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Deer hunters' disease risk sensitivity over time

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ABSTRACT
Risk sensitivity is a predisposition to rate all risks as large. Miller and Shelby (2009) examined hunters' risk sensitivity relative to chronic wasting disease (CWD), Mad cow, E. coli, Salmonella, Lyme disease, and West Nile virus (WNV). This article replicated their analysis and compared risk sensitivity over time. Data from Illinois hunters in 2004 (n = 1,879) and 2012 (n = 3,391) showed the "no risk" cluster reported the lowest risks across all six diseases, the "moderate risk" segment always had the highest risks, and the "slight risk" group was in between. Perceived risks declined over time for CWD, Mad cow, WNV, and Lyme disease. For E. coli and Salmonella, risks increased. Collectively, however, these hunters became slightly more risk sensitive, as the proportion in the most risk sensitive group ("moderate risk") increased (19% in 2004, 26% in 2012) while the least risk sensitive group ("no risk") decreased (24%, 20%).

KEYWORDS
Hunters; perceived risk; wildlife; disease; risk sensitivity

Introduction

Human dimensions (HD) research can facilitate understanding the societal consequences of wildlife diseases (Decker et al., 2006; Otupiri, Adam, Laing, & Akanmori, 2000). Although the epidemiology of wildlife diseases has been widely explored, HD research on wildlife diseases is more limited (Vaske, 2010; Vaske, Shelby, & Needham, 2009). Managers hesitant to make decisions without biological information should be equally reluctant to make decisions without HD data. Perceived disease risks can be mitigated by understanding relevant stakeholders and implementing policies that incorporate public opinion. For example, understanding landowner risk perceptions was helpful for addressing foot and mouth disease in deer (Simonetti, 1995).

Perceived risk is the extent that individuals believe they could be exposed to a specific hazard such as a wildlife disease (Siegrist, Gutscher, & Earle, 2005; Slovic, 2000, 2010). Such risks involve subjective evaluations of the potential impacts of a given disease (Roberts, Hall, Madden, & Hughes, 2011). Specific concerns about a disease, however, sometimes do not influence perceived risks because some individuals are inherently predisposed to rate all risks as large (Sjöberg, 2000a, 2002). This phenomenon reflects a general risk sensitivity (Miller & Shelby, 2009; Needham, Vaske, & Petit, 2017) or risk amplification (Kasperson & Kasperson, 2005; Sjöberg, 2004). The current article replicated a 2009 article by Miller and Shelby that examined disease risk sensitivity relative to chronic wasting disease (CWD), bovine spongiform encephalopathy (BSE or mad cow

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disease), Escherichia coli (E. coli), Salmonella, West Nile virus (WNV), and Lyme disease. This article extended the 2009 paper by comparing disease risk sensitivity over time. The six diseases and illnesses were examined individually and collectively.

These diseases and illnesses were selected for a variety of reasons. Both Lyme disease and WNV are common to Illinois, the focus of this article, and individuals who engage in outdoor activities (e.g., hunters) are encouraged to take precautions (Marks & Kalaitzandonakes, 2001). E. coli and Salmonella are illnesses contracted through consumption of contaminated food (primarily meat) (Lin, Jensen, & Yen, 2005). Individuals who are concerned with CWD may also be concerned about E. coli and Salmonella. Mad cow disease is closely related to CWD, and both diseases have received considerable media attention (Boyd & Jardine, 2011; Heberlein & Stedman, 2009; Lewis & Tyshenko, 2009). Given this background, people were likely aware of these diseases and illnesses.

Understanding the Diseases and Illnesses

CWD is a transmissible spongiform encephalopathy (TSE) caused by a prion protein mutation. The disease causes emaciation in all infected animals and is always fatal (Edmunds et al., 2016). The disease is found in several cervid species (e.g., white-tailed deer [*Odocoileus virginianus*], mule deer [*Odocoileus hemionus*], elk [*Cervus elaphus*], moose [*Alces alces*], reindeer [*Rangifer tarandus*]) (Haley & Hoover, 2015; Saunders, Bartelt-Hunt, & Bartz, 2012; Williams, Miller, Kreeger, Kahn, & Thorne, 2002). CWD was first discovered in Colorado and is currently found in 28 states, including Illinois where it was discovered in 2002. By 2012 (the 2nd year of this study), there were 372 confirmed cases of CWD in cervids in 10 northern Illinois counties (Miller, McCleary, Harper, & Campbell, 2013).

CWD has not been proven to affect human health, but future transmission to people cannot be dismissed (Belay et al., 2004; Haley & Hoover, 2015; MaWhinney et al., 2006). Given this uncertainty, some hunters have stopped hunting. For example, CWD was discovered in Wisconsin in early 2002 and nine months later, hunting license sales declined by 11% (Heberlein, 2004). Research has shown that changes in behavior such as quitting hunting are affected by perceptions of risks associated with CWD (Harper, Miller, & Vaske, 2015; Lyon & Vaske, 2010; Miller, 2004; Needham & Vaske, 2008; Needham, Vaske, & Manfredo, 2004, 2006; Vaske & Lyon, 2011).

CWD is similar to BSE in cattle, scrapie in sheep, and variant Creutzfeldt-Jakob disease (vCJD) in humans (McKintosh, Tabrizi, & Collinge, 2003). Similar to CWD, BSE is also a TSE caused by a prion mutation and is always fatal in all infected animals. In the United Kingdom, more than 180,000 cattle were infected with BSE and 4.4 million were slaughtered during an eradication program (Brown, 2001). The TSE in humans (vCJD) is inevitably fatal, but rare, and has extremely low-level potential for transmission. vCJD killed 177 people in the United Kingdom and 52 elsewhere, primarily in Western Europe, by June 2004 (Estenson, 2015).

Public reactions to discoveries such as BSE have led to avoidance of beef by consumers in Europe and Japan, but not in North America (Lewis & Tyshenko, 2009; Pennings, Wansink, & Meulenberg, 2002; Schroeder, Tonsor, Pennngs, & Mintert, 2007; Setbon, Raude, Fischler, & Flahault, 2005). Comparisons of BSE risk perceptions between the U.S. and Europe, however, are difficult due to the precautionary principle, which states that when a situation threatens human health, precautionary measures should be taken even if causal relationships have not been scientifically established (Tosun, 2013). In the European Union, the precautionary principle has become a statutory requirement (e.g., mandatory eradication program of cattle).

E. coli and Salmonella are the most common food-borne diseases in the U.S. (Centers for Disease Control [CDC], 2017a, 2017b). Escherichia is a genus of bacteria that are harmless and occur naturally in human digestive tracts. Virulent strains of the bacteria, however, can cause severe illness. The most common strain associated with food-borne illness in the U.S. is Shiga-toxin E. coli O157, commonly transferred via contaminated food or water (CDC, 2017b). Symptoms range from mild gastrointestinal distress to fever, nausea, and dehydration that can be severe (CDC, 2017a). The CDC estimated 390 outbreaks (defined as ≥ two people contracting from a common source) occurred in the U.S. between 2003 and 2012 (Heiman, Mody, Johnson, Griffin, & Gould, 2015). Salmonella is a genus of bacteria estimated to cause more than one million cases of food-borne illnesses in the U.S. annually, resulting in more than 400 deaths (Centers for Disease Control and Prevention, 2017b). Symptoms are similar to E. coli infection, but Salmonella differs in that it can enter the bloodstream and infect organs or tissues in the body.

Risk perceptions about food-borne diseases stem from complex combinations of social, economic, political, and psychological factors (Dosman, Adamowicz, & Hrudey, 2001; Fein, Lando, Levy, Teisl, & Noblet, 2011; Miles, Braxton, & Frewer, 1999). For example, differences in perceived risks have been shown between people who have and have not experienced Salmonella food poisoning (Perry, Miles, Tridente, & Palmer, 2004). Similar to CWD (Harper et al., 2015; Needham & Vaske, 2008; Vaske, Timmons, Beaman, & Petchenik, 2004), trust in information from respected sources (e.g., agencies), such as food safety information, influences risk perceptions (Gordon, 2003; Lobb, Mazzocchi, & Traill, 2007).

This article also examined two vector-borne diseases: WNV and Lyme disease. WNV is an arbovirus in the same family as Dengue fever, Zika virus, and St. Louis encephalitis (Dalrymple, Vogel, Teramoto, & Russell, 1973). WNV can infect birds and a wide range of mammals, including horses, dogs, and humans (CDC, 2012). Warmer, drier years often result in more cases of this disease. Surveillance during 2012 (one of the study years) included 5,674 cases in the U.S. and 286 fatalities (Centers for Disease Control and Prevention, 2012). Zielinski-Gutierrez and Hayden (2006) compared a city with high WNV transmission (Fort Collins, Colorado) against a city with low WNV transmission (Colorado Springs, Colorado). People living in Fort Collins reported a heightened sense of awareness to WNV and were more likely to take preventative actions compared to those living in Colorado Springs. Other research (e.g., Brewer, Weinstein, Cuite, & Harrington, 2004; Elliott, Loeb, Harrington, & Eyles, 2008; Tuiten, Koenraadt, McComas, & Harrington, 2009), however, has found that although awareness and knowledge of the virus may be high in some locations, personal protective behaviors are not always adopted.

WNV provides an interesting comparison with CWD, as this disease was diagnosed in Illinois in September 2001, 14 months prior to the discovery of the first CWD case in the state (Illinois Department of Public Health [IDPH], 2018). The following year, WNV cases in Illinois peaked to the highest number in the U.S. at 884 cases with 67 human deaths. In 2003, WNV had moved west and the number of cases in Illinois declined to 54 with one death. During subsequent years, Illinois ranked between second and sixth in the nation for the number of cases and deaths associated with WNV. A total of 90 cases, including eight deaths, were reported in the state during 2017 (IDPH, 2018).

Lyme disease is caused by Borrelia bacteria transmitted by adult deer ticks (Shapiro, 2014). Early symptoms usually include a rash and meningitis symptoms (e.g., headache, stiff neck; Pritt et al., 2016). In late stages without treatment, Lyme disease can lead to chronic encephalomyelitis and Lyme arthritis (Hess et al., 1999; Puius & Kalish, 2008). Although Lyme disease accounts for more than 90% of all reported cases of vector-borne illness in the U.S., little is known about public perceptions and practices regarding prevention of tick bites and this disease (CDC, 2016). One national study (Herrington, 2004), however, found that factors most predictive of specific tick-bite preventive behaviors included: (a) knowledge of the disease, (b) knowing someone who had Lyme disease, (c) concerns about being bitten, and (d) the perceived effectiveness of insect repellent. An 18-month longitudinal study by Brewer et al. (2004) hypothesized that perceptions of personal risk cause people to take protective action associated with Lyme disease. Results, however, supported the opposite conclusion (i.e., higher perceived risk led to less protective behavior). The authors cautioned researchers about formulating risk perception-behavior hypotheses when using cross-sectional data and argued for examining these relationships over an extended period.

Risk Sensitivity and Change over Time

Some perceptions reflect broader risk sensitivities to hazards in general (Sjöberg, 2000a, 2000b, 2004). Risk sensitivity has been applied to a variety of topics including crime, transportation, food, and nuclear waste (Chadee, Austen, & Ditton, 2007; Hohl & Gaskell, 2008; Lund, Nordfjærn, & Rundmo, 2012; Nordfjærn, Jørgensen, & Rundmo, 2011; Sjöberg, 1996, 2000a, 2000b, 2004). Miller and Shelby (2009) examined risk sensitivity relative to risk perceptions among Illinois hunters for CWD, BSE, Lyme disease, WNV, E. coli, and Salmonella. Cluster analysis of these risks revealed three clusters: no, slight, and moderate risk groups. The moderate risk sensitive group reported the lowest hunting participation, were the most likely to change their hunting behavior due to the presence of CWD, and believed that CWD was a risk to humans. The current article replicated the research by Miller and Shelby (2009) and others (Needham et al., 2017), and extended previous research by examining changes in risk sensitivity over time (i.e., 2004 vs. 2012).

Risk perceptions can change over time, vary depending on the hazard, and affect behavior. For example, before the discovery of CWD in Wisconsin, few people had an attitude toward this disease (Stafford, Needham, Vaske, & Petchenik, 2007). Wisconsin newspapers, however, published CWD articles at a rate of more than one per day during 2002 (Heberlein & Stedman, 2009). Hunters who had never heard of CWD quickly developed an attitude toward the disease and that perception affected their behavior. License sales for the 2002 Wisconsin gun deer-hunting season declined by 90,000 following the discovery of CWD (Vaske et al., 2004).

Over time, however, perceptions and behavior can change. Holsman and Smail (2006) compared Wisconsin hunters' attitudes toward CWD over a 3-year period (i.e., 2003–2005) and found they were less concerned about this disease in 2005 than they were in 2003. Two 2010 articles (Cooney & Holsman, 2010; Holsman, Petchnik, & Cooney, 2010) also found that although people were still slightly concerned about getting sick from eating deer infected with

CWD, their perceived risks had diminished since the discovery of this disease in Wisconsin. Time and experience with this disease may have tempered some of the initial concerns identified in earlier studies (Needham & Vaske, 2006, 2008; Needham et al., 2004, 2006; Stafford et al., 2007; Vaske et al., 2004). License sales now show that hunter numbers have returned to approximately where they were before the discovery of this disease in Wisconsin (Kamal, 2017).

Based on the previous literature (e.g., Miller & Shelby, 2009; Needham et al., 2017), the following research questions (RQ) were advanced and examined in this article:

RQ_1 To what extent do hunters' perceived risks associated with TSEs (i.e., CWD, BSE), food-borne illnesses (i.e., E. coli, Salmonella), and vector-borne diseases (i.e., Lyme disease, WNV) change over time (2004 vs. 2012)?

RQ_2 Can hunters' perceived risks associated with specific TSEs, food-borne illnesses, and vector-borne diseases be grouped into homogeneous and meaningful subgroups that reflect general risk sensitivity?

RQ_3 To what extent does general risk sensitivity change over time (2004 vs. 2012)?

Methods

Data Collection

Data from two mail surveys were analyzed. Both surveys followed the same protocol. Each survey participant was first mailed a questionnaire, letter, and stamped return envelope. A postcard reminder was mailed 14 days after the first mailing, and a second complete mailing (i.e., questionnaire, letter, envelope) was sent 14 days later to non-respondents. A final postcard reminder was mailed 14 days after the second complete mailing to individuals who did not respond to the previous mailings.

The 2004 mail survey included a random sample of 3,000 Illinois resident deer hunters. Of the 3,000 questionnaires initially mailed, 114 were undeliverable and 1,879 usable questionnaires were returned (response rate = 65%). In 2012, questionnaires were mailed to 6,000 randomly selected northern Illinois deer permit holders stratified by county where their permits were issued. A total of 3,391 (response rate = 58%) completed questionnaires were received. Funding limitations prohibited any checks for potential nonresponse bias.

Data Analysis

The independent variable was the study year (2004 vs. 2012). The dependent variables were perceptions of risks from two TSEs (CWD, BSE), two food-borne illnesses (E. coli, Salmonella), and two vector-borne diseases (Lyme disease, WNV). Each item was coded on a 4-point scale of: (1) no risk, (2) slight risk, (3) moderate risk, and (4) high risk to people.

Preliminary analyses compared 2004 and 2012 datasets in terms of age and sex (i.e., male, female). Independent samples *t*-tests examined RQ_1. Given the sample sizes, a $p < .01$ was considered statistically significant. Eta (η) was used to indicate the strength of the relationship with an η of < .10 considered a "minimal" relationship, .243 a "typical" relationship, and $\eta > .371$ a "substantial" relationship (Vaske, 2008).

RQ_2 was examined using the same procedures as Miller and Shelby (2009). K-means cluster analysis clustered respondents into more homogeneous groups based on their responses to the six diseases and illnesses. RQ_3 compared the cluster analysis groups from the 2004 data against the groups produced from the 2012 data. The Likelihood Ratio Chi-square was used to test for differences and Cramer's *V* or Phi were the effect size indicators where .10 was considered to be "minimal," .30 was "typical," and .50 was "substantial" (Vaske, 2008).

Results

The 2004 and 2012 samples were statistically equivalent in terms of sex and age (Table 1). More than 95% of respondents in both years were male. Mean age in 2004 was 46.71 and in 2012 it was 47.18. Neither of these comparisons varied statistically.

Perceived risks associated with TSEs (CWD, BSE) declined from 2004 to 2012 (Table 2). For CWD, means decreased from 2.12 to 1.64, whereas means for BSE declined from 1.93 to 1.50 ($t \geq 18.22$, $p < .001$, in both tests) and effect sizes were generally "typical" (i.e., $\eta \geq .242$). There were also statistical differences ($t \geq 3.10$. $p \leq .002$) between years for both of the food-borne diseases (E. coli, Salmonella), however, mean risk increased for these diseases. For the vector-borne diseases, risks declined from 2004 to 2012 (WNV, $M = 2.45$ to 2.22; Lyme, $M = 2.43$ to 2.27, respectively). These differences were statistically significant ($t \geq 6.40$, $p < .001$), but the effect sizes were "minimal" ($\leq .087$). These findings supported RQ_1 that disease risk perceptions change over time and, with the exception of the food-borne diseases, risks declined.

Following Miller and Shelby (2009), separate cluster analyses on the six diseases and illnesses were performed for two, three, four, and five group solutions. The three-group solution provided the best fit for the data. To validate this solution, data were randomly sorted and a cluster analysis was conducted after each of three random sorts. Similar to the 2009 article, all of these additional cluster analyses supported the initial three-group solution. A comparison of the individual items for each year against the three clusters indicated that those in the "no risk" cluster consistently reported the lowest means, whereas those in the "moderate risk" cluster consistently had the highest means (Table 3). Means for respondents

Table 1. Demographic comparison of the two samples of Illinois deer hunters.

	2004	2012	Test statistic	*p*-value
Sex			$\chi^2 = 0.24$	.878
Male (%)	97	96		
Female (%)	3	4		
Age (*M*)	46.71	47.18	$t = 0.57$	.903

Table 2. Comparison of means for perceived risks of TSE, food-borne, and vector-borne diseases among Illinois deer hunters by year.[a]

Dependent: Perceived risk from…	2004 *M*	2012 *M*	*t*-value	*p*-value	η
CWD	2.12	1.64	21.09	<.001	.247
Mad cow	1.93	1.50	18.22	<.001	.242
Salmonella	2.10	2.21	4.89	< .001	.058
E. coli	2.13	2.20	3.10	.002	.036
West Nile virus	2.45	2.22	10.32	<.001	.121
Lyme disease	2.43	2.27	6.40	<.001	.087

[a] Items coded on a 4-point scale: (1) no risk, (2) slight risk, (3) moderate risk, and (4) high risk

in "slight risk" cluster were always in between those for the other two clusters. These findings support RQ_2; hunters' perceived risks associated with specific TSEs, food-borne illnesses, and vector-borne diseases can be grouped into homogeneous and meaningful subgroups that reflect general risk sensitivity.

Results from the 2004 and 2012 cluster analyses are shown in Table 4. The percentages of individuals in the "no risk" cluster decreased from 2004 (24%) to 2012 (20%), as did the percentages for the "slight risk" cluster (i.e., 2004 = 57%, 2012 = 54%). The percentages of respondents in the "moderate risk" (i.e., most risk sensitive) cluster, however, increased between 2004 (19%) and 2012 (26%). Distributions for the two years (2004 vs. 2012) differed statistically ($\chi^2 = 43.31$, $p < .001$). In addition, dummy variables created for each of the three levels of risk (i.e., no risk [yes or no], slight risk [yes or no], moderate risk [yes or no]), revealed significant differences for the "no risk" and "moderate risk" levels ($\chi^2 \geq 15.14$ $p < .001$), but not for "slight risk" ($p = .047$) given the $p < .01$ significance cut-off. All effect sizes, however, were minimal. Regardless, these results are consistent with RQ_3 and suggest that Illinois hunters are becoming slightly more risk sensitive over time, as the percent in the most risk sensitive cluster ("moderate risk") increased while the proportion in the least risk sensitive cluster ("no risk") decreased.

Table 5, however, highlights the complexity of this time component. For CWD and mad cow, the average perceived risk for each of the three cluster levels (i.e., no, slight, moderate risk) statistically decreased between 2004 and 2012 ($t \geq 6.35$, $p < .001$, $\eta \geq .219$, in all tests). For Salmonella and E. coli, perceived risk declined for "no risk" group between 2004 and 2012

Table 3. Validity check of risk groups from the cluster analyses.[a]

Dependent: Perceived risk from…	No Risk	Slight Risk	Moderate Risk	*F*-value	*p*-value	η
2004						
CWD	1.52 [a]	2.06 [b]	2.96 [c]	402.50	< .001	.589
Mad cow	1.21 [a]	1.85 [b]	2.94 [c]	530.92	< .001	.642
Salmonella	1.19 [a]	2.09 [b]	3.27 [c]	1,308.38	< .001	.796
E. coli	1.23 [a]	2.13 [b]	3.26 [c]	1,299.46	< .001	.795
West Nile virus	1.83 [a]	2.43 [b]	3.21 [c]	337.51	< .001	.555
Lyme disease	1.92 [a]	2.45 [b]	2.99 [c]	220.58	< .001	.475
2012						
CWD	1.24 [a]	1.54 [b]	2.15 [c]	583.93	< .001	.420
Mad cow	1.05 [a]	1.41 [b]	1.99 [c]	816.88	< .001	.480
Salmonella	1.10 [a]	2.12 [b]	3.24 [c]	7,605.39	< .001	.858
E. coli	1.10 [a]	2.10 [b]	3.21 [c]	7,612.91	< .001	.858
West Nile virus	1.50 [a]	2.13 [b]	2.95 [c]	1,786.97	< .001	.629
Lyme disease	1.64 [a]	2.23 [b]	2.82 [c]	1,010.46	< .001	.520

[a] Items coded on a 4-point scale: (1) no risk, (2) slight risk, (3) moderate risk and (4) high risk.
Means with different letter superscripts across each row differ statistically at $p < .05$ based the Tamhane's T2 post-hoc test.

Table 4. Cluster analysis risk segments for Illinois deer hunters by year.[a]

Cluster analysis risk segment	2004 %	2012 %	χ^2	*p*-value	Phi
No risk	24	20	15.14	< .001	.047
Slight risk	57	54	4.08	.047	.024
Moderate risk	19	26	38.37	< .001	.072

[a] $\chi^2 = 43.31$, $p < .001$, Cramer's $V = .077$

Table 5. Comparison of means for perceived risks of TSE, food-borne, and vector-borne diseases among Illinois deer hunters by level of risk (no, slight, moderate) and year (2004, 2012).[a]

Dependent: Perceived risk from…	2004 *M*	2012 *M*	*t*-value	*p*-value	η
CWD					
No risk	1.52	1.24	8.21	< .001	.229
Slight risk	2.05	1.51	22.65	< .001	.336
Moderate risk	2.96	2.15	14.53	< .001	.310
Mad cow					
No risk	1.21	1.06	6.35	< .001	.219
Slight risk	1.85	1.41	18.17	< .001	.316
Moderate risk	2.94	1.99	15.89	< .001	.368
Salmonella					
No risk	1.19	1.10	3.83	< .001	.115
Slight risk	2.09	2.12	1.47	.143	.026
Moderate risk	3.27	3.24	0.84	.400	.023
E. coli					
No risk	1.23	1.10	5.27	< .001	.162
Slight risk	2.13	2.10	1.61	.107	.029
Moderate risk	3.26	3.21	1.25	.213	.034
West Nile virus					
No risk	1.83	1.50	8.51	< .001	.227
Slight risk	2.43	2.13	12.49	< .001	.216
Moderate risk	3.21	2.95	5.42	< .001	.129
Lyme disease					
No risk	1.92	1.64	7.26	< .001	.185
Slight risk	2.45	2.23	9.36	< .001	.151
Moderate risk	2.99	2.82	3.60	< .001	.085

[a] Items coded on a 4-point scale: (1) no risk, (2) slight risk, (3) moderate risk and (4) high risk.

($t \geq 3.83$, $p < .001$, $\eta \geq .115$). For these two food-borne diseases, however, there were no statistical differences in the mean responses for individuals in either the "slight risk" or "moderate risk" categories. Similar to the TSEs (CWD, BSE), the means for the two vector borne diseases (WNV, Lyme disease) statistically decreased over time ($t \geq 3.60$, $p < .001$, $\eta \geq .085$) for each of the three levels of the risk clusters.

Discussion

Findings here addressed the three research questions. In response to RQ_1, hunters' risk perceptions associated with the TSEs (i.e., CWD, BSE), and the vector-borne diseases (i.e., Lyme disease, WNV) declined between 2004 and 2012. Perceived risks associated with the food-borne illnesses (i.e., E. coli, Salmonella), however, increased between these years. Hunters' perceived risks associated with the six specific diseases and illnesses could also be grouped into more homogeneous and meaningful subgroups that reflected general risk sensitivity, and these groups paralleled previous research (Miller & Shelby, 2009) as suggested by RQ_2. Finally, hunters' overall risk sensitivity increased slightly over time between 2004 and 2012 (RQ_3).

Results also showed, however, that this general risk sensitivity is complex and does not necessarily generalize across all diseases. Risks that are new, potentially catastrophic, and involve dread, all tend to elicit strong initial concerns and reactions (Kasperson & Kasperson, 2005). CWD has many of these elements in states where the disease has been recently discovered (i.e., a "new" event). Initial media coverage in these states has typically associated CWD with mad cow disease and vCJD, creating dread that it is a threat to humans (Milius, 2002). This media attention could amplify the risk perception associated with CWD (Boyd & Jardine, 2011), especially when it is a new event. As shown by these Illinois data and the data from Wisconsin (Cooney & Holsman, 2010; Holsman et al., 2010; Holsman & Smail, 2006), however, perceived risks associated with CWD have declined over time, along with a decline in media attention.

Some hunters may also be under the impression that their behaviors can mitigate risks associated with harvests of CWD-positive deer (Miller, Anderson, Campbell, & Leiter, 2006). Over time, hunters may believe they can identify a CWD positive deer in the field due to the animal's behaviors and appearance, and then take appropriate preventive actions. CWD testing of harvested deer, which is mandatory for all deer harvested during firearm season in Illinois counties with CWD, may provide hunters with a sense of risk reduction through a perception of control. Noting deer behavior and testing harvested deer may reduce risk perceptions.

The perceived risks for mad cow disease also declined between 2004 and 2012. Individuals may have taken preventative actions and not eaten beef. Alternatively, they could have reappraised the situation and rationalized that: (a) cattle, not humans, get mad cow; (b) mad cow cases in the U.S. are rare; and (c) the TSE that affects humans (vCJD) rarely occurs.

Means for WNV and Lyme disease also declined between 2004 and 2012. Respondents might have known that WNV and Lyme disease can be addressed with medication, and that behaviors on their part (e.g., closing pants legs and using insect repellent to guard against ticks) can go far to mitigate risks. The initial outbreak of WNV occurred little more than a year before the outbreak of CWD and resulted in human deaths; WNV may have influenced risk perceptions of CWD, but further research is needed to explore relationships between differing diseases.

Perceived risks for the two food-borne diseases (Salmonella, E. coli), however, increased between the two years. This increase may have occurred because respondents did not believe there were actions that could be taken to prevent these diseases, or that actions available to them would be ineffective. Outbreaks of these food-borne diseases also occur with greater frequency than other diseases and illness in this study, and such outbreaks result in media attention.

Management Implications

The Illinois Department of Natural Resources has aggressively fought the spread of CWD within the state. Sharpshooting (targeted removal), for example, can be effective in slowing the prevalence and distribution of CWD (Harper et al., 2015), but this strategy is highly contentious. From a management perspective, perceived risks associated with CWD declined between 2004 and 2012. With less perceived risk, management strategies such as sharpshooting may be even more contentious. Perceived risks from CWD may differ in states with different management programs, higher occurrence of CWD, and larger hunter populations. Furthermore, relationships between hunters and the state wildlife management agency (e.g., trust) will also influence acceptance of CWD messaging, management actions, and risk perception (Harper et al., 2015).

Perceived risks related to wildlife diseases are often included in information campaigns conducted by state wildlife agencies (Decker et al., 2012). Agency communication campaigns state that there is no evidence that CWD currently poses a human health risk (Eschenfelder, 2006). These same messages, however, also advise hunters to take precautions such as testing animals for CWD and wearing gloves when processing, suggesting that a risk may be present. Although agencies are likely to continue communicating precautionary messages primarily for legal reasons, this ambiguity in the messages may influence perceptions of risk. Hunters may believe that mixed messages suggest wildlife agencies are uncertain about CWD, which may influence trust and risk evaluations (Harper et al., 2015; Needham & Vaske, 2008; Siegrist & Cvetkovich, 2000). Wildlife agencies should consider these issues when developing CWD communication campaigns and planning their long-term response to CWD. Moreover, messaging may be needed to reinforce behaviors that reduce risks associated with CWD among hunters.

Additional communication campaigns, however, may not be successful for educating risk-sensitive hunters. This inherent predisposition to rate most risks as moderate makes it challenging for agencies to single out a specific hazard such as CWD and then reduce risk perceptions associated with this one hazard (Sjöberg, 2000a, 2002). Specific communications, especially about the lack of evidence showing connections between CWD and human health problems should be reiterated, emphasized, and targeted to risk sensitive groups (Needham & Vaske, 2008; Needham et al., 2017). Perceptions of risk from CWD and other hazards that are based on erroneous information and misconceptions may render management efforts ineffective, so it is important for agencies to measure public risk evaluations and then target groups who hold these perceptions, as well as track these perceptions over time (Miller & Shelby, 2009).

References

Belay, E. D., Maddox, R. A., Williams, E. S., Miller, M. W., Gambetti, P., & Schonberger, L. B. (2004). Chronic wasting disease and potential transmission to humans. *Emerging Infectious Diseases*, *10*, 977–984. doi:10.3201/eid0905.020577

Boyd, A. D., & Jardine, C. G. (2011). Did public risk perspectives of mad cow disease reflect media representations and actual outcomes? *Journal of Risk Research*, *14*, 615–630. doi:10.1080/13669877.2010.547258

Brewer, N. T., Weinstein, N. D., Cuite, C. L., & Herrington, J. E. (2004). Risk perceptions and their relation to risk behavior. *Annals of Behavioral Medicine*, *27*, 125–130. doi:10.1207/s15324796abm2702_7

Brown, D. (2001). The recipe for disaster that killed 80 and left a £5bn bill. *The Daily Telegraph*.

Centers for Disease Control and Prevention. (2012). *West Nile virus national surveillance data for 2012*. Atlanta, GA: US Department of Health and Human Services, CDC.

Centers for Disease Control and Prevention. (2016). *Data and statistics: Lyme disease*. U.S. Department of Health & Human Services. Retrieved from https://www.cdc.gov/lyme/stats/index.html.

Centers for Disease Control and Prevention. (2017a). *E. coli*. U.S. Department of Health & Human Services. Retrieved from https://www.cdc.gov/ecoli/index.html.

Centers for Disease Control and Prevention. (2017b). *Foodborne diseases active surveillance network (FoodNet)*. U.S. Department of Health & Human Services. Retrieved from https://www.cdc.gov/ecoli/index.html.

Chadee, D., Austen, L., & Ditton, J. (2007). The relationship between likelihood and fear of criminal victimization: Evaluating risk sensitivity as a mediating concept. *British Journal of Criminology*, *47*, 133–153. doi:10.1093/bjc/azl025

Cooney, E. E., & Holsman, R. H. (2010). Influences on hunter support for deer herd reduction as a chronic wasting disease (CWD) management strategy. *Human Dimensions of Wildlife*, *15*, 194–207. doi:10.1080/10871201003598785

Dalrymple, J. M., Vogel, S. N., Teramoto, A. Y., & Russell, P. K. (1973). Antigenic components of group A arbovirus virions. *Journal of Virology*, *12*, 1034–1042.

Decker, D. J., Siemer, W. F., Evenson, D. T., Stedman, R. C., McComas, K. A., Wild, M. A., … Leong, K. M. (2012). Public perceptions of wildlife-associated disease: Risk communication matters. *Human–Wildlife Interactions*, *6*(1), 13.

Decker, D. J., Wild, M. A., Riley, S. J., Siemer, W. F., Miller, M. M., Leong, K. M., … Rhyan, J. C. (2006). Wildlife disease management: A manager's model. *Human Dimensions of Wildlife*, *11*, 151–158. doi:10.1080/10871200600669908

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health- and food safety-related risk perceptions. *Risk Analysis*, *21*, 301–317. doi:10.1111/0272-4332.212113

Edmunds, D. R., Kauffman, M. J., Schumaker, B. A., Lindzey, F. G., Cook, W. E., Kreeger, T. J., … Cornish, T. E. (2016). Chronic wasting disease drives population decline of white-tailed deer. *PloS one*, *11*(8), e0161127. doi:10.1371/journal.pone.0161127

Elliott, S. J., Loeb, M., Harrington, D., & Eyles, J. (2008). Heeding the message? Determinants of risk behaviours for West Nile virus. *Canadian Journal of Public Health*, *99*, 137–141.

Eschenfelder, K. R. (2006). What information should state wildlife agencies provide on their CWD websites? *Human Dimensions of Wildlife*, *11*, 221–223. doi:10.1080/10871200600669940

Estenson, J. G. (2015). *Creutzfeldt-Jakob disease: A resource and reference guide*. Washington, DC: Capitol Hill Press.

Fein, S. B., Lando, A. M., Levy, A. S., Teisl, M. F., & Noblet, C. (2011). Trends in US consumers' safe handling and consumption of food and their risk perceptions, 1988 through 2010. *Journal of Food Protection*, *74*, 1513–1523. doi:10.4315/0362-028X.JFP-11-017

Gordon, J. (2003). Risk communication and foodborne illness: Message sponsorship and attempts to stimulate perceptions of risk. *Risk Analysis*, *23*, 1287–1296.

Haley, N. J., & Hoover, E. A. (2015). Chronic wasting disease of cervids: Current knowledge and future perspectives. *Annual Review of Animal Biosciences*, *3*, 305–325. doi:10.1146/annurev-animal-022114-111001

Harper, E. E., Miller, C. A., & Vaske, J. J. (2015). Hunter perceptions of risk, social trust, and management of chronic wasting disease in Illinois. *Human Dimensions of Wildlife*, *20*, 394–407. doi:10.1080/10871209.2015.1031357

Heberlein, T. A. (2004). Fire in the sistine chapel: How Wisconsin responded to chronic wasting disease. *Human Dimensions of Wildlife*, *9*, 165–179. doi:10.1080/10871200490479954

Heberlein, T. A., & Stedman, R. C. (2009). Socially amplified risk: Attitude and behavior change in response to CWD in Wisconsin deer. *Human Dimensions of Wildlife*, *14*, 326–340. doi:10.1080/10871200903115435

Heiman, K. E., Mody, R. K., Johnson, S. D., Griffin, P. M., & Gould, L. H. (2015). Escherichia coli O157 outbreaks in the United States, 2003–2012. *Emerging Infectious Diseases*, *21*, 1293. doi:10.3201/eid2101.140256

Herrington, J. E. (2004). Risk perceptions regarding ticks and Lyme disease: A national survey. *American Journal of Preventative Medicine*, *26*, 135–140. doi:10.1016/j.amepre.2003.10.010

Hess, A., Buchmann, J., Zettl, U. K., Henschel, S., Schlaefke, D., Grau, G., & Benecke, R. (1999). Borrelia burgdorferi central nervous system infection presenting as an organic schizophrenialike disorder. *Biological Psychiatry*, *45*, 795. doi:10.1016/S0006-3223(98)00277-7

Hohl, K., & Gaskell, G. (2008). European public perceptions of food risk: Cross-national and methodological comparisons. *Risk Analysis*, *28*, 311–324. doi:10.1111/j.1539-6924.2008.01021.x

Holsman, R. H., Petchenik, J., & Cooney, E. E. (2010). CWD after "the fire": Six reasons why hunters resisted Wisconsin's eradication effort. *Human Dimensions of Wildlife*, *15*, 180–193. doi:10.1080/10871201003718029

Holsman, R. H., & Smail, R. A. (2006). *Tracking DEZ deer hunters: A report of the hunter effort and attitudes for the 2005 deer hunting season with relevant three-year trends*. Stevens Point, WI: University of Wisconsin-Stevens Point.

Illinois Department of Public Health. (2018). *West nile virus*. Retrieved from http://www.dph.illinois.gov/topics-services/diseases-and-conditions/west-nile-virus

Kamal, R. (2017). *Wisconsin's chronic wasting disease response plan: 2010-2025*. Retrieved from https://dnr.wi.gov/topic/wildlifehabitat/regulations.html

Kasperson, R. E., & Kasperson, J. X. (2005). *The social contours of risk volume 1: Publics, risk communication and the social amplification of risk*. London, UK: Earthscan.

Lewis, R. E., & Tyshenko, M. G. (2009). The impact of social amplification and attenuation of risk and the public reaction to mad cow disease in Canada. *Risk Analysis*, *29*, 714–728. doi:10.1111/j.1539-6924.2008.01188.x

Lin, C. T. J., Jensen, K. L., & Yen, S. T. (2005). Awareness of foodborne pathogens among U.S. consumers. *Food Quality and Preference*, *16*, 401–412. doi:10.1016/j.foodqual.2004.07.001

Lobb, A. E., Mazzocchi, M., & Traill, W. B. (2007). Modelling risk perception and trust in food safety information within the theory of planned behavior. *Food Quality and Preference*, *18*, 384–395. doi:10.1016/j.foodqual.2006.04.004

Lund, I. O., Nordfjærn, T., & Rundmo, T. (2012). Associations between risk judgments and demand for transport risk mitigation. *Journal of Risk Research*, *15*, 1171–1182. doi:10.1080/13669877.2012.705317

Lyon, K. M., & Vaske, J. J. (2010). Predicting hunting participation in response to chronic wasting disease in four states. *Human Dimensions of Wildlife*, *15*, 208–220. doi:10.1080/10871201003770004

Marks, L. A., & Kalaitzandonakes, N. (2001). Mass media communications about agrobiotechnology. *AgBioForum*, *4*, 199–208.

MaWhinney, S., Pape, W. J., Forster, J. E., Anderson, C. A., Bosque, P., & Miller, M. W. (2006). Human prion disease and relative risk associated with chronic wasting disease. *Emerging Infectious Diseases*, *12*, 1527–1535. doi:10.3201/eid1210.060019

McKintosh, E., Tabrizi, S. J., & Collinge, J. (2003). Prion diseases. *Journal of Neurovirology*, *9*, 183–193. doi:10.1080/13550280390194082

Miles, S., Braxton, D. S., & Frewer, L. J. (1999). Public perceptions about microbiological hazards in food. *British Food Journal*, *101*, 744–762. doi:10.1108/00070709910293670

Milius, S. (2002). Mad deer disease? Researchers puzzle over brain illness in North American wildlife. *Science News*, *162*, 346–348. doi:10.2307/4013947

Miller, C. A. (2004). Deer hunter participation and chronic wasting disease in Illinois: An assessment at time zero. *Human Dimensions of Wildlife*, *9*, 237–238. doi:10.1080/10871200490480033

Miller, C. A., Anderson, W. L., Campbell, L. K., & Leiter, P. D. (2006). *An assessment of hunters' perceptions of chronic wasting disease in Illinois' deer herd: Impacts of hunter participation in 2002-2003 and 2003-2004*. Human Dimensions Program Report HR 03-05. Champaign, IL: Illinois Natural History Survey.

Miller, C. A., McCleary, M. E., Harper, E. E., & Campbell, L. K. (2013). *Stakeholder attitudes toward deer management and chronic wasting disease in Illinois*. Technical Report 32. Champaign, IL: Illinois Natural History Survey.

Miller, C. A., & Shelby, L. B. (2009). Hunters' general disease risk sensitivity and behaviors associated with chronic wasting disease. *Human Dimensions of Wildlife*, *14*, 133–141. doi:10.1080/10871200802716556

Needham, M. D., & Vaske, J. J. (2006). Beliefs about chronic wasting disease risks across multiple states, years, and interest groups. *Human Dimensions of Wildlife*, *11*, 215–220. doi:10.1080/10871200600669932

Needham, M. D., & Vaske, J. J. (2008). Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. *Society and Natural Resources*, *21*, 197–214. doi:10.1080/08941920701816336

Needham, M. D., Vaske, J. J., & Manfredo, M. J. (2004). Hunters' behavior and acceptance of management actions related to chronic wasting disease in eight states. *Human Dimensions of Wildlife*, *9*, 211–231. doi:10.1080/10871200490479990

Needham, M. D., Vaske, J. J., & Manfredo, M. J. (2006). State and residency differences in hunters' responses to chronic wasting disease. *Human Dimensions of Wildlife*, *11*, 159–176. doi:10.1080/10871200600669973

Needham, M. D., Vaske, J. J., & Petit, J. D. (2017). Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. *Human Dimensions of Wildlife*, *23*, 197–216. doi:10.1080/10871209.2017.1298011

Nordfjærn, T., Jørgensen, S., & Rundmo, T. (2011). A cross-cultural comparison of road traffic risk perceptions, attitudes towards traffic safety and driver behaviour. *Journal of Risk Research*, *14*, 657–684. doi:10.1080/13669877.2010.547259

Otupiri, E., Adam, M., Laing, E., & Akanmori, B. D. (2000). Detection and management of zoonotic diseases at the Kumasi slaughterhouse in Ghana. *Acta tropica*, *76*, 15–19.

Pennings, J. M. E., Wansink, B., & Meulenberg, M. T. G. (2002). A note on modeling consumer reactions to a crisis: The case of the mad cow disease. *International Journal of Research in Marketing*, *19*, 91–100. doi:10.1016/S0167-8116(02)00050-2

Perry, S. M., Miles, S., Tridente, A., & Palmer, S. R. (2004). Differences in perceptions of risk between people who have and have not experienced *Salmonella* food poisoning. *Risk Analysis*, *24*, 289–299. doi:10.1111/j.0272-4332.2004.00429.x

Pritt, B. S., Mead, P. S., Johnson, D. K. H., Neitzel, D. F., Respicio-Kingry, L. B., Davis, J. P., … Paskewitz, S. M. (2016). Identification of a novel pathogenic Borrelia species causing Lyme borreliosis with unusually high spirochaetaemia: A descriptive study. *The Lancet Infectious Diseases*, *16*, 556–564. doi:10.1016/S1473-3099(15)00464-8

Puius, Y. A., & Kalish, R. A. (2008). Lyme arthritis: Pathogenesis, clinical presentation, and management. *Infectious Disease Clinics*, *22*, 289–300. doi:10.1016/j.idc.2007.12.014

Roberts, N., Hall, C., Madden, L. V., & Hughes, G. (2011). Perceptions of disease risk: From social construction of subjective judgements to rational decision making. *Phytopathology*, *101*, 654–665. doi:10.1094/PHYTO-04-10-0126

Saunders, S. E., Bartelt-Hunt, S. L., & Bartz, J. C. (2012). Occurrence, transmission, and zoonotic potential of chronic wasting disease. *Emerging Infectious Diseases*, *18*, 369. doi:10.3201/eid1803.110685

Schroeder, T. C., Tonsor, G. T., Pennngs, J. M. E., & Mintert, J. (2007). Consumer food safety risk perceptions and attitudes: Impacts on beef consumption across countries. *The B.E. Journal of Economic Analysis and Policy*, *7*, 1935–1□82. doi:10.2202/1935-1682.1848

Setbon, M., Raude, J., Fischler, C., & Flahault, A. (2005). Risk perception of the "mad cow disease" in France: Determinants and consequences. *Risk Analysis*, *25*, 813–826. doi:10.1111/j.1539-6924.2005.00634.x

Shapiro, E. D. (2014). Lyme disease. *New England Journal of Medicine*, *370*, 1724–1731. doi:10.1056/NEJMcp1314325

Siegrist, M., & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk Analysis*, *20*, 713–720.

Siegrist, M., Gutscher, H., & Earle, T. C. (2005). Perception of risk: The influence of general trust, and general confidence. *Journal of Risk Research*, *8*, 145–156. doi:10.1080/1366987032000105315

Simonetti, J. A. (1995). Wildlife conservation outside parks is a disease-mediated task. *Conservation Biology*, *9*, 454–456. doi:10.1046/j.1523-1739.1995.9020454.x

Sjöberg, L. (1996). A discussion of the limitations of the psychometric and cultural theory approaches to risk perception. *Radiation Protection Dosimetry*, *68*, 219–225. doi:10.1093/oxfordjournals.rpd.a031868

Sjöberg, L. (2000a). Factors in risk perception. *Risk Analysis*, *20*, 1–12. doi:10.1111/0272-4332.00001

Sjöberg, L. (2000b). Specifying factors in radiation risk perception. *Scandinavian Journal of Psychology*, *41*, 169–174. doi:10.1111/1467-9450.00184

Sjöberg, L. (2002). Are received risk perception models alive and well? *Risk Analysis*, *22*, 665–669.

Sjöberg, L. (2004). Explaining individual risk perception: The case of nuclear waste. *Risk Management*, *6*, 51–64. doi:10.1057/palgrave.rm.8240172

Slovic, P. (2010). *The feeling of risk: New perspectives on risk perception*. New York, NY: Earthscan.

Slovic, P. E. (2000). *The perception of risk*. New York, NY: Earthscan.
Stafford, N. T., Needham, M. D., Vaske, J. J., & Petchenik, J. (2007). Hunter and nonhunter beliefs about chronic wasting disease in Wisconsin. *Journal of Wildlife Management*, *71*, 1739–1744. doi:10.2193/2006-557
Tosun, J. (2013). How the EU handles uncertain risks: Understanding the role of the precautionary principle. *Journal of European Public Policy*, *20*, 1517–1528. doi:10.1080/13501763.2013.834549
Tuiten, W., Koenraadt, C. J. M., McComas, K., & Harrington, L. C. (2009). The effect of West Nile virus perceptions and knowledge on protective behavior and mosquito breeding in residential yards in upstate New York. *EcoHealth*, *6*, 42–51. doi:10.1007/s10393-009-0219-z
Vaske, J. J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. State College, PA: Venture.
Vaske, J. J. (2010). Lessons learned from human dimensions of chronic wasting disease research. *Human Dimensions of Wildlife*, *15*, 165–179. doi:10.1080/10871201003775052
Vaske, J. J., & Lyon, K. M. (2011). CWD prevalence, perceived human health risks, and state influences on deer hunting participation. *Risk Analysis*, *31*, 488–496. doi:10.1111/j.1539-6924.2010.01514.x
Vaske, J. J., Shelby, L. B., & Needham, M. D. (2009). Preparing for the next disease: The human-wildlife connection. In M. J. Manfredo, J. J. Vaske, P. J. Brown, D. J. Decker, & E. A. Duke (Eds.), *Wildlife and society: The science of human dimensions* (pp. 244–261). Washington, DC: Island Press.
Vaske, J. J., Timmons, N. R., Beaman, J., & Petchenik, J. (2004). Chronic wasting disease in Wisconsin: Hunter behavior, perceived risk, and agency trust. *Human Dimensions of Wildlife*, *9*, 193–209. doi:10.1080/10871200490479981
Williams, E. S., Miller, M. W., Kreeger, T. J., Kahn, R. H., & Thorne, E. T. (2002). Chronic wasting disease of deer and elk: A review with recommendations for management. *Journal of Wildlife Management*, *66*, 551–563. doi:10.2307/3803123
Zielinski-Gutierrez, E. C., & Hayden, M. H. (2006). A model for defining West Nile virus risk perception based on ecology and proximity. *EcoHealth*, *3*, 28–34. doi:10.1007/s10393-005-0001-9