

Perceptions, concerns, and management of white-tailed deer among municipal officials

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Abstract

Municipal governments are emerging as important stakeholders in managing the populations and geographic distributions of white-tailed deer (*Odocoileus virginianus*) in urban and suburban areas of the Northeastern United States. To understand the variation in municipal-level concerns about deer and municipal policies related to deer management, we distributed a questionnaire to all 351 municipalities across the Commonwealth of Massachusetts in 2017 (response rate = 74%) and collected data on local bylaws that influence hunting access. We found that concerns about deer vary across the state and some municipalities are taking action to manage increasing deer populations. In particular, our analysis established the importance of deer and deer management in the suburban regions of Massachusetts, while uncovering many local differences within similar suburban areas. The varying relationships between deer populations, public concerns, and municipal actions illustrated the complex role of municipal decision-makers in shaping wildlife management programs.

Keywords: municipality, *Odocoileus virginianus*, suburban, wildlife management, white-tailed deer

Introduction

In North America, many suburban and urban municipalities are debating and creating local management plans to address concerns about increasing wildlife populations. Although the expansion of urban and suburban land uses leads to habitat loss for many species (McKinney, 2008), other species adapt to and thrive in these human-dominated landscapes by exploiting anthropogenic resources (Bateman & Fleming, 2012; DeStefano & DeGraaf, 2003; Francis & Chadwick, 2012; McDonnell & Hahs, 2015). As wildlife and human populations increase, urban and suburban residents and wild animals increasingly interact in new and sometimes unanticipated ways (Soulsbury & White, 2015). These interactions raise questions about ecological and human well-being, the overall habitability of these places for both humans and wildlife, and when and how to manage wildlife in urban and suburban areas.

White-tailed deer (*Odocoileus virginianus*) thrive in suburban and urban environments, benefiting from supplemental food, absence of predators, and patchworks of edge habitat (Etter et al., 2002; Garrott et al., 1993). In recent decades, this species has become the subject of concern and debate in many suburban and urban communities across North America as their populations have increased (Decker & Gavin, 1987; Storm et al., 2007). In the United States, responsibility for managing game species belongs to state wildlife agencies. Although wildlife managers have a long history of successfully regulating populations of game species such as deer in rural regions, managers face novel challenges when working in urban and suburban settings. There, communities often lack the historical relationship to game species, hunting is less common, and residents may lack trust in wildlife management agencies as well as traditional management approaches (DeStefano & DeGraaf, 2003). In dense urban and suburban environments, management is further complicated by ecological and institutional complexities. In these highly fragmented landscapes, state wildlife management agencies must coordinate with local officials and property owners and

managers to implement strategies for management on private and municipal-owned properties. In some areas, this requires changes to local regulations governing access to land, firearms use, and hunting.

In light of the increasing efforts to manage and regulate deer and other suburban and urban wildlife, new scholarship is needed to understand this process of making local management strategies and policies. Research on the human dimensions of suburban deer management has focused on practices of state agencies (e.g., Urbanek et al., 2011), resident concerns (e.g., Siemer et al., 2004; Stewart, 2011; Urbanek et al., 2013), and the diverging views that citizens, managers, and politicians hold regarding adequate responses to increasing deer populations (Rudolph et al., 2011). However, little attention has been given to concerns about deer management among municipal decision-makers. Although actions of municipal governments are often assumed to follow public concerns and perceptions about deer densities (Decker et al., 2004), wildlife-related concerns do not always emerge in the public sphere in straightforward ways (Triezenberg et al., 2011). For instance, changes in local wildlife-related policies are often the consequence of a few private stakeholders who have the ability to amplify their concerns regarding a specific issue through their networks and do not necessarily address the initial concerns expressed by all residents (Triezenberg et al., 2011).

Our research addresses this gap by: (a) investigating the variation in concerns about and management of deer across municipalities in the Commonwealth of Massachusetts (MA), and (b) exploring how municipal officials perform their role while mediating their perceptions and ideas with those of residents, wildlife managers, and the general public. Understanding the processes through which municipal management actions happen is particularly important, as wildlife management in urban and suburban landscapes requires high levels of public engagement and coordination with local officials (Decker et al., 2016). Our objectives were to answer three research questions: (a) how do municipal concerns about

deer vary across MA, (b) how have municipal-level policies and practices affecting deer management changed in different parts of the state over the past decade, and (c) how do municipal officials perceive resident concerns about deer?

Building on the literature, as well as findings from earlier research (Connors & Short Gianotti, 2021), we expected to find regional differences in the levels of concerns related to deer and the local-level responses to these concerns across the state. First, we anticipated that respondents from the most suburban regions of the state would report higher levels of concern about deer effects compared to rural regions. Second, we anticipated that suburban communities would be more likely than rural communities to have implemented deer management programs or to have changed their local bylaws to alter hunting practices. Third, we predicted that municipal officials perceive their primary concerns regarding deer to be different from those of residents, with municipal officials expressing more concerns for forest health and estimating that residents' concerns are higher for private property and human health.

Methods

Study Area

Our study focused on all municipalities in MA. Similar to other states in New England, municipalities are the main unit of local government in MA and have more power than most townships in the country. Although the MA Division of Fisheries and Wildlife (MassWildlife) is responsible for managing deer populations in MA, the implementation of management programs often requires management at the municipal level. Municipal governments in MA influence access to land and regulate the use of firearms. They do so by changing local regulations, opening up municipal properties to hunting, and working with local property owners to allow access to their property for management activities (David Stainbrook, MassWildlife, personal communication; O'Shea, 2009).

MA is divided into five Wildlife Management Districts (WMDs) based on geophysical and biological characteristics (Figure 1). The WMDs located in eastern MA mostly comprise densely populated urban and suburban municipalities (Short Gianotti et al., 2016), with a patchwork of single-family homes and forest fragments. The proportion of less densely populated rural municipalities (Short Gianotti et al., 2016) and contiguous forest areas increases toward central and western MA (Table 1). Additionally, municipalities in the eastern WMDs of MA tend to have higher median household income levels compared to those located in the central and western parts of the state (Table 1).

[Figure 1 and Table 1 here]

Deer densities tend to be higher in the eastern, more developed part of the state. Deer density is estimated to range from 4/km² to 19/km² in the eastern portion of the state and between 4/km² and 7/km² in the central and western parts of the state (David Stainbrook, MassWildlife, personal communication). Although this rough pattern holds across the state, deer densities are heterogeneous within each WMD. In more rural WMDs, deer densities can be greater than 7 deer/km² on properties closed to hunting, especially large properties. For example, MassWildlife has estimated densities of greater than 19 deer/km² on a conservation property in the Connecticut Valley WMD and densities less than 6 deer/km² just a mile away (David Stainbrook, MassWildlife, personal communication). In the most eastern and suburban areas of the state (Northeast and Southeast WMDs), deer densities range from 4/km² to 11/km² in areas open to hunting and more than 15/km² in areas with limited or no hunting access (David Stainbrook, MassWildlife, personal communication).

Data Collection

To investigate variation in local concerns about deer and municipal actions related to deer management (e.g., permitting hunting on municipal land, changing bylaws to allow hunting), we distributed a questionnaire to all 351 municipalities across MA in 2017 and we

also compiled data about municipal bylaws related to hunting in 2020.

Municipal Survey

We administered a questionnaire to municipal officials in all of MA in August 2017.¹

We used a modified Tailored Design Method (Dillman, 2014) to distribute the questionnaire to an employee or volunteer in each of the 351 MA municipalities. The instructions invited the recipient to consult or work with other municipal officials to answer the questions.

Recipients received three email contacts: (a) a pre-questionnaire notification, (b) an email with a link to the questionnaire, and (c) a thank you note to those who completed the questionnaire or a reminder and redistribution of the link to non-respondents. Beginning three weeks after the questionnaire was distributed, we attempted to contact all remaining non-respondents by telephone to encourage completion or to conduct the questionnaire via telephone. Although the questionnaire was web-based, we provided a paper version or the opportunity to complete by telephone upon request.

The sample included municipal officials occupying an executive or administrative position (e.g., clerk, supervisor, select board member), officials holding a position related to conservation activities (e.g., conservation commission member and staff, department of natural resources), animal control officers, members of the local Board of Health, and people holding other municipal positions (e.g., police chief, highway superintendent). To generate the sample, we first contacted the municipal clerk or manager in each MA municipality and asked them to identify the best person (or people) to complete the questionnaire in their municipality. The resulting sample thus reflects the diversity in local officials who are most

¹ As determined by the lead author's University IRB, the research reported in this paper meets the criteria for exempt human subjects research (Protocol #: 4026X). Exempt studies do not require signed consent, but do require consent scripts. The opening page of the questionnaire contained required language and details regarding consent.

involved and knowledgeable about deer.

The questionnaire content was informed by a review of the literature on human dimensions of deer management, conversations with staff at MassWildlife, and observations of public meetings about deer management. The questionnaire was pre-tested with town clerks and conservation commission members in both suburban and rural municipalities in MA. The final questionnaire contained multiple-response and scale questions, as well as some open-ended questions. The questionnaire included questions about the positions held by the primary respondent and any other municipal officials who helped to complete the questionnaire and addressed the following three topic areas.

Perceived status of deer populations. We asked respondents to assess if deer numbers are *currently* increasing, stable, or declining within their municipality, and if they have been increasing, stable, or declining over the past 20 years. Whereas we acknowledge that many respondents may not have a strong sense of population changes over that long timeframe, we selected the 20-year time horizon to capture the timeframe when municipalities in eastern MA started to be more active in addressing deer populations. An additional question about ongoing changes in deer populations drew attention to current concerns and understanding of management effectiveness and needs.

Local concerns about deer populations. We gauged levels of concern about deer in three ways. First, we asked respondents to estimate the proportion of residents who consider deer to be a problem in their municipality, with responses on a five-point scale from “none or nearly none” to “all or nearly all.” Second, the questionnaire contained questions about the frequency and nature of deer-related complaints received by the municipality, and if the frequency of resident complaints has changed over the past 10 years. Third, we asked respondents to estimate the levels of concerns that residents and municipal officials hold about four specific problems often linked to high deer densities: deer-vehicle collisions,

property damage due to deer, tick-borne disease, and impacts of deer on forests. For each of those concerns, respondents were asked “how concerned are residents in your town or city?” and “how concerned are you and other officials in your town or city?” Responses were on a four-point scale of “strong,” “moderate,” “minimal,” and “no concern,” as well as “don’t know.” Answers reflected respondent *perceptions* and their estimation of concern among residents rather than a measurement of residents’ actual concerns.

Local hunting access and municipal efforts to manage deer populations. We inquired about local actions to manage deer, as well as changes in municipal deer management strategies and relevant bylaws over the past decade. The questionnaire contained questions about the types of land open to hunting within the municipality, hunting-related bylaws, if the municipality had recently taken or was considering actions related to deer management (including changes to bylaws and expanding and/or reducing access to hunting on municipal properties), and if there had been any unsuccessful efforts to change bylaws or hunting access in the past decade in their municipalities. For all of these questions, respondents were asked to provide details about the management actions that were considered and/or implemented.

Municipal Bylaws

To examine the distribution of hunting-related bylaws and update the questionnaire responses with respect to reported discussions of local ordinances in 2017, we collected and analyzed the texts of municipal bylaws across the state in 2020. Municipal bylaws and ordinances can directly or indirectly restrict hunting locally by extending the state’s discharge setbacks, limiting access to particular properties, requiring written permission to discharge firearms and/or arrows on public and/or private property, or restricting discharge of firearms and/or arrows. We obtained the text of local bylaws for all municipalities in MA through municipal websites or by directly querying municipalities. We searched the bylaws using specific keywords related to hunting (e.g., hunting, firearm, archery) and categorized any

relevant bylaws based on their direct and indirect impacts on hunting access and opportunities.

Data Analysis

After gathering responses, we cleaned and recoded the dataset, and analyzed the data in RStudio. We treated categorical answers as nominal data and considered scale responses as ordinal. As the Shapiro-Wilk's normality test showed that our data were not normally distributed, we relied on non-parametric tests to analyze responses. We used Pearson's Chi-square test of independence (χ^2) and Fisher's Exact test with nominal variables to identify differences in responses across the WMDs. We estimated the magnitude of the relationship between responses across the five WMDs using Cramer's V measure of effect sizes for tests of association for nominal variables. This measure helps contextualize p -values that give information on whether an effect exists, but does not provide the size of this effect. Whereas the results from the Chi-square and Fisher's Exact tests determined whether an effect existed among the five WMDs, they did not reveal in which group the effect exists. We used *post hoc* pairwise comparison tests to differentiate among the WMDs. To test for variations in ordinal responses among the five WMDs, we ran the non-parametric Kruskal-Wallis (H) Rank Sum test. The effect size (eta-squared based on the H statistic) for the Kruskal-Wallis test was also computed to quantify the magnitude to which one group has data with higher ranks than another group. To differentiate responses among the five WMDs, we followed Kruskal-Wallis tests with the *post hoc* Dunn's test. Further, we created indices of overall perceived concern of municipal officials and residents. We calculated the indices by recoding and summing the scale responses regarding levels of concerns over four different deer-related impacts. The resulting index ranged from 1 (no overall concern) to 16 (strong overall concern). To test for differences between these two indices, we used the Wilcoxon signed-rank test (W). For questions related to residents' and municipal officials' levels of concerns regarding deer, we also tested for differences among categories of respondents holding

different positions. In the following section, we report and describe results at the .05 level of significance, along with the effect sizes.

Results

Local officials from 260 municipalities completed the online questionnaire,² yielding a response rate of 74%. Respondents included 87% of urban municipalities (13 out of 15), 78% of suburban municipalities (143 out of 183), and 68% of rural municipalities (104 out of 153). Although respondents came from municipalities in all WMDs (Figure 1), the response rate was significantly higher in the Northeast and Southeast WMDs than in the Central and Western WMDs, $\chi^2(4, N = 351) = 24.297, p < .001, V = .26$. The difference in response rates across the more suburban and rural WMDs likely reflects the greater salience of concerns about deer in suburban and exurban municipalities. Some non-respondents in the rural municipalities in the Central and Western WMDs referred us to MassWildlife as the entity with local knowledge about deer.

Just over two-thirds (68%) of respondents completed the questionnaire alone, and the remaining 32% of respondents completed it in groups of two to six municipal officials. Respondents held a range of positions in their municipalities. The vast majority of questionnaires were completed by either an individual or a group of respondents all holding the same type of positions: 52% were completed by individuals or groups all holding conservation-related positions, 14% were completed by individuals or groups who are all animal control officers, 12% were completed by individuals or groups all holding executive

² Some respondents elected not to answer certain questions or responded “don’t know” (where that was an option). In the results that follow, we report the number of useable responses for each question (when less than 260) and include the number/percent of “don’t know” responses. For questions that included “don’t know,” we tested for differences in the frequency of “don’t know” responses across WMDs and found no significant differences across the five WMDs ($p = .069 – .940$).

or administrative positions, 4% were completed by individuals or groups all affiliated with the local Board of Health, and 8% were completed by individuals holding other municipal positions (Figure 2A). The remaining 10% of questionnaires were completed by groups with individuals spanning the five positions described above (Figure 2A). Across the five categories, the types of respondents significantly varied across WMDs, $N = 234$, $p < .001$, $V = .24$. Significantly more respondents held conservation-related positions in the Central (58%), Southeast (62%), and Northeast (72%) WMDs than in the Connecticut Valley (30%) and Western (37%) WMDs (Figure 2B). The Connecticut Valley and Western WMDs had greater proportions of respondents occupying executive and administrative positions (37% in the Western WMD, and 27% in the Connecticut Valley WMD) compared to the Southeast (7%) and Northeast (2%) WMDs (Figure 2B). The Connecticut Valley WMD had a significantly greater proportion of respondents occupying positions in the animal control office (30%) compared to the five other WMDs. Driven primarily by responses from municipalities on the islands of Martha's Vineyard and Nantucket, the Southeast WMD had a statistically significantly greater proportion of respondents affiliated with the Board of Health (11%; Figures 2A and 2B).

[Figure 2 here]

In the rest of this results section, we do not report differences in responses based on the position or affiliation of respondents because we only found significant differences in responses for two questions. Specifically, respondents holding positions in the Board of Health tended to report that a larger proportion of residents are concerned about deer ($N = 227$, $p = .001$, $V = .27$) and reported higher levels of concern about deer among municipal officials, $H(4, N = 227) = 17.71$, $p = .001$, $\eta^2 = .06$.

Perceived Changes in Deer Populations

Although nearly half (45%) of respondents stated that deer populations were currently

stable as of 2017, many municipal officials reported changes in deer numbers during the past two decades. More than one-third of respondents (37%) reported that deer populations have increased in the past 20 years, 23% reported that populations have been stable, 11% reported that they have declined, and the remaining 29% reported that they did not know how deer populations have changed (Figure 3A). Perceptions of past changes in deer populations varied across WMDs, with a larger proportion of respondents in the Southeast (48%), Northeast (40%), and Central (37%) WMDs, as compared to the Connecticut Valley (25%) and Western (20%) WMDs, reporting that deer populations have increased (Figure 3B). The Western WMD had the greatest proportion of respondents (37%) who reported no change in deer numbers during the past 20 years (Figure 3B). These moderate differences among WMDs were significant at the .05 level, $N = 184$, $p = .039$, $V = .20$. Results from *post hoc* pairwise comparison tests showed limited evidence for a strong difference in perceptions of deer population changes between the most urban/suburban WMD (i.e., Northeast WMD) and the most rural one (i.e., Western WMD), $N = 90$, $p = .061$, $V = .33$.

[Figure 3 here]

Complaints and Concerns across WMD

Reported Proportions of Residents Considering Deer to be a Problem

Most respondents did not believe that deer were a concern for residents in their municipalities. When asked to estimate the proportion of residents who considered deer to be a problem, 38% of respondents reported that no residents considered deer to be an issue in their municipality, 43% thought that a minority of residents considered deer to be a problem, 11% reported that about half of their residents considered deer to be a problem, and only 8% thought that the majority of residents considered deer to be a problem (Figure 4A). The Kruskal-Wallis Rank Sum test revealed strong evidence for moderate difference in responses on the proportion of concerned residents among the five WMDs, $H (4, N = 260) = 22.12$, $p <$

.001, $\eta^2 = .07$. Respondents in the more urban and suburban Northeast and Southeast WMDs were more likely to indicate that their residents are concerned about deer populations compared to those in the more rural Western and Connecticut Valley WMDs (Figure 4B) and a *post hoc* Dunn's test was significant at the .05 level comparing these four WMDs. The majority of responses indicating high proportions of concerned residents (i.e., half or the majority of residents) came from the outer suburbs of Boston and from the islands of Nantucket and Martha's Vineyard (Figure 4A).

[Figure 4 here]

Received Complaints from Residents Regarding Deer-Related Issues

More than one-third of respondents (38%) reported that municipal officials receive complaints about deer-related issues, half of the respondents (50%) reported that they do not receive complaints about deer, and 12% did not know (Figure 5A). A Pearson's Chi-square test showed strong evidence for moderate differences in the proportion of municipalities that reported complaints among the five WMDs, $\chi^2 (4, N= 229) = 12.33, p = .015, V = .23$. Most municipalities that reported receiving complaints from residents were located in the outer suburbs of Boston (Figure 5A). The Southeast WMD had the highest proportion of municipalities that reported receiving complaints about deer and the Connecticut Valley WMD had the lowest, although the *post hoc* pairwise comparison test did not show a significant difference between the two (Figure 5B).

[Figure 5 here]

Among the 229 municipalities that reported receiving complaints about deer, 35% reported that they "sometimes" received complaints, and only 3.5% reported that they "often" received complaints about deer (Figure 5A). A Kruskal-Wallis Rank Sum test showed evidence for difference in responses regarding the frequency of received complaints among the five WMDs, $H (4, N= 229) = 1.45, p = .022, \eta^2 = .03$.

Levels of Concerns among Municipal Officials Regarding Deer-Related Issues

The majority of respondents (72%) reported moderate or strong levels of concern about tick-borne diseases and 38% reported moderate or strong levels of concern about deer-vehicle collisions. Respondents reported relatively lower levels of concern about property damage and forest health. Only 21% and 25% reported moderate or strong levels of concern about property damage from deer or impacts of deer on forests, respectively. Across the five WMDs, responses varied significantly for concerns about tick-borne diseases, $H(4, N = 245) = 12.25, p = .016$, eta = .03. A high number of respondents in the Southeast (84%) and Western (77%) WMDs expressed moderate or strong levels of concern regarding tick-borne diseases. Responding municipalities in the Southeast WMD expressed levels of concern that were significantly different from municipalities in the Northeast WMD ($N = 154, p = .022$) and Central WMD ($N = 89, p = .024$). Although concerns regarding the effects of deer on forests were low, we identified significant differences among the five WMDs, $H(4, N = 233) = 9.86, p = .043$, eta = .03. A higher proportion of respondents held moderate to strong levels of concern regarding impacts of deer on forests in the Northeast (36%) and Southeast (35%) WMDs compared to the three other WMDs (i.e., 11% in Central, 10% in Western, 3% in Connecticut Valley WMDs). We did not see detectable variations across WMDs in concerns regarding deer-vehicle collisions and property damage due to deer.

In general, concerns about deer varied greatly among municipalities with some neighboring municipalities expressing different levels of concerns from each other (Figure 6A). The average index of overall level of concern across the WMDs ranged between 7.66 in the Central WMD to 9.96 in the Southeast WMD (Figure 6B). Results from a Kruskal-Wallis test showed evidence for small differences in the index across the WMDs, $H(4, N = 251) = 12.56, p = .014$, eta = .03. These differences were only significant between the Southeast WMD and Central WMD, $N = 92, p = .009$ (Figure 6B).

[Figure 6 here]

Perceived Levels of Concerns among Municipal Officials and Residents

Respondents estimated that they and other municipal officials held similarly high levels of concerns about tick-borne diseases and deer-vehicle collisions as residents (Figure 7A, 7B). Although reported concerns about property damage due to deer were relatively low (Figure 7C), we found differences in the estimated levels of concern between residents and municipal officials, with greater levels of concern among residents than among municipal officials, $\chi^2 (1, N = 469) = 4.14, p = .042, V = .10$. These differences in concerns about property damage were most pronounced in the Northeast and Southeast WMDs compared to the more rural areas (Central, Connecticut Valley, Western WMDs). Conversely, respondents estimated that municipal officials held higher levels of concern than residents about impacts of deer on forests, $\chi^2 (1, N = 448) = 20.73, p < .001, V = .22$, although few respondents reported moderate or strong concern for those impacts (Figure 7D). Only 8.5% of respondents estimated that residents held moderate or strong levels of concern about the impacts of deer on forests, whereas 25% estimated that municipal officials held these levels of concern about the same issue. Again, this difference was only statistically significant for municipalities located in the more urban and suburban Northeast and Southeast WMDs.

[Figure 7 here]

When summing responses in our index of the overall level of concern across all respondents, they reported that they and other officials held a higher level of concern than residents, $W (N = 249) = 9327.50, p < .001$. The difference in the reported overall level of concern among municipal officials and residents was more striking in the suburban and urban Southeast and Northeast WMDs than in the more rural and western WMDs.

Hunting Access and Deer Management Actions

Land Open to Hunting

Most respondents (83%) indicated that hunting is permitted on some private, state, municipal, or other land within their municipality ($N = 260$). Among the responding municipalities, 71% reported hunting on private land, 52% reported hunting on state land, 42% reported hunting on land owned by a land trust, and 48% reported hunting municipal land.³ Across the WMDs, the Northeast WMD had the lowest proportion of responding municipalities with land open to hunting. In this WMD, 66% of responding municipalities had land open to hunting ($N = 101$), whereas 89% of responding municipalities in the Central ($N = 35$) and Connecticut Valley ($N = 36$) WMDs, and 97% of responding municipalities in the Southeast ($N = 58$) and Western ($N = 30$) WMDs had land open to hunting.⁴ Results from several Fisher's Exact tests and *post hoc* pairwise comparison tests indicated significant differences in the types and amount of land open to hunting between municipalities in the Northeast and all other WMDs. Municipalities in the Northeast WMD were less likely to report hunting access for all types of land ownership.

Municipal Bylaws and Ordinances

Our analysis of municipal bylaws in all 351 MA municipalities showed that 46% of these municipalities have bylaws or ordinances that restrict hunting beyond state regulations (Figure 8A). Although the exact restrictions vary, bylaws that limit hunting are in place in most municipalities in the Northeast WMD (88%, $N = 122$), where 63% of the municipalities

³ Although some respondents did not know how to answer these questions (16% of "don't know" responses regarding private land, 28% regarding land owned or managed by land trust, 26% regarding state land, and 16% regarding municipal land).

⁴ Some respondents did not know how to answer this question: 11% in the Central WMD, 10% in the Northeast WMD, 8% in the Connecticut Valley WMD, 3% in the Western WMD, and 2% in the Southeast WMD.

require written permission to discharge firearms and/or archery, sometimes combined with additional restrictions on access to particular areas for hunting (Figure 8B). The Northeast WMD also had the largest proportion of municipalities with local ordinances that prohibit the use of firearm and/or archery (20%, $N = 122$). These municipalities include Boston and some of its nearby suburbs, and several municipalities in the northern part of the WMD (Figure 8A). Municipal bylaws that affect hunting are less common in other parts of the state, varying from 17% of municipalities in the Western WMD ($N = 52$) to 25% of municipalities in the Southeast WMD ($N = 68$; Figure 8B).

[Figure 8 here]

Changes in Municipal Rules

Respondents from 14% of responding municipalities indicated that their municipality considered or initiated local deer management strategies in the past decade (Figure 9A). Sixteen of the surveyed municipalities (6%) expanded hunting access by reducing restrictive bylaws or opening municipal properties to hunting (Figure 9A). During this same time, six municipalities (2%) implemented changes that reduced hunting access and 15 municipalities (6%) considered altering hunting access, but did not implement those changes (Figure 9A). Some respondents did not know how to answer these questions (28%; Figure 9A). Most municipalities that considered or initiated local deer management strategies are located within the two most urban and suburban Northeast and Southeast WMDs (Figure 9B) and we found strong evidence for large differences among WMDs in their engagement toward deer management, $N = 186$, $p < .001$, $V = .34$. In the Western, Connecticut Valley, and Central WMDs, only two of the responding municipalities have implemented changes in hunting access (Figure 9A).

[Figure 9 here]

Public opposition to hunting is often viewed as a major obstacle to effective wildlife management efforts and 34% of respondents reported opposition to hunting in their municipalities.⁵ Most responding municipalities in the Southeast (48%) and Northeast (38%) WMDs had opposition to hunting in their municipalities, whereas the rural WMDs had a minority of municipalities with opposition to hunting (i.e., 20% in Central, 25% in Connecticut Valley, 23% in Western WMDs).

Discussion

Municipal-level regulations shape access to lands for hunting and implementing wildlife management programs. As wildlife populations, such as those of white-tailed deer, increase in these communities, wildlife managers, municipal decision-makers, and residents face a range of human and ecological concerns (e.g., Augustine & Decalesta, 2003; Côté et al., 2004; Decker & Gavin, 1987). Many municipalities are exploring and implementing new conservation and wildlife management activities (Adams, 2016), but options to manage deer in suburban communities are often limited and contentious. Given the local constraints that can affect implementation of management plans in the suburbs, municipal governments have become crucial actors in shaping local hunting access and wildlife management activities, and serve as intermediaries among residents, hunters, and state agencies. Our results showed that relationships among deer populations, public concerns, and municipal action vary, illustrating the complex role of municipal decision-makers in shaping wildlife management.

Heightened (Yet Heterogeneous) Concerns about Deer in Suburban Regions of the State

Respondents from the Northeast and Southeast WMDs reported the greatest levels of concern about deer among municipal officials. These WMDs include the majority of MA suburban municipalities. Many respondents from these WMDs also reported high concerns

⁵ Although 31% of them did not know how to answer this question.

about deer among residents. The perception of greater concerns among municipal officials and residents in the Southeast and Northeast WMDs likely reflects the intersection of changing deer populations and the distinct socioecological context of suburban landscapes where human development patterns shape human-wildlife interactions. Deer were once extirpated from much of MA, but are now believed to be at greater densities than they were in the 19th Century (McCabe & McCabe, 1997). Respondents in the suburban WMDs were more likely to report that they perceived deer populations to be increasing. Studies in similar suburban landscapes have documented increasing deer populations, supported by the abundant edge habitat that allows deer to move comfortably between forest spaces and garden vegetation (Decker & Gavin, 1987; Gaughan & DeStefano, 2005).

Although our results establish the greater levels of concern about deer in the suburban WMDs, our findings also reveal spatial heterogeneity within each WMD. For example, respondents from neighboring municipalities with similar landscape features frequently reported different perceptions of deer population trends (Figure 3), proportion of concerned residents (Figure 4), and frequency of complaints about deer (Figure 5). These differences in responses among communities across and within WMDs are likely due to a combination of social and environmental factors, including actual differences in deer presence due to variations in density at a fine scale within communities enabled by uneven hunting access (David Stainbrook, MassWildlife, personal communication). Variations in the levels of concern toward deer among nearby municipalities in the more suburban Northeast and Southeast WMDs, however, suggest the presence of complex and localized social and political factors. For instance, prior research suggests that stakeholders within and among particular communities may differ in their ability to amplify concerns through local networks (Triezenberg et al., 2011), which could cause the experiences and views of some residents to be better known to officials in some municipalities and not others. Thus, the practices of

individual stakeholders, as well as local cultural norms and political dynamics, are important underlying factors that produce these differences in concerns about deer and management decisions (as discussed below). Investigating relationships among local-level politics, hunting access, and deer density at a local scale could help to better understand the variations in wildlife management strategies.

Increasing Importance and Heterogeneity of Deer Management in Suburban Regions of the State

Our analysis of local bylaws revealed that rural communities rarely have bylaws that restrict hunting beyond the existing state rules and regulations. However, major differences in bylaws and management practices exist among suburban and urban communities, even those with similar biophysical and socio-economic characteristics. Our results also demonstrated that communities in suburban regions are more likely than rural areas to have considered or implemented changes to manage white-tailed deer. In contrast, few rural municipalities have considered or initiated local actions to manage deer populations. These differences highlight several challenges facing wildlife managers and the importance of municipal governments in shaping wildlife management. First, rural areas generally have fewer bylaws that constrain hunting, limiting the need for involvement of municipal governments in efforts to manage wildlife populations. By contrast, hunting-related bylaws that limit land access and use of firearms and archery in many suburban communities necessitate that municipal officials engage in the implementation of wildlife management programs. Second, the variation in policy and management efforts among suburban and urban communities, even in some with similar environmental conditions and public perceptions of deer, suggests that an array of other social factors influence management practices (Figures 8 and 9). Local politics, histories, culture, and institutional contexts are important for explaining these differences. These differences also demonstrate the significant role of municipal decision-makers in

wildlife management and the need for state agencies to understand the priorities and decision-making processes of these groups.

Perceived Priorities of Municipal Officials

Although previous research highlighted ways that residents' concerns and attitudes toward deer are shaped by experiences with deer (Stewart, 2011; Urbanek et al., 2013) and are moderated by individuals' underlying beliefs and core values (DeNicola et al., 2000; Manfredo et al., 2017), our results revealed the importance of examining the concerns and perceptions of municipal officials themselves. Our findings suggest that the priorities and concerns that municipal officials hold about deer differ from the perceived concerns of residents. For instance, respondents perceived: (a) damage to private property to be a greater concern for residents relative to municipal officials, and (b) forest health—although not the top concern—to be a greater concern for municipal officials, particularly in suburban areas. Given the importance of local bylaws in determining hunting access and wildlife management in many suburban municipalities, municipal officials are important stakeholders in shaping wildlife management policies in advancing municipal agendas and as necessary mediums for understanding and responding to resident concerns.

Municipal officials from various offices and roles may be involved in making decisions about municipal actions that intersect with wildlife management. To build our sample of respondents, we contacted each municipality to determine who would be the most knowledgeable about deer-related issues and the resulting sample contained officials holding diverse positions. As documented here, the responses to some questions differed depending on the position of the respondent. These differences may reflect the various priorities and interests of these respondents as they interpret deer-related issues through their professional roles and obligations (Rudolph et al., 2011). Members from the Board of Health, for example, may be more attentive to tick-borne illnesses, whereas conservation officers might be more

attuned to issues of forest health. More research on how the influence of officials in these different roles varies among communities could provide a greater understanding of the local politics that shape human-wildlife relationships and also offer insight into why concerns about deer are elevated in some locations but not others. Further exploration of the ways that environmental and health concerns of the public articulate with the interests of municipal officials and local bylaws could provide important insights into why some communities ultimately choose to engage in wildlife management activities.

Conclusions and Future Research

As deer and other wildlife populations increase in suburban and urban landscapes, state wildlife managers are navigating municipal governance structures, engaging with municipal officials, and managing the interests of diverse stakeholders. Our results offer insight into differences in the actions and concerns of municipalities related to deer, particularly within suburban communities. These findings suggest that municipal governments in suburban and urban areas play an important role in shaping wildlife management, but their decisions may not always directly follow from broad public concern or environmental changes. Greater understanding of municipal decision-making processes can support the efforts of wildlife managers as they navigate these governance structures and local politics to work with communities on wildlife issues. Our results contribute to building knowledge on the roles of municipal governments in wildlife management and the local politics of wildlife management in the suburbs.

Although our study focused specifically on white-tailed deer in MA, the findings and issues discussed here are relevant to the management of other species in other urban and suburban locations. Future research could explore the role of municipal governments in shaping and responding to other wildlife challenges. Open questions include: What behavioral and policy actions are suburban and urban stakeholders taking to manage different

wildlife species? What are the relationships among resident concerns, local culture, and municipal actions? What cultural and political factors drive some municipalities to actively manage wildlife while others do not take action?

The effectiveness of wildlife management efforts can be improved by further investigation of how regulations and politics at multiple levels, including municipal levels, play a role in shaping wildlife management practices. This is particularly important as many wildlife populations continue to increase in urban and suburban communities, where municipal governments have influence over and have historically regulated access to lands for hunting. Wildlife managers already frequently engage with municipal governments, but results from research, such as those presented here, provide insights into what contributes to the success and failures of these collaborations, and may lead to novel approaches for wildlife management. A deeper understanding of the social, political, cultural, and environmental factors that drive municipal decision-making can support productive collaborations among municipal governments, wildlife agencies, residents, and other stakeholders in wildlife management.

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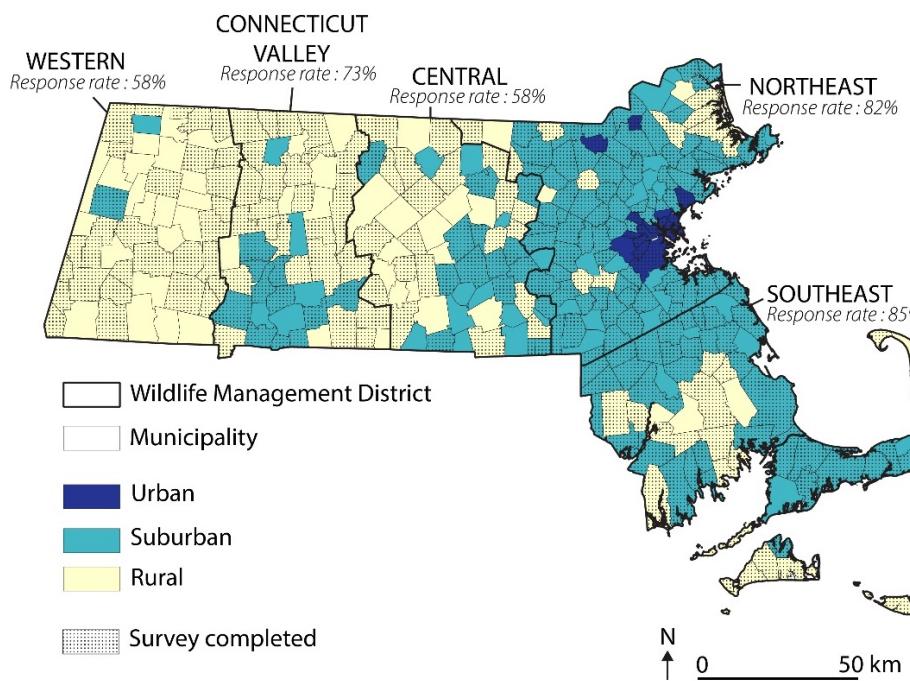
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Wildlife Management District ¹	Total Municipalities	Typology of municipalities ²	Average municipal population density ³	Average municipal median household income ³	Landscape feature (Average % per municipality) ⁴	Settlement patterns	Other notes
Northeast (NE)	122	urban: 15 (12%) suburban: 93 (76%) rural: 14 (12%)	1,083 pop/km ²	\$103,984	forested land: 34% developed land: 40%	very dense	includes Boston and suburbs
Southeast (SE)	68	urban: 0 suburban: 45 (66%) rural: 23 (34%)	302 pop/km ²	\$79,212	forested land: 28% developed land: 22%	dense	includes outer suburbs of Boston, Cape Cod peninsula, islands of Nantucket and Martha's Vineyard
Central (C)	60	urban: 0 suburban: 27 (45%) rural: 33 (55%)	224 pop/km ²	\$85,263	forested land: 55% developed land: 13%	sparse	includes outer suburbs of Boston, and Worcester
Connecticut Valley (CV)	49	urban: 0 suburban: 16 (33%) rural: 33 (67%)	212 pop/km ²	\$68,684	forested land: 58% developed land: 11%	sparse	includes Springfield and stretches of cultivated crops along the Connecticut river
Western (W)	52	urban: 0 suburban: 2 (4%) rural: 50 (96%)	38 pop/km ²	\$67,827	forested land: 76% developed land: 2%	isolated	includes large portions of state-owned open and recreational spaces

Table 1. Characteristics of Wildlife Management Districts in Massachusetts (USA). Sources:¹ Massachusetts Division of Fisheries and Wildlife, ² Short Gianotti et al. (2016), ³ US Census Bureau (2013-2017), ⁴ NLCD 2016.

Figure 1. Wildlife Management Districts and municipalities categorized as urban, suburban, and rural (Short Gianotti et al., 2016). Information on questionnaire completion among municipalities and response rate per Wildlife Management District



of positions occupied by respondents (A) in responding municipalities, and (B) across Wildlife Management Districts (%)

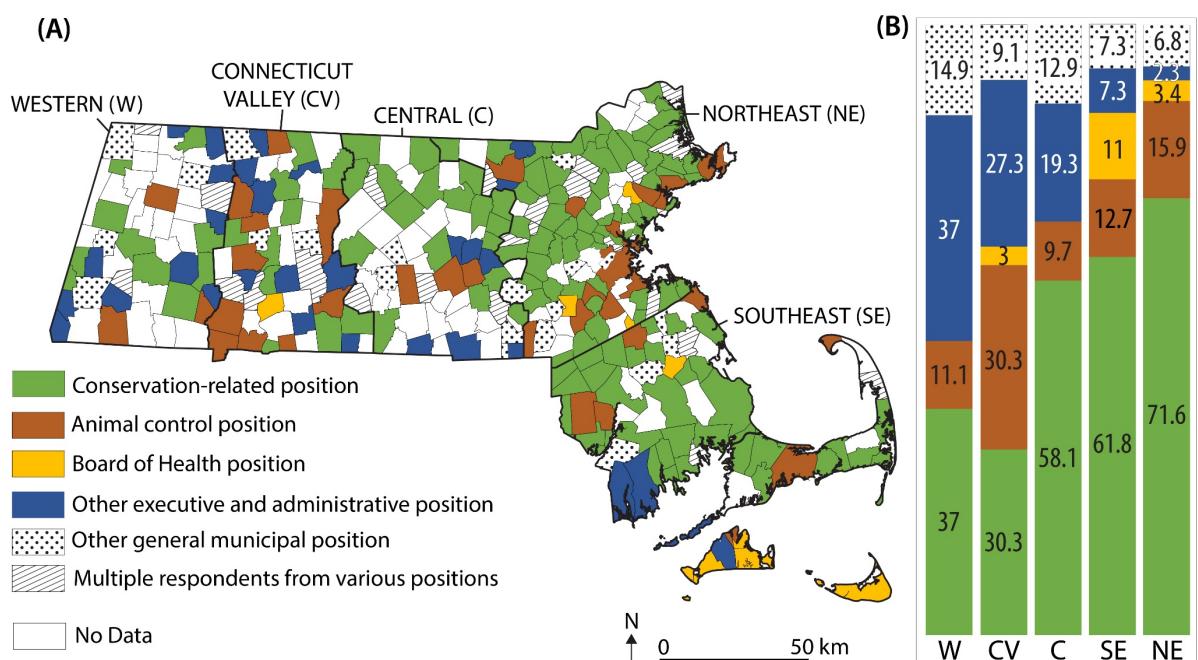


Figure 3. Change in deer populations over the past two decades as estimated by respondents (A) in responding municipalities, and (B) across Wildlife Management Districts (%)

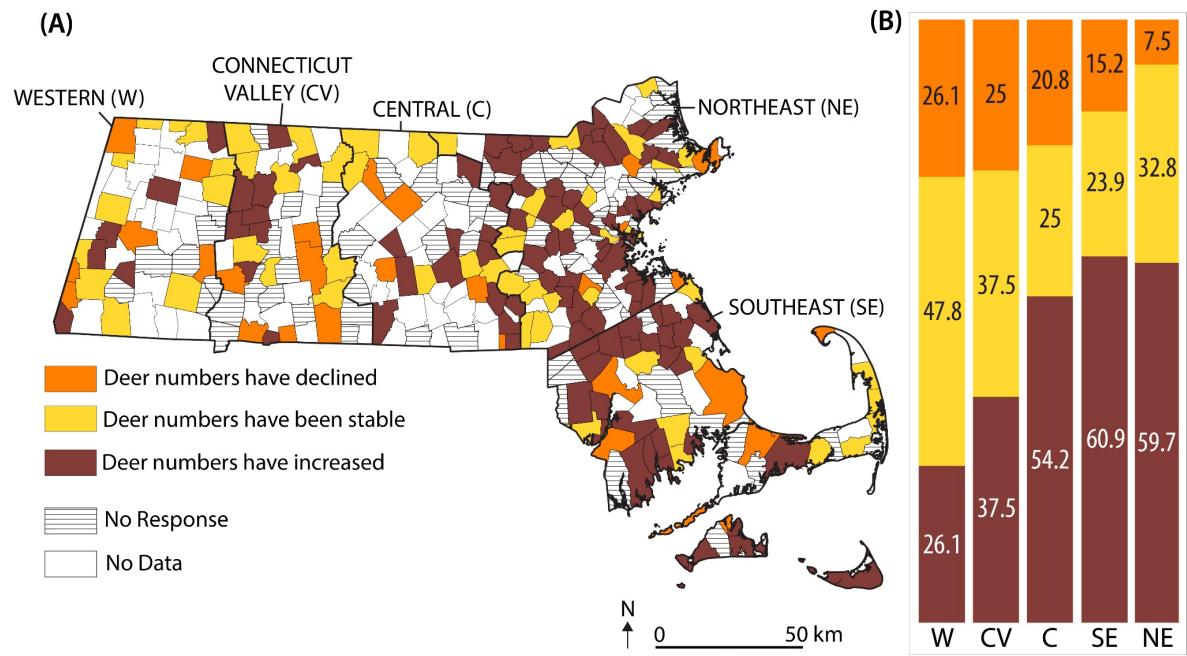


Figure 4. Proportion of residents who consider deer to be a problem as estimated by respondents (A) in responding municipalities, and (B) across Wildlife Management Districts (%)

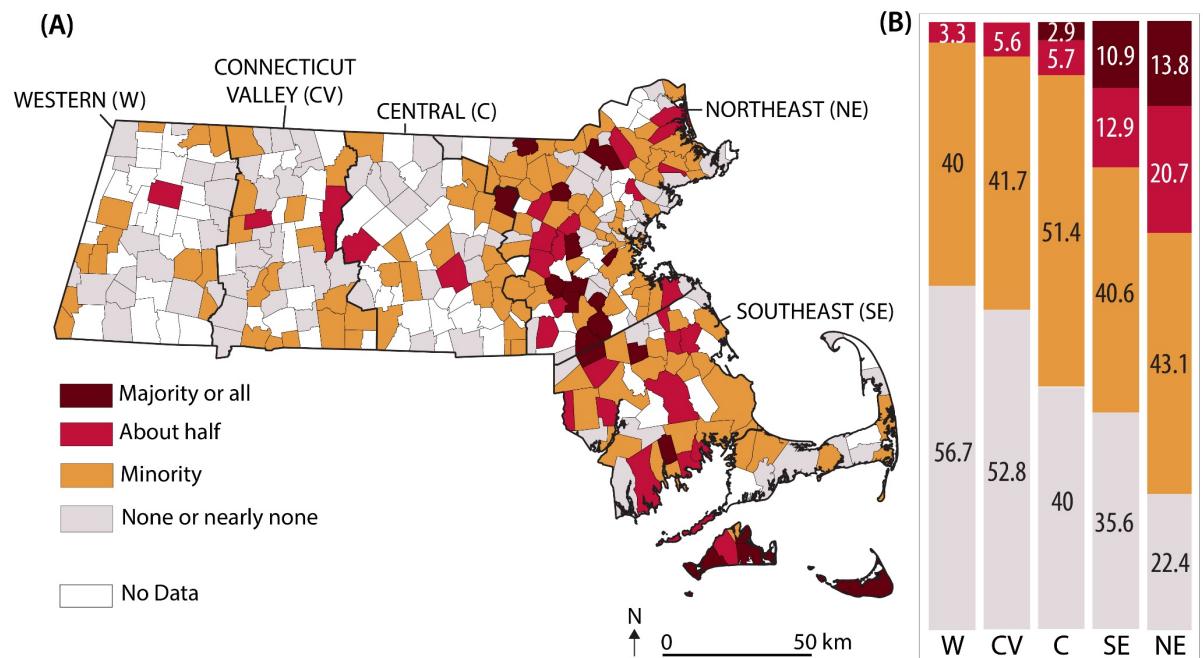


Figure 5. Frequency of received complaints from residents on deer-related issues (A) in responding municipalities, and (B) across Wildlife Management Districts (%)

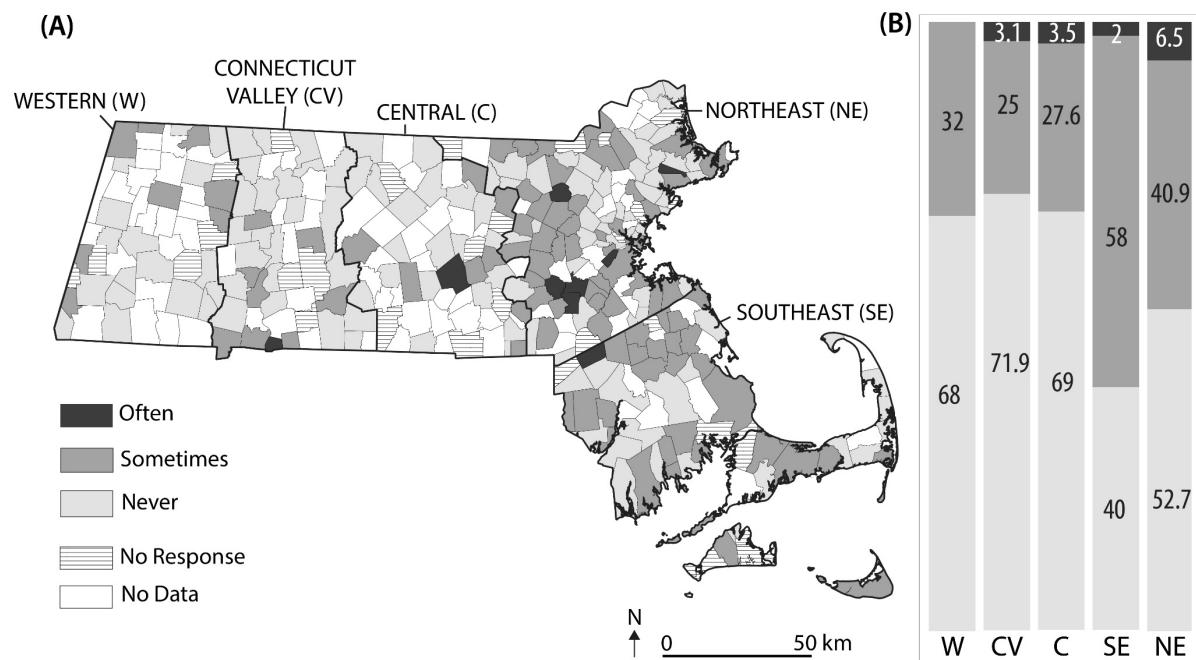


Figure 6. Overall level of concern among municipal officials (A) in responding municipalities, and (B) across Wildlife Management Districts

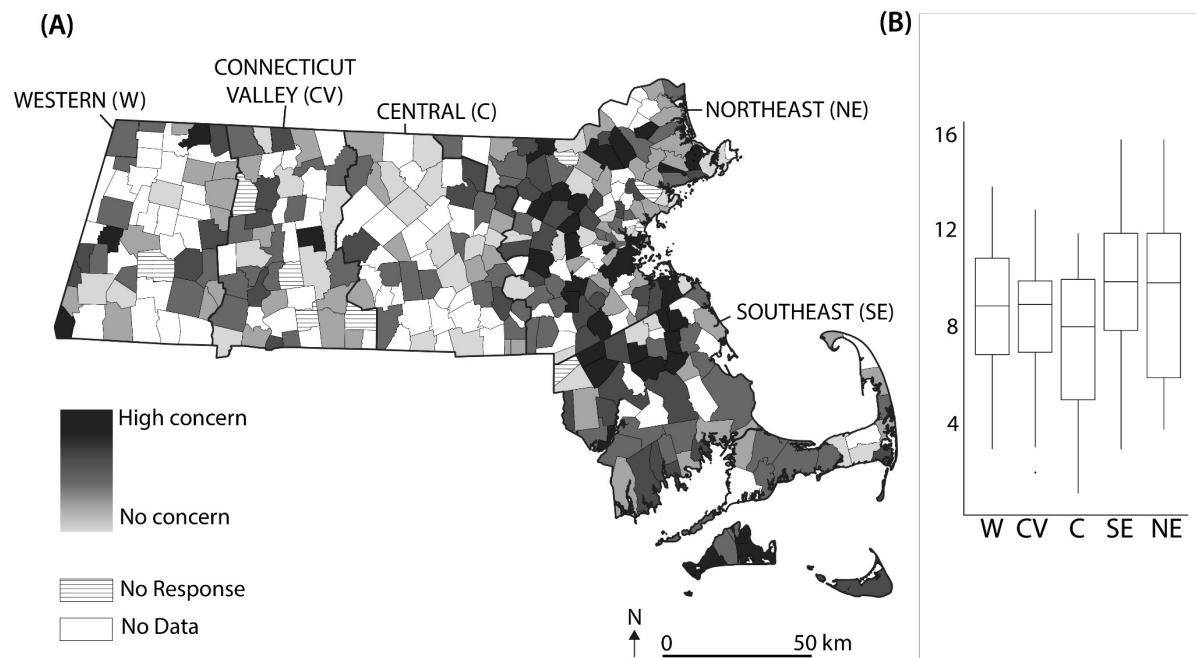


Figure 7. Respondents' perception of the levels of concerns held by municipal officials and residents about (A) tick-borne diseases, (B) deer-vehicle collisions, (C) property damage due to deer, and (D) impacts of deer on forests in each Wildlife Management District (%)

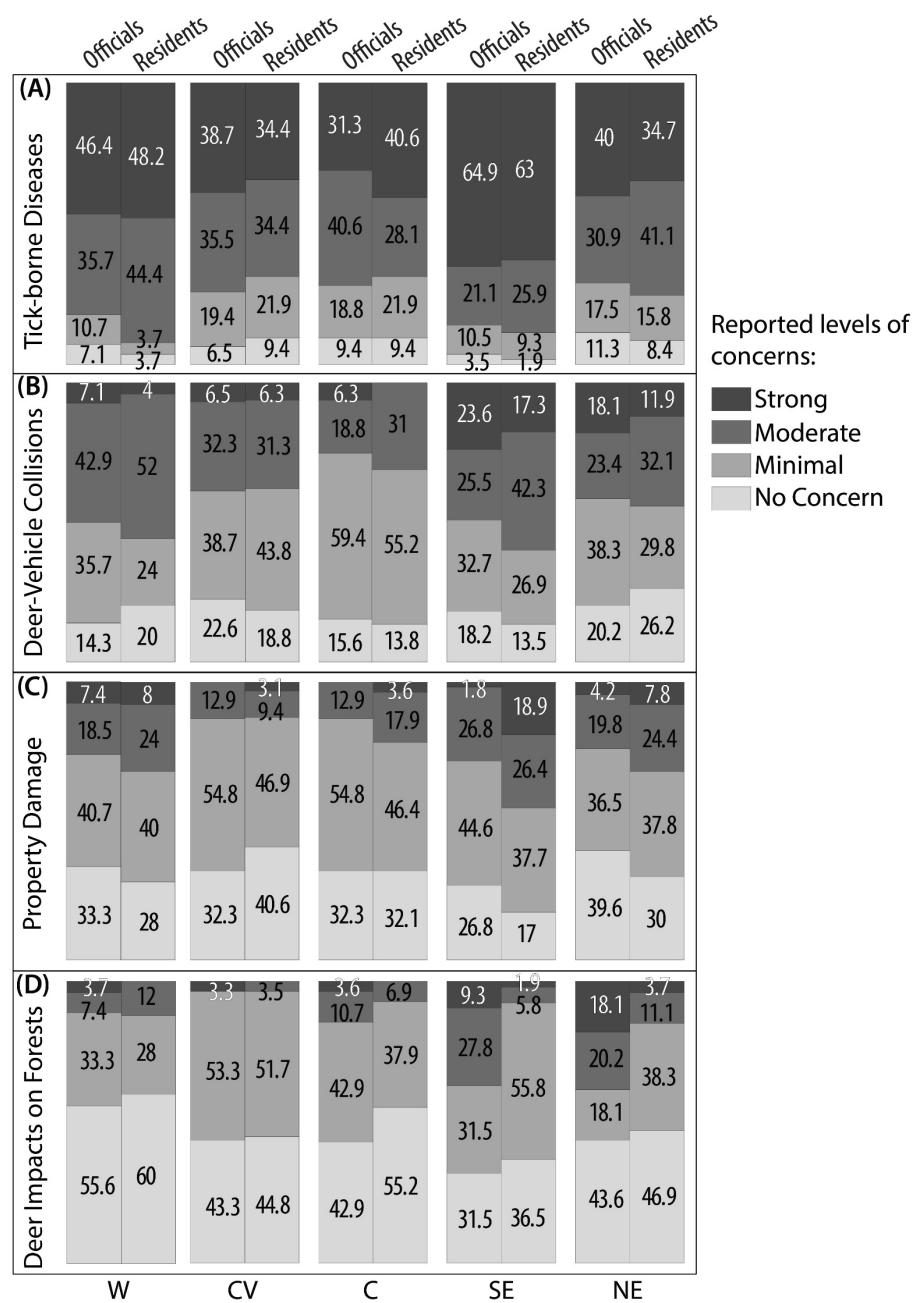


Figure 8. Municipal ordinances and bylaws that restrict hunting beyond state regulation (A) in all MA municipalities, and (B) across Wildlife Management Districts (%)

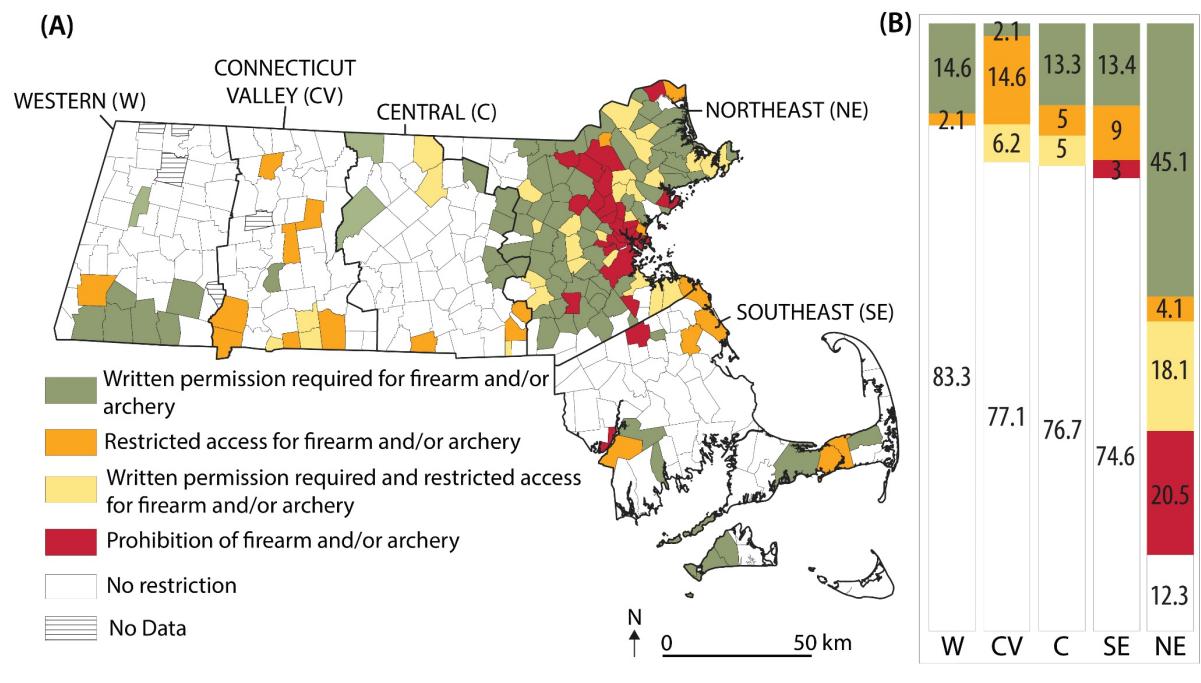


Figure 9. Implemented and discussed changes in hunting opportunities (A) in responding municipalities, and (B) across Wildlife Management Districts (%)

