on the transport of lagomorphs from states with confirmed RHDV2 cases. We found no correlation between respondents' risk sensitivity to lagomorph deaths or sensitivity to the economic impacts of RHDV2 and their willingness to engage in or support biosecurity actions. Respondents who trusted state agencies to manage RHDV2 were more likely to report suspicious rabbit deaths, clean lagomorphs at home, cook lagomorphs to the appropriate temperature, sanitize their hunting equipment, support restrictions on hunting in areas with threatened and endangered lagomorphs, and support a ban on the transport of lagomorphs between states until a domestic RHDV2 vaccine was produced.

Respondents' willingness to sanitize their hunting equipment was negatively correlated with whether they were aware of the existence of RHDV2, but positively correlated with their level of knowledge of RHDV2. Respondents from states with confirmed RHDV2 cases were more likely to properly dispose of lagomorph remains. However, these respondents were less likely to support the relocation of field trials and a ban on the transport of lagomorphs from states with confirmed RHDV2 cases or until a domestic RHDV2 vaccine was produced.

Respondents who also hunted with dogs were more likely to report suspicious rabbit deaths and support the relocation of field trials. They were less likely to sanitize their hunting

equipment. Respondents who hunted multiple game animals were less likely to wear gloves when handling lagomorph carcasses and properly dispose of lagomorph remains. We found no correlation between respondents' willingness to engage in or support biosecurity and whether they hunted out of state.

Female respondents were more likely to report suspicious rabbit deaths, wear gloves when handling lagomorph carcasses, properly dispose of lagomorph remains, and sanitize their hunting equipment. Male respondents more likely to support a ban on the transport of lagomorphs from states with confirmed RHDV2 cases. Older respondents were less likely to clean carcasses at home and properly cook lagomorphs. However, older respondents were more likely to support bans on the movement of lagomorphs from RHDV2-positive areas and until a domestic vaccine was produced. Respondents with higher education levels were more likely to report suspicious rabbit deaths.

### Discussion

Understanding stakeholder willingness to engage in biosecurity measures and support for potential government disease management strategies is important to engage key stakeholders in efforts to prevent the spread of foreign animal pathogens. Our study provided the first investigation of falconers' willingness to engage in or support biosecurity actions in the United States. We found that falconers were likely to engage in all biosecurity behaviors addressed in this study and were generally supportive of potential management actions that could be implemented by state agencies to lower the risk of human-mediated RHDV2 spread. Response rates were low for survey distribution (we surveyed ~10–13% of all falconers in the United States), which is consistent with the general decline in response rates for social science surveys (Stedman et al. 2019). However, we implemented best practices in conducting this research and our respondents shared similar demographic characteristics to Wallen and Bickford's (2020) study of NAFA members—the only other existing study of falconers in the United States that we could locate in peer-reviewed journals.

When presented with different biosecurity behaviors, respondents expressed the greatest

**Table 5.** Ordinal regression analysis (estimated coefficients) of falconers’ willingness to engage in voluntary biosecurity actions designed to prevent the human mediated spread of rabbit (Leporidae) hemorrhagic disease virus 2 (RHDV2), April 2021 to March 2022, USA.

Explanatory/predictor variable	Report suspicious rabbit deaths to state wildlife agency	Wear disposable gloves when handling rabbit carcasses	Place remains of cleaned rabbits in bag, sanitize bag, and either bury bag or dispose of it in trash	Wait to clean rabbit carcasses until you have returned home	Cook rabbits to an internal temperature of 165°F (73.89°C)	Sanitize all tools, equipment, or other items used to hunt/clean rabbits before and after contact with wild rabbits
Prior awareness of RHDV2	-0.234	-0.440	-0.344	-0.131	-0.154	-1.452***
Knowledge of RHDV2	-0.150	0.693	0.465	-0.110	-0.195	1.057*
Perceived importance of biosecurity actions	0.821***	0.892***	0.718***	0.262	0.674***	0.888***
Susceptibility to economic impacts of RHDV2	0.600**	0.573**	0.626**	0.388*	0.724**	0.247
Sensitivity to economic impacts of RHDV2	-0.023	0.124	-0.173	-0.072	-0.311	0.124
Concern about the impact of RHDV2 on hunting	0.245	-0.395*	-0.039	-0.101	-0.053	0.036
Sensitivity to lagomorph deaths	0.146	0.132	0.092	-0.041	-0.059	0.117
Trust in state agencies to manage RHDV2	0.406**	-0.110	0.207	0.279*	0.415**	0.370**
Hunt with dogs ( <i>Canis lupus familiaris</i> )	0.444*	-0.258	0.195	0.088	0.182	-0.476*
Hunt out of state	-0.273	-0.161	0.080	0.040	-0.183	-0.193
Number of species hunted	0.012	-0.084*	-0.131**	-0.024	0.064	-0.053
Gender <sup>a</sup>	-0.505***	-0.248*	-0.287*	-0.170	-0.194	-0.283*
Age <sup>b</sup>	0.001	0.004	0.002	-0.022***	-0.024**	-0.010
Education <sup>c</sup>	0.127*	0.023	-0.032	-0.023	0.117	0.077
RHDV2 status of state	-0.010	0.346	0.434*	-0.166	-0.336	0.219
Intercepts:						
$\beta_1$	1.703	-0.475	-0.542	-1.958	1.303	-2.372
$\beta_2$	2.193	1.180	0.612	-0.933	1.731	-1.115
$\beta_3$	2.739	1.624	1.013	-0.556	2.163	-0.545
$\beta_4$	4.298	2.742	2.293	0.480	3.100	0.817
N	465	466	462	462	316	459
Log likelihood	-373.79	-601.67	-496.05	-620.20	-334.07	-495.60
AIC <sup>d</sup>	769.57	1225.35	1010.10	1258.40	688.14	1013.20

\*  $P < 0.05$

\*\*  $P < 0.01$

\*\*\*  $P < 0.001$

<sup>a</sup> Coded as female = -1; prefer not to answer = 0; male = 1.

<sup>b</sup> Coded as 18–24 years old = 21; 25–34 = 30; 35–44 = 40; 45–54 = 50; 55–64 = 60; 65–74 = 70;  $\geq 75$  years old = 75.

<sup>c</sup> 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.

<sup>d</sup> 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 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).

**Table 6.** Ordinal regression analysis results (estimated coefficients) of falconers’ willingness to support management actions designed to prevent the human mediated spread of rabbit (*Leporidae*) hemorrhagic disease virus 2 (RHDV2), April 2021 to March 2022, USA.

Explanatory/predictor variable	Relocate field trials that use rabbits at least 150 mi (241.2 km) from counties with RHDV2	Restrict rabbit hunting in areas with rabbits that are threatened or endangered	Ban the transport of rabbits (alive and dead) that come from states with confirmed RHDV2 cases	Ban transport of rabbits until domestic RHDV2 vaccine is produced
Prior awareness of RHDV2	-0.040	-0.122	-0.053	-0.199
Knowledge of RHDV2	0.155	-0.023	-0.097	-0.066
Perceived importance of biosecurity actions	1.135***	0.721***	0.853***	0.771***
Susceptibility to economic impacts of RHDV2	0.357*	0.363*	0.527**	0.531**
Sensitivity to economic impacts of RHDV2	0.049	0.030	-0.191	0.001
Concern about the impact of RHDV2 on hunting	0.389**	0.048	0.303*	0.167
Sensitivity to lagomorph deaths	-0.054	-0.059	0.107	0.072
Trust in state agencies to manage RHDV2	0.164	0.286*	0.156	0.260*
Hunt with dogs ( <i>Canis lupus familiaris</i> )	0.392*	-0.066	0.209	0.177
Hunt out of state	-0.209	-0.083	-0.334	-0.121
Number of species hunted	-0.038	0.010	-0.014	0.003
Gender <sup>a</sup>	-0.110	-0.043	0.240*	0.050
Age <sup>b</sup>	0.007	0.003	0.035***	0.027***
Education <sup>c</sup>	0.041	0.079	-0.013	-0.062
RHDV2 status of state	-0.864***	-0.319	-1.117***	-0.557**
Intercepts:				
$\beta_1$	-1.047	0.688	1.564	1.146
$\beta_2$	0.647	1.704	3.110	2.300
$\beta_3$	2.776	2.789	4.513	3.884
$\beta_4$	4.724	4.565	6.200	5.381
<i>N</i>	470	470	470	470
Log likelihood	-567.93	-664.78	-629.14	-666.12
AIC <sup>d</sup>	1153.86	1347.57	1282.28	1350.24

\*  $P < 0.05$

\*\*  $P < 0.01$

\*\*\*  $P < 0.001$

<sup>a</sup> Coded as female = -1; prefer not to answer = 0; male = 1.

<sup>b</sup> Coded as 18–24 years old = 21; 25–34 = 30; 35–44 = 40; 45–54 = 50; 55–64 = 60; 65–74 = 70;  $\geq 75 = 75$ .

<sup>c</sup> 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.

<sup>d</sup> 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 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).

willingness to report suspicious rabbit deaths, which would increase the effectiveness of current passive disease surveillance efforts by state wildlife agencies. State wildlife agencies often do not have a dedicated lagomorph biologist (Osborn and D'Angelo 2022). Rather, small game biologists are responsible for the management of numerous small game species, including lagomorphs. Even if there are only a small number of falconers within a state, these individuals can greatly expand monitoring efforts by agency biologists. The falconers in our study hunted lagomorphs multiple times in the season, with a subset of respondents hunting lagomorphs at least 50 times per year.

We also found that respondents were supportive of 3 of the 4 potential management actions that could be implemented by state agencies to lower the risk of human-mediated RHDV2 spread. However, we caution against agencies relying solely on top-down management approaches to control RHDV2 spread for several reasons. First, wildlife agencies should engage with licensed falconers in their state when developing management actions or rules to ensure these actions are supported, feasible, and will have high compliance. Second, top-down management strategies are ineffective if they are not enforced. Many state agencies currently do not have the resources or staffing to enforce existing rules concerning lagomorph movement (Shapiro et al. 2022), so additional regulations should only be implemented if agencies are able to allocate the necessary resources to enforce these regulations. Finally, management actions and rules, especially concerning the movement of lagomorphs, should be consistent between states to be effective (Shapiro et al. 2022). We recommend that wildlife agencies focus their efforts on increasing falconers' adoption of voluntary biosecurity behaviors by recognizing falconers' concerns about RHDV2, actively engaging with falconer organizations, and using persuasive communication.

Based on our findings, agencies may engage falconers in biosecurity behaviors by emphasizing the importance and effectiveness of these behaviors in mitigating the economic and hunting risks associated with RHDV2 spread. Consistent with previous research on hunters, pet owners, and livestock owners, we found that falconers were more likely to engage in or sup-

port biosecurity measures when they perceived the importance of biosecurity (Cooney and Holsman 2010, Schemann et al. 2012, Brennan and Christley 2013, Mankad 2016, Damiaans et al. 2018, Episcopio-Sturgeon and Pienaar 2020, Souvestre et al. 2021, Shapiro et al. 2023). Respondents also recognized the economic risks that RHDV2 poses to the domestic rabbit trade and hunting. Respondents' perceived susceptibility to economic risks increased their willingness to engage in and support biosecurity measures (Triezenberg et al. 2014, Pienaar et al. 2022, Shapiro et al. 2023). Respondents who were concerned about the risks that RHDV2 poses to hunting were more likely to support relocation of field trials and bans on the transport of lagomorphs from states with RHDV2. However, we note that respondents' sensitivity to lagomorph deaths did not influence their willingness to engage in or support biosecurity actions, even though most respondents were concerned about wild lagomorph deaths from RHDV2 and biodiversity loss from the disease-related deaths of native lagomorphs. One explanation for this finding is that falconers assumed that wild lagomorphs would rebound from RHDV2 owing to high fecundity, an assumption that is shared by state wildlife agencies (Shapiro et al. 2022).

Given that state wildlife agencies are responsible for managing hunting by falconers and rely on falconers to assist in RHDV2 surveillance, it is concerning that most respondents did not have an opinion about their agency's handling of RHDV2, indicating that they either do not know about measures taken or they did not believe the government has been effective at managing this threat. It is important for state wildlife agencies to engage more effectively with falconers. Respondents who trusted state agencies to manage RHDV2 were more likely to engage in or support biosecurity measures (Hanisch-Kirkbride et al. 2014, Harper et al. 2015, Vaske and Miller 2018, Meeks et al. 2021, Shapiro et al. 2023). Stakeholders are more likely to express trust in their state government if they evaluate agencies' past performance in managing disease risks positively and if the agency shares their goals and objectives (Needham and Vaske 2008, Hanisch-Kirkbride et al. 2014, Vaske and Miller 2018). Respondents' uncertainty about their government's handling

of RHDV2 is thus not surprising, as wildlife agencies' management of lagomorphs and response to RHDV2 has been limited (Shapiro et al. 2022). There are some state wildlife agencies that have consistently connected with stakeholder groups, created and distributed educational materials, recommended ways in which falconers can prevent RHDV2 spread, and instituted rule changes to protect their lagomorph populations from RHDV2, but these efforts vary greatly between states (Shapiro et al. 2022). Low prioritization of wild lagomorph management and RHDV2 response by multiple states (Shapiro et al. 2022) may have undermined falconers' belief that wildlife agencies share their goals, priorities, and concerns (Needham and Vaske 2008).

Creating and distributing consistent, carefully written risk communication information about RHDV2 to falconers is important for voluntary adoption of biosecurity behaviors and support for RHDV2 management actions (Triezenberg et al. 2014). Currently, numerous agencies, wildlife health groups, and rabbit-specialist organizations have disseminated information by websites or factsheets. However, there is inconsistency in the information provided (e.g., mortality rates, pathogen transmission to other animals, recommended actions that stakeholders should take), which may undermine trust in RHDV2 messaging. Importantly, 2 commonly recommended actions included in our survey (i.e., cooking rabbits to the appropriate temperature, wearing gloves when handling lagomorph carcasses) are consistent with protecting human health. Suggesting that measures should be taken to prevent human infection when there is no evidence of RHDV2 transmission to humans may undermine falconers' trust in the agencies making these recommendations and their willingness to adopt suggested biosecurity measures, especially for those individuals who are knowledgeable about RHDV2 (Needham and Vaske 2008, Vaske and Miller 2018). Although these are standard recommendations when communicating about disease, agencies should emphasize that there is no evidence of RHDV2 transmission to humans and that some biosecurity practices to protect human health are also relevant to limiting the spread of RHDV2.

Persuasive communication is needed that fo-

cuses on issues that falconers care about, such as opportunities to hunt lagomorphs, the hunting and economic risks associated with RHDV2 spread, actions that other stakeholders (e.g., hunters) are taking to reduce RHDV2 transmission, what voluntary actions agencies are asking falconers to adopt, and the importance of biosecurity measures in preventing the continued spread of RHDV2 (Triezenberg et al. 2014). Improving falconers' understanding of the vectors for RHDV2 transmission is also important. Most respondents did not know about the multiple vectors for RHDV2 transmission or that infected lagomorphs are unlikely to show signs of disease, which are important considerations in disease management. Since we found some evidence that support for biosecurity depended on awareness and knowledge of RHDV2, both the vectors for RHDV2 transmission and economic and hunting risks associated with RHDV2 may be used in messaging and outreach to highlight the need for biosecurity measures to falconers. We suggest that wildlife health practitioners partner with falconry associations (e.g., NAFA) and communication specialists to develop communication materials that are persuasive and provide clear recommendations on voluntary biosecurity actions that are safe for raptors and feasible for falconers to implement. State agencies may then use these materials in their outreach efforts.

### Management implications

Agencies could better engage falconers by communicating their recognition of the important stake falconers have in wild lagomorph management, the critical role falconers can play in RHDV2 surveillance and biosecurity, and how falconers and management agencies can collaborate moving forward. Rather than relying on one-way dissemination of RHDV2 facts, agencies should consider the social norms and cultural heritage of falconers. To increase voluntary behavioral change and support for RHDV2 management, wildlife agencies should (1) meet with falconry associations, (2) encourage falconers to report changes in lagomorph populations or potential RHDV2 cases to the agency, and (3) use messaging specifically for falconers that recognizes the unique characteristics of the sport (e.g., equipment, safety of raptors) and falconers' values.

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## Supplemental material

Supplemental material can be viewed at <https://digitalcommons.usu.edu/hwi/vol17/iss3/8>.

## Literature cited

- Abade dos Santos, F. A., A. Pinto, T. Burgoyne, K. P. Dalton, C. L. Carvalho, D. W. Ramilo, C. Carneiro, T. Carvalho, M. Conceição Peleteiro, F. Parra, and M. D. Duarte. 2022. Spillover events of rabbit haemorrhagic disease virus 2 (recombinant Gl. 4P-Gl. 2) from Lagomorpha to Eurasian badger. *Transboundary and Emerging Diseases* 69:1030–1045. <https://doi.org/10.1111/tbed.14059>
- Association of Fish and Wildlife Agencies. 2020. Rabbit hemorrhagic disease: guidance for hunting and outdoor recreation. Association of Fish and Wildlife Agencies, Washington, D.C., USA, <[https://www.fishwildlife.org/application/files/2215/9662/4075/AFWA\\_FAQ\\_Rabbit\\_Hemorrhagic\\_Disease\\_Virus2-6-29-2020.docx](https://www.fishwildlife.org/application/files/2215/9662/4075/AFWA_FAQ_Rabbit_Hemorrhagic_Disease_Virus2-6-29-2020.docx)>. Accessed May 10, 2022.
- Barton, K., and M. K. Barton. 2015. Package “mumin.” Version 1:439.
- Bosch, A. M., K. J. Benson, and A. J. Mead. 2016. Declining frequency of road-killed rabbits in central Georgia. *Georgia Journal of Science* 74:1–5. <https://digitalcommons.gaacademy.org/gjs/vol74/iss2/2>
- Brennan, M. L., and R. M. Christley. 2013. Cattle producers' perceptions of biosecurity. *BMC Veterinary Research* 9:71. <https://doi.org/10.1186/1746-6148-9-71>
- Brown, D. E., A. T. Smith, J. K. Frey, and B. R. Schweiger. 2020. A review of the ongoing decline of the white-tailed jackrabbit. *Journal of Fish and Wildlife Management* 11:341–352. <https://doi.org/10.3996/042019-JFWM-026>
- Brown, T. L., D. J. Decker, J. T. Major, P. D. Curtis, J. E. Shanahan, and W. F. Siemer. 2006. Hunters' and other citizens' reactions to discovery of CWD in central New York. *Human Dimensions of Wildlife* 11:203–214. <https://doi.org/10.1080/10871200600669924>
- Burnham, K. P., and D. R. Anderson. 2004. Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods & Research* 33:261–304. <https://doi.org/10.1177/0049124104268644>
- California Department of Food and Agriculture. 2022. Rabbit hemorrhagic disease (RHD). California Department of Food and Agriculture, Sacramento, California, USA, <[https://www.cdffa.ca.gov/AHFSS/Animal\\_Health/RHD.html](https://www.cdffa.ca.gov/AHFSS/Animal_Health/RHD.html)>. Accessed September 1, 2022.
- Cooney, E. E., and R. H. Holsman. 2010. Influences on hunter support for deer herd reduction as a chronic wasting disease (CWD) management strategy. *Human Dimensions of Wildlife* 15:194–207. <https://doi.org/10.1080/10871201003598785>
- Cronbach, L. J. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika* 16:297–334. <https://doi.org/10.1007/BF02310555>
- Damiaans, B., S. Sarrazin, E. Heremans, and J. Dewulf. 2018. Perception, motivators and obsta-

- cles of biosecurity in cattle production. *Vlaams Diergeneeskundig Tijdschrift* 87:150–163. <https://doi.org/10.21825/vdt.v87i3.16079>
- Diefenbach, D. R., S. L. Rathbun, J. K. Vreeland, D. Grove, and W. J. Kanapaux. 2016. Evidence for range contraction of snowshoe hare in Pennsylvania. *Northeastern Naturalist* 23:229–248. <https://doi.org/10.1656/045.023.0205>
- Episcopio-Sturgeon, D. J., and E. F. Pienaar. 2020. Investigating support for management of the pet trade invasion risk. *Journal of Wildlife Management* 84:1196–1209. <https://doi.org/10.1002/jwmg.21867>
- Gliem, J. A., and R. R. Gliem. 2003. Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. Pages 82–88 in *Proceedings of the Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education*, Columbus, Ohio, USA.
- Gore M. L., R. S. Wilson, W. F. Siemer, H. Wiczorek Hudenko, C. E. Clarke, P. Sol Hart, L. A. Maguire, and B. A. Muter. 2009. Application of risk concepts to wildlife management: special issue introduction. *Human Dimensions of Wildlife* 14:301–313. <https://doi.org/10.1080/10871200903160944>
- Hanisch-Kirkbride, S. L., J. P. Burroughs, and S. J. Riley. 2014. What are they thinking? Exploring layperson conceptualizations of wildlife health and disease. *Human Dimensions of Wildlife* 19:253–266. <https://doi.org/10.1080/10871209.2014.883653>
- Hanisch-Kirkbride, S. L., S. J. Riley, and M. L. Gore. 2013. Wildlife disease and risk perception. *Journal of Wildlife Diseases* 49:841–849. <https://doi.org/10.7589/2013-02-031>
- Harper, E. E., C. A. Miller, and J. J. Vaske. 2015. Hunter perceptions of risk, social trust, and management of chronic wasting disease in Illinois. *Human Dimensions of Wildlife* 20:394–407. <https://doi.org/10.1080/10871209.2015.1031357>
- Hay, M. 2014. The US Falconry revival couldn't get more American. Vice Digital Publishing, Nashville, Tennessee, USA, <<https://www.vice.com/en/article/ppmpgg/the-us-falconry-revival-cant-get-more-american>>. Accessed May 9, 2022.
- Henning, J., J. Meers, P. R. Davies, and R. S. Morris. 2005. Survival of rabbit haemorrhagic disease virus (RHDV) in the environment. *Epidemiology and Infection* 133:719–730. <https://doi.org/10.1017/S0950268805003766>
- Kao, S. Y. Z., K. VanderWaal, E. A. Enns, M. E. Craft, J. Alvarez, C. Picasso, and S. J. Wells. 2018. Modeling cost-effectiveness of risk-based bovine tuberculosis surveillance in Minnesota. *Preventive Veterinary Medicine* 159:1–11. <https://doi.org/10.1016/j.prevetmed.2018.08.011>
- Katayama, A., A. Miyazaki, N. Okazaki, T. Nakayama, and O. Mikami. 2021. An outbreak of rabbit hemorrhagic disease (RHD) caused by *Lagovirus europaeus* Gl. 2/rabbit hemorrhagic disease virus 2 (RHDV2) in Ehime, Japan. *Journal of Veterinary Medical Science* 83:931–934. <https://doi.org/10.1292/jvms.21-0128>
- Kays, R. W., and A. A. DeWan. 2004. Ecological impact of inside/outside house cats around a suburban nature preserve. *Animal Conservation* 7:273–283. <https://doi.org/10.1017/S1367943004001489>
- Le Gall-Reculé, G., A. Lavazza, S. Marchandeanu, S. Bertagnoli, F. Zwingelstein, P. Cavadini, N. Martignelli, G. Lombardi, J. Guérin, E. Lemaitre, A. Decors, S. Boucher, B. Le Normand, and L. Capucci. 2013. Emergence of a new lagovirus related to rabbit haemorrhagic disease virus. *Veterinary Research* 44:1–13. <https://doi.org/10.1186/1297-9716-44-81>
- Manfredo, M. J., J. J. Vaske, P. J. Brown, D. J. Decker, and E. A. Duke, editors. 2009. *Wildlife and society: the science of human dimensions*. Island Press, Washington D.C., USA.
- Mankad, A. 2016. Psychological influences on biosecurity control and farmer decision-making. A review. *Agronomy for Sustainable Development* 36:40. <https://doi.org/10.1007/s13593-016-0375-9>
- Marcato, P. S., C. Benazzi, G. Vecchi, M. Galeotti, L. Della Salda, G. Sarli, and P. Lucidi. 1991. Clinical and pathological features of viral haemorrhagic disease of rabbits and European brown hare syndrome. *Revue Scientifique et Technique Office International des Épizooties* 10:371–392.
- McCleery, R. A., A. Sovie, R. N. Reed, M. W. Cunningham, M. E. Hunter, and K. M. Hart. 2015. Marsh rabbit mortalities tie pythons to the precipitous decline of mammals in the Everglades. *Proceedings of the Royal Society B: Biological Sciences* 282:20150120. <https://doi.org/10.1098/rspb.2015.0120>
- Meeks, A., N. C. Poudyal, L. I. Muller, and C. Yoest. 2021. Hunter concerns and intention to hunt in forested areas affected by wildlife disease. *Forest Science* 68:85–94. <https://doi.org/10.1093/forsci/xfab049>
- Meurens, F., C. Dunoyer, C. Fourichon, V. Gerdtts, N. Haddad, J. Kortekaas, M. Lewandowska, E.

- Moncharte-Leroy, A. Summerfield, P. J. Wichgers Schreur, W. H. M. van der Poel, and J. Zhu. 2021. Animal board invited review: risks of zoonotic disease emergence at the interface of wildlife and livestock systems. *Animal* 15:100241. <https://doi.org/10.1016/j.animal.2021.100241>
- Miller, R. S., M. L. Farnsworth, and J. L. Malmberg. 2013. Diseases at the livestock–wildlife interface: status, challenges, and opportunities in the United States. *Preventive Veterinary Medicine*. 110:119–132. <https://doi.org/10.1016/j.prevetmed.2012.11.021>
- Monterroso, P., G. Garrote, A. Serronha, E. Santos, M. Delibes-Mateos, J. Abrantes, R. Perez de Ayala, F. Silvestre, J. Carvalho, I. Vasco. A. M. Lopes, E. Maio, M. J. Magalhães, L. S. Mills, P. J. Esteves, M. A. Simón, and P. C. Alves. 2016. Disease-mediated bottom-up regulation: An emergent virus affects a keystone prey, and alters the dynamics of trophic webs. *Nature*. 6:36072. <https://doi.org/10.1038/srep36072>
- Mutze, G., N. De Preu, T. Mooney, D. Koerner, D. McKenzie, R. Sinclair, J. Kovaliskli, and D. Peacock. 2018. Substantial numerical decline in South Australian rabbit populations following the detection of rabbit haemorrhagic disease virus 2. *Veterinary Record* 182:574. <https://doi.org/10.1136/vr.104734>
- National Assembly of State Animal Health Officials. 2020. RHDV frequently asked questions guidance. National Association of State Departments of Agriculture, Arlington, Virginia, USA, <[https://www.in.gov/boah/files/RHDV\\_Frequently\\_Asked\\_Questions\\_Guidance\\_6\\_30\\_20.pdf](https://www.in.gov/boah/files/RHDV_Frequently_Asked_Questions_Guidance_6_30_20.pdf)>. Accessed February 10, 2022.
- Needham, M. D., and J. J. Vaske. 2008. Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. *Society of Natural Resources* 21:197–214. <https://doi.org/10.1080/08941920701816336>
- Needham, M. D., J. J. Vaske, M. P. Donnelly, and M. J. Manfredo. 2007. Hunting specialization and its relationship to participation in response to chronic wasting disease. *Journal of Leisure Research* 39:413–437. <https://doi.org/10.1080/00222216.2007.11950115>
- Needham, M. D., J. J. Vaske, and J. D. Petit. 2017. Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. *Human Dimensions of Wildlife* 22:197–216. <https://doi.org/10.1080/10871209.2017.1298011>
- North American Falconers Association. 2022. About falconry. North American Falconers Association, <<https://www.n-a-f-a.com/page/AboutFalconry>>. Accessed May 9, 2022.
- Osborn, D., and G. D'Angelo. 2022. Rabbit and hare population status and management considerations in the eastern United States. Proceedings of the 6th World Lagomorph Conference, Montpellier, France.
- Pennsylvania Game Commission. 2021. Game commission takes measures to address rabbit hemorrhagic disease. Pennsylvania Pressroom, Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA, <<https://www.media.pa.gov/pages/game-commission-details.aspx?newsid=507>>. Accessed February 22, 2022.
- Pepin, K. M., E. Spackman, J. D. Brown, K. L. Pablonia, L. P. Garber, J. T. Weaver, D. A. Kennedy, K. A. Patyk, K. P. Huyvaert, R. S. Miller, A. B. Franklin, K. Pedersen, T. L. Bogich, P. Rohani, S. A. Shriner, C. T. Webb, and S. Riley. 2014. Using quantitative disease dynamics as a tool for guiding response to avian influenza in poultry in the United States of America. *Preventive Veterinary Medicine* 113:376–397. <https://doi.org/10.1016/j.prevetmed.2013.11.011>
- Pienaar, E. F., D. J. Episcopo-Sturgeon, and Z. T. Steele. 2022. Investigating public support for biosecurity measures to mitigate pathogen transmission through the herpetological trade. *PLOS ONE* 17(1): e0262719. <https://doi.org/10.1371/journal.pone.0262719>
- Portier, J., M. P. Ryser-Degiorgis, M. R. Hutchings, E. Monchâtre-Leroy, C. Richomme, S. Larrat, W. H. M. van der Poel, M. Dominguez, A. Linden, P. Tavares Santos, E. Warns-Petit, J. Y. Chollet, L. Cavalerie, C. Grandmontagne, M. Boadella, E. Bonbon, and M. Artois. 2019. Multi-host disease management: the why and the how to include wildlife. *BMC Veterinary Research* 15:1–11. <https://doi.org/10.1186/s12917-019-2030-6>
- Ramsey, D. S., T. Cox, T. Strive, D. M. Forsyth, I. Stuart, R. Hall, P. Elsworth, and S. Campbell. 2020. Emerging RHDV2 suppresses the impact of endemic and novel strains of RHDV on wild rabbit populations. *Journal of Applied Ecology* 57:630–641. <https://doi.org/10.1111/1365-2664.13548>
- Ripley, B. 2015. Support functions and datasets for Venables and Ripley's MASS. R package version, 7.3-64. <https://rdrr.io/documentation/packages/MASS/versions/7.3-64>
- Rouco, C., J. A. Aguayo-Adán, S. Santoro, J. Abran-

- tes, and M. Delibes-Mateos. 2019. Worldwide rapid spread of the novel rabbit haemorrhagic disease virus (Gl. 2/RHDV2/b). *Transboundary and Emerging Diseases* 66:1762–1764. <https://doi.org/10.1111/tbed.13189>
- Ryser-Degiorgis, M. P. 2013. Wildlife health investigations: needs, challenges and recommendations. *BMC Veterinary Research* 9:1–17. <https://doi.org/10.1186/1746-6148-9-223>
- Schemann, K., S. M. Firestone, M. R. Taylor, J. A. Toribio, M. P. Ward, and N. K. Dhand. 2012. Horse owners'/managers' perceptions about effectiveness of biosecurity measures based on their experiences during the 2007 equine influenza outbreak in Australia. *Preventive Veterinary Medicine* 106:97–107. <https://doi.org/10.1016/j.prevetmed.2012.01.013>
- Shapiro, H. G., G. D'Angelo, M. G. Ruder, and E. F. Pienaar. 2023. Engaging stakeholders in wildlife disease management: hunters' willingness to adopt and support biosecurity actions to prevent the spread of rabbit hemorrhagic disease. *Conservation Science and Practice* 5:e12858. <https://doi.org/10.1111/csp2.12858>
- Shapiro, H. G., E. F. Pienaar, and M. T. Kohl. 2022. Barriers to management of a foreign animal disease at the wildlife-domestic animal interface: the case of rabbit hemorrhagic disease in the United States. *Frontiers in Conservation Science* 3:857678. <https://doi.org/10.3389/fcosc.2022.857678>
- Siegrist, M., and G. T. Cvetkovich. 2000. Perception of hazards: the role of social trust and knowledge. *Risk Analysis* 20:713–719. <https://doi.org/10.1111/0272-4332.205064>
- Siegrist, M., H. Gutscher, and T. C. Earle. 2005. Perception of risk: the influence of general trust, and general confidence. *Journal of Risk Research* 8:145–156. <https://doi.org/10.1080/1366987032000105315>
- Siembieda, J. L., R. A. Kock, T. A. McCracken, and S. H. Newman. 2011. The role of wildlife in transboundary animal diseases. *Animal Health Research Reviews* 12:95–111. <https://doi.org/10.1017/S1466252311000041>
- Souvestre, M., M. Delpont, C. Guinat, C. Dumat, L. Guichard, L. Manis, H. Duret, J. Guérin, and G. Le Loc'h. 2021. Backyard poultry flocks in France: a diversity of owners and biosecurity practices. *Preventive Veterinary Medicine* 197:105511. <https://doi.org/10.1016/j.prevetmed.2021.105511>
- Stafford, N. T., M. D. Needham, J. J. Vaske, and J. Petchenik. 2007. Hunter and nonhunter beliefs about chronic wasting disease in Wisconsin. *Journal of Wildlife Management* 71:1739–1744. <https://doi.org/10.2193/2006-557>
- Stedman, R. C., N. A. Connelly, T. A. Heberlein, D. J. Decker, and S. B. Allred. 2019. The end of the (research) world as we know it? Understanding and coping with declining response rates to mail surveys. *Society and Natural Resources* 32:1139–1154. <https://doi.org/10.1080/08941920.2019.1587127>
- Stephen, C., P. Zimmer, and M. Lee. 2019. Is there a due diligence standard for wildlife disease surveillance? A Canadian case study. *Canadian Veterinary Journal* 60:841–847.
- Triezenberg, H. A., M. L. Gore, S. J. Riley, and M. K. Lapinski. 2014. Perceived risks from disease and management policies: an expansion and testing of a zoonotic disease risk perception model. *Human Dimensions of Wildlife* 19:123–138. <https://doi.org/10.1080/10871209.2014.844288>
- U.S. Department of Agriculture (USDA). 2022. 2020-22 Rabbit hemorrhagic disease affected counties. U.S. Department of Agriculture, Washington, D.C., USA, <<https://www.aphis.usda.gov/aphis/maps/animal-health/rhd>>. Accessed May 24, 2022.
- U.S. Fish and Wildlife Service and U.S. Census Bureau. 2018. 2016 National survey of fishing, hunting and wildlife-associated recreation. U.S. Fish and Wildlife Service and U.S. Census Bureau, Washington, D.C., USA, <[https://www.fws.gov/wsfrprograms/subpages/nationalsurvey/national\\_survey.htm](https://www.fws.gov/wsfrprograms/subpages/nationalsurvey/national_survey.htm)>. Accessed October 22, 2021.
- Vaske, J. J., and C. A. Miller. 2018. Hunters and non-hunters chronic wasting disease risk perceptions over time. *Society and Natural Resources* 31:1379–1388. <https://doi.org/10.1080/08941920.2018.1463424>
- Vaske, J. J., N. R. Timmons, J. Beaman, and J. Petchenik. 2004. Chronic wasting disease in Wisconsin: hunter behavior, perceived risk, and agency trust. *Human Dimensions of Wildlife* 9:193–209. <https://doi.org/10.1080/10871200490479981>
- Wallen, K. E., and N. A. Bickford. 2020. Stakeholder perspectives on raptor conservation and falconry in North America. *Global Ecology and Conservation* 24:e01280. <https://doi.org/10.1016/j.gecco.2020.e01280>
- Wiethoelter, A. K., D. Beltrán-Alcrudo, R. Kock, and S. M. Mor. 2015. Global trends in infectious diseases at the wildlife–livestock interface. *Proceedings of the National Academy of Sciences* 112:9662–

9667. <https://doi.org/10.1073/pnas.1422741112>  
 Williams, L. B., S. E. Edmonds, S. R. Kerr, L. E. Broughton-Neiswanger, and K. R. Snekvik. 2021. Clinical and pathologic findings in an outbreak in rabbits of natural infection by rabbit hemorrhagic disease virus 2 in the northwestern United States. *Journal of Veterinary Diagnostic Investigation* 33:732–735. <https://doi.org/10.1177/10406387211022466>

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