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Research Article

Explaining Deer Hunter Preferences for Regulatory Changes Using Choice Experiments

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ABSTRACT Achieving state wildlife agency goals for white-tailed deer (*Odocoileus virginianus*) management may conflict with hunter traditions and desires. Optimizing deer herd management given conflicting biological and social goals means that agencies will need to better understand what trade-offs can be made. In North Carolina, USA, the harvest of deer by hunters is skewed towards males <2.5 years old and all firearm hunting seasons begin prior to the rut. Both trends can have undesirable consequences for deer populations, hunters, and deer managers. To provide better information to mitigate the potential for undesirable consequences, we modeled deer hunter choice behavior using a discrete choice experiment to identify their preferences for regulatory components and policy alternatives. Discrete choice experiments explain the choice behavior of humans via preference elicitation. We obtained the data used in our analysis after contacting 171,880 resident deer hunters by email and postcard to encourage their participation in a web-based survey. We received valid responses from 25,508 resident deer hunters. Respondents identified gun season length as the most important regulatory attribute influencing their decisions about policy, followed by bag limits. Results also suggest that North Carolina's hunters may be more willing to make trade-offs when attributes least affecting their decision making, such as season opening date and blackpowder season length, are altered by decision makers to benefit the deer herd. By employing wildlife valuation methods, such as discrete choice experiments, agencies can gain deep insights into viable trade-offs between different attributes that underpin multidimensional policies, such as deer seasons, not achieved through attitudinal measures alone.

KEY WORDS choice behavior, discrete choice experiment, hunter, hunting season, North Carolina, *Odocoileus virginianus*, stated preference, white-tailed deer.

White-tailed deer (*Odocoileus virginianus*) is a primary big game animal in North America. Over 10 million people hunted deer in North America between 2010 and 2013, harvesting >6 million animals (U.S. Fish and Wildlife Service [USFWS] 2011, Adams and Ross 2015). Beginning with Rhode Island in 1646, most colonial settlements enacted hunting seasons by the mid-1700s but omitted bag limits (Hewitt 2015). Initial deer seasons were not enforced, and by the late nineteenth and early twentieth centuries, unrestricted market hunting, upgrades in firearms, and habitat alteration reduced the North American deer population to 300,000–500,000 animals nationwide (Downing 1987). In response to wildlife and fish population declines, Congress passed the Lacey Act of 1900, regulating interstate commerce of deer and other wildlife, and states became more proactive and innovative in crafting and enforcing regulations (Severginhaus and Brown 1956) and improving management techniques (Downing 1987). Deer populations subsequently rebounded and were once again abundant by the 21st century (Sumners et al. 2015).

Hunters are state wildlife management agency clients and willing partners in deer recovery and management (Decker et al. 1996). As such, their views have been valued by managers because their activities can be managed to achieve biological outcomes (Decker and Connelly 1989, Stedman et al. 2004, Adams and Hamilton 2011). Hunters often oppose policies that run counter to their personal interests (Diefenbach et al. 1997, Van Deelen et al. 2010). Accordingly, researchers have demonstrated that a state agency's ability to influence the biological parameters of deer populations through harvest management is closely associated with hunter acceptance, satisfaction, and support (Riley et al. 2002, Jacobson and Decker 2006, Andersen et al. 2014). Regulations that optimize ecological, social, and economic outcomes can be elusive for state agencies to realize because each set of management

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strategies and tactics will trigger unique social and ecological consequences that affect the hunter experience (Sunde and Asferg 2014).

Season timing, season length (Schwabe et al. 2001, Andersen et al. 2014, Sunde and Asferg 2014), and bag limits (Ringelman 1997, Schroeder et al. 2014*b*) are 3 principal management components used by state wildlife agencies to manage the hunter experience and deer populations. They are largely responsible for the proportion of antlered males within the deer population (Cornicelli and Grund 2011, Robinson et al. 2015), antler and deer size (Hewitt 2015), population densities (Miller and Graefe 2001), and numbers on the landscape (D'Angelo and Grund 2015). These parameters play an important role in hunters' perception of management effectiveness (Miller and Graefe 2001, Schroeder et al. 2018). Consequently, they are recurrent topics of study among researchers interested in hunter perceptions of and support for regulations.

State wildlife agencies and hunters will often need to make trade-offs to optimize deer herd management policies that conflict with biological and social goals (Cornicelli et al. 2011). Research examining linkages between support for hunting regulations and hunter preferences suggests that a hunting season may be viewed as a composite recreational or wildlife management good, or a good that has multiple uses. In other words, hunting seasons are demanded for a variety of biological and social reasons and can be evaluated through trade-off analysis (Robinson et al. 2017). Problematically, hunter surveys tend to involve scales or methods that permit hunters to maximize their preferences (Fieberg et al. 2010) or reaffirm what managers may suspect about hunter interests, such as more or bigger deer (Cornicelli et al. 2011). Thus, trade-offs that diminish utility maximizer tendencies for the betterment of the resource at the landscape scale are seldom revealed.

Stated preference methods (SPM), such as conjoint analysis or discrete choice experiments (DCE; Brown et al. 2017), have a few noted criticisms (Bennett and Blarney 2001, Boxall et al. 2009) but are emerging in wildlife management research. They are robust and ideally suited to provide decision makers with detailed estimations about sportsperson preferences for policy changes and hunting-specific issues (Mackenzie 1990, Bullock et al. 1998, Zimmer et al. 2011, Mingie et al. 2017, Soliño et al. 2017). These methods were developed by economists interested in identifying ways to mathematically represent human decision making (Louviere et al. 2010). They are widely accepted in market and policy research (Ben-Akiva et al. 2015) and increasingly being used in hunter surveys (Schroeder et al. 2018). Discrete choice experiments explain the choice behavior of humans through preference elicitation (Louviere et al. 2010). These experiments ask respondents to value a product or composite good by deciding their preferred option from a set of $\geq$2 choice tasks. Tasks are comprised of a set number of attributes that characterize the product or composite good; there are >2 and usually <5 attributes, which are sub-divided by a set of levels (Orme 2002, Johnson and Orme 2003). The results reveal which attributes are most important in determining their selection, and variations in value are a function of levels employed. Model estimation arises from random utility theory (logit estimation). It asks the respondent to compare the attributes horizontally, compare the randomly generated combination of levels horizontally, and then choose the most appealing option. The result is an analysis of innate, complex decision making not characteristic of rating or ranking measures.

In this descriptive study, we used a DCE approach to investigate how 5 attributes underpinning deer management in North Carolina might influence hunter preferences for alternative deer hunting seasons. Specifically, we explored spatial differences in the value of hunting season attributes and levels across 5 potential (i.e., new) hunting zones (Western [W], Northwestern [NW], Central [C], Northeastern [NE], Southeastern [SE]; Fig. 1) in North Carolina and hunters' preferences for up to 4 potential regulatory profiles affecting a range of herd demographics (e.g., adult sex ratio, density).

STUDY AREA

Our study area encompassed the state of North Carolina, USA (139,390 km^2, elevation range = sea level–2,037 m), which spans from the Atlantic Ocean to the Appalachian Mountains. The state is characterized by 4 ecoregions: Blue Ridge, Piedmont, Middle Atlantic Coastal Plain, and Southeastern Plains. The mountains are characterized by deciduous and Boreal conifer forests, and longleaf pine (*Pinus palustris*) has been the historically dominant species in the Piedmont. Marshes, dunes, swamps, and hardwood swampforests differentiate the Coastal Plain from the other regions (https://www.ncpedia.org/vegetation, accessed 02 Aug 2018). The largest population centers are Charlotte, Raleigh, Greensboro, and Winston-Salem; all are located in the Piedmont. The state has a dynamic climate, with warm humid summers, pleasant autumn temperatures, and mild winters, dotted with the occasional blast of arctic air or snowfall, hurricane, flood, or tornado (Robinson 2015). Forests, developed land, cropland, and water comprise 84% of the state's land cover and use (https://www.nrcs.usda.gov/Internet/NRCS_RCA/reports/nri_nc.html, accessed 02 Aug 2018).

In North Carolina, deer were largely extirpated by European settlers after the colony was settled in the seventeenth century (Malone 2010). Restocking occurred intermittently between 1890 and 1985, reinforced by a major restoration effort starting in the 1940s. The deer population expanded to nearly 1 million by the early 1990s, and either-sex harvest opportunity was eventually made available to all 100 counties (North Carolina Wildlife Resources Commission [WRC] 1993). Deer hunting is popular in the state, and deer hunters contribute nearly $400 million to the state economy (Allen et al. 2012). An estimated 46% of 253,165 deer hunters successfully harvested $\geq$1 deer during the 2016–2017 hunting season. Mandatory reported harvest totaled 149,811 deer, including 76,206 antlered males.

The WRC unsystematically established the existing state deer season zones in the 1970s and early 1980s as deer populations recovered across the state. Changes to deer

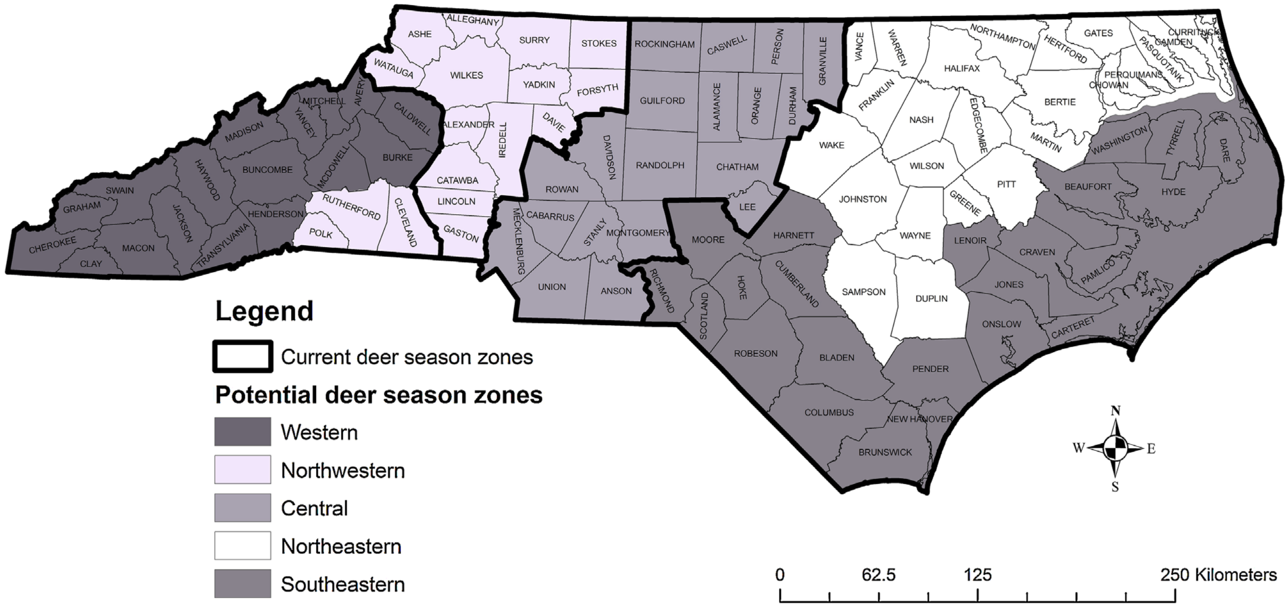


Figure 1. Existing North Carolina deer seasons (through Jul 31, 2018) overlapped with proposed white-tailed deer season zones designed to improve capture of variability in herd parameters. We used this context to inform a 2016 deer hunter season preference survey, North Carolina, USA.

hunting seasons went into effect on 1 August 2018 as a result of the 5 years of research discussed in this paper. The agency created 7 biological objectives in 2010: a viable population is maintained within nutritional carrying capacity, all age classes of males and females are adequately represented, adult sex ratios are balanced during breeding season to increase the likelihood of synchronized breeding and parturition, yearling male dispersal is adequate, standing genetic diversity is maintained, the herd is free-ranging, and the risk of disease introduction and transmission is minimal. Using these objectives as a guide, the WRC initiated an intensive 3-year data collection project in 2011 to determine if the objectives were being met. The agency also developed Biological Deer Management Units (BDMUs) to explain biological variation within the data collected. The agency then assessed progress toward attaining biological objectives set for the state's deer herd under both the existing season zones and BDMUs (Howard et al. 2015). Howard et al. (2015) concluded that the BDMUs would be a better framework than existing deer season zones to meet the objectives.

Further, North Carolina has experienced changes over the past few decades in anthropogenic land use, distribution and relative abundance of predator populations (Chitwood et al. 2015), deer population demographics (Howard et al. 2015), and deer hunter demographics (USFWS 2011). The WRC surmised that these shifts led to changes in deer hunter perceptions, expectations, and desires that were originally described in a 2006 agency survey of deer hunters (Palmer 2009).

METHODS

Sampling and Data Collection

To better understand hunter preferences and potential support for management changes, WRC embarked upon a statewide, county-level, web-based survey. Because deer hunters are not specifically identified by license type within the WRC's Automated License and Vessel Information Network (ALVIN), we drew the sample from the population of license-exempt and standard Big Game Harvest Report Card (BGHRC) holders with valid licenses during the 2015–2016 hunting season ($N = 418{,}020$). We removed duplicates based on WRC customer number and generated a sample of adult BGHRC holders (>18 yr old) for each county, based on the county of residence listed in their ALVIN license record. To verify that estimates could be refined down the most simplistic regulatory scale (county) and to ensure a 90% confidence level and 10% error rate at that level, we calculated necessary sample sizes based on a predicted 10% response rate. To meet this goal, we emailed all BGHRC holders who had provided an email address in ALVIN ($n = 196{,}770$). We removed participants with undeliverable emails (~20%), due to invalid or closed email addresses and spam-blocking internet service providers, from the final sampling frame ($n = 171{,}880$).

We selected to use a web-based questionnaire to survey our study population. Web-based surveys are becoming more popular because they are viewed as more efficient even though they may produce lower response rates than mail surveys and tend to be biased toward younger urban citizens (Zickuhr and Smith 2012). To counter this potential bias, we developed a push-to-web postcard mailing. We generated a stratified random sample of postcard recipients ($n = 83{,}120$ statewide; range = 506–562/county) comprised of BGHRC holders with a valid mailing address (some also had email addresses on file). We screened mailing addresses with National Change of Address and Coding Accuracy Support System software to minimize undeliverable addresses. We compared mean responses for each contact mode group (email only, postcard only, and email-postcard) with a 1-way analysis of variance (ANOVA) and then visual inspection. Results did not reveal statistical differences between means.

We designed and administered our survey with SSI Web 8.4.8 (Sawtooth Software, Orem, UT, USA). We assigned a unique customer access code to each respondent. We conducted email and postcard mailing campaigns in tandem, roughly 1 month apart, based upon the Tailored Design Method (Dillman et al. 2014). We completed the first full postcard mailing and email solicitation in July 2016. We sent a follow-up postcard and email to non-respondents in August and September 2016. Because it was important to discuss results with stakeholders at the 90% confidence level with 10% error and because of low response rates for some counties after the first mailing, we randomly selected additional participants to meet county minimum sample size goals ($n = 4{,}115$). We removed refusals, mail returns, and deceased participants from our analyses, and we eliminated oversampled respondents from our choice behavior analysis.

To account for potential non-response bias, we employed researcher discretion (Vaske 2008) and used a combination of methods (Lewis et al. 2013). We mailed 1,000 shortened surveys to non-respondents, including those who did not complete the choice modeling section, and then compared responses between samples. We also employed a continuum of resistance approach, where the underlying assumption is that late respondents are comparable to non-respondents (Serenari et al. 2015). We divided respondents into 2 groups based on whether they submitted an early or late response and compared wave responses for the same 10 survey questions. We then examined mean responses for each question for both methods and also explored effect sizes employing Cohen's d (Cohen 1988).

Choice Scenarios

We used Sawtooth Software's choice-based conjoint (CBC) package to measure respondents' preferences for various management strategies and what-if policies using Sawtooth's simulator. Sawtooth's CBC method adheres to a DCE and not a conjoint analysis underpinning (https://sawtoothsoftware.com/forum/8199, 1 Aug 2018). We identified 5 key regulatory attributes that influence deer herd parameters. For each attribute, we identified corresponding levels based on regulatory frameworks within existing deer seasons zones in North Carolina and levels needed to meet all biological objectives throughout the state (Table 1).

We developed a full-profile season choice scenario, employing a balanced overlap design with 300 versions and without attribute randomization, restrictions, or prohibitions. Our design employed 2,400 choice tasks (8 per version). Each choice task included 3 concepts and 5 attributes. Standard error scores for our design were acceptable ($P < 0.050$). After pilot testing the survey with 20 North Carolina deer hunters and agency staff, we chose a design that did not include a none option for 3 reasons. First, the WRC was most interested in gathering as much information as possible to estimate the utilities of the attribute levels most critical to hunter decision making. Second, aspects of status quo were incorporated into the attributes and levels used; therefore, employing a constant alternative would have yielded redundancy within our analysis and with our policy preference simulations. Finally, the none option is argued to be underused by respondents and can diminish the strength of DCE results (https://sawtoothsoftware.com/forum/278, 4 Aug 2018). We provided brief instructions (Fig. 2) before asking respondents to complete each choice task. We also provided the timing of existing gun seasons across the state.

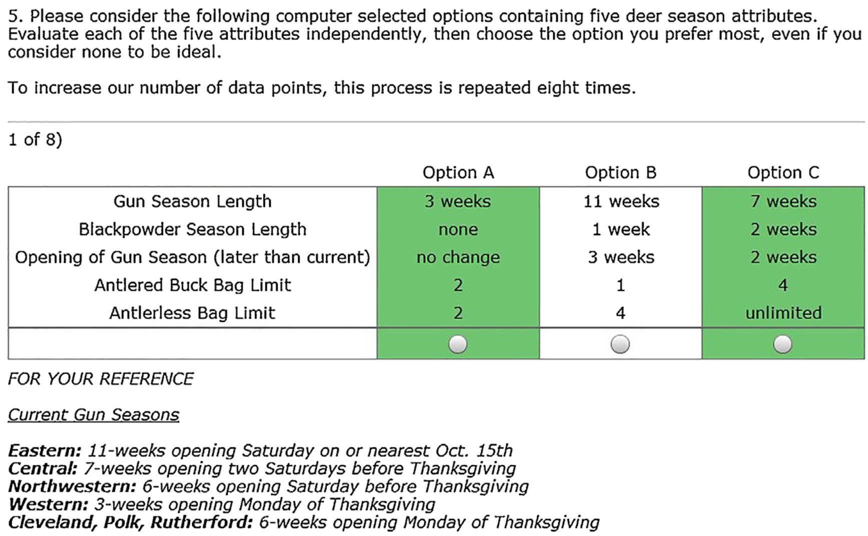
Table 1. Attributes and levels included in 2016 discrete choice experiment examining North Carolina, USA, white-tailed deer hunter preferences.

Attributes	Levels
Gun season length (weeks)	3, 5, 7, 9, 11
Blackpowder season length	None, 1 week, 2 weeks
Opening of gun season (later than current; weeks)	No change, 1, 2, 3
Antlered male limit	1, 2, 4
Antlerless bag limit	2, 4, 6, unlimited

Demographics and Deer Management

We collected demographic information on hunters (county and hectares hunted in North Carolina, days spent hunting per year, gender, age, employment, education, race, income). We asked hunters to rate their level of satisfaction with WRC deer management (1 = very unsatisfied to 5 = very satisfied), state their desire for deer population numbers (1 = significant increase to 5 = significant decrease), and tell us how the deer population changed during the past 3 years (1 = decreased; 2 = remained the same; 3 = increased; unsure [removed from analysis]). One survey question stated that the deer herd is in good condition but could be improved. We then asked respondents to provide their position on changes to deer seasons (I prefer no changes to the current deer season, I am willing to accept some minor changes to the current deer season in order to make improvements to herd condition, I am willing to accept any changes the WRC considers biologically necessary to optimize the condition of the herd, I have no opinion on this matter).

Our study involved human subjects in that we contacted our study population via postcard and e-mail and used their responses to conduct our analyses. We informed the respondents that they were participating in an approved WRC project that was designed to assess hunter preferences regarding deer hunting seasons in North Carolina and their responses were important to the success of the project. The WRC has not yet established guidelines or policies involving research on human subjects but does have a redaction policy to safeguard subjects from some risks due to public records requests. We also followed North Carolina State University human subjects research standards. To protect the subjects involved in this study, we sent them a secure link and a password to access the web-based questionnaire and we did not record their Internet Protocol (IP) addresses. We disclosed to subjects that their identities and responses would be protected. We gave respondents a unique identifying number to replace personal identifying information. Access



5. Please consider the following computer selected options containing five deer season attributes. Evaluate each of the five attributes independently, then choose the option you prefer most, even if you consider none to be ideal.

To increase our number of data points, this process is repeated eight times.

1 of 8)

	Option A	Option B	Option C
Gun Season Length	3 weeks	11 weeks	7 weeks
Blackpowder Season Length	none	1 week	2 weeks
Opening of Gun Season (later than current)	no change	3 weeks	2 weeks
Antlered Buck Bag Limit	2	1	4
Antlerless Bag Limit	2	4	unlimited

FOR YOUR REFERENCE

Current Gun Seasons

Eastern: *11-weeks opening Saturday on or nearest Oct. 15th*
Central: *7-weeks opening two Saturdays before Thanksgiving*
Northwestern: *6-weeks opening Saturday before Thanksgiving*
Western: *3-weeks opening Monday of Thanksgiving*
Cleveland, Polk, Rutherford: *6-weeks opening Monday of Thanksgiving*

Figure 2. Screen shot of sample choice scenario of hunting season alternatives presented to white-tailed deer hunters who participated in a 2016 hunting season preference survey, North Carolina, USA.

to passwords and the master list of passwords relating the participant names to the passwords was restricted to the lead author, password-protected, and stored on a password-protected and encrypted WRC hard drive. We analyzed and presented data in aggregate.

Data Analysis

Discrete choice experiment.—Following Schroeder et al. (2018) and Boesch (2012), we employed Hierarchical Bayesian (HB) estimation to extract individual utility scores for respondents within the 5 potential hunting zones. Hierarchical Bayes estimates a multinomial log model for each respondent, thereby accounting for heterogeneity directly (Huber and Train 2001). We conducted 10,000 preliminary iterations, 10,000 draws used per respondent, and 20,000 iterations. We disclose conjoint importance scores, which measure the importance of the 5 attributes in the respondent's choice. Attribute importance percentages are calculated by dividing the utility score range for each attribute by the total utility range and then multiplying by 100 (Orme 2010). To facilitate comparisons between levels, we permitted standardization of raw part-worth utilities (preference scores), rescaling according to the zero-centered differences method (Allenby et al. 1995, Childs and Drake 2009, Orme 2010). To validate our results at the 0.05 level, we used t-tests to compare differences between attribute importance scores and to compare differences between part-worth utility scores (Sawtooth Software 2004).

Policy simulation.—We explored the utility of potential new seasons using Sawtooth's online simulator software. We uploaded previously computed individual part-worth values into the program to simulate and predict hunters' percent share of preference for practical alternative regulations (i.e., profiles). Preference simulations have been used to estimate support for guidelines and policy (Kruk et al. 2009, Morgan-Davies and Waterhouse 2010, Lüthi and Prässler 2011, Serenari et al. 2015). We initially created 4 alternative regulation profiles for each of the 5 potential zones. We created these profiles after inspection of the choice experiment results to look for geospatial similarities using a geographic information system (ArcGIS version 10.2; Environmental Systems Research Institute, Redlands, CA, USA), and then overlaid choice experiment results with GIS-created maps generated from the WRC's 3-year deer herd study. Profiles were context-specific and focused on trade-offs. We also compared preferences for status quo and balanced profiles because these profiles were the most realistic of the 4 conceived. We conducted 2 sets of simulations because gun season length could be odd or even numbered, depending on hunting location. We employed odd numbers by increments of 2, reflecting the shortest and longest seasons in North Carolina. One set rounded up gun season length and the other rounded down gun season length. We assigned the following profile labels: 1) status quo (reflecting the existing season); 2) hunter optimal (reflecting hunter preferred levels, drawn from our DCE results); 3) bio optimal (reflecting levels needed to meet only biological objectives, drawn from the 3-year biological study findings); and 4) balanced (reflecting a WRC staff-informed balance between hunter and bio optimal profiles and based on feasibility of implementation). We conducted a sensitivity analysis (varying all attribute levels to achieve practical fit) to fine-tune our profiles.

We inspected the root likelihood (RLH) value as one measure goodness of fit (Schroeder and Fulton 2014). The RLH is the geometric mean of predicted probabilities. An RLH value of 1 equates to a perfect fit. This data set had 3 alternatives per choice task, so the expected RLH value for a chance model would be $1/3 = 0.333$. An RLH value >0.333 reflects improvement over the chance level (Orme 2009).

RESULTS

We received 33,750 valid survey responses for an overall response rate of 17% (6,071 postcard-only, 11% response rate; 18,959 email-only, 16% response rate; 8,720 email-postcard, 32% response rate). Deer hunters were represented in all 100 counties and inferences could be made within ±10% error at 90% confidence at the county level and ±5% error at 95% confidence at the state, existing deer season zone, and administrative district level. We calculated a maximum sampling error of 0.51 percentage points for the entire sample. Most respondents indicated they deer hunted in North Carolina ($n = 30{,}738$, 91%) and a cross-check with ALVIN records revealed that 65% of respondents lived in the county they hunted. Respondents indicated their primary interest was in deer management in the existing Eastern season, followed by Central, Northwestern, and Western (Table 2).

Our non-response check yielded 149 responses, with most non-respondents indicated they forgot to respond (28%), did not receive our invitation (21%), or did not deer hunt (16%). We then compared responses between non-respondents and study respondents to 10 key survey questions. Results revealed mean differences between non-respondents and respondents ($P < 0.050$). Wave analysis comparing early (after the first email; $n = 24{,}938$) and late (after the third reminder; $n = 8{,}434$) respondents detected statistical significance ($P < 0.05$) between groups for a fewer number of questions. To further address these mixed results, we employed a visual inspection of mean responses. We did not identify meaningful differences between groups. Effect sizes were between 0.030 and 0.281, signifying small differences between the 2 groups. Given these analyses, we did not deem non-response bias a problem or weight the data.

Respondents were mainly satisfied with WRC deer management (46% satisfied, 22% neither unsatisfied or satisfied, 32% unsatisfied), and most indicated they would like deer numbers to slightly increase (30%) or remain at the current level (33%). Most respondents indicated that the deer population had decreased during the past 3 years (36%), and fewer indicated it remained the same (28%) or increased (24%). Respondents also indicated they were willing to make minor (42%) or any (39%) changes necessary to improve herd condition.

We obtained 25,508 valid responses (SE = 5,700, NE = 6,617, W = 2,607, NW = 4,385, C = 6,199) for our choice behavior analysis. The large RLH value (0.657) indicated good model fit. We validated observed differences between attribute importance scores and differences between part-worth utility scores with t-tests. We noted statistical differences at the 0.05 level in all but 2 cases.

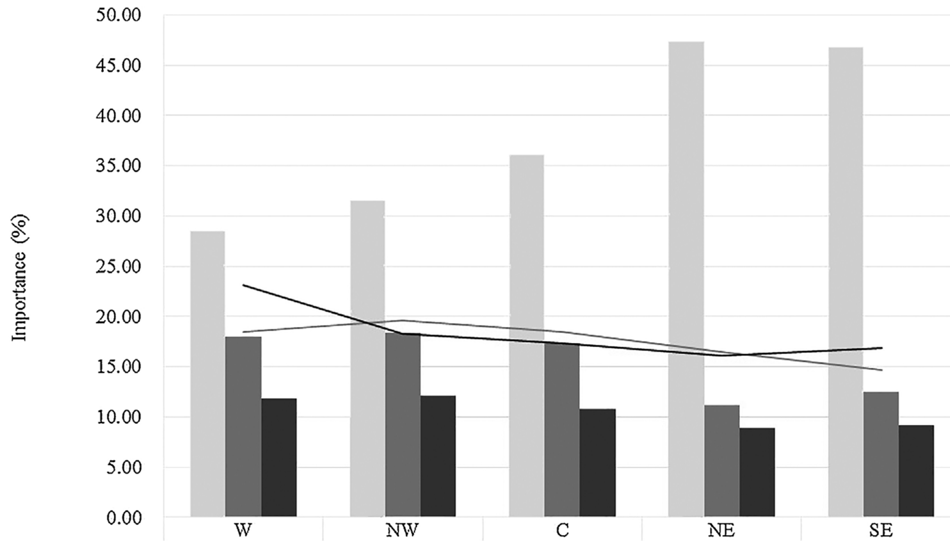
Gun season length followed by bag limits were the most important attributes to hunter decision making (Fig. 3), with antlerless bag limits being the second most important among hunters in the SE, W, and C zones. There was a statistical tie between the importance of antlered and antlerless bag limits among NE hunters. In the NW zone, antlered bag limits were second most important to hunter decision making. Moving west to east across the state, the importance of gun season length increased, whereas importance of blackpowder season length, and bag limits generally decreased (Fig. 3).

Examination of part-worth utilities revealed that North Carolina hunters tended to prefer existing gun season lengths (NE and SE) or desire seasons that are 2 (W, C, NW) or 4 weeks (W) longer (Table 3). Southeastern hunters preferred the gun season open 1 week later, whereas the remainder of the sample preferred no change. Hunters in the NE and SE season zones did not prefer the existing 4 male bag limit, preferring 2, and hunters in each potential zone preferred to harvest fewer females than they were allowed.

Table 2. Demographics of respondents who participated in 2016 North Carolina, USA, white-tailed deer hunter preference survey ($n = 33{,}750$).

Variable	n	%
Zone of hunting interest		
Central	7,798	25.4
Eastern	14,642	47.6
Northwestern	4,298	14.0
Western	3,994	13.0
Gender		
Male	27,494	95.5
Female	1,281	4.5
Race		
White	26,980	94.1
White (Hispanic)	619	2.2
African-American	469	1.6
Asian	83	0.3
American Indian	314	1.1
Native Hawaiian, Pacific Islander	23	0.1
Education		
<High school	620	2.2
High school or General Education Diploma	7,490	26.1
Technical	4,888	17.0
Associate's	5,219	18.2
Bachelor's	6,990	24.4
Graduate, Professional	3,482	12.1
Employment		
Self-employed	3,953	13.7
Full-time	16,215	56.4
Part-time	807	2.8
Unemployed	399	1.4
Disabled or unable to work	1,098	3.8
Retired	6,292	21.9
Time spent hunting (days)		
<2	3,665	12.0
2–5	4,854	15.9
6–10	5,504	18.0
11–21	7,817	25.6
22–41	6,061	19.8
>41	2,684	8.8
Income (U.S. $)		
<25,000	1,866	6.8
25,000–49,999	5,413	19.7
50,000–74,999	6,728	24.5
75,000–99,999	5,162	18.8
>100,000	8,282	30.2
Where hunted[a]		
Private lands only	20,349	69.9
Mostly private lands, but also game lands	4,931	16.9
Evenly on public and private	1,155	4.0
Mostly game lands, but also some private lands	1,140	3.9
Game lands only	1,081	3.7
Hectares hunted[a]		
<8	4,337	15.1
8–54	9,295	32.3
55–202	8,010	27.8
203–404	2,629	9.1
405–809	1,466	5.1
810–2,023	1,203	4.2
>2,023	959	3.3

[a] Results do not equal 100% because only data for individuals who hunted are given.



	W	NW	C	NE	SE
Gun season length	28.56	31.55	36.14	47.36	46.82
Blackpowder season length	17.96	18.41	17.30	11.19	12.50
Opening of gun season (later than current)	11.84	12.10	10.76	8.86	9.17
Antlered buck bag limit	18.50	19.63	18.43	16.44	14.68
Anterless bag limit	23.13	18.31	17.37	16.15	16.83

Figure 3. Results of the Hierarchical Bayes estimation illustrating attribute importance, representing which white-tailed deer season attributes most influenced choice task selection by respondents in a 2016 deer hunter season preference survey, North Carolina, USA. We conducted 10,000 preliminary iterations, 10,000 draws used per respondent, and 20,000 total iterations. The average root likelihood was 0.657. The importance of each attribute is given in percent. The higher the percent, the larger the influence on hunter decision making. We note a statistical tie between the importance of antlered and antlerless bag limits among northeastern zone (NE) hunters.

The hunter optimal profile was the most preferred for all potential season zones except the SE, where the most preferred was status quo. The second most preferred was the balanced package for the W and NW zones, status quo for C and NE, and hunter optimal for the SE zone. Comparing status quo and balanced profiles revealed that when gun season length was rounded up (longer season, less conservative) respondents preferred the balanced profile (Fig. 4). When gun season length was rounded down (shorter season, more conservative), W and SE zone hunters preferred the balanced profile over the status quo, and status quo was preferred over the balanced profile by NW, C, and NE zone hunters (the SE group was excluded from this analysis because gun season length remained the same; Fig. 5).

DISCUSSION

We demonstrate that by treating hunting seasons as a composite good (i.e., they have social and biological purposes) agencies can determine what trade-offs between different attributes that underpin multidimensional policies can be made. Decision makers need to remove some degree of decision making uncertainty about hunter preferences for regulatory changes. Reduced hunter support for these changes could result in *ex post facto* political backlash noted in other regulation change situations, specifically those associated with deer (Diefenbach et al. 1997, Fulton and Manfredo 2004, Frye 2006). Resultantly, conflict can negatively affect agencies economically and politically, which could then stimulate deleterious ecological effects (Fieberg et al. 2010). We demonstrate that state of the art environmental valuation techniques, such as DCE, can be used to remove uncertainty about hunter decision making, forecast how they might react to regulatory change, and posit ways to increase hunter support for change (Mackenzie 1990, Hoyos 2010, Schroeder et al. 2018). This study also suggests that conflict over regulation changes can originate from geospatial differences in hunter decision making. Taking these points in aggregate, future research should consider testing SPM in other wildlife regulation change scenarios because attributes and levels will vary by stakeholder group and the context in which they reside (Miller and McGee 2001).

Firearm season length (essentially gun) and bag limits are primary mechanisms for managing deer populations in the United States (Van Deelen et al. 1997, 2010). Collectively, these 2 regulatory attributes capture a high degree of political, social, and biological variability and complexity across North Carolina, likely explaining their influence on hunter decision making in our study. Of these, gun season length is not a practical starting point for regulatory change in North Carolina. Our findings mirror those studies demonstrating that, for a variety of reasons, shortening season length is unpopular among hunters (Pierce et al. 1996, Cornicelli et al. 2011). We propose that decision makers first attend to attributes least important to hunter decision making. Rather than pulling socially or politically sensitive levers first (e.g., altering gun season length), we focused on season opening date and blackpowder season length to develop alternative regulatory profiles that would yield hunter support and benefits for the deer herd. Future

Table 3. Results of the Hierarchical Bayes estimation illustrating utilities (a measure of desirability or worth [i.e., preference]) of individual hunting season attribute levels, based on 2016 survey of North Carolina, USA, white-tailed deer hunter preferences ($n = 25{,}508$). The higher the utility, the more desirable the attribute level is to the respondent and influential it is on a respondent choice.[a,b]

Gun season length	Utility	Black powder season length	Utility	Opening of gun season (later than current)	Utility	Antlered male limit	Utility	Antlerless bag limit	Utility
3 Weeks		None		No Change		1		2	
Northeastern	−120.25	Northeastern	−25.24	Northeastern	4.51	Northeastern	−14.16	Northeastern	−28.21
Central	−87.24	Central	−39.30	Central	14.22	Central	−3.50	Central	−27.87
Northwestern	−66.39	Northwestern	−45.12	Northwestern	20.51	Northwestern	0.95	Northwestern	−23.25
Southeastern	−116.91	Southeastern	−30.08	Southeastern	2.16	Southeastern	−14.54	Southeastern	−25.10
Western	−26.32	Western	−43.75	Western	7.79	Western	−2.36	Western	6.91
5 Weeks		1 Week		1 Week		2		4	
Northeastern	−44.67	Northeastern	9.37	Northeastern	1.84	Northeastern	21.93	Northeastern	9.15
Central	−17.51	Central	12.61	Central	7.09	Central	26.68	Central	9.64
Northwestern	−2.70	Northwestern	14.09	Northwestern	5.29	Northwestern	25.39	Northwestern	12.42
Southeastern	−42.25	Southeastern	10.56	Southeastern	3.67	Southeastern	17.82	Southeastern	10.88
Western	16.36[c]	Western	15.21	Western	4.25	Western	25.70	Western	21.53
7 Weeks		2 Weeks		2 Weeks		4		6	
Northeastern	19.70	Northeastern	15.86	Northeastern	1.97	Northeastern	−7.76	Northeastern	14.57
Central	28.75	Central	26.69	Central	−2.33	Central	−23.17	Central	15.77
Northwestern	25.33	Northwestern	31.03	Northwestern	−5.47	Northwestern	−26.34	Northwestern	14.70
Southeastern	16.84	Southeastern	19.52	Southeastern	2.68	Southeastern	−3.27	Southeastern	14.27
Western	15.78[c]	Western	28.53	Western	−0.15	Western	−23.35	Western	7.50
9 Weeks				3 Weeks				Unlimited	
Northeastern	58.58			Northeastern	−8.32			Northeastern	4.49
Central	40.43			Central	−18.98			Central	2.47
Northwestern	26.97			Northwestern	−20.32			Northwestern	−3.87
Southeastern	55.74			Southeastern	−8.51			Southeastern	−0.05
Western	9.17			Western	−11.90			Western	−35.94
11 Weeks									
Northeastern	86.65								
Central	35.58								
Northwestern	16.79								
Southeastern	86.58								
Western	−14.99								

[a] Only levels within an attribute can be compared.
[b] Central ($n = 6{,}199$); Northeastern ($n = 6{,}617$); Northwestern ($n = 4{,}385$); Southeastern ($n = 5{,}700$); Western ($n = 2{,}607$).
[c] Statistical tie.

research will need to establish whether this approach yields acceptable and long-term levels of hunter support for new regulations.

Given WRC staff understandings of the North Carolina hunting culture, we did not expect that North Carolina hunters would generally prefer lower bag limits for antlered and antlerless harvests. These results support the claim that hunters tend to prefer more restrictive bag limits over shortening seasons (Pierce et al. 1996, Cornicelli et al. 2011). This preference may work in concert with differences in hunters' political and cultural contexts to explain our results. For instance, we (Shaw et al. 2017) reported that Western season hunters, who experience low deer densities and have a short gun season (3 weeks), were most concerned about poaching of deer, whereas hunters in the Eastern zone, who experience moderate deer densities and a long gun season (11 weeks), were most concerned about predators killing deer. To add depth to our findings and those conducting similar studies, researchers should explore how political and cultural contexts affect preferences for hunting regulations.

Hunters may prefer a balanced approach to deer management where regulations are grounded in a trade-off rather than a biocentric or anthropocentric emphasis. Our what-if policy simulation results indicated that the right combination of preferences may yield broad support for a regulatory approach that enhances the hunting experience and also improves the deer herd. Research has demonstrated that regulations designed to sustain the resource, champion an archetypal deer-type preference focused on health and abundance rather than trophy qualities, and preserve hunting traditions stand to affect a greater number of hunters and their levels of satisfaction with deer management (Miller and Graefe 2001, Cornicelli et al. 2011, Schroeder et al. 2014*a*). Moreover, because researchers suggest satisfaction is linked to support for regulations through beliefs about net benefits to both deer and hunters (Miller and Graefe 2001, Fulton and Manfredo 2004), the WRC may also benefit from increased hunter trust originating from hunter acceptance and support and legitimatization of regulations (Needham and Vaske 2008, Schroeder et al. 2017). We do not fully understand the popularity of the status quo option in our study. Research examining the status quo effect in choice experiment studies highlighted several reasons for its preference, including respondents protesting new regulations or study design complexity (Boxall et al. 2009). To better understand hunter decision making, survey efforts employing

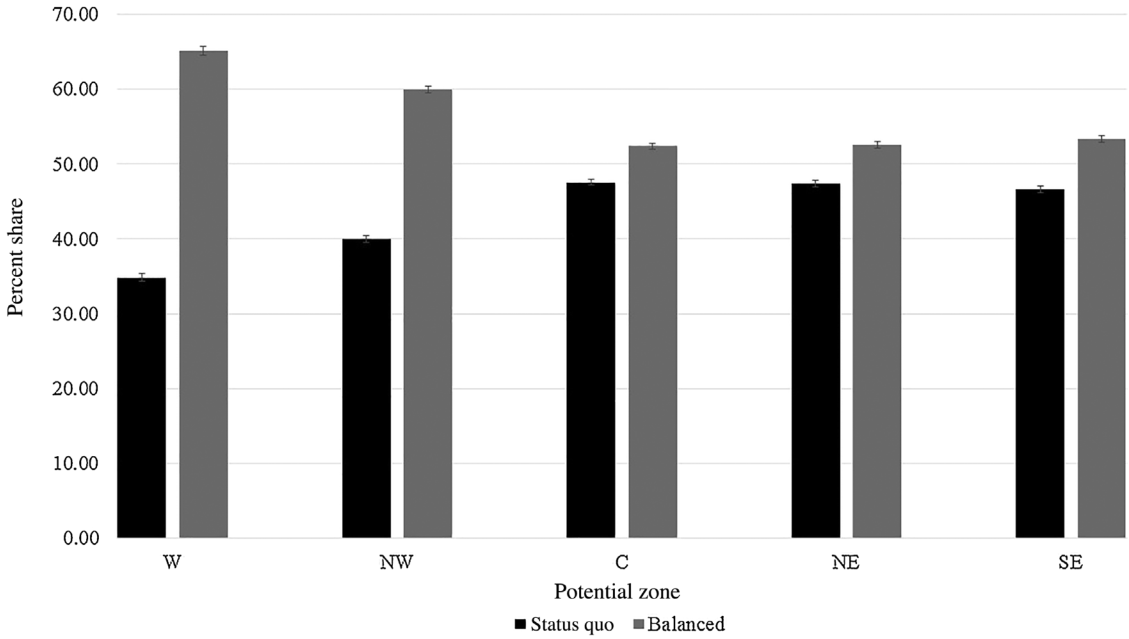


Figure 4. Share of preference (95% CI) for hypothetical season choices for North Carolina, USA, deer hunters who participated in a 2016 hunting season preference survey, representing their preferences for alternative white-tailed deer hunting seasons, with gun season length rounded down (shorter season, more conservative) to reflect a less conservative regulation profile. Status quo refers to the existing season structure. Balanced means a season structure that evenly benefits hunters and the deer herd. The higher the percent the more desirable the policy.

SPM should elicit reasons why hunters do not prefer regulatory change when it does not yield biological or ecological benefits.

MANAGEMENT IMPLICATIONS

By investigating choice behavior of hunters, we informed the process of developing and proposing comprehensive changes to North Carolina deer hunting seasons. Final regulation changes by the WRC reduced bag limits for antlered and antlerless deer, shifted either-sex days to the beginning of either-sex seasons, moved a few counties from one season to another, and divided the Eastern zone into 2 new zones. Though decisions regarding regulation changes are underscored by politics, for which the approach cannot account, we

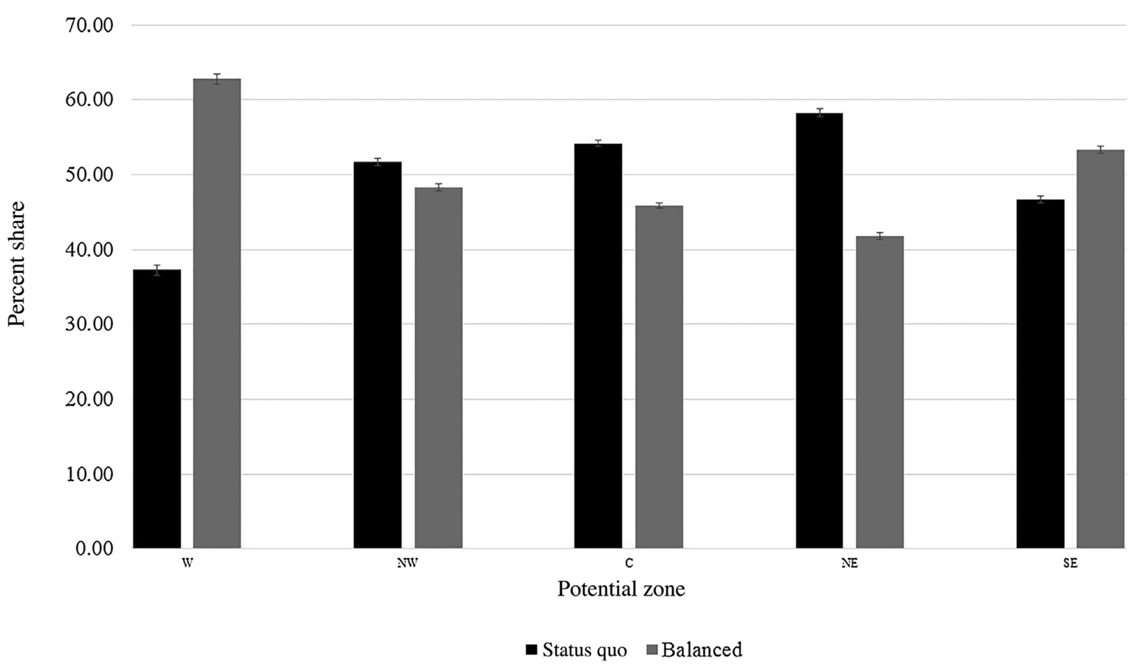


Figure 5. Share of preference (95% CI) for hypothetical season choices for North Carolina, USA deer hunters who participated in a 2016 hunting season preference survey, representing their preferences for alternative white-tailed deer hunting seasons, with gun season length rounded up (longer season, more conservative) to reflect a more conservative regulation profile. Status quo refers to the existing season structure. Balanced means a season structure that evenly benefits hunters and the deer herd. The higher the percent, the more desirable the policy.

conclude that the inclusive capability of SPM, specifically DCE, could be an alternative to incremental policy changes based on attitudinal measures alone. This capability may also promote longitudinal and occasional, rather than frequent, study of deer hunter preferences. State wildlife agencies could then focus resources on monitoring the often discounted long-range social and biological effects of the regulatory change.

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