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Understanding the Externality of Wildlife Health: A Case of Chronic Wasting Disease (CWD) in Hunting Lease Values

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The spread of chronic wasting disease (CWD) has threatened the future of the hunting economy in North America. A discrete choice experiment survey of deer hunters showed a progressively higher premium for sites with lower CWD rates, revealing the tradeoff between the disease prevalence and other site attributes. While this study focuses on the case of CWD in white-tailed deer, the findings help explain how the externality from declining game health affects hunters' welfare and how it reflects in lease values.

Key words: discrete choice experiment; hunter; lease hunting; random parameter logit model; wildlife disease; welfare loss; white-tailed deer

Introduction

Game hunting has significant importance in managing wildlife populations, supporting the local and national economies, keeping rural tradition of outdoor adventure, and generating license revenue for conservation funding (Heffelfinger, Geist, and Wishart, 2013). However, the spread of infectious disease in wildlife has added management complexities in maintaining healthy game populations, which is the primary ingredient in producing quality hunting experience. Some of the wildlife diseases that are impacting game species include parasitic diseases (e.g. large lungworm), bacterial diseases (e.g., leptospirosis, bovine tuberculosis), viral diseases (e.g., hemorrhagic disease, pseudorabies), and prion diseases (e.g., chronic wasting disease) (Kurpiers et al., 2015; Xu et al., 2012). Of all, chronic wasting disease (CWD) is a prion disease with the highest spillover potential affecting cervid populations (Escobar et al., 2020). Prions spread through animal-to-animal contact or exposure to contaminated environmental fomites (Cohen et al., 1994). In addition, prions can pass vertically from mother to offspring (Nalls et al., 2013). Animal dispersal behavior and anthropogenic movements are major pathways of CWD

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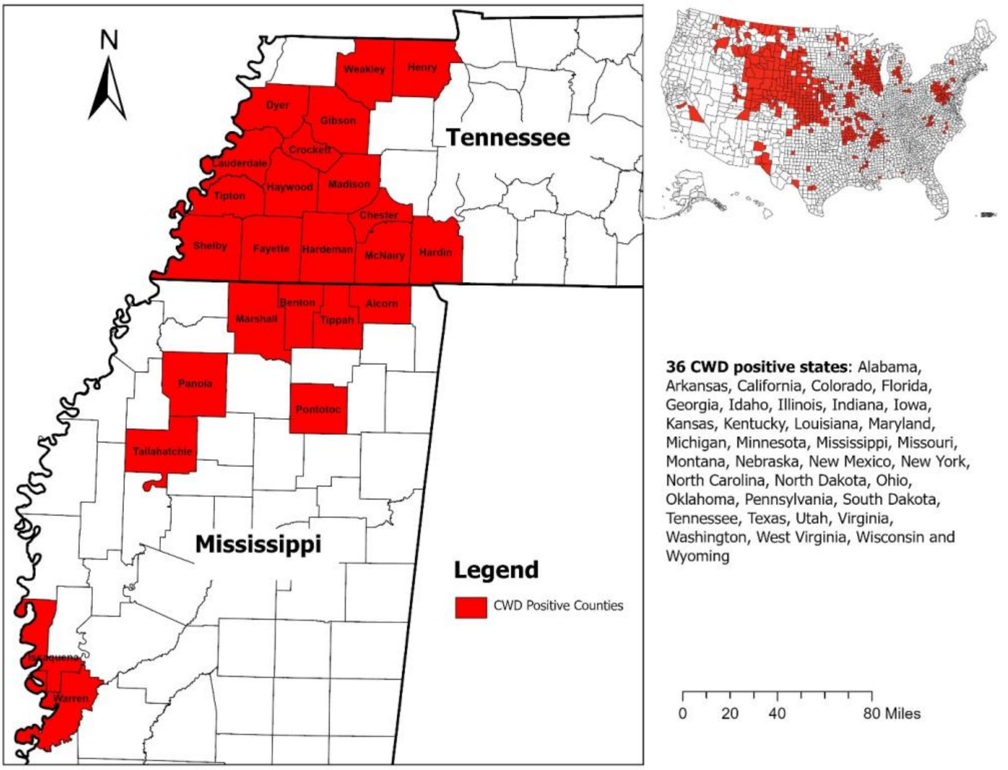

Figure 1. The Study Area Consisting of CWD Positive Counties in Western Tennessee and Northern Mississippi [Inset Map: Counties with CWD Detections Across the United States]

transmissions (Jennelle et al., 2014). Thus, the approaches that consider both ecological and biological aspects may help control the spread of CWD in cervid populations.

In the United States, CWD was first detected in 1967 in captive mule deer in Colorado (Tennessee Wildlife Resources Agency [TWRA], 2023). As of April 2025, CWD was detected in 543 counties of 36 states (Figure 1 Inset map; U.S. Centers for Disease Control and Prevention [CDC], 2025). Cervids susceptible to CWD infection included white-tailed deer (Odocoileus virginianus), mule deer (Odocoileus hemionus), elk (Cervus canadensis), and moose (Alces alces) (Edmunds et al., 2016). As the presence of CWD in cervid populations contaminates the natural ecosystems and pose high risks to human wellbeing due to its negative impact on hunting and venison contamination, it can be considered a case of "public bad". Past studies showed that hunters were willing to pay a disease testing fee, deer processing fee, and a management fee to avoid high CWD prevalence in their hunting areas (Zimmer, Boxall, and Adamowicz, 2012; Adhikari, 2022, 2023). No conclusive evidence exists to the potential occurrence of CWD transmission to people; however, experimental studies do raise the concern that CWD may present a risk to humans (Hannaoui et al., 2022; CDC, 2024). However, it is unknown how hunters value the hunting sites with various levels of CWD prevalence.

Game hunting has significant societal benefits through the generation of license revenue for conservation agencies, management of wild animal populations, and creation of jobs and income in rural economy (Poudel, Munn, and Henderson, 2016; Di Minin et al., 2021). In the United States, over 14.4 million people participated in game hunting and spent over $45.2 billion on hunting trips and equipment in 2022 (U.S. Department of the Interior et al., 2023). However, the presence of CWD in cervid populations has decreased the participation in hunting and resulted in substantial impact on hunter welfare (Bishop, 2004; Seidl and Koontz, 2004). For example, after the emergence of CWD in state's deer population in 2001, deer hunting expenditures were decreased by $55 million in 2002 and $33 million in 2003 in Wisconsin (Bishop, 2004). Moreover, deer hunters in the state lost an estimated $96 million in surplus values between 2002 and 2015 (Erickson, Reeling, and Lee, 2019). The surplus values represented the dollar values of permits for Wisconsin deer hunters in excess of permit costs. As the CWD has now spread to 36 states, the disease threatens the viability of cervid populations and the future of deer hunting as an economic and outdoor activity.

In addition to hunting expenditures, game hunting also serves as the source of funding for state wildlife agencies in the United States. Nearly 60% of the total budget of state wildlife agencies comes from sources related to hunting and fishing (Watkins, 2019). However, revenues from license sales and excise taxes have been decreasing in recent years due to CWD outbreak and decrease in the hunter population (Heffelfinger, Geist, and Wishart, 2013; Price Tack et al., 2018; Watkins, 2019). For example, demand for deer hunting permits decreased by 5.4% between 2002 and 2015, resulting in a nearly $17 million loss in permit sale revenues in Wisconsin (Erickson et al., 2019). However, the impact of CWD on hunting license sales decreases in the long-run due to a decline in CWD risk perceptions and liberal hunting regulations (e.g., increased bag limits, removal of antler restrictions) (Vaske and Miller, 2019; Chiavacci, 2022). Nonetheless, the state natural resources agencies bear increased managerial costs for CWD management activities such as disease surveillance, testing, targeted removal, education campaigns etc. In 2020 alone, state natural resources agencies from the continental United States spent $25.5 million on CWD management activities (Chiavacci, 2022). The cost of collecting and testing samples, management and education were the major expenditure items in states with known CWD presence while surveillance and awareness campaigning were the major expenditure items in states with states yet to have a confirmed CWD. On average, CWD management expenditures of agencies from CWD affected states were over eight times as much as the expenditures of agencies from other states. Thus, it is crucial to determine the economic impact of CWD presence on deer hunting because research findings can help wildlife agencies determine the level of CWD expenditures and also shows the importance of implementing CWD management activities to decrease the CWD prevalence rate.

Most of the deer hunting in the United States occurs on private lands although access to public hunting lands is relatively cheaper than private lands. In 2021, 88% of hunting took place in private lands either with or without a lease (National Deer Association, 2023). Non-lease hunting involves landowners giving access to friends and relatives for hunting whereas in lease hunting, hunters pay access fees to landowners in exchange for hunting rights (for a game season). Lease hunting can provide the quality hunting opportunities for hunters as public hunting lands are more congested and have less intense management. For example, Mingie et al. (2019) found that big game hunters valued hunting access to leased private lands twice as much than that on public lands due to controlled access, less crowding and better management. Lease hunting is also beneficial to landowners because it provides supplemental income that is also capitalized in real estate values (Hussain et al., 2013). Understanding the effect of CWD prevalence on lease hunting values helps to partially quantify negative externalities created by this disease.

Past studies indicated that hunting site choice behavior was affected by different lease attributes such as game quality, game diversity, land size, distance to residence, and lease price (Hussain, Zhang, and Armstrong, 2004; Hussain et al., 2010; Munn et al., 2011). However, it is unknown how the presence of disease in the game populations, particularly the prevalence of CWD affects hunter site choice behavior. Usually, hunter behavior is believed to be influenced more by CWD prevalence as it spreads (Vaske and Lyon, 2011; Zimmer et al., 2012). While human dimension studies of hunters have found that hunting demand in CWD-affected areas would gradually rebound over time due to the decrease in CWD risk perceptions (Haus et al., 2017; Vaske and Miller, 2019; Holland et al., 2020; Pattison-Williams et al., 2020), whether and how hunters make the tradeoff between CWD prevalence rate and other factors they consider important in selecting a lease hunting site is currently unknown. Understanding the trade-off between CWD prevalence and other hunting site attributes can help landowners make management decisions that enhance the value of their resources in the context of increased CWD-positive cases in deer populations.

Previous studies that estimated the welfare loss caused by CWD were not limited to lease hunting (Bishop, 2004; Zimmer et al., 2012; Erickson et al., 2019; Ufer et al., 2022). For example, Zimmer et al. (2012) estimated hunters' willingness to pay to avoid higher CWD prevalence using an indirect utility framework. However, results from that study may have limited inference in the United States because it was based on a limited sample size (90 respondents) and involved travel cost and site choice options of much larger geographic areas (i.e., wildlife management units) as compared to lease rates at the individual property level.

This study was conducted to estimate the impact of CWD on lease hunting and to understand how deer hunters make the tradeoff between CWD prevalence rate and other attributes of lease hunting such as travel distance involved, size of lease, and deer density. This was achieved by designing and implementing a choice experiment of lease hunting sites among the active deer hunters of a region, where CWD was recently detected. The main motivation was to help inform the stakeholders of the anticipated benefits of strategies that mitigate CWD. The novel aspects of this study include the incorporation of CWD prevalence as a hunting lease attribute in the site choice experiment model and the estimation of welfare measures based on changes in the CWD prevalence rate.

Methods

Study area

This study was conducted in Tennessee and Mississippi (Figure 1). First discovered in December 2018 in Tennessee, CWD has been detected in 16 western counties by the end of 2023. Between July 2022 to June 2023, the prevalence rate ranged from 0.13% (Chester County) to 18.40% (Fayette County) (TWRA, 2023). In Mississippi, CWD case in white-tailed deer was first detected in February 2018 and now the disease has spread to 10 counties mainly in the northern and delta region. Between 2018 and 2023, average CWD prevalence rate was 0.52% in Mississippi (Mississippi Department of Wildlife, Fisheries, and Parks, 2023).

Tennessee Wildlife Resources Agency (TWRA) and Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) are responsible for CWD management in Tennessee and Mississippi, respectively. These agencies designate a county or part of it as CWD management zone based on at least a confirmed case of CWD on white-tailed deer. Based on the samples provided by hunters, game processors, taxidermists and landowners, as well as that collected from road-kills, state agencies continuously monitor the presence of CWD in the CWD management zone and its neighboring counties. State agencies provide the CWD testing results with sample providers and publicize the prevalence rate among the public through awareness events, public hearings, and agency's web portal. Once the CWD is discovered in a new location, state agencies respond with many CWD focused interventions such as awareness campaign, harvest incentive programs (to reduce herd size), carcass transportation restrictions and feeding/mineral ban.

State agencies report the prevalence rate at county level, which is number of CWD positive cases divided by number of tested samples. Agencies focus the CWD surveillance effort more on CWD positive counties and its neighboring counties, however a lot of this depends on the budget and hunter's willingness to provide samples. Also, there may be difference between how agency measures CWD and the way hunters perceive prevalence rates. This is because the prevalence rate at the site level or lease property where a given hunter hunts could be much higher than the regional average based on thousands of samples from a larger geographic region. For example, some hunters in our focus groups indicated that all deer harvested in their property tested positive for CWD.

Table 1. Attributes and Levels Included in the Discrete Choice Experiment

Attributes	Levels	Description
Land size	250, 750, 1250	Size of lease hunting property in acres.
Distance from home	30, 60, 90	Distance from a current hunter residence in miles.
Deer density	30, 45, 60	Number of deer per square mile.
Opportunity to harvest at least an 8-point buck	Very low, moderate, very high	Buck quality as an opportunity to harvest at least an 8-point buck.
CWD positive rate	1, 3, 5	The number of CWD-positive deer in every 10 deer harvested
Annual access fee	7, 10, 15	Payment vehicle: annual access fee to a hunting site in dollars

Choice experiment survey design

Choice experiment (CE) is typically used to estimate the economic value associated with a characteristics or attribute of a natural resource good or service (Champ, Boyle, and Brown 2017). In this study, the choice experiment survey assessed deer hunter preferences between alternative lease hunting sites with different levels of attributes. One of the attributes of the hunting sites included a CWD positive rate. There were three levels for CWD positive rate such low (1 positive out of 10 deer tested or 10%), moderate (3 positive out of 10 deer tested or 30%) and high (5 positive out 10 deer tested or 50%). While the prevalence rate reported at the regional level are smaller, some of the hunters and landowners who participated in our focus groups indicated that all of the deer harvested in their property in the most recent deer season tested positive for CWD, suggesting that prevalence rate could be as high as 100% at the site level, which is what the participants in this choice experiment are evaluating. In addition, the CWD positive rate presented in our choice sets are for the deer harvested at that particular property and not exactly the same as the rates reported by stage agencies for regionally aggregated testing. The way we presented the levels in questionnaire (1 out of 10, 3 out of 10 and 5 of 10) is also important as matured bucks, which are targeted and harvested by substantially more hunters, and also are likely to have up to 3 times higher likelihood of getting infected with CWD than their female counterparts (Rogers et al., 2022). The other attributes of the hunting site included land size (hunting lease size), distance from home, deer density, buck quality (opportunity to harvest at least an 8-point buck) and annual access fee (Table 1).

With the inclusion of these attributes, we wanted to determine how hunters make trade-offs between the CWD prevalence rate and the other attributes of the hunting site. The selection of these attributes was informed partly by the relevant literature related to the economics of deer hunting (Hussain et al., 2010; Munn and Hussain, 2010; Munn et al., 2011; Mingie et al., 2017; Truong et al., 2018). Land size attribute included three levels (250, 750 and 1250 acres) and these levels were based on a Mississippi Study (Hussain et al. 2010) which used 500, 500 – 1000, and >1000 acres as levels for the attribute. We made slight modifications in these levels considering smaller lease hunting sites in adjacent state of Tennessee. Similar to the Mississippi study (Hussain et al., 2010), we also used 30, 60 and 90 miles as levels for “distance from home” attribute. A deer hunter survey conducted in Tennessee also showed that hunters used to travel 46.70 miles (one-way) on average from their home for deer hunting (Adhikari and Poudyal, 2022). Considering these state level reports and existing CWD presence in study area, we used 30, 60, and 90 miles as levels for “distance from home” attribute. For deer density levels, we relied on a deer population survey conducted by TWRA in western Tennessee. According to the population survey, deer densities in different sites of CWD positive counties of Tennessee ranged from 13.4 deer per square mile to 88.6 deer per square mile (Kissell and Warr, 2021). Considering this population survey report and focus group discussions, we used 30, 45 and 60 deer per square mile as levels for deer density attribute. Based on the literature review and focus group discussion with deer hunters, buck quality (opportunity to harvest at least an 8-point buck) was identified as a very important factor for hunting site selection but we did not find a quantitative level for this attribute. However, we felt that having this controlled for even with a qualitative measure is better than leaving it out altogether. This is not an atypical practice as several recent choice experiment studies have used such qualitative levels in their choice design (Bronnmann et al., 2023; Jolland and Mahieu, 2023; Nguyen et al., 2023). We relied on available market information, going rate to develop a range of price levels for the access fee attribute. A statewide deer hunter survey in Tennessee also indicated that they were paying on average \$10.43 per acre lease fee (Adhikari and Poudyal, 2022). We asked in terms of per-acre rate because per-acre rate is commonly used by lease hunters in evaluating their lease alternatives. Since hunters in lease market are familiar with 'going rate" that is expressed in per acre unit, price in per-acre basis is a common practice in lease price-related surveys (Hussain et al., 2010; Mensah and Elofsson, 2017).

The attributes and the levels were finalized based on the discussion with deer hunters and landowners during two focus groups in the study area. The focus group discussions were held in Jackson, Tennessee and Holy Springs, Mississippi during the 2021-2022 deer season. Participants of those focus group discussions were hunters and landowners from CWD positive counties. At our request, they were recruited by the University Extension Offices through their outreach events and using an online platform to voluntarily sign up for the event. There was a total of 13 hunters and landowners (no clear disaggregation as they own hunting properties and engage in deer hunting) in the focus group discussion held in Tennessee and 10 participants (5 hunters and 5 landowners) in Mississippi. Participants with deer hunting experience or leasing land to hunters were invited to the focus group discussions. To avoid any bias in selection of participants, neither the investigators nor the state wildlife agencies managing CWD were involved in recruiting of these participants and having prior experience with CWD was not a precondition to participate. The choice design was also reviewed by economists with previous experience in choice experiment research, human dimension survey specialists, and relevant wildlife agency personnel from Tennessee and Mississippi. Those reviews provided feedback and suggestions on re-defining and/or clarifying discrete choice questions and addressing consequentiality, hypothetical bias, and validity issues for choice experiment design.

We introduced several features in the questionnaire to make the questions consequential, reduce hypothetical bias and make them incentive-compatible. The consent form of the survey incorporated following statement to increase hunter belief in policy consequentiality and confidentiality (Vossler and Holladay, 2018; Parthum and Ando, 2020; Adhikari et al., 2023): "You are one of the few randomly selected sportspersons who may have hunted deer in or around the CWD-positive counties in Tennessee and Mississippi (see map above). Your responses to the attached survey will help wildlife professionals in both states make informed decisions regarding CWD management and maintaining the quality of deer hunting opportunities. Your responses will be fully confidential." The questionnaire also included a reminder for an opt out option not to force the uncertain respondents to select the Yes or No option, and a modified cheap talk script before choice questions to decrease a potential hypothetical bias. The cheap talk script was as follows: "The experience from previous survey is that people often state a higher willingness to pay than what a person actually is willing to pay for the good. It is important that you make your selection as you would if you were actually facing these choices in your actual purchasing decisions, noting that allocation of funds for hunting on these means you have less money available to spend on other items." We used trichotomous choice formats (Site A, Site B, Neither Site A nor Site B) to answer choice questions although dichotomous choice formats are more incentive-compatible than these formats (Carson and Groves, 2007). Multinomial choice format is often used in choice experiment to reflect real-world scenario. Such a multinomial choice format brings statistical efficiency and some studies indicated that values elicited are even comparable (e.g., less observed deviations than theoretical observations) with binary choice format (Collins and Vossler, 2009). In our study, all attributes of lease hunting, including the payment mechanism, (i.e. lease fee) were relatively familiar to the hunters. To minimize hypothetical bias, certainty follow-up questions and/or debriefing statements are often used after the CE questions (Johnston et al., 2017; Penn and Hu, 2023). Considering that deer hunters in our study are likely to be highly familiar with lease structures, we only used several debriefing statements including “I do not believe these options are realistic”, “The per acre lease price was too expensive”, “I am not interested in any lands with CWD” and “I already stopped hunting deer because of CWD”. These debriefing questions were used to identify protest responses in the survey. If respondents provided either ‘I do not believe these options are realistic’ or ‘I am not interested in any lands with CWD’ or both as reasons for choosing opt out option for the choice set question, their responses were considered protest responses.

We used an efficient design which is a fractional factorial design and identify the choice sets considering D-efficiency (or D-error) criterion (Kuhfeld, 2010). Compared to other available fractional factorial designs such as orthogonal arrays and random design, efficient design is better suited for smaller sample size, imposing of constraints, and estimating trade-off between different attributes. The optimal orthogonal design was specified using SAS macros (Kuhfeld, 2010). In the full factorial design, six factors with 3 levels each can be combined in 36 ways to form 729 possible combinations. We selected 18 unique choice sets from the full factorial design without violating orthogonality and balance (D-Error = 0.17). To reduce respondent fatigue or nonattendance, these 18 choice sets were divided into three blocks of six choice sets and each respondent was randomly assigned to one of the three blocks. An example of choice set is presented in Figure 2.

30. If Site A and Site B (described below) were the only options available to you, what would be your preferred choice? (Please indicate your choice at the bottom of the table below).

Site Attributes	**Site A**	**Site B**	**Neither Site A nor Site B**
Land size	250 acres	1250 acres	
Distance from home	30 miles	90 miles	
Deer density	30 deer/square mile	45 deer/square mile	
Opportunity to harvest at least an 8-point buck	Very high	Very low	
CWD positive rate	1 out of 10 deer	3 out of 10 deer	
Annual access fee	$10/acre	$7/acre	
Your choice (please check one box)	☐	☐	☐

Figure 2. An Example of a Choice Set

We imposed two restrictions before obtaining the final choice set designs. The first restriction was to make sure that all 18 choice sets did not have an alternative that was strictly dominated by another alternative on the same choice set. The second restriction was an inclusion of opt out alternative in each choice set. Thus, each of the choice sets had three alternatives, where first and second alternatives were unlabeled such as ‘Site A’ and ‘Site B’, and third alternative ‘Neither Site A nor Site B’ was forced to be a constant while determining final designs in SAS macros.

Hunter survey

A mixed-mode survey of 9,814 hunters in CWD-affected counties of Tennessee and Mississippi was conducted in the fall of 2022. A stratified random sample was adopted to ensure hunter representation from Tennessee and Mississippi. For Tennessee, the sampling frame included a database of hunters who reported harvesting at least one deer during the 2018-19, 2019-20 and 2020-21 hunting seasons in CWD-positive and high-risk counties. The high-risk counties are neighboring counties located 10 miles away from the location of confirmed CWD cases. We excluded hunters whose age was less than 18 years at the time of survey because of human subjects research restriction. We also removed hunters who had informed our institution of opting out of all future hunter surveys. A total of 5,000 hunters were selected randomly out of 28,435 hunters who met the above criteria. This subsample included hunters from 21 counties of which 15 were CWD-positive counties (Chester, Crockett, Dyer, Fayette, Gibson, Hardeman, Hardin, Haywood, Henry, Lauderdale, McNairy, Madison, Shelby, Tipton, and Weakley) and 6 counties were CWD high-risk counties (Benton, Carroll, Decatur, Henderson, Lake, and Obion, Figure 1). An effective subsample from Tennessee was 4,986 hunters after removing few randomly selected hunters who did not have complete address information. In Mississippi, a contact list of 5,000 randomly selected hunters was obtained from nine CWD positive counties (Alcorn, Benton, Issaquena, Marshall, Panola, Pontotoc, Tallahatchie, Tippah, and Warren (Figure 1). However, the effective list became 4,828 after removing hunters younger than 18 years of age. As reporting a harvest is not mandatory in Mississippi, a random sample came from the statewide database of deer hunting license holders who had a residence in CWD-affected counties. We assumed the difference in sampling frame between the two states had a minimal effect, if any because our study was conducted at regional level (group of counties) and hunters typically hunt in their own county or adjacent county. State wildlife agencies in respective states maintain the database of hunting license holders and that implies that the hunter population has not changed drastically over the years.

The survey administration followed a modified tailored design method (Dillman et al., 2014). Hunters with email addresses on file were first contacted by sending a personalized email message with a link to the survey in Qualtrics. Those who did not respond to the initial invitation received up to three follow-up emails tentatively a week apart. After the email survey phase, the mail survey was administered to those who did not have email addresses on file or did not respond to our email invitations. We made four contacts during the mail survey phase including 1– an initial pre-notification postcard, 2 – a personalized initial cover letter along with a questionnaire, 3 – a thank you/reminder postcard, and 4 – the final personalized follow-up cover letter with a questionnaire. Each survey questionnaire mailing included with a pre-paid business reply envelope. Survey instrument and protocols adopted were reviewed and approved by the UTK Institutional Review Board (IRB) (Approval# UTK IRB-22-06858-XP).

The survey questionnaire had four sections (see SI A). The first section included questions related to deer hunting experience such as type of land hunted, characteristics of lease hunting site and CWD presence, and motivation of deer hunting. The second section included questions related to hunting trip expenditures and concerns regarding CWD issues. The third section included questions related to the discrete choice experiment used in this paper, while the final section included questions related to sociodemographic characteristics. This study used the questions mainly from third and fourth sections.

Econometric modeling

Individuals derive utility from the characteristics of goods rather than directly from the goods itself, as implied in the Lancaster's theory of consumer demand (Lancaster, 1966). Random utility theory provides theoretical foundation for discrete-choice models of demand. According to the random utility theory, a rational decision maker compares multiple alternatives in a choice set and chooses the one that provides maximum utility (McFadden, 1974). Specifically, the utility U_{njt} of an individual n from an alternative j in a choice set t is described by price (p) and non-price attributes (x), which are observable characteristics, and a random component ε_{njt} which is unobservable to the researcher. The utility function associated with accessing a site for hunting, for example, can be written as (Train and Weeks, 2005):

(1) $$U_{njt} = -\lambda_n p_{njt} + c_n' x_{njt} + \varepsilon_{njt}$$

where p_{njt} is represented by an annual access fee and x_{njt} is vector of non-price attributes including an alternate specific constant (ASC) that is equal to 1 for the opt out alternative for each choice set, and 0 otherwise. The non-price attributes include land size, distance from home, deer density, opportunity to harvest at least an 8-point buck and CWD prevalence rate (Table 1). The ε_{njt} is independently and identically distributed (iid) type-one extreme value, with constant variance $\pi^2/6$. The equation (1) is called preference-space model where utility coefficients are allowed to be heterogeneous across individuals such that these coefficients have mean and variance (standard deviation). We used log-normal distribution for price coefficient and normal distribution for non-price coefficients. We can derive willingness to pay (WTP) estimates directly using following utility specification in WTP-space:

$$U_{njt} = -\lambda_n(p_{njt} + wtp_n' x_{njt}) + \varepsilon_{njt} \tag{2}$$

where $wtp_n = c_n/\lambda_n$, represents the WTP for an attribute and is scale-free. Here, the WTP for an attribute is presented as the ratio of the marginal utility of the attribute to the marginal utility of price (Greene, 2018). We specified normal distribution for *wtp* coefficients and log-normal distribution for price coefficient.

We can derive the WTP estimates from the preference-space model with correlated or uncorrelated coefficients. However, Mariel and Meyerhoff (2018) argued that the model with correlated random parameters performs better than the model with uncorrelated random parameters. Train and Weeks (2005) compared the models in preference-space and WTP-space and found that the preference-space model had better model fit. However, the WTP estimates derived from the preference-space model have the greater variation compared to the estimates obtained from WTP-space model (Train and Weeks, 2005). Therefore, we estimated fully correlated WTP-space model. Unlike Train and Weeks (2005), the WTP-space model had better model fit than preference-space model in our study.

We estimated equations (1) and (2) using the maximum simulated likelihood of the random parameter logit (RPL) model (mixed logit model), available in the Apollo package in R to estimate these RPL models (Bunch et al., 1993; Hess and Palma, 2019). MLHS (Modified Latin Hypercube Sampling) draws were used in the maximum likelihood simulation, 2,500 draws for the preference-space model and 2,500 draws for the WTP-space model. There were no interaction terms in the models as the choice design considered only the main effects. In addition, we included ASC in the models to represent the opt out alternative of the choice set.

We estimated several RPL models to analyze the effects of attribute types (categorical versus continuous) and protest responses on hunter preferences. We estimated RPL models (preference- and WTP-space models) treating all attributes except annual access fee as categorical variables. We used dummy coding to parameterize categorical choice attributes because coefficient estimates are more straightforward to interpret and less prone to errors than the estimates from effect coding (Mariel et al., 2021; Hu et al., 2022). We also estimated RPL models (preference- and WTP-space models) treating all attributes except 'opportunity to harvest at least an 8-point buck' as continuous variables. Similarly, we estimated RPL models (preference- and WTP-space models) with and without removing protest responses.

Calculating welfare effects

We computed the welfare effects of an increase in CWD positive rate both at individual hunter and study area (CWD positive counties) levels. For the model in preference space, welfare calculation is a two-step process. First, we estimate the model parameters and second, we calculate welfare measures using the simulation from estimated parameters (Scarpa and Thiene, 2009). However, we also estimated the model in the WTP-space and its estimated parameters can be directly interpreted as WTP measures. In other words, the point estimates of the WTP-space model are interpreted as a mean of marginal WTP across respondents for each attribute (Gonzalez-Santader et al., 2022). As we are interested in welfare estimates of an attribute (i.e. CWD positive rate), we used the following equation to derive individual-specific estimates, known as conditional parameter estimates (Vollmer et al., 2016):

$$\hat{\beta}_i = \frac{\sum_{r=1}^{R}[L(Y_i|\beta_r)\beta_r]}{\sum_{r=1}^{R} L(Y_i|\beta_r)} \tag{3}$$

where β_r with r = 1, ……, R are multi-dimensional draws with equal weight from the distribution $f\ (\beta|\Omega)$ at estimated values of Ω (variance), and $L(Y_i|\beta_r)$ is the probability of observing the sequence of choices *Y* by respondent *i*. Thus, $\hat{\beta}_i$ gives the expected value for marginal utility coefficients, conditional on observed choices for respondent *i*.

We obtained mean of marginal WTP for each state from conditional individual-specific means estimated using equation (3). These state level mean of marginal WTPs were used to calculate aggregate effect of CWD prevalence. In this study, the conditional mean for CWD positive rate represents annual welfare effects in terms of dollars per acre. So, the annual welfare effect at the individual hunter level was obtained by multiplication of conditional mean value and the average lease size that a hunter contracted for. Similarly, aggregate welfare effects at the state level were obtained by multiplication of annual welfare effects for each hunter with a total number of active deer hunters at CWD-affected counties of each state.

Result

Summary statistics

Out of 9,814 questionnaires sent, a total of 2,266 (1,153 via email and 1,113 via mail) responses were received, resulting a response rate of 23.09%. The respondents of email and mail survey modes did not differ statistically ($p > 0.05$) in terms of age and hunting experience but were different in terms of household size, education, and household income ($p < 0.05$). Previous studies also indicated significant differences in demographic variables between online and mail survey modes (Graefe et al., 2011; Carrozzino-Lyon, McMullin, and Parkhurst, 2013; Adhikari and Poudyal, 2023). The difference in mode of participation was not expected to have significant impact on this study because both modes were utilized to give respondents an opportunity to respond rather than recruit them exclusively using only one method. We interacted the survey mode variable (1= mail, 0 = email) with CWD prevalence rate attribute in a RPL model and found that it did not have significant effect ($p = 0.93$).

Hunters reported that the lease size was 891 acres on average and 29 miles away from their residence (Table 2). Approximately, 14% rural hunters reported that CWD had been detected in deer harvested from leased land. On average, hunters paid $6.48 per acre to access to leased land for deer hunting (Table 2). The hunters, on average, were 52 years old and had average hunting experience of 19 years in the study area (Table 2). The majority of the hunters (i.e., 68.85%) completed some college or obtained a higher educational degree but the most frequent category was high school diploma (27%). The hunter's average household size was 3 and their annual household income was $94,729. Approximately, 18% of hunters had household income greater than $150,000. Majority of hunters were from urban areas (56%) than rural areas (Table 2).

Selected socio-economic characteristics of the sample were comparable to past hunter surveys in Tennessee and Mississippi. According to statewide deer hunter survey in Tennessee (n = 2,602), the average age of deer hunters was 49 years and most frequent category of education level was completion of a high school diploma (30%, Adhikari and Poudyal, 2022). Similarly, average household size of the hunter was 3 and 16% of hunters reported that they had greater than $150,000. According to deer hunter survey in Mississippi (n = 726), average age of deer hunters was 44 years and most frequent category of education level was completion of a high school diploma (45%, Hussain et al., 2010). Similarly, Mississippian deer hunters had an average hunting experience of 30 years. Average household income of deer hunters was $73,000 and 8% of deer hunters had household income greater than $150,000 (Hussain et al., 2010). Average values of key socioeconomic characteristics of deer hunters from Mississippi were relatively lower for

Table 2. Summary Statistics of the Variables Related to Lease and Hunter Characteristics

Variable	Entire sample	
	Frequency	Mean/ proportion
Lease hunting attributes		
Lease size (acres)	383	891.36 (1561.79)
Distance from home (one-way, mile)	362	29.24 (28.51)
Has CWD been detected in deer harvested from leased land? (yes proportion)	48	14.41
Lease price ($/ac)	242	6.48 (8.60)
Deer hunter characteristics		
Age (years)	1765	51.52 (14.31)
Household size	1738	2.86 (1.45)
Hunting experience (years)	1691	19.14 (17.08)
Highest level of education completed	1747	
Some high school	74	4.24
High school diploma/GED test	470	26.90
Some college	437	25.01
Associate's degree	198	11.33
Bachelor's degree	363	20.78
Post-graduate degree	205	11.73
Annual household income	1660	
Below $25,000	83	5.00
$25,001 - $50,000	226	13.61
$50,001 - $75,000	327	19.70
$75,001 - $100,000	301	18.13
$100,001 - $125,000	242	14.58
$125,001 - $150,000	177	10.66
Above $150,000	304	18.31
Urban hunters	1267	55.91

*Standard deviation in parentheses

average age and household income and higher for hunting experience and education level but this hunter survey from Mississippi was more than a decade old compared to our hunter survey.

Model results

We estimated preference-space models with both uncorrelated and correlated parameters and found that the models with correlated parameters had better model fit in terms of log-likelihood values. Then, we estimated WTP-space models with correlated parameters (Table 3 and 4) which had better model fit than preference-space models with correlated parameters (see SI B). Results from the models with correlated parameters is selected also because these are unconstrained models and remove any bias in parameter estimation due to inherent correlation among attributes or other variables included in the model. We also estimated four different WTP-space models with correlated parameters considering attribute types (categorical vs continuous) and protest responses. For analyzing effects of site attributes on hunting preferences and computing welfare changes, we used the WTP-space models with random parameters (Table 3, Model I) which was estimated by treating the attributes (except annual access fee) as categorical variables and

Table 3. Estimated Result of the WTP-Space Models (With Correlated Parameters) Treating All Attributes (Except Annual Access Fee) as Categorical Variables

Variable	Model I (Protest responses excluded)		Model II (Protest responses included)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
ASC (opt out)	-7.417***	10.162***	-4.948***	7.904***
	(0.545)	(0.737)	(0.338)	(0.418)
Annual access fee	-2.009***	0.698***	-2.307***	0.616***
	(0.090)	(0.040)	(0.078)	(0.041)
Land size (Base: 250 acres)				
1250 acres	8.517***	0.560	8.196***	10.948***
	(0.795)	(0.457)	(0.871)	(0.818)
750 acres	6.511***	1.196***	7.171***	1.490***
	(0.712)	(0.414)	(0.969)	(0.482)
Distance from home (Base: 30 miles)				
90 miles	18.791***	8.640	21.707***	13.019***
	(1.252)	(0.524)	(1.379)	(0.702)
60 miles	7.763***	0.847**	7.866***	3.539***
	(0.730)	(0.363)	(0.848)	(0.447)
Deer density (Base: 30 deer/sq. mile)				
60 deer/sq. mile	-2.882***	4.396***	-0.176	6.662***
	(0.718)	(0.436)	(0.896)	(0.616)
45 deer/sq. mile	1.376**	2.650***	3.064***	0.283
	(0.675)	(0.300)	(0.786)	(0.397)
Opportunity to harvest at least an 8-point buck (Base: very low)				
Very high	-13.979***	6.520***	-18.996***	6.495***
	(1.111)	(0.506)	(1.415)	(0.543)
Moderate	-9.040***	1.236***	-10.520***	3.427***
	(0.827)	(0.292)	(1.011)	(0.442)
CWD positive rate (Base: 1 out of 10 deer)				
5 out of 10 deer	22.977***	11.302***	27.457***	4.675***
	(1.512)	(0.798)	(1.734)	(0.450)
3 out of 10 deer	9.151***	1.510***	11.551***	2.528***
	(0.966)	(0.380)	(1.065)	(0.433)
Sample size	1517		1858	
Number of observations	8752		10770	
Number of draws (MLHS)	2500		2500	
Number of parameters	90		90	
Log-likelihood	-6128.240		-7720.050	
AIC	12436.480		15620.100	
BIC	13073.420		16275.710	

Standard errors are in parenthesis, ***p<0.01, **p<0.05, *p<0.10

Note: Preference space models and robust correlation matrices of random parameters related to WTP-space models are reported in SI B.

Table 4. Estimated Result of the WTP-Space models (With Correlated Parameters) Treating All Attributes (Except Opportunity to Harvest at Least an 8-Point Buck) as Continuous Variables

Variable	Model III (Protest responses excluded)		Model IV (Protest responses included)	
	Mean	Std. Dev.	Mean	Std. Dev.
ASC (opt out)	-6.111***	8.298***	-6.543***	8.023***
	(0.433)	(0.457)	(0.406)	(0.442)
Annual access fee	-2.286***	0.150***	-2.353***	0.117**
	(0.104)	(0.039)	(0.100)	(0.049)
Land size	0.006***	0.007***	0.003***	0.014***
	(0.001)	(0.001)	(0.001)	(0.002)
Distance from home	0.227***	0.062**	0.273***	0.242***
	(0.027)	(0.024)	(0.030)	(0.026)
Deer density	-0.052	0.416***	-0.217***	0.013
	(0.034)	(0.039)	(0.039)	(0.028)
Opportunity to harvest at least an 8-point buck (Base: very low)				
Very high	-19.761***	17.530***	-17.491***	2.490***
	(2.169)	(1.704)	(1.989)	(2.243)
Moderate	-12.087***	1.573	-10.839***	3.471***
	(1.470)	(1.177)	(1.351)	(1.290)
CWD positive rate	0.505***	0.199***	0.627***	0.350***
	(0.055)	(0.042)	(0.065)	(0.061)
Sample size	1517		1858	
Number of observations	8752		10770	
Number of draws (MLHS)	2500		2500	
Number of parameters	44		44	
Log-likelihood	-6177.760		-7807.330	
AIC	12443.530		15702.670	
BIC	12754.920		16023.190	

Standard errors are in parenthesis, ***p<0.01, **p<0.05, *p<0.10

Note: Preference space models and robust correlation matrices of random parameters related to WTP-space models are reported in SI B.

excluding protest responses because it had better model fit in terms of log-likelihood and information criterion (AIC and BIC) values compared to other WTP-space models with correlated parameters (Table 3 and 4).

Most of the parameters related to WTP space model were statistically significant at the 1% significance level (Table 3). The parameter of opt out option was negative and statistically significant, suggesting that hunters would be willing to engage in some sort of lease hunting. Most of the standard deviations were statistically significant, indicating a strong preference heterogeneity related to hunting site attributes among hunters (Table 3).

Increase in buck quality had same value to hunters as reduction in lease price. Therefore, hunters would be willing to pay nearly $14 per acre per year and $9 per acre per year more for a very high and moderate opportunity to harvest at least an 8-point buck respectively than a very low opportunity to harvest such a buck on the leased land (Table 3, Model I). However, compared to low deer density site (30 deer per square mile), hunters would be willing to pay $1 per acre per year less for the site with medium deer density (45 deer per square mile) and nearly $3 more for the site with high deer density (60 deer per square mile). As standard deviations of deer density variables were larger than mean values, the effect of deer density on hunting site preferences remained inconclusive (Table 3, Model I).

Increase in the size of leased land, hunting site distance from home, or the CWD presence on hunting site had same negative impact on hunter welfare as an increase in annual access fee. Hunters placed an average of nearly $9 per acre per year lower value for larger lease sizes such as 1,250 acres and $7 per acre per year lower value for a lease size of 750 acres compared to a 250 acres-leased land. Similarly, hunters were willing to pay $19 and $8 per acre per year less, respectively for a site located 90 miles and 60 miles away from their residence as compared to one located in 30 miles. Compared to low CWD prevalence level, hunters were willing to pay $9 per acre per year less for a hunting on the site with moderate CWD prevalence level and $23 per acre per year less for a hunting with high CWD prevalence level. In terms of marginal effect, the CWD prevalence level had the largest negative impact on hunter welfare.

Results from the WTP-space models with correlated parameters treating all attributes (except opportunity to harvest at least an 8-point buck) as continuous variables were separately presented in Table 4. Most of the results (Table 4) were consistent with the models estimated after treating all attributes (except annual access fee) as categorical variables (Table 3), however hunter's preference of sites with higher buck quality was slightly inflated in Model III compared to Model I. Interestingly, Model III showed that deer density did not have any significant effect on hunting site preferences (Table 4). The Model III result related to deer density was more definitive than the result from Model I which showed deer density had mixed effect on hunting site preferences.

Aggregate effects

The conditional mean welfare loss associated with moderate CWD positive rate was $11 per acre for Tennessee hunters and $12 per acre for Mississippi hunters. Similarly, the conditional mean welfare loss related to high CWD positive rate was $27 per acre for Tennessee hunters and $28 per acre for Mississippi hunters. Hunters reported that the average size of lease was 651 acres in Tennessee and 1203 acres in Mississippi. On average, each lease land had 6 hunters in Tennessee and 12 hunters in Mississippi. Therefore, lease size per capita hunter was 108 acres in Tennessee and 100 acres of leased land in Mississippi. Thus, annually each lease hunter in Tennessee could have experienced a welfare loss of $951 ($8.77 * 108.49) and $2,403 ($22.15 * 108.49) if the CWD positive rate increased from a low level to moderate and high levels, respectively (Figure 3). Similarly, each lease hunter of Mississippi could have experienced a welfare loss of $942 ($9.39 * 100.27) and $2,319 ($23.13 * 100.27) per year if CWD positive rate increased from low level to moderate and high levels, respectively (Figure 3).

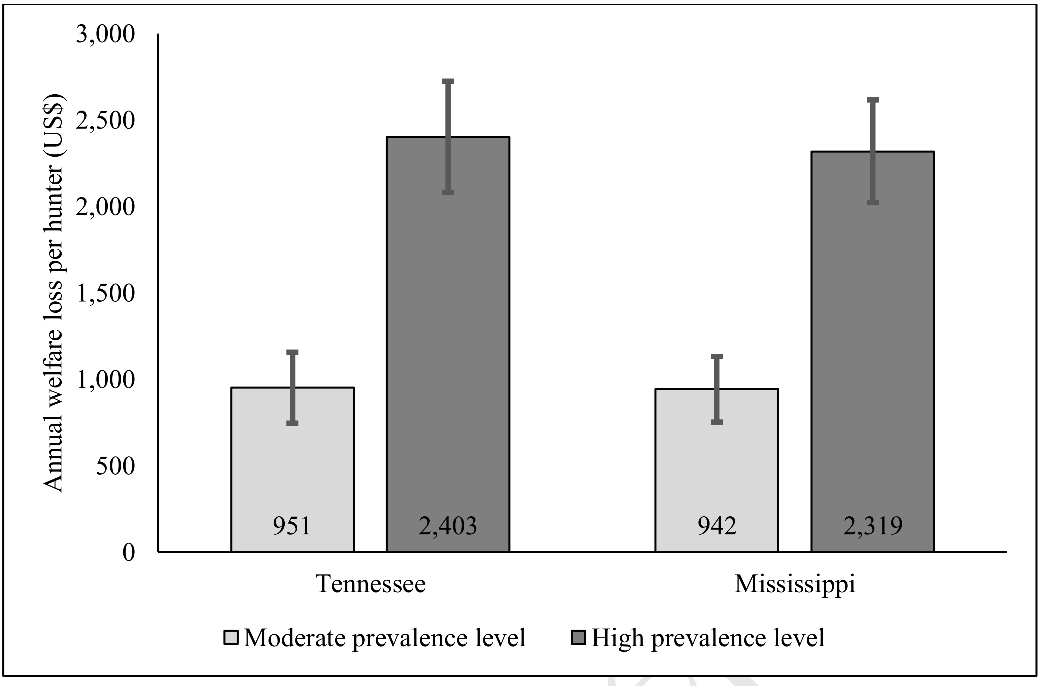

Figure 3. Mean and 95% Confidence Interval for Annual Welfare Loss Per Hunter at CWD-Positive Counties in Tennessee and Mississippi

In addition to the average annual welfare loss of each hunter, Table 4 also summarized an aggregate negative economic effect of the CWD prevalence rate at CWD-positive counties of Tennessee and Mississippi. There were 22,946 total active hunters in 15 CWD-positive counties of Tennessee and 17,614 hunting license holders in nine CWD-positive counties of Mississippi. Based on our survey, 79.83% of total license holders were active deer hunters in those Mississippi counties. Similarly, based on the survey, there were 21.97% lease hunters in Tennessee and 24.63% in Mississippi.

The hunter survey also found that 2.5% of hunters from Tennessee and 2.9% of hunters from Mississippi were not concerned at all with CWD issues. Therefore, we did not include welfare loss for these hunters while calculating aggregate effect of CWD. In terms of the total aggregated effect in both states, an increase in CWD prevalence rate from low to moderate level would amount to a total of $8 million and from low to high level $20 million in annual welfare loss to lease hunters at CWD-positive counties of study area (Table 5, Panel A). In Tennessee, the aggregate negative effect was $5 million for moderate level and $12 million for high level. Similarly, Mississippi lease hunters would suffer an estimated nearly $3 million and $8 million in annual welfare loss if CWD prevalence rate increase from low to moderate and high level, respectively.

The aggregate negative effect of CWD prevalence on deer hunting would be more than four times higher if the welfare loss of all deer hunters from study area accounted for, rather than just the welfare loss of lease hunters. All deer hunters including lease and non-lease hunters, from CWD-positive counties would lose nearly $34 million and $85 million per year in welfare values if the prevalence rate of CWD increased from a low to moderate and high level respectively (Table 5, Panel B). This estimation of aggregation across all hunters, is based on the assumption that there is no significant difference in welfare loss attributable to the CWD between leased and non-leased lands. This may not be too strong assumption considering that similar to lease hunting sites, hunters are required to pay an access fee (in addition to hunting permit) to hunt on public lands.

Table 5. Estimated Aggregate Welfare Loss of CWD Prevalence Level on Deer Hunting at CWD-Positive Counties.

Level of effects	CWD Positive rate	
	Moderate level (3 out of 10 deer tested)	**High level (5 out of 10 deer tested)**
Panel A: For hunters hunting on lease lands (in millions)		
Total amount	$7.84	$19.61
Tennessee	$4.68	$11.81
Mississippi	$3.17	$7.80
Panel B: For hunters hunting on all lands (in millions)		
Total amount	$34.14	$85.43
Tennessee	$21.29	$53.76
Mississippi	$12.86	$31.67

Both Mississippi and Tennessee require buying wildlife management area permit to hunt on public lands. Regarding the aggregate effect at state level (i.e., CWD-positive counties), a rise in CWD prevalence from low to moderate would result in an annual aggregate impact of $21 million in Tennessee and $13 million in Mississippi. The lower economic effect of CWD prevalence in Mississippi were largely attributable to a smaller per capita hunting site (TN = 108.49 acre; MS = 100.27 acres) and number of active deer hunters in CWD-positive counties than in Tennessee (TN = 22,372 hunters, MS = 13,653 hunters).

Discussion

This study addressed a specific limitation of past research on hunter preferences when hunting sites had the problem of negative externalities. First, factors that affect hunting on private lands were identified based on focus group discussions with local hunters of study area. Among many attributes, CWD prevalence rate was one of the important considerations while selecting a site for deer hunting on private lands. Second, reduction in welfare values were estimated within incentive compatible and widely used method, i.e. discrete choice experiment. During data analysis, two important methodological good practices including the log-normal distribution of price parameter and fully correlated parameters were incorporated. The Log-normal distribution of price parameter ensures a finite or well-defined moments (Carson and Czajkowski, 2019). The advantage of allowing fully correlated parameters during model estimation include no constraints imposed on the model and help capture scale heterogeneity and other sources of correlation, for example, behavioral phenomena (Mariel and Meyerhoff, 2018; Mariel and Artabe, 2020). Despite the flexible model, the estimation of RPL model with fully correlated parameters has significant computation burdens due to large number of parameters.

Our study found that hunting site preferences were positively associated with an increased buck quality and negatively associated with an increased distance from home to lease site and lease price. These findings corroborated the conclusions of previous studies (Hussain et al., 2004, 2010). Regarding the impact of lease size on willingness to pay values, our study found that hunters were willing to pay less for large hunting leases, suggesting that lease size of 1250 acres and 750 acres were not preferred compared to a 250-acres hunting site. Hunters might not prefer the large lease sizes in our study probably due to the potential large annual expenses they had to allocate for deer hunting. Hussain et al. (2010) found that Mississippi hunters preferred a lease size with 500 to 1,000 acres over 500 acres tracts. Similarly, Mingie et al. (2017) found that big game hunters in Georgia, U.S. preferred larger lease acreage for hunting, but the range of size used in that study was relatively smaller (i.e., 200 acres to 400 acres). Our research findings imply that lease size had a nonlinear effect on hunting lease values. Hunting lease values may increase with lease size, but beyond a certain point, larger leases can lead to diminishing marginal returns due to higher lease costs. Thus, landowners can maximize the financial return from deer hunting by selling smaller hunting leases (<750 acres).

The negative association of CWD positive rate on WTP values suggested that lease hunters preferred sites with lower CWD positive rates. Our study showed that when compared to the site with a low CWD prevalence rate, hunters were willing to pay $9 per acre per year less for a site with moderate and $23 per acre per year less for a lease with high CWD prevalence rate. Even though there is no preceding literature on CWD valuation to directly compare with our findings, Ufer et al. (2022) found that hunters were willing to pay $11.45 to $21.93 for a CWD stamp to help fund programs combating CWD. This indicated the value hunters place on reducing the negative externality of CWD. However, their estimate of WTP was for a permit or license to hunt rather than access to a hunting site, as evaluated in our study and our approach was more relevant for hunting on private lands. The other study conducted in Canada by Zimmer et al. (2012) found that hunters were willing to pay $20.35 per trip to keep the CWD prevalence rate at the current level. The difference in welfare estimates may be, in part, due to the fact that Zimmer et al. (2012) utilized travel costs to a site, whereas our study controlled for those costs in the choice set and included an access fee to specifically measure hunters' WTP values. Our findings imply that hunters are bearing substantial welfare loss due to increased CWD prevalence in the hunting sites.

Previous studies indicated that hunters were willing to pay more for sites with higher deer density and quality (Hussain, Zhang, and Armstrong, 2004; Knoche and Lupi, 2007). However, our study showed that deer density had mixed effect on site preferences with large variations in hunter responses. Hunters were willing to pay more for a site with higher deer quality. Improving buck quality is not appropriate strategies in CWD-affected areas to compensate for welfare loss caused by CWD prevalence rate as it may increase the deer density at hunting sites. O'Hara Ruiz et al. (2013) found that herd reduction contributed to reducing the CWD prevalence rate in Illinois and Wisconsin. In addition, the quality of deer hunting experiences can be enhanced by having game diversity in lease package (Hussain et al., 2010; Munn et al., 2011). Instead of focusing only on deer, lease contracts can incorporate multiple game species (e.g., turkey, waterfowl etc.) depending on the location. Thus, enhancing game diversity and buck quality without increasing deer density and the reduction of diseased herd can compensate for the hunter surplus decreased by higher CWD prevalence.

Landowners could also implement several best management practices to enhance the quality of hunting leases, such as habitat improvement, avoiding feeding, not using attractants and minerals licks that congregate deer in certain places, encouraging hunters to conduct CWD testing for harvested deer, and ensuring the proper disposal of carcass. Past studies indicated that landowners had limited support for reduction of deer density using monetary incentives (Petchenik, 2006; Landon et al. 2023). Thus, if wildlife agencies focus on these preventive practices, both hunters and landowners will benefit economically and derive greater utility from their leases.

In 2011, the market value (total output) of big game hunting was $426 million in Tennessee and $631 million in Mississippi (Poudel, Munn, Henderson, 2016). Total economic values of big game hunting, where deer hunting constituted nearly 80%, would be much larger in these states as total economic values constitute both market and nonmarket values. Our findings indicated that the annual economic impact of CWD can reach up to $54 million in Tennessee and $32 million Mississippi depending on CWD prevalence rate. These aggregate estimates of welfare loss in both Tennessee and Mississippi would be useful to state natural resources agencies and other stakeholders interested in advocating for and investing public funds for CWD prevention and management. These agencies have already started spending substantial amount of public funds on CWD management. For example, in 2020 alone, state natural resources agencies spent only $1.2 million in Tennessee and nearly half a million dollar in Mississippi for CWD-related management activities (Chiavacci, 2022). With the growing spread of CWD, there may be need for even more funding, which will require economic justification. Estimated welfare loss due to CWD, can be taken as a proxy for anticipated gain in welfare or prevention of welfare loss of policies mitigating CWD. Although these state level expenditures only accounted for direct costs, there are opportunities to increase the investment for CWD prevention and management, particularly for CWD surveillance and diseased herd reduction in both states. CWD expenditures can be higher in the initial years, but the enduring economic benefits from disease containment exceed the costs in the long run. Such investments for CWD management including herd reduction not only help decrease the CWD prevalence rate but also increase revenues from hunting license sales.

A few caveats of this study should be noted. First, the choice sets presented assumed that the hunters believed non-zero probably of CWD prevalence and did not include a 0% prevalence rate, which is possible in some properties. While the variation in levels allowed us to evaluate how hunters tradeoff between CWD and other important attributes, potential effect of not including this level may not be ruled out. Second, while we used a qualitative measure of an attribute (i.e., buck quality) following a common practice in previous studies (Bronnmann et al., 2023; Joalland and Mahieu et al., 2023, Nguyen et al., 2023), a reviewer pointed out a potential effect of using such qualitative levels in choice sets. Even though we are not able to quality its impact, respondents may have different perceptions on such qualitative levels resulting in biased parameter estimates.

Conclusions

Most literature on the management of CWD originates from a population ecology and disease epidemiology perspective. Those studies suggest implementing active surveillance, herd reduction, and a ban on feeding and carcass transportation can help reduce CWD spread and prevalence but perspective on economic impact of CWD is scarcer. With the case of chronic wasting disease in deer population, this study characterized the welfare effect of wildlife health on hunter community. Specifically, an increase in the CWD prevalence rate in deer population from low to moderate will result in substantial amount of loss in hunter welfare. As nothing was known regarding whether and how CWD impacts the value of a hunting site, and how hunters make tradeoffs between CWD prevalence and other site attributes, findings from our study are directly relevant to private landowners who are interested in understanding the anticipated loss in lease revenue and identifying ways to offset that loss. Landowners could enhance the financial returns of their leases by combining different lease attributes that better meet hunter preferences. Buck quality, game diversity and appropriate lease size are some of the important attributes from a hunter perspective. In addition, findings from this study demonstrate that the health of the game population negatively impacts the hunters' site choice and the externality associated with disease prevalence is capitalized negatively in hunting lease value. Such estimates can be compared against the expected cost of containing disease while demonstrating the public value of wildlife health policies. Further research is recommended to understand the welfare of best management practices that landowners can adopt to prevent the spread of CWD and help improve deer habitat and hunting quality.

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