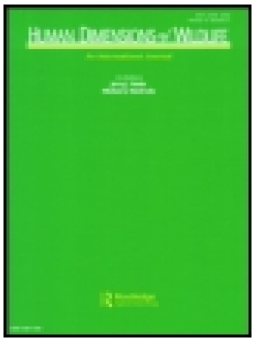

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Predicting private landowner hunting access decisions and hunter density

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ABSTRACT

Urbanization and shifting landowner demographics are changing how and where hunting occurs. We surveyed nonindustrial private landowners (N = 1,843) in North Carolina, USA to examine how demographics and land-use predict whether hunting occurred and hunter density. The optimal logistic regression model correctly predicted whether hunting occurred on 96% of properties. Larger properties, male property ownership, longer ownership tenure, income generation from a property, and landowners originating from rural environments were positively related to whether a property was hunted. Properties with older landowners and properties surrounded by greater housing and road density were less likely to be hunted. Hunter density declined with property size, longer ownership tenure, and the presence of a landowner or family member(s) hunting the property. In the future, increases in hunter density on small properties may facilitate wildlife management through hunting as landscapes become more urbanized.

KEYWORDS

Hunter access; hunter density; landowner decisions; nonindustrial private land; North Carolina; urbanization; white-tailed deer

Introduction

Hunter access to private lands declined rapidly during the early twentieth century, spurring some of the earliest research in human dimensions of wildlife management (Short, 1939). Complex dynamics between landowners and hunters arise because wildlife resources in the United States are legally held under the Public Trust Doctrine, but landowners hold the power to restrict access (Geist, 1995; Morrow, 1950). Beginning in the 1930s, economic value of private land available for hunting and the number of hunters increased relatively quickly, and wildlife agencies began tracking a general transition from tolerance of unrestricted public hunting on private lands toward prohibition or exclusion of many hunters (Morrow, 1950; Short, 1939). Control and limitation of hunter access was supported by economic incentives associated with the commodification of hunting (Chazkel & Serlin, 2010; Mell, 1938), political and economic shifts that decreased free or low-cost access to hunting lands (Serenari & Peterson, 2016), and increased hunting demand from less trusted "outsiders" who used improved transportation and road

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networks to enter new hunting areas (Short, 1939). At the same time landowners grew more concerned about liability associated with hunting, and these concerns persisted even after states enacted statutes to protect landowners from injury claims from recreational users (Kuentzel, Daigle, Chase, & Brown, 2018). Wildlife agencies formulated a three-pronged response: (1) alleviate private landowner concerns by creating regulations that reduced risk or risk perceptions for landowners (e.g., safety zones around buildings, developing stronger trespassing rules; Short, 1939), (2) implement hunter education programs that placed a priority on teaching hunters to respect landowners, and (3) purchase or lease land to open for public hunting access (Peterson, 2014).

Despite these actions, the United States continues to experience an overall decline in land available for hunting (Alig, Plantinga, Haim, & Todd, 2010; Larson, Stedman, Decker, Siemer, & Baumer, 2014; Wright, Kaiser, & Emerald, 2001). Factors beyond landowner restrictions likely also play an integral role in constricting the hunting landscape. Discharging firearms within expanding municipalities commonly is prohibited. Previous research has directly linked property parcelization outside municipalities to a reduction in hunter access and a decline in huntable land (Campa et al., 2011; Harden, Woolf, & Roseberry, 2005; Poudyal, Cho, & Hodges, 2008). This happens, at least in part, because landowners with smaller properties are less likely to allow hunting than landowners with larger properties (Lovely, Mcshea, Lafon, & Carr, 2013). Research on hunter access is especially important in urbanizing regions because exurban sprawl has been the fastest growing type of human development in the United States since the 1950s (Hansen et al., 2005). Exurban sprawl often retains habitat where wildlife persists, and sometimes thrive, but typically limits hunter access (Storm, Nielson, Shauber, & Woolf, 2007).

Hunter access on private land influences wildlife management by shaping hunter density and harvest levels. Hunter density may have multiple definitions, but in this article, we use the term to describe the number of hunters per unit area during all hunting seasons of a given year. Most wildlife agencies tasked with abating overabundant wildlife populations have responded by liberalizing harvest regulations (Kilpatrick & Walter, 1997). For example, registered hunters around Cornell University in New York, USA were allowed to legally harvest two antlerless white-tailed deer (*Odocoileus virginianus*) per day throughout the deer hunting seasons (Siemer, Decker, & Stedman, 2016). However, hunter interest in this program waned rapidly due to limited access to private land, which illustrates how harvest liberalization may not accomplish the desired goals when landowners effectively create refuges by prohibiting hunting. Some view the issue of huntable wildlife overabundance as a self-correcting problem (Brown & Lauber, 2000), wherein the escalation of negative interactions with huntable wildlife will lead more people to allow hunting on their land. Negative interactions with huntable wildlife, however, is only one of many considerations for landowners deciding whether to allow hunting (Golden, Peterson, DePerno, Bardon, & Moorman, 2013; Storm et al., 2007; Zhang, Hussain, & Armstrong, 2006), and this did not seem to persuade landowners to permit or increase access in New York (Siemer et al., 2016).

Studies addressing hunter access on private land highlight the need to evaluate the influence of ongoing subdivision of land into smaller properties and associated landscape-level geographic variables. This research is most important in the eastern United States, including New England, where 84% of hunters use private land. Nearly a third (28%) of western United States (i.e., Mountain & Pacific U.S. Fish and Wildlife Service regions) hunters rely on private land for hunting, making hunting access on private land a national issue (U.S. Department of the Interior and U.S. Department of Commerce, 2012). As subdivision of land continues (Sampson & DeCoster, 2000), landowner decisions regarding hunter access to small properties will become more important. Parsing out landscape-level geographic variables (e.g., housing density, road density), rather than using urbanization as a total sum proxy, allows for individual examination of potentially key aspects involved with predicting whether a property is hunted. Notably, if landscape-level geographic variables surrounding a property can accurately predict whether properties are hunted, then spatial-predictive models of land available for hunting could be created at low cost using extant and typically free geographic data. Such models would allow agencies to identify regions where hunters may easily find access on private land, and areas where alternatives to hunting for managing wildlife populations may be required.

We addressed the knowledge gap associated with small properties (<2.02 hectares) and the efficacy of modeling hunter access using landscape-level geographic variables with a case-study in North Carolina. We expanded upon previous research related to hunter access in three ways: (1) by examining all property sizes (including those <2 hectares), (2) by evaluating the effects of landscape-level geographic attributes around properties while simultaneously considering the suite of landowner-related demographic drivers typically assessed in isolation, (3) by examining hunter density across property size strata. We expected positive relationships between a property's being hunted and landowners who were male, younger, less formally educated, had a rural upbringing, used their property to generate income, owned their property for a longer tenure (Jagnow et al., 2006; Wright, Kaiser, & Fletcher, 1988), and property size (Lovely et al., 2013). We expected that hunter density would have a negative relationship with a landowner or their family hunting the property (Wright et al., 1988) and property size. Although we expected the percentage of small properties hunted to be low, previous research has suggested that white-tailed deer density, and harvest density, can be greatest on smaller properties (Kretser, Sullivan, & Knuth, 2008; Lovely et al., 2013).

Study Area

We studied the hunting landscape on nonindustrial private land outside municipalities in North Carolina (Figure 1). Municipalities were excluded from our study because they almost universally have ordinances against discharging firearms. North Carolina provides a good case-study because the state has struggled to maintain hunter access to private lands in the face of rapid urban sprawl. North Carolina is approximately 90% privately owned (Sharpe, 2010), and urbanization rates are among the highest in the country (Allen, Moorman, Peterson, Hess, & Moore, 2012; Ewing, Pendall, & Chen, 2011). The percentage of North Carolina hunters residing within increasingly urbanizing metropolitan statistical areas increased rapidly from 46% to 75% between the years of 2006 and 2011 (U.S. Department of the Interior and U.S. Department of Commerce, 2012). Hunter participation rates increased by 14% during 2001–2011, creating a situation where more hunters have less land to hunt. The potential incompatibility between increased trends in urbanization and hunter participation has created a need for evaluating the contemporary hunting landscape in many regions. Our findings, however, may have less inference to

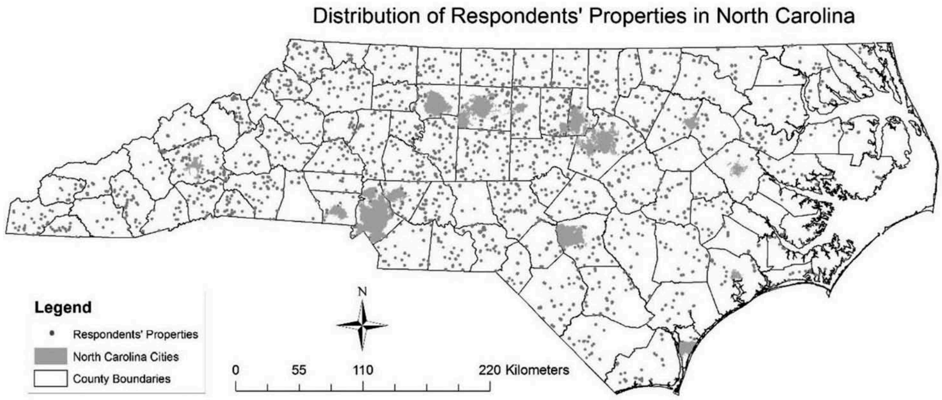

Figure 1. Respondents' properties and major cities for the study area, North Carolina, USA, 2015 (N = 1,843).

areas where hunting occurs primarily on public land and areas where rapid urbanization is not occurring.

Methods

Sampling

Surveys were distributed during June and July 2015. We mailed self-administered surveys to 8,000 randomly selected, nonindustrial, private landowners in North Carolina. We used a stratified random sample and attempted to survey 1,600 landowners in each of five property size strata: <0.40, 0.41–2.02, 2.03–4.05, 4.06–8.10, >8.10 hectares, to ensure adequate coverage of landowners controlling all key property sizes. We obtained the sample frame from the North Carolina Department of Agriculture and Consumer Service's 2014 county parcel databases. We removed all industrial properties except for limited liability corporations, which were included to avoid excluding hunting clubs and larger farms (Cecil, Ciccotello, & Grant, 1995).

We mailed a prenotice letter to landowners describing the objectives of this research, followed by the first questionnaire envelope, a reminder postcard, and finally a second questionnaire envelope, if necessary, at intervals of one, two, and two weeks, respectively (Dillman, Smyth, & Christian, 2014). Of the 8,000 questionnaires mailed, 26 (0.3%) were undeliverable, and 1,843 usable questionnaires were returned for an overall response rate of 23%. Within strata response rates increased as property size strata increased (<0.40 hectares = 18% response rate, 0.41–2.02 = 19%, 2.03–4.05 = 24%, 4.06–8.10 = 26%, >8.10 = 29%). This reflects mail survey response rates being greater in rural areas, where properties tend to be larger, than in urban areas (Dillman et al., 2014; Fowler, 2009). To evaluate nonresponse bias, we randomly telephoned 300 (60 from each property strata) nonrespondents to ask them a sub-set of questions (Chavez, Gese, & Krannich, 2005). We were able to contact 83 nonrespondents and achieved a 65% compliance rate (n = 54). We used two-sample z-tests to detect potential bias between respondent and nonrespondent populations for several questions: whether the property was hunted, ownership tenure, rural/urban upbringing of a landowner, landowner characteristics (i.e., gender, age, and highest level of formal education achieved), and annual household income. We detected no differences ($p > .05$) between respondents and nonrespondents.

Questionnaire Design

After developing the original questionnaire, we conducted individual cognitive interviews ($n = 10$) to identify and correct issues associated with wording, question comprehension, and skip patterns (Dillman et al., 2014). We used a pretest of 300 randomly selected (60 from each property strata) nonindustrial private landowners in North Carolina to further evaluate the questionnaire draft ($n = 26$ pretest respondents). In the final questionnaire, all respondents were asked whether their property was hunted by anyone during the previous year, including themselves (yes = 0, no = 1). Response to this question served as the dependent variable in the logistic regression model of whether or not a property was hunted. We also asked questions about the landowners' property: how long the property had been in their immediate or extended family (1 = < 5 years, 2 = 5–10 years, 3 = 11–-20 years, 4 = 21–30 years, 5 = > 30 years), if the property was used to earn income (yes = 1, no = 0), if they lived on the property (yes = 1, no = 0). The questionnaire included items assessing age, gender (male = 0, female = 1), highest level of formal education achieved (1 = < high school, 2 = high school or GED, 3 = vocational or trade school, 4 = associates degree, 5 = bachelor's degree, 6 = professional degree), if they ever lived on a farm, ranch, or rural property outside of a town or city before they turned 18 (yes = 1, no = 0), and annual household income before taxes (1 = < \$25,000; 2 = \$25,000–\$50,000; 3 = \$50,001–\$75,000; 4 = \$75,001–100,000; 5 = \$100,001–\$125,000; 6 = \$125,001–\$150,000; 7 = > \$150,000). We included ownership tenure in the models as a binary variable (0 = less than or equal to 30 years, 1 = more than 30 years), because the data distribution was binary with half of respondents (50%) owning property for more than 30 years, and the other half owning their property for much shorter duration. We also included education in the models as a binary variable (0 = less than college degree, 1 = college degree or higher) because a college degree was the most meaningful division within education level categories (Hayes, Peterson, Heinen-Kay, & Langerhans, 2015). Finally, annual household income was converted to a continuous variable (Dalrymple et al., 2012) in the models using the midpoint of a respondents' self-selected income category and reported in units of \$1,000 (e.g., respondents who selected the \$50,001–\$75,000 income bracket were coded as 62.5). Respondents who permitted hunting on their property were asked if they or family members hunted the property (yes = 1, no = 0). Similarly, we asked landowners who allowed hunting if they leased property hunting rights (yes = 1, no = 0), which game species were hunted (including a specific check box option for white-tailed deer coded as yes = 1, no = 0), and to estimate the total number of hunters who hunted their property during all hunting seasons in the most recent year (2014).

Data Analysis

Our analysis focused on two dependent variables: (1) whether a property was hunted in the previous year, and (2) hunter density (hunters/ha/year) for a property. Project collaborators at the North Carolina Wildlife Resources Commission indicated aggregate measures of hunting (i.e., all species, seasons, methods) were most valuable because collecting data in relation to multiple forms of hunting may be cost prohibitive in the future. Based on this feedback, we focused on aggregate measures but collected data to ensure the aggregate measures were applicable for the most important game species (e.g., white-tailed deer). For widespread species, the aggregate measure was adequate. For example, white-tailed deer were hunted on 95% of properties that allowed hunting of any kind; and properties where white-tailed deer hunting occurred were marginally smaller than properties where it did not occur (22.3 hectares with deer hunting, 25.9 hectares without). Our aggregate measures, however, would be least representative for wildlife species that require narrow landscape characteristics such as waterfowl, which are hunted over water, or northern bobwhite (*Colinus virginianus*) that require early successional vegetation. Because sampling was stratified, enough properties were hunted in the smallest property size strata (<0.40 ha) to facilitate accurate modeling.

We adopted an information theoretic approach to model selection because it is well suited for preliminary research attempting to maximize learning in contexts with many variables (Burnham & Anderson, 2003). We selected 15 independent variables to evaluate for inclusion in the model selection process for predicting whether a property was hunted. Eight of the independent variables (ownership tenure, if the property was used to earn income, if the landowner lived on the property, landowner attributes [i.e., gender, age, highest level of formal education achieved, rural/urban upbringing], and annual household income) were derived from survey data, and seven of the independent variables (distance to nearest city, property size, distance to nearest city × property size interaction, region, population density, housing density, and road density) were geographic attributes associated with each respondent's property. Housing and population data were obtained from the U.S. Census Bureau, and road network data were obtained from the North Carolina Department of Transportation. Population and housing densities were collinear (r = .98), so we removed population density from the model selection process. We defined cities as any municipality with 50,000 or more residents following U.S. Census Bureau conventions for "Urbanized Areas" (https://www.census.gov/geo/reference/urban-rural.html). We explored the interaction term between distance to nearest city and property size to see if properties of the same size were hunted at different rates across levels of urbanization. We detected no interaction effects ($p \geq .05$), so the interaction term was excluded from the model selection process. We used data transformations (i.e., log, cubic, quadratic) on the distance to nearest city variable to examine potential non-linear relationships. We evaluated the effect of each transformation on the dependent variable individually and included the variant with the lowest Akaike Information Criterion (AIC) value in the model selection process (Burnham & Anderson, 2004). We determined the log transformation to be the best fit for this variable because it normalized the effects of highly skewed data associated with many properties being relatively close to city boundaries and few properties being extremely rural (Figure 1). We created a region variable to explore the possibility of spatial non-stationarity, breaking North Carolina into coastal plain, piedmont, and mountain regions. We conducted ANOVA on the region variable for hunted property rates and hunter density but did not detect differences ($p \geq .05$) once we controlled for property size, so we removed this variable from the model selection process.

We adopted a two-step model selection process that accounted for potential scale effects: (1) selecting best fit spatial scales for landscape-level geographic variables, and (2) selecting optimal predictive models where all models being compared used the best fit geographic scales for landscape-level variables. We calculated density values for landscape-level geographic variables (i.e., housing density, road density) around each sample property, at five spatial scales (radii of 0.25, 0.50, 1.0, 2.0, and 5.0 km). To select the spatial scale at which the landscape-level geographic variables had the greatest predictive effect, we fit full logistic regression models that included all combinations of housing and road densities (five spatial scales for housing density × five spatial scales for road density = 25 model combinations) and chose the full model with the combination of housing and road density that had the lowest AIC score. This process allowed us to identify the scales for landscape-level geographic variables best supported by data (Altmoos & Henle, 2010; Piorecky & Prescott, 2006; Wang, Rahbek, & Fang, 2012).

After completing the first round of model selection used to select best fit geographic scales for housing and road density, we conducted another round of model selection to identify the optimal models for predicting whether a property was hunted and hunter density. We ran best-subsets logistic regression (King, 2003) on all possible combinations of variables, with the exception of interaction and transformation terms (unless explicitly stated above) and used AIC criteria to determine the optimal model. Any models within ▲AIC <2 were considered candidate models. Because the optimal model contained geographic variables, it was necessary to test for spatial autocorrelation on model residuals (Carl & Kuhn, 2007). We ran a Global Moran's I test in ArcGIS 10.2 (ESRI, Redlands, CA) on optimal model residuals to test for spatial autocorrelation, but it was not present ($p \geq .05$). We used the utility demand theory to determine the optimal probability cut-point for most accurately predicting whether a property was hunted (Hartley, Harris, & Lester, 2006).

The same two-step model selection process was used with zero-inflated Poisson linear regression to predict hunter density with the addition of two additional independent variables (if the landowner or their family hunted their property, and whether they leased their property hunting rights). Hunter density models included all hunters for all hunted species, across all hunting seasons, in a given year. We conducted ANOVA, with Tukey-Kramer multiple comparison correction, to determine if the percent of properties hunted and hunter density differed by property size strata. We analyzed data using JMP Pro 12 software (SAS Institute Inc., Cary, NC).

Results

Hunting occurred on less than half (42%) of all sample properties. Mean age of respondents was 62 years old and 67% were male. Over half (59%) of respondents had a college education (associates degree or higher), and the median annual household income was between $75,001 and $100,000. Sociodemographic attributes of nonindustrial private landowners in North Carolina (e.g., age, education, and household income) were similar to those reported in other studies conducted in the southeastern Unites States (Jarrett, Gan, Johnson, & Munn, 2009; Measells et al., 2005). Demographics of landowners in each strata of property size were similar, although owners of the smallest parcels had owned their land longer and were less likely to allow non-family members to hunt their property

Table 1. Descriptive statistics comparing non-industrial landowners that allowed and did not allow hunting.

	Property strata (hectares)									
	<0.40		0.41–2.02		2.03–4.05		4.06–8.1		> 8.10	
Variables										
Property hunted	yes	no	yes	no	yes	no	yes	no	yes	no
% properties allow non-family to hunt	50.00%	-	53.19%	-	59.09%	-	63.06%	-	73.64%	-
Gender (% female)	0.00%	39.70%	25.10%	39.80%	19.00%	33.80%	18.52%	39.40%	19.90%	46.00%
Average age (years)	60	64	59	61	60	64	58	67	63	68
Property used to earn income (% yes)	16.67%	7.04%	27.27%	10.75%	19.05%	2.75%	18.35%	13.40%	53.83%	34.34%
Ownership tenure (% > 30 years)	83.33%	25.00%	63.64%	28.83%	66.67%	42.47%	49.54%	45.13%	65.54%	54.84%
% rural upbringing	83.33%	37.50%	65.91%	53.43%	81.82%	63.01%	67.27%	60.31%	71.06%	63.03%

than were landowners in the larger property size strata (Table 1). Women, in general, were less apt to allow hunting on properties they owned or on which they were in charge of granting permission to hunt. Descriptive statistics broken down by property size strata for independent variables used in modeling whether a property was hunted and hunter density are located in Table 2.

Two candidate models emerged for the best fit spatial scale of using housing and road density to predict whether hunting occurred on a property. The best fit full model contained the combination of housing density at a 0.5-km (radius) spatial extent and road density at a 2-km (radius) spatial extent. The second best fit candidate model (▲AIC = 0.94) contained the combination of housing density at a 1-km (radius) spatial extent and road density at a 2-km (radius) spatial extent. Analyses used to determine the best fit spatial scale for housing and road density for predicting hunter density produced 25 candidate models. The best fit full model contained the combination of housing density at a 0.25-km (radius) spatial extent and road density at a 0.5-km (radius) spatial extent.

Table 2. Descriptive statistics for variables used in predicting whether a property was hunted and hunter density on non-industrial properties.

		Property strata (hectares)									
		< 0.40		0.41–2.02		2.03–4.05		4.06–8.1		> 8.10	
Variable[a]	Description	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Property size	Hectares	0.2	0.1	0.8	0.4	2.8	0.6	5.6	1.2	23.7	24.6
Age	In years	60.4	12.4	58.7	12.2	61.4	12.6	62.4	12.3	65.5	12.7
		Proportion of positive responses[b]									
Gender	Male = 0, Female = 1	0.37		0.37		0.32		0.29		0.32	
Property used to earn income	No = 0, Yes = 1	0.02		0.09		0.17		0.38		0.56	
Ownership tenure	0 = < 30 years, 1 = > 30 years	0.69		0.63		0.52		0.49		0.28	
Rural upbringing	No = 0, Yes = 1	0.45		0.39		0.36		0.33		0.27	
Landowner or family hunts the property [c]	No = 0, Yes = 1	0.06		0.15		0.34		0.40		0.54	
Landowner leases property hunting rights [c]	No = 0, Yes = 1	0.00		0.00		0.01		0.02		0.11	

[a] Two variables (housing and road density) were excluded from this table because their values did not change by property strata.
[b] We do not report standard deviation for binary dummy variables where it lacks an informative interpretation.
[c] Independent variables used as predictors only for hunter density models.

Table 3. Candidate models for predicting whether a property was hunted and hunter density on non-industrial properties.

Hunting occurrence models	No. parameters	-Log likelihood	AIC	▲ AIC	Akaike wts.
Null model	intercept	1036.05	-	-	-
Model 1: Property size, Gender, Ownership tenure, Age, Property used to earn income, Housing density, Road density	8	830.03	1679.05	-	0.35
Model 2: Model 1 + Distance to nearest city	9	829.55	1679.25	0.20	0.32
Model 3: Model 2 + Income	10	829.04	1680.25	1.20	0.19
Model 4: Model 3 + Education	11	828.95	1681.01	1.96	0.13
Hunter Density Models	**No. parameters**	**T ratios**	**AIC**	**▲ AIC**	**Akaike wts.**
Null model	intercept	3.67	-	-	-
Model 1: Landowner or family hunts property, Property size, Ownership tenure	3	−9.89, −5.42,−2.49	9097.67	-	0.44
Model 2: Model 1 + Landowner leases property hunting rights	4	−1.21	9098.08	0.41	0.36
Model 3: Model 2 + Property used to earn income	5	−0.94	9099.14	1.47	0.21

Table 4. Optimal models for predicting whether a property was hunted and hunter density on non-industrial properties.

Hunting occurrence model[a]	B	SE	Odds ratio	Standardized odds ratio
Intercept	1.23**	0.34	-	-
Property size (ha)	0.06**	0.01	1.06	2.64
Gender [male]	0.65**	0.07	3.67	1.84
Ownership tenure [> 30 years]	0.41**	0.06	2.27	1.50
Property used to earn income [yes]	0.30**	0.07	1.83	1.31
Age	−0.02**	0.01	0.97	0.73
Housing density (0.5 km)	−0.006*	0.00	0.99	0.77
Road density (2 km)	−0.01**	0.01	0.98	0.80
Rural/Urban upbringing [rural]	0.17**	0.07	1.42	1.18
Hunter density model[b]	**B**	**SE**	***B***	
Intercept	2.91**	0.87	0.12**	
Landowner or family hunts their property [yes]	−3.49**	0.26	−0.31**	
Property size (ha)	−0.24**	0.03	−0.14**	
Ownership tenure [> 30 years]	−0.52*	0.16	−0.08*	

[a] Hunting occurrence model: n = 1,521, McFadden's R^2 = 0.20, percent correct = 96%.
[b] Hunter density model: n = 1,488, Generalized R^2 = 0.92.
$^{**}p \leq .01$, $^{*}p \leq .05$

Best-subsets logistic regression analysis for predicting whether a property was hunted produced four candidate models (Table 3). The optimal model correctly predicted whether a property was hunted 96% of the time (Table 4). In this model, odds that hunting occurred on a property increased with property size (B = 0.06, SE = 0.01), male landownership (B = 0.65, SE = 0.07), landowners having a rural upbringing (B = 0.17, SE = 0.07), properties used to earn income (B = 0.30, SE = 0.07), and properties being owned >30 years (B = 0.41, SE = 0.07; Table 4). Conversely, odds of a property being hunted decreased as landowner age (B = −0.02, SE = 0.01), housing density (B = −0.006, SE = 0.00), and road density (B = −0.01, SE = 0.01) increased (Table 4). In terms of relative importance, property size was the strongest predictor of whether a property was hunted (Standardized odds ratio [SOR] = 2.64), followed by landowner's gender (SOR = 1.84) and

Table 5. Percentage of properties hunted and mean hunter density on non-industrial sample properties.

Property size (hectares)	Percent hunted (sig. letter)	Mean hunter density (sig. letter)	Hunter density *SE*	*n*
<0.40	10% (A)	0.93 (A)	0.12	284
0.41–2.02	19% (A)	0.65 (AB)	0.12	302
2.03–4.05	38% (B)	0.42 (BC)	0.10	385
4.06–8.10	51% (C)	0.33 (BC)	0.10	411
>8.10	70% (D)	0.19 (C)	0.10	461

Note. Values not sharing a sig. letter were significantly different ($p \leq .05$) based on Tukey post hoc tests with Kramer multiple comparison corrections.

ownership tenure (SOR = 1.50; Table 4). Only 10% of properties smaller than 0.40 hectares were hunted, increasing up to 70% hunted for properties larger than 8.10 hectares (Table 5). The odds of hunting occurring on property owned by men were nearly double the odds of hunting occurring on property owned by women (Table 4). The odds of hunting occurring on a property increased by 1.42 times if a landowner had a rural upbringing (Table 4). The odds of a 65-year-old landowner allowing hunting on their property were 0.97 times the odds for that of a 64-year-old landowner (i.e., one year difference in age; Table 4).

Zero-inflated Poisson linear regression analyses for predicting hunter density produced three candidate models (Table 3). In the optimal model, hunter density was negatively related to property size ($B = -0.24$, $SE = 0.03$), ownership tenure ($B = -0.52$, $SE = 0.16$), and if the landowner and/or their family members hunted the property ($B = -3.49$, $SE = 0.26$; Table 4). In terms of relative importance, a landowner and/or their family members hunting their property was the strongest predictor of hunter density (standardized coefficient [SC] = −0.31), followed by property size (SC = −0.14) and ownership tenure (SC = −0.08; Table 4). If all other variables were held constant, hunter density was 3.49 hunters per hectare lower when a landowner or any of their family members hunted their property (Table 4). Similarly, all other variables held constant, hunter density was 0.52 hunters per hectare lower on properties owned >30 years (Table 4). Hunter density decreased with increasing property size (Table 5).

Discussion

This article builds on research exploring how small properties may shape the role of hunting as a wildlife management tool at the exurban-suburban interface. Collectively, thousands of two hectare or smaller parcels in North Carolina likely constituted over 100,000 hectares of land being hunted. The large number of parcels compensated for the relatively low proportion where hunting was allowed. Hunting access on these small parcels, however, may be skewed toward family members because only half of landowners with properties <0.4 hectares provided non-family hunters access compared to almost three quarters of landowners with parcels >8.1 hectares. Agencies may need to consider safety issues associated with hunting occurring on thousands of private land parcels <0.4 hectares, particularly when someone lives on the parcels. Even after accounting for the low percent of small properties where hunting was allowed, hunter density was greatest on extremely small parcels. Lovely et al. (2013) suggested that white-tailed deer harvest density was greatest on 2.0–4.0 hectare property sizes despite less than 30% of land in that size class being hunted. These results can be explained in part by the rapid growth in the number of small properties associated with urbanizing areas creating a situation with more hunters per unit area on the landscape, despite the lower percentage of hunted properties. To illustrate this point, we present a theoretical example of aggregate hunting (all species and all methods) on two 5-km^2 areas (5 km^2 = 500 hectares), one in a rural area where properties tend to be larger (e.g., >8.1 hectare range) and one at the exurban-suburban interface where properties tend to be smaller (e.g., 0.41–2.02 hectare range). Using a mean property size of 20 hectares for the rural area and 1.25 hectares for the exurban-suburban area, and the percentage hunted by property strata from our results, 76 properties in the exurban-suburban area would be hunted versus 18 properties in the rural area. As white-tailed deer hunting occurred on 95% of properties, and was independent of property size, this translates to deer hunting on 74 exurban-suburban properties versus 18 properties in the rural area. Similarly, using hunter density by property strata from our results, 325 hunters would be allowed to hunt the exurban-suburban landscape in a -given year, whereas 95 hunters would be allowed to hunt the equal sized rural landscape. This translates to 315 white-tailed deer hunters in the exurban-suburban landscape and 92 in the equal sized rural landscape. Although hunter density was almost four times greater on the smallest properties than the largest, we note that hunter density may not be a good predictor of hunter efficiency or hunting pressure unless other factors are considered (Harden et al., 2005). Hunter skills and tactics, movement behavior and vigilance of hunted species, safety zones, and extent and distribution of refuges for hunted species may shape hunting pressure and hunter success. Further, even on very large (>400 hectare) properties, land management priorities shape access decisions with land owners managing for timber being more likely to allow hunting than landowners who managed for recreation or nature conservation (Daigle, Utley, Chase, Kuentzel, & Brown, 2012). Our findings suggest that hunting may persist in urbanizing regions but with relatively high numbers of hunters sharing access to small private land parcels. Future research is needed to unravel how this trend combined with large numbers of de facto refuges mixed among the many small parcels may influence the efficacy of hunting as a wildlife management tool in urbanizing areas.

Results from this article contributed to the body of research on hunter access issues by demonstrating that landscape-level geographic variables can affect hunter access, but not necessarily hunter density. Multiple explanations (e.g., geometry or cognitive tricks that skew risk perception) for these results are possible and could be tested with future research. First, landowner risk perception (e.g., safety concerns for family or neighbors) associated with housing and road density around their property may shape their decision-making about whether to allow hunting on their land, but not how many hunters they allow per hectare – once they ultimately decide to allow hunting. This seems reasonable because landowners who choose to allow hunting may have low risk perceptions of hunting as a practice (Stout, Stedman, Decker, & Knuth, 1993), and thus do not perceive significant, added risks associated with greater hunter density on their land. Second, the aforementioned geometry associated with fragmentation of large properties into many smaller parcels may promote more hunters per unit area on the landscape and do so without individual landowners being aware of the trend.

Ongoing gender role changes in land ownership and management present unique challenges to the future of hunting as a wildlife management tool, because the odds of women permitting hunting on their land were much lower compared to men. Hunting may occur less often on properties with female decision-makers because they have fewer hunters in their social networks than men, tend to hold more humanistic and moralistic attitudes toward wildlife than do men, and are generally less supportive of hunting than are men (Gamborg & Jensen, 2017; Kellert & Berry, 1987; Walker, McGrath, Nilsson, Waran, & Phillips, 2014). Irrespective of the mechanisms involved in the gender gap in permitting hunting, the ultimate outcome may impact future use of hunting as a wildlife management tool. Women in the United States are entering the workforce at greater rates, outpacing men in terms of education (U.S. Bureau of Labor Statistics, 2017), delaying marriage (U.S. Census Bureau, American Community Survey, 1890–2010; https://www.census.gov/programs-surveys/acs/), and are more likely than men to acquire land through inheritance (Eells, 2010; Effland, Rogers, & Grim, 1993); suggesting women will constitute a larger percentage of sole property owners and property decision-makers in the future. Further, the trend in transformation of gender roles makes it likely that women will have greater influence over household decision-making in the future (Bianchi, Robinson, & Milke, 2006; Spain & Bianchi, 1996), even for properties with shared ownership.

The other property attributes and landowner demographics used to predict whether a property was hunted largely were consistent with the results of previous studies (Jagnow et al., 2006; Wright et al., 1988). Property size was the strongest predictor of whether a property was hunted, which can be explained by economy of scale (Hanson, 1964). In this context, we employed economic theory to posit that a landowner's cost per unit area associated with allowing hunting decreased as property size increased. Benefits reported by landowners who allow hunting (e.g., money generated by leases, reduced wildlife damage) typically increase on larger properties (Storm et al., 2007; Zhang et al., 2006). Conversely, many costs (e.g., time devoted to managing hunters, concern about property damage or theft) do not decrease linearly with property size (Jagnow et al., 2006; Zhang et al., 2006). Ownership tenure was a strong predictor of whether a property was hunted, suggesting high turnover rates of land ownership associated with urbanization and increasing property values may contribute to lower levels of hunter access on private land in the future (Clawson, 2013). Jagnow et al. (2006) suggested that shorter ownership tenure correlates with decreased hunter access. Underlying causes of this correlation may include less knowledge of landowner liability rights and local wildlife population levels, and a relative unfamiliarity with social and cultural norms of their neighbors. Although rural residents are more likely to hunt themselves, or at least support hunting (Ryan & Shaw, 2011; Stedman & Herberlein, 2001), our analysis indicates that suburban and rural property location was relatively unimportant in terms of whether a property was hunted. Low-cost transportation options for hunters and the likelihood that many hunters will hunt wherever they can gain access may explain why distance from urban areas was relatively unimportant. Alternatively, rapid urban sprawl in North Carolina (Ewing et al., 2011; Peterson et al., 2012) may have outpaced cultural change, rendering new urban areas culturally rural and thus reducing impacts of urban proximity on whether a property was hunted. However, rural upbringing of a landowner was an important predictor of whether their current property was hunted, suggesting that the influence of a rural background persists despite factors including geographic mobility potentially making the current location of a property owner less important than it may have been in the past (Ryan & Shaw, 2011).

The exclusionary theory outlined by Wright et al. (1988) may explain why there were fewer hunters per unit area when the landowner or their family members hunted. This theory submits that landowners who hunt may choose to keep the natural resources on their property for their own enjoyment, and may have purchased the property for that express purpose. Also, hunter density was lower on properties with longer ownership tenure, which lends credence to the assertion that landowners may selectively exclude hunters after a single negative experience (Jagnow et al., 2006). Logically, the probability of having a negative interaction with an irresponsible hunter increases the longer a property has been owned. The positive relationship between whether a property was hunted and ownership tenure may persist despite having fewer hunters per unit area if small numbers of trusted hunters are allowed to continue hunting even when other hunters are excluded.

Conclusions

Wildlife managers hoping to promote hunting on private land should frame advocacy programs for hunter access in ways that will engage and appeal to female landowners (Grunig, Toth, & Childers-Hon, 2000), because they are less likely to permit hunting on their property but are poised to make more land-use decisions (Bianchi et al., 2006; Spain & Bianchi, 1996). Where parcelization is inevitable, greater densities of hunters with access to smaller properties coupled with the greater total number of smaller properties hunted may compensate, to some degree, for the low percentage of smaller properties that are actually hunted. Future research could determine if this would enable hunting to persist as a management option in urbanizing areas. Our models only addressed hunting in aggregate, for all hunted species, and a logical next step would be developing species-specific models. For such models, adding a land-use/cover variable may be important because land cover is strongly related to some types of hunting and differs by species pursued (e.g., upland game birds, waterfowl). Future research may evaluate the relative importance of proximity to public land as a driver of hunting access on private land.

Many wildlife management agencies combine harvest data with estimates of the amount of land where hunting is legal to create indices of hunted species density (Downing, 1980). Such estimates, however, will violate underlying assumptions of indices until land where hunting is not allowed by landowners is accounted for. This study provides empirical evidence that geographic variables, including property size and housing and road density, may play an important role in predicting whether a property is hunted; highlighting the value in quantifying and mapping huntable land using spatial-predictive modeling. These data would facilitate the development of improved indices of hunted species density by providing a more rigorous denominator of land that is huntable.

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