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RESEARCH ARTICLE

Hunter Willingness-to-Pay for Disease Testing: Evidence from Chronic Wasting Disease in White-Tailed Deer

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Abstract
Using the case of chronic wasting disease (CWD) in white-tailed deer, we estimated hunters' willingness-to-pay (WTP) for testing their game and determined how their perception of disease risk, trust, and confidence in wildlife agency affected hunter participation in ongoing disease surveillance. The average WTP for testing was $23.75 per deer, and it was positively related to trust and confidence in the wildlife agency and the perception of risk about deer populations in the declining area and the pathogen spreading to other areas. These findings imply that implementing active outreach programs can improve hunter participation in user-paid systems for CWD surveillance.

Keywords: big game; disease surveillance; testing fee; Tobit model; user-paid system
JEL classifications: C34; D62; Q18; Q57

1. Introduction

Game hunting has significant importance in managing animal populations, supporting the local and national economies, and generating hunting license revenue for conservation funding (Heffelfinger, Geist, and Wishart, 2013). Every year, millions of people engage in game hunting for outdoor recreation and bushmeat. For example, 11.5 million people in the United States (U.S.) participated in game hunting in 2016 (U.S. Department of the Interior et al., 2018). In the U.S., more than 65% of state wildlife agency budgets are funded by the sale of hunting licenses and excise taxes (Heffelfinger et al., 2013; Price Tack et al., 2018). Thus, game management helps wildlife conservation as well as contributes to human well-being (Casola et al., 2022; Engelman, Lagerkvist, and Gren, 2018).

The spread of infectious diseases in wildlife has added management complexities in maintaining healthy game populations and increased threats to wildlife conservation. The public is increasingly concerned with the health risks of zoonotic diseases and willing to contribute more to wildlife conservation than ever before (Brouwer, van Beukering, and Sultanian, 2008; Dobson et al., 2020). Wildlife agencies are investing a substantial amount of funding and managerial effort to address wildlife disease concerns and improve nature-based recreational opportunities (Chiavacci, 2022). Hunters, as consumptive users of game resources, are willing to participate in the management of wildlife diseases to address any existing barriers such as funding and infected game harvesting (Adhikari et al., 2022; Ufer et al., 2022).

Chronic wasting disease (CWD) is one of the most infectious wildlife diseases impacting free-ranging cervids and captive cervid facilities in 26 U.S. states, three Canadian provinces, as well

as Norway, Finland, Sweden, and South Korea (Ableman et al., 2019). In the U.S., state wildlife agencies are actively involved in controlling CWD in the white-tailed deer (*Odocoileus virginianus*) populations. Even though the hunting and viewing of deer are economically important ecosystem services in both public and private lands, wildlife agencies are struggling to eradicate or prevent the spreading of CWD (Escobar et al., 2020). However, with support from hunters and landowners in disease surveillance (e.g., sample collection and testing) and law enforcement (e.g., a ban on the baiting practice and transportation of harvested deer), some areas have seen some success in reducing the CWD prevalence rate in deer populations (Petchenik, 2006; Rickenbach, Guries, and Schmoldt, 2006).

Disease surveillance is one of the key components of effective CWD management and involves the systematic collection, analysis, and dissemination of animal health data for management actions. Passive (reactive) surveillance depends on hunted, dead, or dying wild animals, while active (proactive) surveillance follows planned disease monitoring using trapped or hunted wild animals (Guberti, Stancampiano, and Ferrari, 2014). Although disease surveillance includes antemortem and postmortem testing techniques, antemortem testing is not easy and efficient for a wild-ranging animal population. Postmortem testing for CWD requires retropharyngeal lymph nodes sampled from collected deer heads. Only laboratories that are part of National Animal Health Laboratory networks in the U.S. or Canada are allowed to conduct CWD diagnostic testing (Gillin et al., 2018). Currently, it takes about 2 weeks to obtain testing results, which makes some hunters reluctant to engage in CWD testing. For disease surveillance purposes, wildlife agencies usually rely on hunter-killed deer for CWD testing samples and collect them from drop-off freezers, taxidermists, and selected meat processors. Although the efficacy of CWD monitoring depends on collecting high-value samples from multiple sources, support from hunters is crucial because of their extensive reach and cost-effectiveness in sample collection.

Even with hunter cooperation, arranging for sample collection and testing requires wildlife agencies to spend significant public funding essential for other conservation programs. In Missouri, collecting 6,000 heads from hunter-killed deer and testing the tissues for CWD took 1,487 person-days and cost $172,162 (excluding salaried wages) in total, of which testing fees covered almost 70% of the total cost (Beringer et al., 2003). Between 2002 and 2008, the Wisconsin Department of Natural Resources spent $30 million on CWD management (Vaske, 2010). In Minnesota, the state wildlife agency spent $2.7 million in the fiscal year 2020 alone for CWD testing and this cost excluded thousands of staff hours (Schroeder et al., 2022). In Tennessee, the Tennessee Wildlife Resources Agency (TWRA) pays $18 per deer for CWD testing, which is a huge cost burden to the agency as disease surveillance expands across the state. Given the rise of CWD infections, establishing a user-paid system for CWD surveillance could help wildlife agencies with efficient disease management and provide funding for other priority management activities such as coordination, sample collection, or implementing other management actions.

For many U.S. states, CWD testing is mandatory if a hunter harvests deer in a known CWD-affected area (Vaske and Miller, 2019). To incentivize hunters to cooperate in CWD surveillance, a wildlife agency in Alberta, Canada, began providing an extra hunting license for hunters who submitted heads of harvested deer for CWD testing (Zimmer, Boxall, and Adamowicz, 2012). Wildlife agencies have also implemented a variety of harvest incentive programs such as "earn a buck" and "replacement buck" to increase hunting pressure and reduce herd density in CWD areas (TWRA, 2021). Mandatory regulations, harvest incentive programs, or voluntary sample submissions can help establish a large-scale disease surveillance program, but how to alleviate the financial burden of subsidized testing programs on agency budgets remains a challenge. Moreover, cooperation to increase hunting pressure, interest in CWD testing, and sharing costs associated with testing can help establish an extensive and effective CWD surveillance program (Guberti et al., 2014; Schroeder et al., 2022). However, no studies in the U.S. have been conducted to understand hunter willingness to pay (WTP) for CWD testing. Previous studies related to hunter WTP were mostly limited to understanding how hunters make tradeoffs between different

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attributes of hunting sites (Engelman et al., 2018; Hussain et al., 2010; Mensah et al., 2019; Mingie et al., 2017; Munn et al., 2011). Similarly, few human dimensions studies have focused on the role of landowners in CWD management including disease surveillance (Durocher et al., 2022; Landon et al., 2023; Poudyal, 2022). However, Durocher et al. (2022) indicated that the general public is more supportive of engaging hunters than landowners in CWD management strategies. Even though state agencies subsidize testing fees to speed up disease surveillance in the initial days of discovering CWD, they must find alternative sources to fund the testing. In the absence of preceding literature on this topic, whether and how much hunters themselves may be willing to pay is still unclear.

To fill the gap in knowledge, the objective of this study was to estimate hunter's WTP a fee for CWD testing in harvested deer. This study specifically determined how the perception of disease risk, the presence of CWD in the hunting area, and trust and confidence in an agency managing wildlife affected the hunter's WTP for testing. If hunters do not trust and have confidence in the overall CWD management led by a wildlife agency, they may not contribute to CWD testing (Meeks et al., 2022; Schroeder et al., 2021). Insights from this study can help set up a user-paid system for disease surveillance and expand the options for CWD management plans.

2. Method

2.1. Study Area

This study was conducted in the CWD-impacted region of Tennessee, USA. The study area included two categories of counties: counties with a confirmed case of CWD (i.e., positive counties) and neighboring counties located 10 miles away from the location of confirmed CWD cases (i.e., high-risk counties). The CWD-positive counties included Fayette, Hardeman, and Madison. The neighboring high-risk counties were Chester, Haywood, McNairy, Shelby, and Tipton. However, CWD was identified in deer herds of other counties after the data collection for the study was implemented in 2019 (Figure 1). CWD is also presented in adjoining states in the region including Arkansas, Mississippi, Missouri, and Virginia.

Since the first detection of CWD in 2018, the TWRA has implemented several programs to prevent its spread. Some of those initiatives include the change from general surveillance to intensive monitoring efforts to determine the spatial distribution and prevalence of CWD, collecting testing samples from hunters and local game processors, making CWD testing free for deer hunted in CWD counties, launching a public information campaign to educate the hunters, changing hunting seasons and bag limit to incentivize harvest, placing restriction on carcass movement or transportation, and enforcing a feeding/mineral ban (TWRA, 2021). In CWD-positive and high-risk counties, TWRA provided additional deer harvest opportunities to hunters through the Fight CWD Incentive Program, replacement buck, and earn-a-buck programs (Adhikari et al., 2022). On top of the bag limits, hunters would receive a replacement buck if they harvested a CWD-positive antlered deer, or they could earn an additional antlered deer for every antlerless deer harvested and submitted for CWD testing. Similarly, the Fight CWD Incentive Program provides a $75 voucher to hunters who harvest a CWD-positive deer redeemable for processing fees on their next harvest at participating processors. This program also incentivizes hunters with an annual sportsman license for next season if a hunter kills two or more CWD-positive deer during the season.

2.2. Survey Design

The survey instrument was developed based on inputs from TWRA officials, human dimension experts, and a few active deer hunters. Especially, their input helped make the survey questions simple, practical, and easy to understand by respondents. The survey instrument

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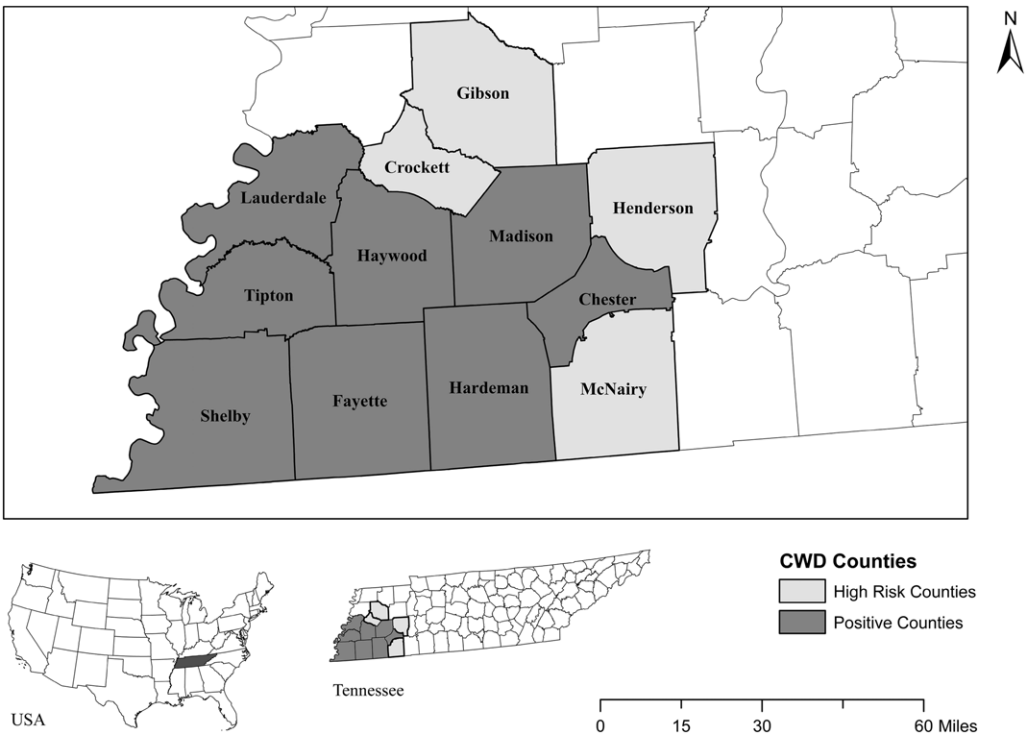

Figure 1. Chronic wasting disease (CWD) positive (counties with confirmed cases) and high-risk counties (neighboring counties located 10 miles away from location of confirmed cases) of Tennessee in the Map of USA as of January 2021.

included questions related to hunting experience, awareness about CWD, and socioeconomic characteristics.

A mixed-mode survey of Tennessee hunters was conducted in August and September 2019, following a modified tailored design method (Dillman, Smyth, and Christian, 2014). Survey participants were contacted several times using email and or mail (mixed mode). First, hunters who had email addresses were sent a personalized email message with a Qualtrics survey link. If hunters did not respond, they then received up to three reminder emails. The survey was mailed to hunters who did not have email addresses or who did not respond to the email survey. The mail survey included two contact attempts made a week apart: a personalized cover letter with the survey questionnaire and then a follow-up letter with the survey questionnaire. For this study, survey participants were selected from license holders who reside in CWD counties (positive and high-risk counties) or reported having harvested at least one deer in these CWD counties during the 2018–2019 season. In total, 16,741 hunters met this selection criterion in the TWRA license database. A total of 5,000 hunters were selected from the TWRA license database, and a stratified random sampling method was used to ensure representation from both CWD-positive and high-risk counties. Thus, there were two sampling strata, i.e., CWD-positive and high-risk counties, which were mutually exclusive.

It should be noted that disease testing services possess the characteristics of market goods (rather than nonmarket goods), and the design of value elicitation questions slightly differed from those typically used in nonmarket valuation studies. Furthermore, to account for the current context of testing arrangement in the study area, hunter WTP for the CWD testing fee was obtained using the two-stage question format as below:

The laboratory fee for testing a deer for CWD costs the TWRA $18 and the agency currently pays this fee for all deer submitted for sampling within the CWD-impacted counties. If TWRA is unable

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to cover this cost due to lack of funding in the future, are you willing to pay this amount if TWRA continues coordinating the submission of samples for testing for hunters?

- *Yes, go to Section C*
- *No, continue below*

If you said "No" above, are you willing to share a part of this cost with TWRA or other institutions to have your deer tested?

- *Yes, I am willing to share $_____per deer*
- *No*

This question format was based on a real-world example, and it was not a hypothetical question. This question was for an understanding of whether a hunter was interested to change in the existing flow of private goods, i.e., disease testing or not (Carson and Groves, 2007). The above two-stage question format was less susceptible to some of the biases of traditional double-bounded question format, for example, starting point bias and serial dependence, because all respondents received a fixed bid level in first stage question and they would not need to answer second stage question if he or she selected "yes" in the first stage (Kim, Petrolia, and Interis, 2012). Moreover, most hunters were familiar with the CWD testing fee, which was currently paid by TWRA, and the benefits of CWD testing. Although the WTP questions were presented as an advisory referendum, the consent form of the survey incorporated the following statement to increase hunter belief in consequentiality (Parthum and Ando, 2020; Vossler and Holladay, 2018): "You are one of the few randomly selected deer hunters in the region to participate in this survey. Your response will help TWRA, and other stakeholders understand hunters' perception of CWD risk and inform their management decisions." To reveal the accuracy of WTP estimates, several ex-post analysis related to data problems and survey errors was conducted such as nonresponse bias, response mode bias, and multicollinearity test.

2.3. Econometric Modeling

Empirical modeling used survey responses to particular questions regarding testing fees. Hunters reported \$18 or less as their WTP for a testing fee, and their WTP was assigned zero if they declined to answer the second stage question. Therefore, hunter WTP for the CWD testing fee was observed between \$0 and \$18. As ordinary least squares would result in asymptotic bias of the model coefficients because WTP values were not continuous but bounded or censored by 0 (lower) and 18 (upper), a maximum likelihood procedure was followed (Stewart, 1983). Thus, the two-limit Tobit model was deemed suitable for estimating the hunter WTP function because of double limits. The general form of the two-limit Tobit model can be presented as follows:

$$WTP_i^* = \boldsymbol{X_i'\beta} + \varepsilon \tag{1}$$

where WTP_i* is the unobserved latent variable; $\boldsymbol{X_i}$ is a vector of independent variables represented by hunting and processing characteristics, psychosocial factors, including perceived risk of CWD, trust, and confidence in wildlife agency, and socioeconomic characteristics; β is a vector of parameters; and ϵ is error terms, which is distributed normally N ($\mathbf{0}$, $\sigma^2\mathbf{I}$). If the observed dependent variable (WTP) is denoted by WTP_i, the model for observation i is defined as below:

$$WTP_i = \begin{cases} L_i \text{ if } WTP_i^* \le L_i \\ WTP_i^* \text{ if } L_i < WTP_i^* < R_i \\ R_i \text{ if } WTP_i^* \ge R_i \end{cases} \tag{2}$$

In equation (2), L_i and R_i denote censoring thresholds for the lower and upper tails, which were 0 and 18 in this study.

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With the model censored on both lower and upper limits, it can be estimated by maximizing the following log-likelihood function (Bradt, 2019):

$$\ln L(\boldsymbol{\beta}, \sigma | WTP_i, X_i, L_i, R_i) = \sum_{i \in \{WTP_i = L_i\}} ln\left[\Phi\left(\frac{L_i - \boldsymbol{X_i'\beta}}{\sigma}\right)\right] + \sum_{i \in \{L_i < WTP_i < R_i\}} ln\left[\frac{1}{\sigma}\phi\left(\frac{WTP_i - \boldsymbol{X_i'\beta}}{\sigma}\right)\right] + \sum_{i \in \{WTP_i = R_i\}} ln\left[\Phi\left(-\frac{R_i - \boldsymbol{X_i'\beta}}{\sigma}\right)\right] \quad (3)$$

where σ is the error variance, $\Phi(\cdot)$ is the standard normal cumulative density function, and $\phi(\cdot)$ is the standard normal probability density function.

Above, all the equations including the log-likelihood function are relevant for a two-limit censored model. When the dependent variable is censored only by a lower or upper limit, these equations are still relevant because when the probability of observation for any censored observation becomes zero, the equation becomes relevant for the lower or upper limit Tobit model. The mean of true WTP distribution was computed by using equation (1) and regression coefficients were directly used as marginal effects. The two-limit Tobit model was estimated using the command *tobit* in STATA/SE 16.1 (StataCorp, 2019).

2.4. Description of Variables

Four categories of independent variables were used to model hunter's WTP for the CWD testing fee. Those included hunting and processing characteristics, perceived risk of CWD, trust, and confidence in wildlife agencies, and socioeconomic characteristics (Table 1). The selection of variables in the model was guided by recent literature on WTP and psychosocial constructs such as risk perception and trust (Lim et al., 2014; Oh and Hong, 2012; Wang et al., 2018; C. E. Watkins and Poudyal, 2021). Explanatory variables related to hunting and processing characteristics included years of hunting (EXPERIENCE), ownership of hunting property in CWD counties (LEASE), hunting in CWD-positive counties (POSITIVE), days spent hunting in CWD counties (DURATION), and use of processing services (PROCESSING). These independent variables were selected to control the effects of hunting characteristics on the hunter's WTP for CWD testing.

Perceived risks affect hunter WTP depending on whether wildlife management actions increase or decrease the risk levels (Ufer et al., 2022; Watkins and Poudyal, 2021). Meeks et al. (2022) found that hunter acceptability of CWD management actions was influenced by specific concerns associated with CWD. Assuming CWD risks can affect hunter WTP for disease surveillance, hunter risk perception was measured by hunter concern about CWD spreading throughout Tennessee (SPREAD), the safety of eating deer meat (MEAT), deer population decline (POPULATION), and not having enough mature bucks to hunt (BUCKS).

When citizens' trust in the government increases, their WTP for government efforts increases because the trust indicates the government's past behavior and reputation (Oh and Hong, 2012). In the case of CWD management, Schroeder et al. (2021) found that the perceived effectiveness of management actions was influenced by trust in the wildlife agency. Similarly, Watkins and Poudyal (2021) found that hunters with high levels of trust and confidence in wildlife agencies were likely to pay more for conservation efforts, e.g., elk reintroduction. Thus, trust variables were used to explain hunter WTP for disease surveillance and measured agency trust in the specific context of CWD rather than general institutional trust. Variables related to trust and confidence in wildlife agency included hunter opinions on "I trust TWRA officials to have an appropriate plan

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Table 1. Description of variables used in the two-limit Tobit model to estimate hunter's willingness to pay (WTP) a laboratory fee for chronic wasting disease (CWD) testing in Tennessee in 2019

Category	Variable	Description	N	Mean	SD
Dependent variable					
WTP	TESTING	Hunter's WTP an amount for the laboratory fee for CWD testing in dollars per deer	1,249	11.372	7.938
Independent variable					
Hunting and processing characteristics	EXPERIENCE	Number of years of hunting in CWD-positive and high-risk counties of Tennessee	1,393	20.665	13.991
	LEASE	Ownership of the property in CWD positive and high-risk counties where hunter most often hunted deer (1 = leased land, 0 = otherwise)	1,305	0.268	0.443
	POSITIVE	Hunting in CWD positive counties (1 if they hunted in CWD positive counties such as Fayette, Hardeman, and Madison, 0 otherwise)	1,495	0.667	0.471
	DURATION	Total number of days spent hunting in CWD positive and high-risk counties during 2018–2019 season	1,324	22.279	19.456
	PROCESSING	Usage of a processing service for harvested deer (1 = whole or part of the deer processed elsewhere, 0 = self-processed or gave the deer away before processing	1,495	0.662	0.473
Perceived risk of CWD	SPREAD	CWD spreading throughout Tennessee (1 = not at all concerned, 2 = somewhat concerned, 3 = very concerned)	1,347	2.689	0.572
	MEAT	Safety of eating deer meat (1 = not at all concerned, 2 = somewhat concerned, 3 = very concerned)	1,357	2.520	0.699
	POPULATION	Deer population declining dramatically (1 = not at all concerned, 2 = somewhat concerned, 3= very concerned)	1,367	2.328	0.715
	BUCKS	Not having enough mature bucks to hunt (1 = not at all concerned, 2 = somewhat concerned, 3 = very concerned)	1,322	2.216	0.771
Trust and confidence in wildlife agency[a]	PLAN	I trust Tennessee Wildlife Resources Agency (TWRA) officials to have an appropriate plan for CWD in Tennessee (1 = agree, 0 = otherwise)	1,332	0.615	0.487
	PUBLIC	TWRA has made a reasonable effort to educate the public about CWD (1 = agree, 0 = otherwise)	1,327	0.790	0.408
	INFORMATION	CWD information provided by TWRA is clear (1 = agree, 0 = otherwise)	1,326	0.697	0.460
Socio-economic characteristics	AGE	Respondent age (in years)	1,494	49.174	16.270
	OWNERSHIP	Landownership in CWD positive or high-risks counties (1 = yes, 0 = no)	1,293	0.504	0.500
	HOUSEHOLD	Number of people living in the household	1,283	2.991	1.343
	INCOME	Annual household income (1 = < $25,000, 2 = $25,001 - $50,000, 3 = $50,001 - $75,000, 4 = $75,001 - $100,000, 5 = $100,001 - $125,000, 6 = $125,001 - $150,000, 7 = >$150,001)	1,184	4.376	1.861

[a]These variables were originally measured on a 5-point Likert scale: 1 = very disagree, 2 = slightly disagree, 3 = neutral, 4 = slightly agree, and 5 = very agree. It was recoded into binary variable where "slightly agree," and "very agree" were coded as 1 (agree), and "very disagree," "slightly disagree," and "neutral" coded as 0 (otherwise).

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for CWD in Tennessee" (PLAN), "TWRA has made a reasonable effort to educate the public about CWD" (PUBLIC), and "CWD information provided by TWRA is clear" (INFORMATION).

Independent variables related to risk perception, trust, and confidence (7 variables) might be endogenous in the econometric model due to omitted variables (Lundhede et al., 2015). However, it was not possible to check the endogeneity problem due to a lack of valid instrumental variables. We tried to test for endogeneity bias of those attitudinal variables in the econometric model using socioeconomic factors (instruments) by following Interis and Petrolia (2014) but failed to report results due to an under-identification problem. Four socioeconomic characteristics included hunter age (AGE), landownership in CWD counties (OWNERSHIP), number of people living in the household (HOUSEHOLD), and annual household income (INCOME).

3. Results

3.1. Respondent Characteristics

From the mixed-mode survey, a total of 1,642 completed surveys were received. After adjusting for bad addresses and deceased contacts, the adjusted response rate was 33%. Although not ideal, this response rate is consistent with similar surveys conducted in the region where the license database was used as a sampling frame (Mingie et al., 2019; Watkins et al., 2019). On average, three people were living in a household, and households had an annual income of $96,896 (Table 1). About 50% of respondents owned land in CWD counties. A follow-up nonresponse survey was not conducted but the sample characteristics were similar to those of respondents in recently conducted hunters' surveys in Tennessee. For example, the average age of the respondents in our sample was 49 years, 96% of respondents were male, and 60% had a household income between 50,000 and 150,000, which are very similar to the demographics of big game hunters in Tennessee as reported in Watkins et al. (2018). The effect of the survey mode was assessed by comparing available demographics between email and mail respondents and found that these two groups did not differ significantly ($P = 0.05$) in terms of household size, land ownership, gender, and income.

A total of 67% of respondents reported they hunted deer in one or more CWD-positive counties during the previous two deer seasons. On average, a hunter spent 23 days hunting deer during the 2018–2019 season in those CWD counties. The proportion of respondents who hunted deer most often on nonleased private land (34%), owned land (33%), and leased land (27%) was similar, whereas the proportion of respondents who hunted on public lands (6%) was substantially lower.

Most respondents were concerned with the risks posed by CWD and trusted the information about CWD provided by the TWRA. About 64% and 75% of respondents were very concerned with the "safety of eating deer meat" and "CWD spreading throughout Tennessee," respectively. Similarly, more than 40% of respondents were very concerned with "deer population decline" and "not having enough mature bucks to hunt." A total of 62% of respondents believed that TWRA has an appropriate plan for CWD. Similarly, 79% of respondents believed TWRA has made reasonable efforts to educate the public about CWD, and 70% of respondents mentioned that CWD information provided by TWRA was clear to them.

3.2. Willingness to Pay for CWD Testing Fee

Hunters indicated different amounts of WTP for testing their game for CWD, ranging from $0 to $18 per deer (Figure 2). A total of 56% of hunters agreed to pay the full testing fee ($18 per deer). However, 27% of hunters declined to pay any amount for testing. About 17% of respondents were interested in sharing part of the testing fee. Estimates from the two-limit Tobit model indicated that hunters' mean WTP for the CWD testing (laboratory) fee was $23.75 per deer. The 95% confidence interval for mean WTP ranged from $20.38 to $27.12 per deer.

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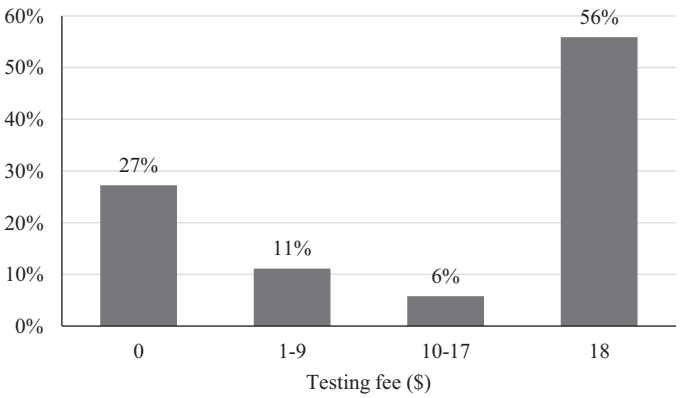

Figure 2. Distribution of Tennessee hunters' willingness to pay (WTP) values for chronic wasting disease (CWD) testing fee (n = 1,249) in 2019.

3.3. Factors Influencing Hunter's Willingness to Pay for CWD Testing Fee

Result from two-limit Tobit model (Table 2) presented regression estimates on variables that determine hunter's WTP for the testing fee. The model fit statistics was significant at 1% level of significance. The variation inflation factor (<1.3) suggested no multicollinearity issue in the model.

Having more hunting experience in CWD counties (EXPERIENCE) was negatively associated with hunter's WTP for the testing fee ($P < 0.01$). A year increase in hunting experience led to a 49-cent decrease in hunter's WTP values (Table 2). However, if a person hunted most often in CWD-positive counties (POSITIVE), their WTP was $7.54 higher than a hunter who hunted more outside of CWD-positive counties ($P < 0.05$, Table 2).

Risk perception about CWD spreading (SPREAD, $P < 0.01$) and deer population decline (POPULATION, $P < 0.05$) appears to have positive effects on WTP. Perceived risk about CWD spreading particularly had a stronger effect on WTP values, in that a point increase in the hunter concern level led to an increase in the hunter WTP values by $13.65. However, perceived risk related to "not having enough mature bucks to hunt" (BUCKS) was negatively associated with hunter WTP for CWD testing fee ($P < 0.10$).

The independent variables related to trust and confidence in wildlife agencies had the strongest effect on the hunter's WTP the testing fee. For example, hunters who trusted the wildlife agency for having an appropriate plan for CWD (PLAN) were more interested in sharing $14.14 more for the testing fee than hunters who did not have such a belief. Similarly, if hunters believed that CWD information provided by the wildlife agency was clear to them (INFORMATION), they were willing to pay $14.16 more for the testing fee.

Among the socioeconomic characteristics, landownership in CWD counties (OWNERSHIP, $P < 0.10$) and household income (INCOME, $P < 0.01$) had positive associations with hunter WTP for CWD testing. Hunters who owned land in CWD counties were willing to pay $5.24 more than hunters who did not own land in these counties. Similarly, an increase in annual household income by $25,000 led to an increase in hunter WTP of $3.93.

4. Discussion

This study estimated Tennessee hunters' WTP for CWD testing for their deer harvested from CWD-impacted regions. Although a laboratory fee is only part of the total CWD testing cost, hunter contribution is important because of increased disease spread and funding limitations (Gillin et al., 2018). There are mainly three types of costs associated with wildlife disease testing,

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Table 2. Estimates from two-limit Tobit model used to determine factors influencing hunter's willingness to pay (WTP) for laboratory fee for chronic wasting disease (CWD) testing in Tennessee in 2019

Category	Variable	Coefficient	Standard error
Deer hunting and processing characteristics	EXPERIENCE	− 0.491***	0.119
	LEASE	− 3.352	3.348
	POSITIVE	7.540**	3.107
	PROCESSING	− 0.107	0.072
Perceived risk of CWD	SPREAD	13.652***	3.291
	MEAT	− 1.614	2.376
	POPULATION	5.517**	2.568
	BUCKS	− 3.804*	2.220
Trust and confidence in wildlife agency	PLAN	14.139***	3.361
	PUBLIC	0.804	4.018
	INFORMATION	14.155***	3.705
Socioeconomic characteristics	AGE	0.171	0.106
	OWNERSHIP	5.237*	3.006
	HOUSEHOLD	0.575	1.157
	INCOME	3.928***	0.834
	Constant	− 54.008***	12.062
	Variance (e.depvar)	1,188.390	175.450
Model fit statistics	Total observations	929	
	Uncensored observations	155	
	Left-censored observations	242	
	Right-censored observations	532	
	Log likelihood	− 1,262.416	
	LR chi-squared (16)	173.300	
	Prob>chi-squared	< 0.001	

***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

which include coordination, sample collection, and laboratory fees (Rivière et al., 2017). CWD testing helps hunters change their risk perception and uncertainty regarding CWD presence in deer herds and avoid potential health hazards by properly disposing of CWD-positive deer (Vaske and Miller, 2019). This study found that most hunters wanted to contribute the full testing fee ($18 per deer) for CWD testing. This implies that, to hunters, the benefits of CWD testing outweigh the cost, and the initiation of a user-paid system for CWD surveillance is, at least in part, feasible in Tennessee. Some U.S. states such as Colorado and Virginia have already started user-paid systems where hunters pay $25 and $35 per animal, respectively, for CWD testing if they are interested in testing deer harvested outside of CWD-infected areas (CPW, 2021; VDWR, 2021).

This study found that the average hunter WTP for CWD testing fee was $23.75 per deer, which is about 32% higher than the existing testing fee for sample testing. This finding implies that hunters can still be economically benefitted even if wildlife agencies charged them a full testing fee. A benefit of user-paid disease surveillance is that it can decrease the huge financial burden on the government. For example, TWRA paid $285,012 to CWD testing laboratories for 15,834 samples

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during the 2021–2022 hunting season. If the user-paid disease surveillance system was in place, it would reduce the cost burden for TWRA by $159,606.72 (15,834*56%*$18). Saved resources can then be used to cover other testing costs associated with coordination and sample collection, or it can help expand disease monitoring into new locations. However, user-paid disease surveillance can also reduce hunter participation in CWD monitoring, as observed in Colorado where sample submissions for CWD testing decreased by 90% when a sample fee of $25 per deer was imposed on hunters who wanted their deer tested (Evans, Schuler, and David Walter, 2014). This may not be the case in Tennessee where only 27% of hunters rejected to share any CWD testing costs (Figure 2). Further, the expectation of cost-share from hunters (i.e., $18 per deer) is also lower for Tennessee hunters, who probably believe the wildlife agency should also share part of the testing fee.

Wildlife disease surveillance depends on stakeholders' (e.g., hunters, processors, and landowners) willingness to participate in disease surveillance, which is affected by disease awareness, incentives, risk attitudes, mutual trust and confidence in a wildlife agency, and logistical difficulties (Brugere, Onuigbo, and Morgan, 2017; Rickenbach et al., 2006). This study also indicated that hunter WTP for CWD testing was affected by the perceived risk of CWD and trust and confidence in the wildlife agency. The positive association of hunter risk perception regarding CWD spread, and deer population decline with their WTP for CWD testing implies that hunter participation in a user-paid system for CWD surveillance would increase if the prevalence of CWD increased in Tennessee. As mutual trust and confidence in the wildlife agency had a positive effect on hunter WTP for CWD testing, TWRA's efforts in increasing awareness about CWD and collaboratively preparing the CWD management plan may help increase hunter participation in CWD surveillance.

It should be noted that CWD was discovered only recently in Tennessee at the time of this study, which found that most hunters were concerned with CWD risks. Vaske and Miller (2019) found that Illinois hunters' risk perceptions associated with CWD declined between 2004 and 2012. Likewise, Holland et al. (2020) reported that hunter behavior changed in the four years from a notable decline in deer harvest rate immediately after the discovery of CWD to a slowly increased harvest rate to pre-CWD levels. Thus, getting hunter support for CWD management including its monitoring can be challenging in the long run due to changes in attitude and behavior toward CWD.

Wildlife disease surveillance also depends on the type of disease and the host populations (Guberti et al., 2014). Deer herds infected with CWD can be monitored by the postmortem testing of hunted or dead deer. Hunter support for wildlife disease surveillance can vary with the potential risk level of hunting areas (i.e., low-risk vs. high-risk areas) (Rivière et al., 2017). Higher WTP for testing fees in CWD-positive counties suggests that hunters require greater cost-share or subsidies for CWD testing in outside counties than in CWD-positive counties. Wildlife agencies can divide outside counties into different risk areas (for example, high, medium, and low) based on the access of diseased herds and determine the cost-share proportion for cost-effective CWD monitoring.

As expected, household income had a positive association with hunter WTP for CWD testing, and this finding indicates that CWD testing service is a normal good. CWD testing not only benefits users/consumers but also society as a whole because it helps wildlife agencies stay informed and provide proper disease management. Bartling et al. (2020) concluded that socially responsible conduct is a normal good, and the growth in consumer income causes an increased WTP for it. Another study found that household income was positively related to WTP for a normal good, i.e., migratory bird species conservation (Haefele et al., 2019). However, Flores and Carson (1997) indicated that an environmental good cannot be characterized as a luxury or normal good as its income elasticity of WTP can be greater than one, less than one, or even negative. Similarly, hunters who own land in CWD counties offered a higher payment for CWD testing because they may want to know the health of deer herds coming to their property. This finding implies that both landowners and hunters are concerned about CWD presence and strongly support a user-paid system for CWD surveillance in CWD counties.

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This study had a few limitations. It focused only on hunters who reside or hunt in CWD counties, and, therefore, hunter opinions about CWD testing may not be representative of the hunters who hunt in the remaining parts of the state where CWD currently does not exist or has not been detected yet. Thus, designing a user-paid system for CWD surveillance outside the CWD-impacted region may require caution. In addition to the laboratory fee, the wildlife agency incurs other costs, such as coordination and sample collection for CWD testing. This study was not explicit about these testing costs while discussing the user-paid CWD surveillance system.

5. Conclusions

With increasing health concerns on wildlife populations across the world, agencies responsible for wildlife conservation and game management are searching for effective ways to conduct disease surveillance. At least for the diseases in game species, securing cooperation from hunters by collecting samples for laboratory testing of disease could be a viable option in disease surveillance. In addition, whether hunters are willing to do so and how much they are willing to pay to have their harvested game tested for disease can be instrumental in designing user-paid testing programs and revising the existing program of subsidizing testing fees. By presenting a case of CWD in deer hunting in Tennessee, this study showed that hunters may be willing to participate in a user-paid system for disease surveillance and willing to pay a significant cost. However, wildlife agencies may still need to continue subsidizing the testing programs because charging $18 per deer to hunters even does not cover all costs associated with CWD testing.

Currently, many wildlife agencies are implementing weighted surveillance because of reduced funding. The strengths of user-paid CWD surveillance include a decrease in the disease testing cost burden to wildlife agencies as well as ensuring the active participation of hunters in CWD monitoring. A user-paid system would also help continue disease monitoring when there are limited government resources and the disease prevalence rate increases in affected areas. Hunter's contributions can also be used to expand disease surveillance and assist in the early detection of disease spread to new locations.

In addition, hunter WTP for testing their game was related to hunting characteristics and other psychosocial factors, including risk perception, and trust and confidence in the wildlife agency. Our findings regarding higher WTP among hunters who hunt in infected counties suggest a possibility for price discrimination or establishing different cost-share provisions for infected versus noninfected areas. Further, building trust between the wildlife agency and the hunter community, and establishing the hunter's confidence in the agency's plans to effectively control the disease may be critical in not only securing their cooperation in disease management but also in getting their financial contribution in testing. Agencies currently dealing with diseases in wildlife populations or expecting a potential outbreak in the future may see the benefit in investing in relationship building and educating hunters and the general public on their actions in response to disease outbreaks and selling the public on their plans to contain the disease.

Understanding diverse opinions characterized by individual factors is important in wildlife disease monitoring because responsible social conduct (i.e., testing for disease) is not only a matter of public interest but also benefits individuals. This study provided useful insights into understanding the factors that influence hunter participation and WTP for the testing process facilitated by agencies. Future studies may be needed to better understand the financial and logistical feasibility of hunter-initiated testing programs, where hunters themselves engage in testing and reporting without needing agency support.

Data availability statement. The data were collected following the privacy and data security protocols for human subjects' research as approved by the University of Tennessee's Institutional Review Board (IRB) and is not publicly available.

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Competing interests. Authors declare none.

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