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Socio-Political and Ecological Dimensions of Municipal Wildlife Management

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ABSTRACT

In urban and suburban areas, the complex socio-environmental landscapes and diverging interests of stakeholders make wildlife management difficult. We analyze how municipalities in Massachusetts make decisions about the management of white-tailed deer (*Odocoileus virginianus*). Combining statistical analyses of a survey of municipal officials, qualitative analysis of management documents, and semi-structured interviews, we investigate (i) the socio-environmental conditions linked to municipal concerns about deer, (ii) the concerns that prompt municipalities to explore deer management actions, and (iii) why some municipalities take management action while others do not. We find that landscape features, Lyme disease incidence, and an array of concerns about deer prompt municipal governments to explore options for deer management. We show that management champions and small-scale politics are crucial in translating concern to management action. Our study illustrates the complexity of wildlife decision-making in sub/urban environments where the movement of wild animals intersects with patterns of development and politics.

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Introduction

Urban and suburban expansion is widely recognized as a driver of habitat loss (McDonald, Kareiva, and Forman 2008; Elmqvist, Zipperer, and Güneralp 2016), but sub/urban¹ landscapes also support myriad species, often in densities exceeding those in other ecosystems (DeStefano and DeGraaf 2003). Across North America, populations of species—such as turkeys, geese, coyotes, and white-tailed deer—are increasing in sub/urban settings. As these populations have grown, so have an array of concerns spanning human health and safety, property damage, animal welfare, and ecosystem health (Rooney and Waller 2003; Koons, Rockwell, and Aubry 2014; McCance et al. 2017; Gibb et al. 2020). The complex biophysical, institutional, and social arrangements in

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sub/urban areas, however, can greatly constrain recreational hunting and culling, which are the conventional tools for managing wildlife in more rural areas (DeStefano and DeGraaf 2003). In sub/urban areas, access to land for these activities is greatly limited, local regulations may directly or indirectly restrict hunting, and acceptance of lethal management strategies tends to be lower than in more rural settings (DeStefano and DeGraaf 2003; Manfredo et al. 2020; Edelblutte, Short Gianotti, and Connors 2022).

Given the constraints on private land access (due to parcel size and density of buildings) and common restrictions on hunting on public lands, sub/urban wildlife management necessitates development of management plans and programs through coordination of municipal governments and wildlife agencies (Curtis 2020; Edelblutte, Short Gianotti, and Connors 2022). This often involves community engagement and sometimes public approval of management (Curtis 2020). In this context, both public perceptions and acceptance of wildlife and the decision-making processes themselves can shape management responses. Although extensive research has explored public acceptance of wildlife, including urban wildlife (Riley and Decker 2000; Bruskotter and Wilson 2014; Inskip et al. 2016; Struebig et al. 2018), limited research has addressed how these acceptance levels “aggregate” within communities (Gigliotti, Decker, and Carpenter 2000) or become salient at municipal levels (c.f. Cash et al. 2003). Addressing this gap is important as management decisions are not strictly reflections of majority views of wildlife concerns. Rather, wildlife management is also an outcome of processes shaped by political power and public trust (Nie 2004; Lute and Gore 2014; Manfredo et al. 2017; Fuller et al. 2020).

In this paper, we attend to the emerging challenges of sub/urban wildlife management by examining how wildlife come to be a concern for municipal governments and how they become subjects of management or not. We seek to situate wildlife acceptance in its broader social and environmental context through an exploration of municipal responses to white-tailed deer (*Odocoileus virginianus*) in Massachusetts (MA), US. We combine qualitative analyses of policy documents, meeting records, and semi-structured interviews with statistical analyses of municipal survey responses to explore the following research questions: (i) What socio-environmental conditions are associated with municipal concerns about deer? (ii) What concerns and conditions prompt municipalities to explore local deer management? and (iii) Why do some municipalities with deer concerns take management action while others do not? Using a mixed-methods approach, we show how environmental and social factors intersect to shape municipal concerns about deer, but also demonstrate that management decisions are more than functional responses to changing environmental conditions. Our findings demonstrate that decision-making about sub/urban wildlife occurs in the context of localized political processes and involves contestations among diverse interests and amidst changing science.

Wildlife Management and Conflict in Sub/Urban Areas

Wildlife management agencies in the US have historically focused on activities in rural settings, but these agencies now commonly undertake management of “overabundant” or “pest” species in sub/urban communities (McShea, Underwood, and Rappole 1997;

DeStefano and DeGraaf 2003; Patterson, Montag, and Williams 2003) where the availability of resources (water, food, and shelter) can support large populations of some species (Gaughan and Destefano 2005; McCance et al. 2015). As sub/urban populations of some species grow, human-wildlife encounters and conflict increase leading many communities to explore or undertake strategies of population management. Yet, the traditional management approach of recreational hunting faces unique challenges in this sub/urban context. In particular, lands for hunting are often limited in sub/urban landscapes due to the greater density of structures, smaller parcels, and less public land (Westerfield et al. 2019). In addition, municipal bylaws may restrict hunting directly or indirectly (through restrictions on land access or firearms use) (Edelblutte, Short Gianotti, and Connors 2022). The process of sub/urban wildlife management, thus, commonly involves changes in municipal policies and negotiations among residents with diverse views of hunting that have been shaped by personal experiences, cultural meanings, and emotions (Manfredo et al. 2017; McCance et al. 2017; Stinchcomb, Ma, and Nyssa 2022).

In the case of white-tailed deer, high densities (upwards of 20-30 deer/km²) are common in sub/urban areas and, in some extreme cases, have been documented to reach over 70 deer/km² (Urbanek et al. 2012). High deer populations raise concerns about impacts on biodiversity and the health of forested ecosystems, deer-vehicle collisions, landscaping and crop damage, and the possible role of deer in the spread of Lyme disease² (Conover 1995; McShea 2012; Curtis 2020). In this context, decision-makers must determine what they believe to be acceptable population levels and management actions.

Within the human dimensions of wildlife literature, scholars describe these acceptable or tolerable populations sizes in terms of “wildlife acceptance capacity” (WAC) or “cultural carrying capacity” (Decker and Purdy 1988; Riley and Decker 2000; Bruskotter and Wilson 2014; Inskip et al. 2016; Struebig et al. 2018). Scholarship in this area has demonstrated how WAC varies across space and time as well as among stakeholder groups (Decker, Jacobson, and Brown 2006; Morzillo and Needham 2015). Individuals who have experienced deer-related problems (e.g., deer-vehicle collisions, damage to landscaping, Lyme disease) tend to have lower tolerance of deer populations and higher acceptance of lethal management strategies than those without such experiences (West and Parkhurst 2002; Siemer et al. 2004). Definitions of what actually constitutes deer-related “problems” reflect individual values and preferences (Decker and Gavin 1987; Siemer et al. 2004; Stewart 2011) and the acceptance of specific management strategies (e.g., sharpshooting, contraception, sterilization, trapping and relocating, and trapping and killing) differs by gender (Lauber, Anthony, and Knuth 2001), existing attitudes toward hunting (Kilpatrick, Labonte, and Barclay 2007; Stewart 2011), and perceived feasibility and effectiveness of management options (Messmer et al. 1997; Siemer et al. 2004). Theories of WAC generally presume an upper limit to the tolerable population size of a species (Minnis and Peyton 1995), but tolerances may vary greatly among the human community, and management decisions do not necessarily correspond directly to overall levels of concern (Decker, Raik, and Siemer 2004; Triezenberg, Knuth, and Yuan 2011; Edelblutte, Short Gianotti, and Connors 2022).

While WAC may help to describe individual or community tolerance of wildlife, sub/urban wildlife management is an outcome of political processes that are shaped by

power relations, values, trust, and cultural norms (Manfredo et al. 2017; Sullivan 2021; Stinchcomb, Ma, and Nyssa 2022; Sullivan, Manfredo, and Teel 2022). The process for making management decisions can vary considerably in the level of public input and engagement (Jacobson et al. 2010; Decker et al. 2016), and community members may differ in their level of influence (Connors and Short Gianotti 2021) and attitudes toward hunting (e.g., Bruskotter et al. 2019). A growing body of research has examined “good governance” in wildlife management, noting the importance (and challenges of) of engaging diverse publics through decision-making processes that are responsive to public concerns, inclusive of diverse perspectives, informed by expert judgment, transparent, and adaptive (see, for example, Decker et al. 2016; Pomeranz et al. 2021). While these principles are important, neglect of the underlying power and political dynamics can contribute to the failure of conservation and wildlife management policies (Pooley et al. 2017; Sullivan 2021), threatening the perceived legitimacy of existing conservation and wildlife management agencies (Jacobson et al. 2010; Lute and Gore 2014).

In this study, we give attention to municipalities as key sites of wildlife politics and management, shifting attention away from state agencies as core decision-makers. Although state agencies hold legal responsibility for wildlife management, municipalities and large landowners have become *de facto* managers in many sub/urban landscapes (Edelblutte, Short Gianotti, and Connors 2022). While taking seriously the ways that human encounters with wildlife shape WAC, we also consider that WAC alone does not explain why some municipalities undertake efforts to reduce wildlife numbers and others do not. Here, we give attention to the concerns, processes, and social dynamics that lead deer to be recognized as a salient problem for municipal officials and residents and hunting to be seen as a solution.

Study Area and Methods

Study Area

Our research focuses on municipal deer management in MA. Like many states across the Northeastern US, white-tailed deer populations have grown in MA over the past few decades, particularly in the eastern, more sub/urban portions of the state where deer densities are estimated to range from 11-19 deer per km² (well over the MassWildlife target range of 4-7 deer per km²; Massachusetts Division of Fisheries and Wildlife (MassWildlife) 2023). Eastern MA is characterized by a mosaic of fragmented forest and suburban residential areas surrounding Boston and other smaller cities. Compared to central and western MA, communities in eastern MA tend to have higher median incomes, higher property values, and a younger population.

High deer populations in eastern MA have raised concerns among wildlife managers as well as some town officials and residents about their impacts on forested ecosystems, damage to residential landscaping, deer-vehicle collisions, and their role in the spread of Lyme disease (Edelblutte, Short Gianotti, and Connors 2022). While MassWildlife holds legal authority to manage wildlife in MA, sub/urban municipalities hold *de facto* authority over hunting through local regulations on firearms, archery use, and land access. This has generated a highly variable landscape of wildlife management with neighboring towns making different decisions about deer management (Edelblutte,

Short Gianotti, and Connors 2022). As deer populations have grown, several sub/urban municipalities have considered and/or implemented local actions to manage growing deer populations by increasing opportunities for recreational hunting. These local management actions include eliminating bylaws that restrict hunting beyond state regulations, opening up public properties to hunting, and/or coordinating with private property owners to expand hunting access on private land.

Methods

We conducted a nested, mixed-method study of municipal-level concerns about and actions to manage deer in MA.³ The study included (1) a state-wide statistical analysis to test the relationships of socio-environmental factors survey responses about municipal level deer concerns and management, (2) a document analysis of deer management plans, meeting minutes, and local media coverage of deer management discussions in 24 sub/urban municipalities to identify the concerns that trigger discussions about deer management and justify deer management actions, and (3) semi-structured interviews with key individuals involved in deliberations over deer management in three neighboring municipalities to explore how and why discussions about deer management have unfolded differently in similar communities.

State-Wide Statistical Analysis of Deer Concern, Actions to Manage Deer, and Socio-Environment Variables

We conducted two logistic regressions to identify relationships between municipal concerns about deer, local deer management action, and a variety of socio-environmental variables. The dependent variables were (a) municipal concern about deer (Model 1) and (b) municipal action to manage deer (Model 2). Data for the dependent variables were collected through a survey administered to municipal officials in all 351 towns and cities across MA in 2017 ($n = 260$; response rate: 74%). The survey was distributed by email to municipal officials with knowledge about deer in their community using a modified Tailored Design Method (see Edelblutte, Short Gianotti, and Connors 2022 for full description of survey methods and results). In the survey, we asked respondents to indicate (1) if deer were a concern in their community and (2) if the municipality had engaged in conversations about or implemented actions to manage deer in their municipality. Based on these responses and additional data on municipal bylaws compiled in 2020, we classified municipalities in three groups: (i) municipalities reporting no concerns about deer and no deer management actions ($n = 71$), (ii) municipalities with concern about deer and no deer management action ($n = 106$), and (iii) municipalities with both concern and action ($n = 23$; Figure 1).

The independent variables included 12 socio-economic, health and safety, and landscape and ecological variables likely to be linked to high deer populations and human-deer interactions (Table 1). To select the independent variables, we first compiled data on 42 candidate variables identified through a literature review (Appendix). We ran Kruskal–Wallis tests for continuous variables and Chi-square tests for categorical variables to test for statistically significant differences across the three groups of municipalities (no concerns/no action, concern/no action, concern/action). We included the 12

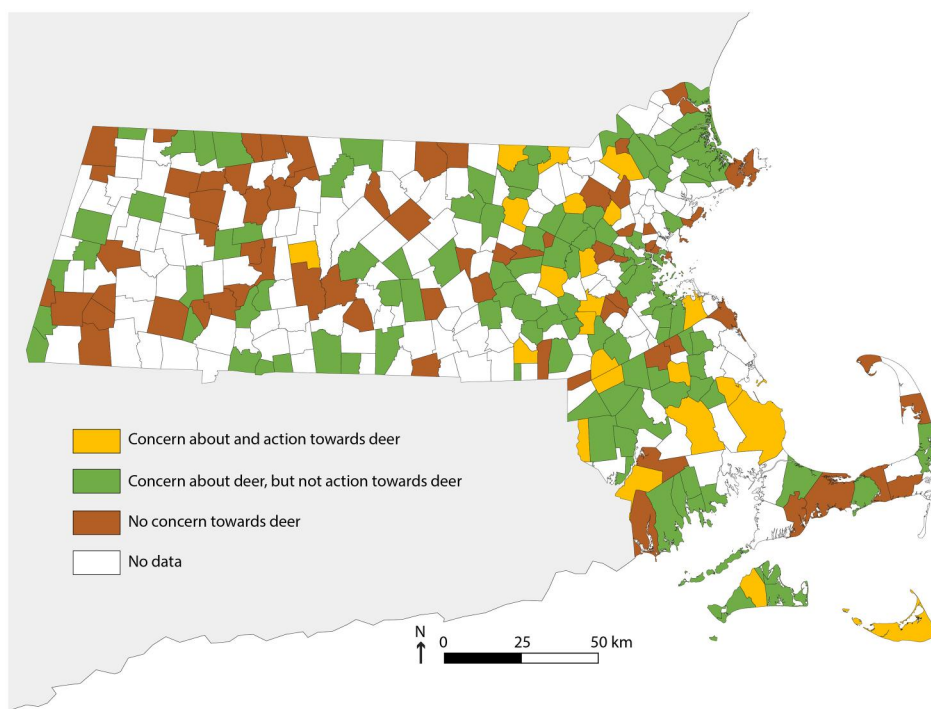


Figure 1. Municipalities in Massachusetts categorized by their concern about and actions toward deer, per responses from 2017 municipal survey.

variables that were significantly different among the groups of municipalities as the independent variables in our regression models.

We then conducted two logistic regressions to identify the relationships among the 12 environmental and socioeconomic variables and our dependent variables: municipal concern about deer (Model 1) and municipal action toward deer (Model 2). We reduced the number of variables using a backward stepwise regression. We checked for multicollinearity using Variable Inflation Factors (VIF) method and assessed model performance by plotting the binned residuals, computing the area under the curve (AUC), and examining the pseudo R^2 .

Document Analysis of Deer Management Plans and Related Documents in 24 Towns

To identify the issues discussed in public deliberations about deer and the formal motivations documented in deer management plans, we conducted a document analysis of deer management plans, meeting minutes, and local newspaper coverage in 24 MA towns that considered or implemented a deer management program between 1998 and 2020. The sample includes municipalities that considered, implemented, and/or consulted with other communities about deer management (as indicated in responses to the 2017 municipal survey and an initial review of related documents of 51 candidate towns). For each of these towns, municipal websites were searched using the terms “deer” and “hunt” (and variations thereof) and materials discussing deer management were collected. In addition, local newspaper articles that discussed municipal deer

Table 1. Municipal characteristics that showed significant differences among three groups of municipalities with associated *p*-value, effect size, and results of the *post hoc* test.

		<i>p</i> -Value	Effect size	Significant difference between:
Socioeconomic status and demographic aspects	Median household income	<0.001	Moderate	Each group
	Median property value	<0.001	Small	Each group
	Median age of population	<0.001	Small	Municipalities with no concern and municipalities with concern/no action
Landscape structure	Proportion of developed open space	<0.001	Small	Municipalities with no concern and the two other groups
	Average forest edge density	<0.001	Moderate	Municipalities with no concern and the two other groups
	Average forest patch density	<0.001	Moderate	Municipalities with no concern and the two other groups
	Average forest contiguity index	0.02	Small	Municipalities with no concern and the two other groups
	Average residential patch density	<0.001	Small	Municipalities with no concern and the two other groups
	Wildland-urban intermix	0.02	Small	Municipalities with no concern and municipalities with concern/no action
	Proportion of municipal open space	0.02	Small	municipalities with no concern and municipalities with concern and action
Human health & safety	Total number of deer-vehicle collision	<0.001	Moderate	Each group
	Lyme disease incidence	<0.001	Moderate	Municipalities with no concern and the two other groups

management were collected for timeframes overlapping with municipal deliberations about deer management (which ranged from 1998 to 2020). In both these searches, we excluded duplicate documents and documents that referred to either deer or hunting out of the context of deer management. In total 202 documents were collected. All documents were coded according to thematic and content codes based both on preexisting and emergent themes. For this analysis, we focused on statements related to (1) the “impetus” for discussions about deer management (i.e., the deer-related issues or concerns discussed when a municipality began to consider deer management actions) and (2) the final “rationale(s)” included in deer management plans as the justification or motivation for local deer action and/or the reasons documented when municipalities decided not to adopt deer management actions.

Semi-Structured Interviews in Three Neighboring Towns with Different Deer Management Histories

In 2021 and 2022, we conducted 23 in-depth interviews with individuals engaged in deliberations and debates about deer management in three neighboring municipalities: Carlisle, Lincoln, and Weston. These three towns share similar socio-economic and landscape characteristics, have local bylaws that restrict the use of firearms and archery to varying degrees, and indicated local concerns about deer in the 2017 municipal survey; yet they have different histories of deer management. Lincoln has held periodic town meetings to explore deer management since the early 2000s but has not implemented a management program. Carlisle initiated discussions about deer management in 2015, had pilot bow hunts on municipal properties in 2018 and 2019, and suspended the hunts in 2020

following resident opposition. Weston initiated discussions about deer management in 2011. Following some initial controversy, they opened town lands to hunting in 2012 and have continuously run a deer management program that involves bow hunting on public properties and landowner outreach to facilitate hunting on private lands. These towns provide an opportunity to explore how and why discussions about deer management unfold differently despite similar socio-economic and biophysical characteristics.

Interview respondents included thirteen current or former municipal officials (including paid staff, elected officials, and appointed committee members; ten from Carlisle, three from Weston, one from Lincoln⁴), seven town residents active in public deliberations (all from Carlisle), one staff person at a land trust that works in all three towns, and two state agency employees who have participated in discussions about deer management in these towns. Across these categories respondents include those who support deer management as well as those who oppose deer management. We identified participants through purposive and snowball sampling, and some respondents reached out to us after learning about our research project in town meetings or local newspapers.

During the interviews, we inquired about the ways discussions about deer started and unfolded. We used open-ended questions to elicit responses about who engaged in discussions, what concerns were expressed and by whom, and what decisions were made for what reasons. Our goal was to unravel the processes, conditions, and relationships that shaped decision-making. All interviews were transcribed and coded using *a priori* defined themes and themes that emerged during the analysis.

Results

Our research reveals how a mix of socio-environmental conditions and processes shape suburban deer management in MA. As we detail below, each method provides a unique entry point for understanding the formation of and response to concerns about deer. The statistical analysis identifies several environmental and socio-economic variables related to concerns about deer and the implementation of municipal actions to manage deer management across MA. The document analysis shows the evolving importance of Lyme disease and forest health as the concerns motivating initial explorations of municipal deer management and the formal rationale for deer management plans. The interviews provide additional context to understand the social and political relationships and additional motivations that underlie municipal deliberations about deer management. In the sections that follow, we report on findings from each of these methods in relation to our research questions.

What Socio-Environmental Conditions Are Associated with Municipal Concerns About Deer?

Statistical Analysis

We find that municipal concerns about deer are related to spatial patterns of forests, Lyme disease incidence, and resident age. After conducting a stepwise selection of the 12 independent variables, Model 1 included four significant independent variables (Table 2). This model demonstrates increasing probability of deer concerns in locations

Table 2. Results of the two logistic regressions (A) with the binary outcome concern/no concern, and (B) action/no action.

A. Binary outcome: concern/no concern				
	Coefficients	Estimate Std. error	Z value	Pr(> z)
Intercept	−0.98321	2.22036	−0.443	0.65790
Age	−0.10397	0.03383	3.073	0.00212**
Forest patch density	0.12150	0.04287	2.834	0.00460**
Forest contiguity index	17.51431	7.16245	2.445	0.01447*
Lyme disease incidence	0.55685	0.23328	2.389	0.01698*
B. Binary outcome: action/no action				
	Coefficients	Estimate Std. error	Z value	Pr(> z)
Intercept	−30.25849	9.709311	−3.204	0.00135**
Housing value	1.765241	0.667674	2.644	0.00820**
Forest contiguity index	19.895859	12.063611	1.649	0.09910
Deer–vehicle collisions	0.018430	0.005431	3.393	0.00069***

* Indicates statistical significance at the 0.05 level, ** Indicates statistical significance at the 0.01 level, *** Indicates statistical significance at the 0.001 level.

with increasing forest patch density, forest contiguity, and Lyme disease incidence. Municipalities with fragmented but densely concentrated forest patches (patch density) with more compact shapes (contiguity) were more likely to express concerns about deer. Further, a one percent increase in Lyme disease incidence was associated with a 75% increase in the probability of concern. The median age of population had a negative effect on municipal concern. When plotting the binned residual, 92% of the observations fell within the confidence interval, indicating a good quality of fit. The model had a mean AUC of 0.7, suggesting the performance of the classification model is acceptable, and a pseudo R^2 of 0.19, which indicates a good model fit.⁵

What Concerns and Conditions Prompt Municipalities to Explore Local Deer Management?

Document Analysis

Our document analysis shows that municipalities present an array of concerns (most commonly Lyme disease and forest health) when opening explorations of deer management activity in their towns. In 18 of the 24 towns in our sample, meeting minutes, websites, and/or media coverage document the reasons municipal officials noted when opening discussions of deer management in their towns (Table 3). Eight of these towns articulated broad concerns about growing deer numbers with town officials and residents using language like “overpopulation”, “too many”, “overabundance”, and “overwhelming” populations as reasons to consider deer management. Discussions about deer management also arose in response to specific concerns about deer including Lyme disease (ten towns), forest health and biodiversity (ten towns), deer-vehicle collisions (six towns), crop damage (three towns), and residential landscaping damage (two towns).

Interviews

Our interviews corroborate the importance of Lyme disease and forest health as core concerns that prompt municipalities to explore deer management. The interviews

Table 3. Impetus for municipal exploration of local actions to manage deer and rationale for management actions.

	Year of adoption	Over-population	Tick-borne disease	Forest health	Deer-vehicle collision	Agricultural damage	landscape damage	Recreational opportunity
Barnstable	1998			Rationale				
Sudbury	1999	Impetus	Impetus	Both	Impetus			
Nantucket	2004	Impetus	Both					
Hingham	2006	Rationale						
Framingham	2007			Both				
North Andover	2007			Both				
Brewster	2008	Both		Impetus	Impetus	Impetus		
Oak Bluffs	2009							
Andover	2010	Both	Both	Impetus	Impetus			Impetus
Dover	2010							
Aquinnah	2011		Both					
Chilmark	2011		Both					
Edgartown	2011		Both					
Medfield	2011		Both					
	2011		Rationale					
Norwell	2011	Rationale		Impetus	Impetus	Impetus	Impetus	
Weston	2011	Both	Impetus		Both			
Westborough	2012							
Lakeville	2013							
Westford	2014	Rationale			Rationale			Rationale
Harvard	2019			Both				
Carlisle [#]	2018–2020	Impetus	Impetus	Both				
Boxborough*	Na	Impetus		Impetus		Impetus	Impetus	
Braintree*	Na			Impetus				
Hanover*	Na	Impetus			Impetus			

Yellow shading indicates concerns that served as the impetus for municipal explorations of local deer management; Grey shading indicates concerns that served as the stated rationale for local deer management actions; Blue shading indicates concerns that served as both the impetus and rationale.

denotes municipalities that adopted and later suspended local deer management actions; * denotes municipalities that explored but did not adopt local deer management actions.

suggest that discussions of deer management are not simply arising in response to broad concerns shared by residents, but are instead getting traction due to the motivation, experiences, and concerns of individual town officials who elevated the concerns to the town agenda. For instance, a key actor on the Weston Conservation Commission was an organic farmer and environmental historian who noticed rising deer populations as he experienced crop losses due to deer. Based on his knowledge about deer dynamics and impacts in other places, the increased signs of deer in the 1990s and early 2000s raised concerns about the future growth trajectory of deer and their eventual impacts on forest health. This official brought these concerns to the Conservation Commission in 2011, compiled information on deer impacts and management strategies, and initiated a municipal exploration of deer management.

Though not mentioned as a reason to consider deer management in public deliberations in any of these towns, hunter requests to open municipal land to hunting accompanied early town discussions about deer management in both Carlisle and Lincoln and hunters provided knowledge and expertise in the early explorations of deer management. For example, around the time town officials started to raise concerns about deer in Carlisle, a hunter and resident of Carlisle reached out to the governing body of the town about opening municipal land to recreational hunting. The hunter explained:

I just wanted more places to hunt. I've already got four places in Carlisle where I can hunt [...] but I just wanted to expand. [...] You don't want to pressure your particular spot too much by hunting there all the time. So, it's nice to have a rotation. (Municipal official, I-17)

While this desire to gain access to new spaces to hunt did not drive the town to explore deer management, it did motivate this hunter to become active in town governance and support the process. This same hunter served as a volunteer member of Carlisle's Deer Control Committee and was seen as "particularly instrumental" in the process (Carlisle town official, I-13).

Why do Some Municipalities with Deer Concerns Take Management Action While Others Do Not?

Statistical Analysis

The stepwise selection for Model 2 yielded three significant independent variables that explain the probability that municipalities with deer concerns undertook management action ($n = 23$) or did not ($n = 106$). The three independent variables – median property value, forest contiguity, and deer-vehicle collisions – all had a positive effect (Table 2). Forest contiguity was not significant at the 0.05 level but increased the overall fit of the model. The model indicated that each additional car crash is associated with two percent increase in the odds of taking management action. On the binned residual plot, 80% of the observations fell within the confidence interval. The model had an AUC of 0.81, indicating acceptable performance, and a pseudo R^2 of 0.25, indicating good model of fit.

Document Analysis

Our document analysis demonstrates that common justifications for deer management have shifted through time and shows the how multi-use conflicts and safety concerns

underlie resistance to local management. Three of the 24 towns in our sample considered but did not implement any deer management actions. In all three of these towns, the plans to expand hunting on municipal lands stalled or were voted down due to concerns about potential conflicts between trail users and hunters as well as ambiguity about the need for and/or effectiveness of the proposals for reducing Lyme disease and/or protecting forest health. In the 21 towns that discussed and then implemented deer management actions, the final rationales for deer management included overpopulation (six towns), Lyme disease (seven towns), forest health (six towns), deer-vehicle collisions (two towns), and the desire to increase recreational hunting opportunities (three towns; [Table 3](#)). While these motivations overlap with the concerns that triggered public discussions, the official rationale for management does not always match the concerns that prompted initial discussions.

Our document analysis reveals a temporal shift in the importance of Lyme disease as a justification for deer management over the past two decades. Lyme disease was a common rationale for deer management plans prior to 2011 (seven of the 16 towns identified Lyme disease as a primary motivation) but was not listed as a rationale in any of the five plans created after 2011. During this latter period, Lyme disease was still a trigger for local explorations of deer management but was not the final rationale in any local management plans or decisions. For example, concerns about Lyme disease prompted some of the early discussion about deer management in the Town of Carlisle but Carlisle's Lyme Disease Subcommittee and the Board of Health determined that Lyme risk reduction should not motivate deer management:

While reduction in the Carlisle deer population afforded by the annual hunt on town property may have benefits to the forest ecology, deer herd health and road safety, reduction in risk of Lyme Disease should not be considered the major rationale for the Carlisle deer hunt. (Carlisle Lyme Disease Subcommittee letter – 2019)

This shift in the discourse aligns with evolving scientific understanding of the role deer play in the incidence of Lyme disease (see, for example, [Levi et al. 2012](#)).

In contrast, forest health and other rationales did not have a clear temporal dimension. Six municipalities identified the impact of deer on forest health as the main rationale for management action. While three towns also emphasized increased opportunities for recreational hunting as a rationale for deer management, at least one town explicitly noted that deer management should not be perceived as an effort to increase recreational hunting activities. As we describe below, local relationships to hunting vary and are often contested within suburban municipalities.

Interviews

Our interviews suggest that moving from the exploration of deer management to adoption and implementation of management activities requires the persistence and sustained interest of key actors as well as trust between residents and town officials. In some cases, the effort required for deer management planning exceeds that capacity of municipal committees, which are often comprised of volunteer members. As one town official who has worked in three sub/urban municipalities notes:

The reality is Conservation Commission work is just so labor intensive and overwhelming that most volunteers just don't have the bandwidth to take on a project like this [i.e., implementing a municipal deer management program]. (Municipal official, I-1)

Yet, as this respondent explained, pursuing a project like deer management takes the support and labor of town committee members. In Lincoln, where deer management has been discussed in town forums every five years or so, the conservation commission has remained somewhat agnostic on the need for deer management, and no one has pushed the project further than data collection (about deer impacts and resident views). In contrast, the continuity of membership, support, and partnership of municipal committees were crucial to the implementation of the Weston management program. As one official explained:

We had a very steady group of Select Board members at the time [...], we had a very solid Conservation Commission that was well known in the town and that people kind of trusted and we were kind of low key in the way we played our cards. (Weston official, I-4)

As noted in the quote above as well as by other respondents, trust in officials, processes, and data shaped the deliberations over management. In Weston, trust emerged through the transparency of town officials who “didn’t make outlandish claims” about the anticipated outcomes of hunting on municipal land (Weston official, I-4). Instead, town officials shared information about the limitations and uncertainties related to deer management and engaged residents in the collection of data on the ways deer were impacting on local forests. Town officials accompanied a wildlife biologist to observe deer impacts on town-owned land, which convinced some officials that “a bunch of stuff is getting hammered [by deer]” and built support for deer management among those serving on relevant town committees (Weston official, I-4). Another official explained:

We had a very committed Commission ... that researched, came up with data, put together reports... And, you know, it was one that was fascinating because I think there were several commission members who weren’t in favor of hunting when you asked them early on. And through this process... it was a unanimous decision to open conservation lands to hunting because they went through this process, and they were open to the idea (Municipal official, I-1)

Residents also participated in data collection and field observations in Weston. These exercises, while sometimes performative, generated buy-in among key actors in the town:

The other funny little thing that we did (which I don’t think has any validity as data) - we started doing a [vegetation] census down the same trails. It was kind of political. It was in the middle of the bow hunting controversy, and I thought “well let’s get the garden clubs out there doing something”, because these people run the town basically. (Weston official, I-4)

In contrast, residents in Carlisle expressed concerns about the adequacy and trustworthiness of data about deer populations and their impacts. Interview respondents frequently described Carlisle as a “data-driven town” and expressed expectations for adequate scientific evidence before advancing management. While the sustained effort of Carlisle’s Deer Committee was important in establishing a pilot hunt, that hunt was suspended two years later in response to strong opposition from residents who voiced concerns about uncertainties with regard to deer numbers, their impacts, and the efficacy of the hunt (see Anderson et al., [in review](#)).

The concerns about data in Carlisle were exacerbated by perceived power imbalances between town officials, residents, and state wildlife managers and a decision-making process that felt top-down to some residents. In our interviews, residents opposed to the hunting program expressed concerns about decreasing community involvement over time and the dissolution of democratic decision-making processes. In 2015, the town voted in favor (350 to 90) of a non-binding referendum proposed by the Board of Health that asked: “Shall Carlisle request the Selectmen to place an Article on the next Town Meeting Warrant to regulate bow hunting on town-owned lands as an approach to deer management?”. Based on this referendum, some residents expected that any hunting program would only go forward after a binding town vote. However, the Deer Control Committee determined that it was in the town’s authority to open land for hunting and the pilot program was approved without a vote leaving some residents upset that the process had bypassed a town vote:

The commitment that the Select Board had made to give the town a chance to give a thumbs up or a thumbs down on this idea. Well, that never happened. They just went ahead and did it. So that was the first thing that really got my dander up. (Carlisle Resident, I-8)

Additionally, in Carlisle, the official rationale toward managing deer evolved over time in response to recent scientific knowledge about deer and Lyme disease. While town officials viewed this evolution of rationales as good decision-making, many opponents to the hunt perceived this as a lack of transparency about the real motivations for deer management and a sign of dishonesty from town officials. Some opponents saw the shifting rationale as indication that officials were primarily motivated by an interest in expanding recreational hunting: “What I object to is deer hunting as recreational hunting under the guise of forest management” (Carlisle Resident, I-14)

For opponents, this distrust was deepened by the involvement of MassWildlife in developing deer management strategies. Many respondents expressed concerns that the agency had an interest in expanding hunting to generate more revenue through hunting licenses and permits. These respondents described MassWildlife’s recommendations as “propaganda” and “a pyramid scheme,” and felt that town officials had “blind faith” in hunting. Further, some residents were skeptical of conservation based on resource extraction as opposed to preservation for the intrinsic value of nature: “I’m wary of involving bodies like Fish and Wildlife whose mandate is really preservation of resources for resource extraction and utilization” (Carlisle Resident, I-22).

Lastly, some respondents expressed concern about whether Carlisle was truly considering the interests and concerns of all residents – arguments that mirror the findings of the document analysis. These respondents worried that hunting and the process to implement it would alienate community members from a communal resource:

That’s something elected officials should really pay a lot of attention to, because it’s not about “I’m anti-hunting, I’m pro-hunting”. It is about community members feeling of belonging and safety on town lands. (Carlisle Resident, I-22)

Overall, our interviews illustrate how actions to manage deer unfolded in the context of local politics and relationships. In particular, trust in local and state decision-makers was important to the implementation of deer management programs. Trust was shaped by participation in processes, interpersonal relationships, transparency, and expectations

for deliberative processes. While information and data were important to decision-making, the processes in which information was produced and how it was communicated also affected perception of deer management plans.

Discussion

Through our mixed-method approach, our study identified characteristics of sub/urban environments and communities that are linked to municipal concerns about deer while also highlighting the local politics of environmental decision-making that shape the transformation of concerns into action. We find that certain ecological and landscape conditions may shape human-deer interactions and perceptions of deer, but for municipalities to understand management plans, these interactions must ultimately become understood as municipal level problems and hunting must be understood as a viable policy solution. In this discussion of our findings, we argue that understanding municipal management *action* requires merging insights from the literature on WAC and multiple policy streams (Kingdon 2010) and giving attention to the both the *process* and *politics* of wildlife management.

Research on WAC offers insights into the conditions in which deer come to be understood as a problem, as residents and decision-makers respond to increasing populations sizes and impacts. Indeed, our statistical analysis indicates that some landscape configurations and development patterns (specifically, higher forest patch density and forest contiguity) are associated with increased probability of concerns about deer at the municipal level. These indicators reflect the environmental conditions that support high deer numbers (e.g., Gaughan and Destefano 2005; McCance et al. 2015) and are likely to bring deer, humans, and other important species (such as ticks and other tick-hosts) into more frequent contact. The statistical analyses, document analysis, and interviews all indicate that concerns about Lyme disease are associated with municipal deer concerns and deliberations about deer management. Many interviewees discussed the role of Lyme disease in shaping conversations about deer management and noted how personal experiences with Lyme disease and other deer damages motivated them to work toward local deer management. Similarly, the statistical analysis shows that the prevalence of deer-vehicle collisions is linked to increased probability of local deer management actions. Collectively, these findings about municipal action correspond to insights from the scholarship on WAC, which has shown higher acceptance of management actions among individuals who report concerns about Lyme disease (e.g., Decker and Gavin 1987) and/or have experienced deer damages (e.g., West and Parkhurst 2002; Siemer et al. 2004).

Our document analysis and interviews, however, indicate that more recent municipal actions to manage deer are often justified by concerns about the impacts of deer on forest health and biodiversity rather than concerns about Lyme disease. This attention to local biodiversity and forest health corresponds to a broader shift toward viewing sub/urban areas as important sites of conservation (e.g., Aronson et al. 2017; Lepczyk et al. 2017) and reflects emerging knowledge about Lyme-deer relationships. Where Lyme disease was identified as the specific problem to be managed, many residents and town officials did not see hunting as a viable solution to the problem. In communities where

deer populations were more broadly framed as a problem, hunting was more readily positioned as a viable solution. Even in communities like Weston and Carlisle, where Lyme disease was not a final rationale for management, the disease was a prominent topic of initial discussions that elevated deer to a municipal concern. Although Lyme disease concerns have been pivotal in the formation of coalitions of diverse actors interested in deer management in some places (Connors and Short Gianotti 2021), the shifting discourse surrounding Lyme disease has also contributed to distrust in decision-makers and the decision-making process. In particular, some residents in Carlisle understood the change in management objectives from Lyme disease to forest health to be indicative that the true goal was simply to expand hunting. While our research shows that municipalities are undertaking deer management for forest health, this motivation appears more controversial and less politically salient than management motivated by human health, safety, and property concerns. This may reflect the ways wildlife acceptance is shaped by the perceived risks of specified problems (c.f. research on risk perceptions of large predators, Riley and Decker 2000; Struebig et al. 2018).

The dynamic decision-making processes discussed in our interviews show that deer management does not simply emerge as a consistent rational response to the perceived risk or community acceptance levels of deer. Rather, our interviews show that a combination of environmental and political conditions must converge for management programs to advance in municipal policy, and communities often have a (individual or small group) champion, or policy entrepreneur, that undertakes the effort of linking hunting as a policy solution to the identified problems related to deer. The literature on multiple policy streams offers insights into why and how these champions push management policies forward and why management emerges in some contexts but not others. Rather than management emerging in response to a need, this work suggests that management action occurs only when there is a convergence of problem recognition, perceived policy solutions, and a political context that allows for a particular policy solution to take hold (Kingdon 2010). Champions of deer management serve as “policy entrepreneurs” (Mintrom and Norman 2009), working to merge the problem, policy, and political streams to make deer management legible to both town officials and the concerned public. In our research, champions include conservation boards concerned with forest health, town officials and community members affected by Lyme disease, and hunters seeking to create new hunting opportunities. In many towns, a champion of a particular issue advocated for hunting discussions on the municipal agenda and built coalitions of support among residents and officials with different types of concerns about deer, but a shared interest in reducing deer numbers.

Our research suggests that the success of these champions or policy entrepreneurs in merging policy streams depends upon the relationships among different actors and their mutual trust. In Weston, strong local political support coupled with early public engagement across different groups of residents helped move toward the implementation of a bowhunting program. In Carlisle, however, the involvement of hunters, who were perceived as self-interested in expansion of hunting, contributed to resentment and distrust among residents skeptical of management plans. Interviewees also noted their concerns about the involvement of MassWildlife, which was perceived to have a financial interest in expanding hunting. Despite Carlisle’s success in implementing a management

program, some residents questioned the decision-making process and began efforts to overturn the program. Our findings thus demonstrate the ways that local politics are informed by and shape trust in scientific knowledge and environmental agencies. This echoes research on the ways that plural perspectives on environment are continuously revised and negotiated (Jacobson and Decker 2008; Jacobson et al. 2010; Decker et al. 2016; Manfredo et al. 2017) and the importance of trust, transparency, and social learning in wildlife management (Raik et al. 2005; Decker et al. 2016). Nonetheless, this study demonstrates that efforts to increase public engagement may build support for wildlife management efforts, but they may also introduce conflict if there is inadequate attention to internal politics and power dynamics.

Giving attention to the municipal level decision-making processes through the lens of policy streams thus complements common notions of WAC and provides a promising framework for understanding management decisions as more than functional responses to changing wildlife numbers. While WAC helps to understand patterns of acceptance of wildlife and management among individuals, our study shows that policy implementation is an outcome of political negotiations. Wildlife management often involves a process of policy (trans)formation, thus wildlife managers must be attentive to the political processes that produce management practices. Our findings thus complement work from scholars calling for deeper attention to the political dimensions of wildlife management and arguing for the need to consider power relations, values, trust, and culture within wildlife management (Manfredo et al. 2017; Sullivan 2021; Stinchcomb, Ma, and Nyssa 2022; Sullivan, Manfredo, and Teel 2022) and shed a light on how local politics influence environmental decision-making.

Conclusion

Our results offer insights on how the movement of wild animals into sub/urban environments intersect with human development, behavior, and politics, and reshape the ways humans relate to these animals and the landscapes they inhabit. Our mixed-methods approach allowed us to envision the complexity of wildlife management, through a better understanding of processes involved in local environmental decision-making. While our research shows that the ecology of deer and forested landscapes matters in these sub/urban areas, our work also complicates the story of human dimensions of wildlife and contributes to thinking more about human politics. With this study, we push for a better recognition of these complex processes in making wildlife management decisions for deer as well as other species that challenge wildlife managers in all social and geographic contexts. Our approach can be replicated in other contexts to help practitioners and managers to pay attention to these themes, and especially reflect on the implications of the role of local politics, risk perception, and culture in the success of local environmental policies.

Notes

1. We use “sub/urban” as short-hand to refer to the human-dominated landscapes of both urban and suburban areas. “Suburban” is used to refer to areas less densely populated than cities that are dominated by single family homes.

2. Lyme disease is a vector borne disease transmitted to humans by *Ixodes scapularis*, commonly known as the blacklegged or deer tick. While role of deer in the regulation of deer ticks and the transmission of Lyme disease is uncertain in the scientific community (e.g., Ostfeld 2010; Levi et al. 2012), concerns about deer are linked to continued perception of this relationship. Concerns about Lyme disease often motivate deer management but these concerns may be challenged by other residents as the complexity of tick-ecology becomes more widely known (Connors and Short Gianotti 2021; Anderson et al. *in review*).
3. The research reported in this paper meets the criteria for exempt human subjects research and was approved by the Boston University IRB (Protocol #4026X). Written consent forms were provided to all research participants. Survey respondents were required to indicate consent before starting the survey and verbal consent was obtained at the start of interviews.
4. One respondent has experience in multiple towns and is double counted in this list.
5. Pseudo R^2 values between 0.2 and 0.4 indicate excellent model fit.

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Appendix

Table A1 contains a list of candidate variables used for the statistical tests and regression analyses. The table also contains a brief description and identifies data sources used to build them.

Table A1. Candidate variables used for regression analysis.

Variables	Description	Sources
Town area	The area of a town computed in sq. meters	MassGIS Bureau of Geographic Information: mass.gov/orgs/massgis-bureau-of-geographic-information
Number of parcel	The number of parcel in a town. Computed using parcel types: tax and fee	Metropolitan Area Planning Council: mapc.org/learn/data/
Average size of parcel	The average size of parcels in a town. Computed using parcel types: tax and fee	U.S. Census Bureau: censusreporter.org
Population density	The 5-year estimates of the total population of a town reported to the town area, over the period 2013–2017	
Median household income	The 5-year estimates of the median Household Income (2013–2017, 2017 Inflation-adjusted dollars)	
Gini Index	The 5-year estimates of the Gini Index of Income Inequality (2013–2017)	
Median property value	The 5-year estimates of the median value of owner-occupied housing units (2013–2017)	
Median age	The 5-year estimates of the median age (2013–2017)	
Owner rate (%)	The 5-year estimates of the tenure rate of occupied housing units (2013–2017)	
Developed area – low to high intensity (%)	Built from the 2016 NLCD data. The variable is a combination of three classes (Developed area: Low, medium and high intensity) reported to the total town area	
Developed open space (%)	The variable is the built using the class "Developed area, Open Space" from the 2016 NLCD data, reported to the total town area	
Developed residential area (%)	Built from the 2016 NLCD data. The variable is a combination of two classes (Developed area: Low and medium intensity) reported to the total town area	National Land Cover Database/mrlc.gov/data/nlcd-2016-land-cover-conus
Cultivated crops (%)	Built from the 2016 NLCD data. The variable is the built using the class "Cultivated Crops" reported to the total town area	
Forest cover (%)	Built from the 2016 NLCD data. The variable is a combination of three classes (Evergreen, deciduous and mixed forest) reported to the total town area	
Wildland-urban interface (%)	The variable describes the proportion of areas where settled areas abut wildland vegetation within each town in 2010	Silvis Lab at University of Madison-Wisconsin: silvis.forest.wisc.edu/data/wui-change
Wildland-urban intermix (%)	The variable describes the proportion of areas where houses and wildland vegetation directly intermingle within each town in 2010	
Road density	Built from road data compiled for the state of MA. Computed using Line Density tool and zonal statistic (mean) in QGIS	Massachusetts Department of Transportation: geo-massdot.opendata.arcgis.com
Protected and recreational open space – type: private (%)	The percentage of private protected and recreation open space in each town. Computed using the protected and recreational open space data layer, which contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. Built in QGIS, by keeping private owners only and using union and pivot table geoprocessing tools	MassGIS Bureau of Geographic Information: mass.gov/info-details/massgis-data-protected-and-recreational-openspace
Protected and recreational open space – type: public (%)	The percentage of all public protected and recreation open space in each town (federal-, state-, county-, and municipal-owned land). Computed using the protected and recreational open space data layer, which contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. Built in QGIS, by keeping public owners only and using union and pivot table geoprocessing tools	

Protected and recreational open space – type: municipal (%)	The percentage of municipal protected and recreation open space in each town. Computed using the protected and recreational open space data layer, which contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. Built in QGIS, by keeping municipal owners only and using union and pivot table geoprocessing tools.
Protected and recreational open space – type: federal (%)	The percentage of federal protected and recreation open space in each town. Computed using the protected and recreational open space data layer which contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. Built in QGIS, by keeping federal owners only and using union and pivot table geoprocessing tools
Protected and recreational open space – type: state (%)	The percentage of state protected and recreation open space in each town. Computed using the protected and recreational open space data layer which contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. Built in QGIS, by keeping state owners only and using union and pivot table geoprocessing tools
Edge density – class: forest	The variable was computed for the ‘forest’ class built from the three classes (evergreen, deciduous, mixed forest) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the configuration of a specific class: forest. An aggregation of the forest class will result in a low edge density
Patch density – class: forest	The variable was computed for the ‘forest’ class built from the three classes (evergreen, deciduous, mixed forest) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the fragmentation of a specific class: forest. A high fragmentation of the forest class will result in high patch density
Mean of Euclidian nearest-neighbor distance – class: forest	The variable was computed for the ‘forest’ class built from the three classes (evergreen, deciduous, mixed forest) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the aggregation of a specific class: forest. A high number of isolated forest patches will result in an increase in the distance to the nearest neighbor
Mean of contiguity index – class: forest	The variable was computed for the ‘forest’ class built from the three classes (evergreen, deciduous, mixed forest) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the spatial connectedness of cells in patches of a specific class: forest. Tighter, more concentrated patches of forest will result in high contiguity index
Edge density – class: residential	The variable was computed for the ‘residential’ class built from the two classes (developed area: low and medium density) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the configuration of a specific class: forest. An aggregation of the forest class will result in a low edge density
Patch density – class: residential	The variable was computed for the ‘residential’ class built from the two classes (developed area: low and medium density) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the fragmentation of a specific class: forest. A high fragmentation of the forest class will result in high patch density

(continued)

Table A1. Continued.

Variables	Description	Sources
Mean of Euclidian nearest-neighbor distance – class: residential	The variable was computed for the ‘residential’ class built from the two classes (developed area: low and medium density) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the aggregation of a specific class: forest. A high number of isolated forest patches will result in an increase in the distance to the nearest neighbor	Massachusetts Department of Transportation geo-massdot.opendata.arcgis.com Information Provided on request by the Massachusetts Department of Public Health Bureau of Infectious Disease Massachusetts Municipal Association mmaa.org/ resources/municipal-government/
Mean of contiguity index – class: residential	The variable was computed for the ‘residential’ class built from the two classes (developed area: low and medium density) from the 2016 NLCD using the R package <i>landscapemetrics</i> . The town-level metric describes the spatial connectedness of cells in patches of a specific class: forest. Tighter, more concentrated patches of forest will result in high contiguity index	
Total number of deer-vehicle collision	The variable was built from a compilation of all car accidents involving a deer from 2010 to 2017 in each MA town	
Lyme disease incidence (%)	The variable was built from a compilation of individual reported Lyme disease cases in each MA town, from 2005 to 2015. Massachusetts discontinued individual case investigations for Lyme disease in 2016	
Towns with open town meetings	Dummy variable identifying towns with open town meetings, i.e., towns where any voter is permitted to attend and vote on legislative matters	Data compiled by authors described in Edelblutte, Short Gianotti, and Connors 2022 wbur.org/news/2020/11/03/2020- massachusetts-election-map sec.state.ma.us/e/e/e/registrationstats/ registrationstats.html
Form of government body	Dummy variable identifying whether a town operates under a Select Board or has a Mayor/Manager.	
Local legislation	Dummy variable identifying towns with municipal bylaws that go beyond state laws in regulating hunting	
Biden Voter during last presidential election (%)	Proportion of residents who voted for Biden during the last presidential election	
Most voters registered (Democrat)	Dummy variable identifying whether a town’s most voters registered are democrats	

The selection of variables was informed by the existing literature on deer ecology, human dimensions of deer management, and preliminary research done by the authors and limited by the availability of data at the municipal scale. The resulting list includes land use, land cover, and landscape variables that may shape both deer habitat and access to land for hunting; health and safety indicators of human-deer conflicts; and demographic, economic, and political variables that may shape the perception of conflict and the municipal governance.