Population and Movement Effects from Alternate White-Tailed Deer Management in Eastern USA

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Skills for Undergraduate Participation in Ecological Research

Stella Schuchart

Allie Kohler

Instructor: Dr. Stacy Lynn

TA: Sean Geer

Names & Affiliations

Allison M. Kohler, NREL
Randall B. Boone, NREL

Research Summary

White-tailed deer (*Odocoileus virginianus*) are widely known across the eastern United States for being overabundant which has led to negative effects including decreases in vegetation abundance through overgrazing, increases in disease spread, increases in vehicle collisions, and more that is affecting wildlife and human well-being. Management strategies vary around the U.S. depending on different types of parameters that effect deer behavior which include population dynamics, landcover, movement, and habitat fragmentation which plays a big role in how management plans can be improved to implement population control. To test these parameters, Netlogo was used to create a model that used social (interviews, surveys) and ecological (deer population estimates, camera traps, landcover) data to test how different types of management plans influence the movement and population of white-tailed deer in the studied areas of Massachusetts and New York from 2019-2023. Data for land cover, deer populations, and management types (no harvest, sharpshooter, archery, shotgun, primitive, and archery) were collected for each area. Preliminary literature states that the hunting strategy of sharpshooting management can be the most effective on population control. An implication to the sharpshooting method is that it can be argued to be unethical due to various opinions in humaneness and the view of “human control”, but the outcomes prove that this method compared to others, like fertility control, allows them to still live a natural lifestyle. Using Agent Based Modeling can form a better understanding of what these management strategies can conclude when addressing population control.

Introduction

White-Tailed Deer and Management

White-tailed deer (*Odocoileus virginianus*) (Figure 1) have been living alongside human beings for thousands of years and is arguably one of the most popular species in America. Since they are the most popular species that can mean that their population has grown to quite the numbers. This overabundance in deer population has led to negative effects including decreases in vegetation abundance through overgrazing, increases in disease spread, increases in vehicle collisions, and more that is affecting wildlife and human well-being (Stinchcomb et al., 2022). As humans have spread and developed throughout North America, habitat loss and fragmentation has become the leading factor in the effects of wildlife populations and

movement (Darlington, 2022). This can contribute to many changes that include how species interact with each other and how their populations spread out over a landscape. Many factors can change a species behavior, this includes community structure and species distributions (Darlington, 2022). Habitat fragmentation and other factors that affect species behavior can also play a huge role on how disease is spread within wildlife communities and possibly between human-wildlife communities (Willgert, 2022).

States across the country are doing their part in managing white-tailed deer population and distribution in their own ways. Deer have proven to be resilient when it comes to landscape change and urbanization. This resilience has caused deer to become very friendly in urban settings that can cause concern in ecological and human-wellbeing (Edelblutte et al., 2022). Many studies have been done with the concern of what management plans make the most sense when considering what areas are in the highest of need while also considering the ethics of deer removal. Some of the most common management plans, which are the ones that will be discussed in this paper, include no harvest, sharpshooter, and archery. Each of these have their pros and cons and some work more effectively than others depending on the state of the deer population and the laws in the state. In terms of the more ethical approaches, many studies had been conducted showing that fertility control is more supported due to it being safe and humane (Hernandez et al., 2006) while lethal control has a higher chance of achieving desired population numbers but is seen as inhumane due to the viewing of it as “human control” (Gamborg et al., 2020). While both have their pros and cons other alternatives like fencing along highways has proven to be the most effective and economical strategy in terms of roadside management (Gulsby et al., 2011).

To test the parameters of landcover and management, Netlogo was used to create a model that used social (interviews, surveys) and ecological (deer population estimates, camera traps, landcover, management) data to test how different types of management plans influence the movement and population of white-tailed deer in the studied areas of Massachusetts and New York from 2019-2023 (Figures 2 & 3)(Table 1). The model incorporates three sectors that include management, environment, and population and each have various effects on deer population and movement that will be evaluated.

Figure 1. Picture of a male white-tailed deer (*Odocoileus virginianus*)(Google Images).

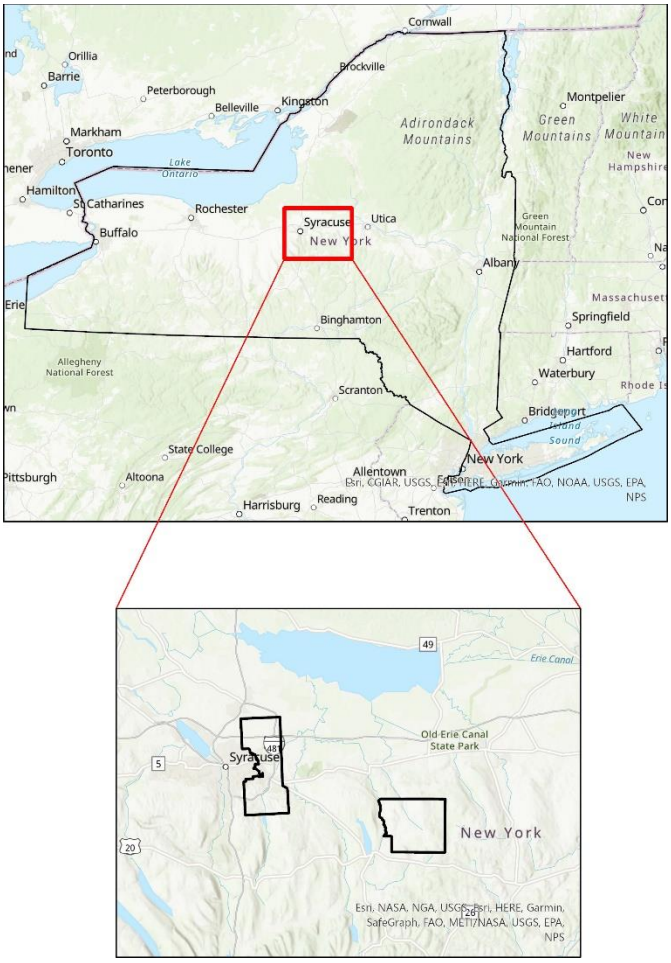

Figure 2. Topographic map showing the location of the two study areas in New York. Manlius is shown on the left and Fenner is shown in the right.

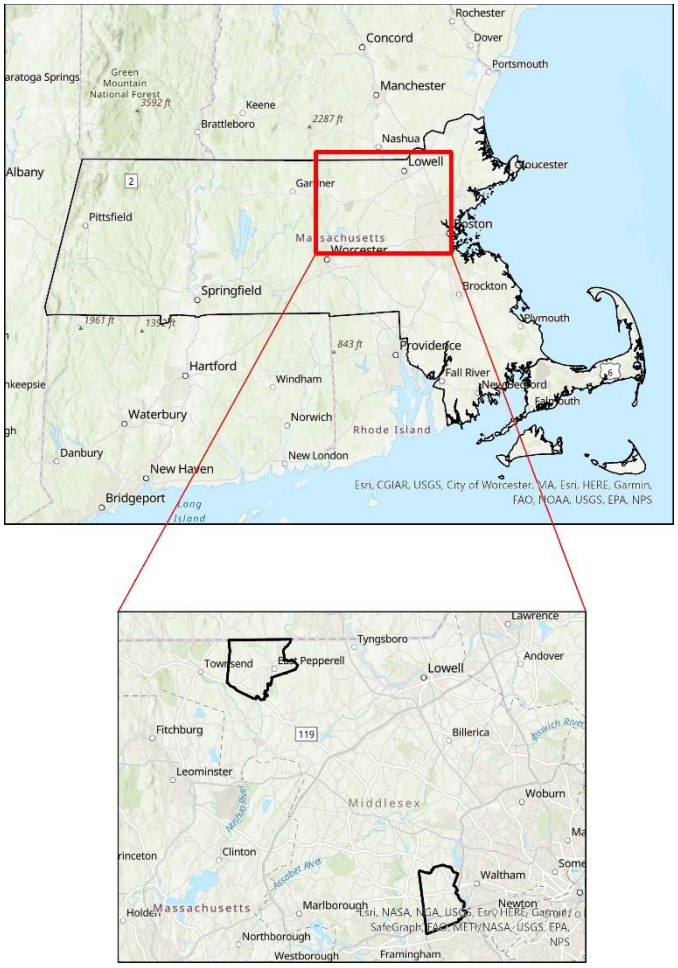

Figure 3. Topographic map showing the location of the two study areas in Massachusetts. Pepperell is shown on the upper left and Weston is shown in the lower right.

Agent Based Modeling

In ecology and other scientific fields, simulation models that describe individual organisms or agents have become a very popular tool that deal with complex systems that are composed up of independent variables (Grimm et al., 2006). Agent Based Models (ABMs) give researchers the opportunity to understand systematic levels of adaptive behavior of individuals and how they are affected by their environment (Grimm et al., 2006). Using ABMs for this project will be important to gain an understanding of what parameters are important when deciding what management plans are more effective in white-tailed deer management.

Research Questions and Hypotheses

Research Question:
How do different types of management plans and landcover influence the movement and population of white-tailed deer in selected towns in New York and Massachusetts?

Expected outcome/hypothesis:
The different types of management plans (or no management plans), landcover, and deer behavior in both New York and Massachusetts will have a significant effect on the movement and population of white-tailed deer. Implementation of a new management plan can change the population and movement of deer significantly.

Explanation:
To figure out how management plans influence white-tailed deer movement and population I, along with my mentor Allie Kohler, used ArcGIS software to configure landscape and management layers for each of the study site then used those layers in a model using NetLogo to determine how these layers and other factors like deer dynamics attributed to deer population and movement.

Methods

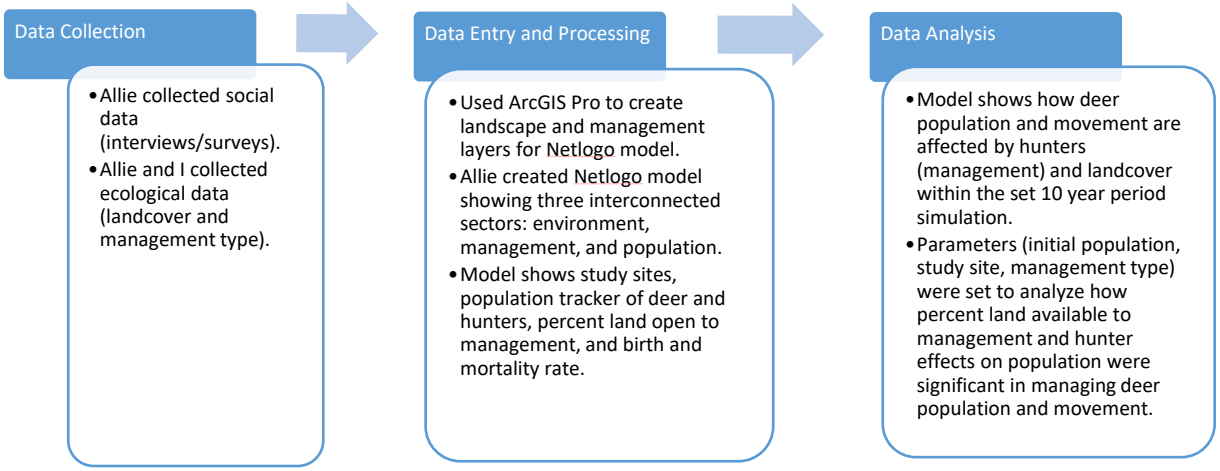

Figure 4. Steps of methods and workflow used to answer research question and objective. Steps include work done by mentor (Allie Kohler) and student (Stella Schuchart).

Data Collection:
Allie and her technicians collected ecological data across study sites from various sources. In order to see the trends in deer dynamics, they collected year-round camera trap images. For the model, land cover data from the National Land Cover Database (NLCD) and weather data from Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group was collected by Allie, her technicians, and myself. They also used social science aspects to collect both qualitative and quantitative data by conducting surveys/interviews from state agencies, town officials, landowners, and hunters in the study areas (Figure 4). Table 1 shows the chosen studied towns in relation to their context and management.

Data Entry and Processing
For data entry and processing, most of the data were entered into the model by Allie and Dr. Boone, this data is the data that is listed above as well as landcover and management layers that Allie, Jamie Goethlich, and I created in ArcGIS. For the GIS data layers we created landscape layers that showed forest, open space, development, and water. For the management layers we created layers that represented huntable public and huntable private lands in the studied areas. We then used these layers to form parameters for the deer in the model. The model displays different aspects of the data that include the three interconnected sectors: environment, management, and population. Within each of these sectors the data displays hunter behavior, deer harvested/mortality, landcover/use ratio, initial population size/sex of the deer, and other factors that account for the parameters of deer population dynamics. Lengths of coding were put into Netlogo by Allie to build the interface tab, this is where the town selection is showed along with switches to turn on and off deer and hunters**,** population tracker of deer and hunters (graph)**,** percent of land that is open access (slider), age over time (graph), birth and growth rate (graph), and deer density for rural, suburban, available and unavailable land.

Data Analysis
Analyzing the data is the model part of this project, this is analyzing how landcover and management affect the population and movement of deer within each of the NY and MA towns. Using an empirical agent-based approach, the agents in the model represent deer and humans and the interaction between the two depending on the shared environment, which is stimulated to represent real responses. These agents react to the different types of landcover and management that is put into the model, which is crucial to understanding where deer move and where the humans (hunters) can hunt in the specified towns. The model showed us various types of outputs summarizing what the deer and the hunters do. This may show that the hunters decreased the deer population through the management strategy, or it can show that the management strategy was not a dictator to deer population and movement.

Table 1. This table shows the studied towns in both MA and NY in relation to their context and management. (Kohler, 2022)

State	Townships	Context	Management Notes
MA	Pepperell	Rural	• Pepperell does not have a deer management plan.
	Weston	Suburban	• Weston has had a bow hunt program on town lands since 2012 and facilitates hunter access on private lands.
NY	Fenner	Rural	• Fenner does not have a deer management plan.
	Manlius	Suburban	• Manlius adopted a maintenance sharpshooting program in 2018.

Preliminary Results

Table 2. This table shows how percent land available to management and hunter effects on population have affected the population.

Town	Management Plan	Percent land available to management (%)	Hunter effects on population (n= 100)	Population before management implementation	Population after management implementation
Pepperell, MA	None	21	N/A	407	648
Weston, MA	Bow hunt	11	Effect	581	424
Fenner, NY	None	64	N/A	1544	1749
Manlius, NY	Sharpshooter	33	Effect	1765	1583

Based on the results above, it concludes that a management plan does influence deer population. For these preliminary results though, we didn't have the exact numbers showing why each one (sharpshooting and bow hunt) had the effect they did. For each of the towns the hunter population was set to 100 (chosen from the scale of 0, 50, and 100) so that the maximum amount of possible management could be shown. For the land available to management, it was decided that reduced access to available management land was set to 0% so that we could also get the maximum amount of possible management.

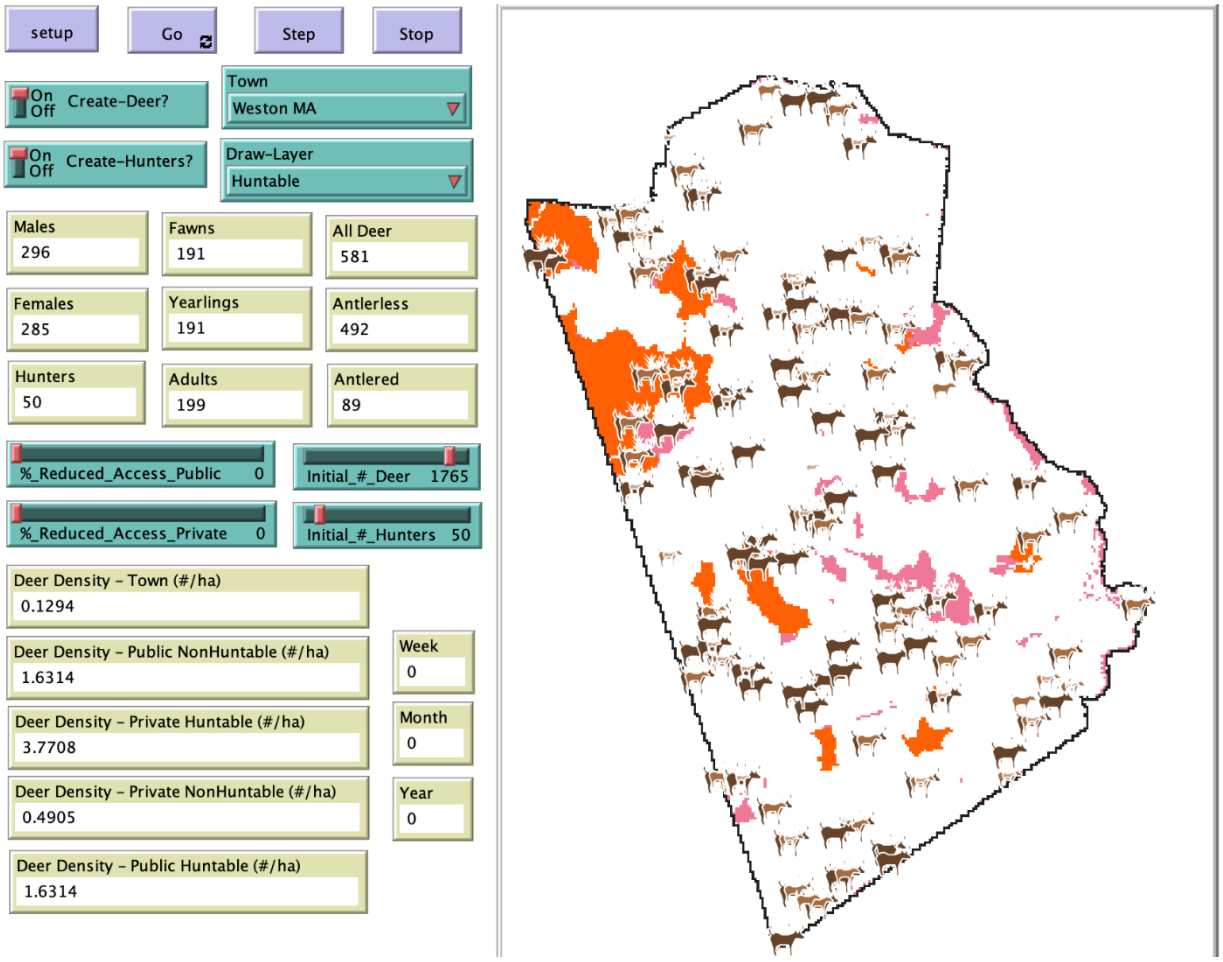

Figure 5. Screenshot of interface in model showing the town of Weston, MA that displays the 11% land available to management. Orange and pink are separated by public and private huntable land.

Discussion

Results discussion

White Tailed deer in the Eastern region of the US have to endeavor habitat fragmentation, changes in land uses and cover, and the overall presence of humans. This means that behavior, population, and movement are all a changing factor in their livelihoods that can affect the relationship that is present between them and humans. Management plans are implemented all around the US to mitigate overabundance and the movement that goes with it. Deer have become smarter and more resilient in urban settings so the need for management has been at an all time high. The question is though, how do different types of management plans and landcover influence the movement and population of white-tailed deer in selected towns in New York and Massachusetts? The results from Table 2 shows the answer to this question. When conducting how to find these results it was clear that two factors contributed to deer population and movement, those factors being percent land available to management and how

the management (hunters) affected the deer population. In the results we found that both management plans played a role in how they affect deer population. The reason for representing a town in both states with no management plan was to have a set control of the population so it could be compared to the towns with management plans. This is important because Table 2 shows similar initial populations for each town in the same state, so to show how a management plan can have an effect on population is represented this way. It is also important to note that the two types of plans could be implemented for each town due to initial deer population, town weapon regulations, and the amount of accessible management land. When the model was ran, deer were interacting, moving, dying, and reproducing and movement and population fluctuated throughout the studied towns, which is similarly realistic to real-life scenarios.

When discussing how landcover and use affect the movement of deer it is noted that when a selected town has more open space and forested areas, the deer tend to be drawn to those areas for apparent reasons like shelter, food, and gathering (mating). When moving between those areas deer tend to get themselves in situations that involve human-deer interactions like vehicle collisions and the possibility of disease spread. This is more apparent when there is a higher population of both humans and deer in the area, that is why there is a need for deer management plans in towns that have a high interaction possibility. Human-deer interactions have caused both sides lives and complications that in turn result in a loss in human and wildlife well-being. The need for White-Tailed deer management plans may be higher in some areas than others, and that is where a model like ours can step in a evaluate what parameters are affecting the population and movement of deer based on landcover and management plans.

Based on the results I suggest that these management plans stay in effect as long as they need them to. I also think that similar towns could take these plans into consideration when addressing the need to adopt one.

Limitations discussion

Wildlife management has been a sensitive topic in the realm of ethics and management sectors. This being due to how the plans are put into place and how people feel about the control that humans have on the lives of deer populations. Many studies have been conducted testing the complexity of deer population control in relation to beliefs and ethics. Gamborg 2020 states that when considering humanness it is considered as bringing the best overall well-fare for the deer that is managed, this includes taking into account deer's positive experience during its life. Controversies on the ethics of deer control mainly focus on two practices those being fertility control where female deer are captured and injected with the application and then there is lethal control where management implements sharpshooters or hunters into an area. Fertility control raises concerns because of the reduction in positive life experiences like the capturing of the deer as well as the unnaturalness of not being able to reproduce (Gamborg, 2020). Lethal control raises concerns due to the concern of robing the animal of something that it deserves (life) and also the factor of an unclean kill can cause pain and suffering (Gamborg, 2020).

More limitations within this research include that these kinds of models can have an inherent bias because they are simplifications of reality and are only meant to capture an aspect of a real system. This meaning that when changing how management plans can affect population and movement of White-Tailed deer, it is only taking into account of how it will effect that specific species. This, in the bigger picture, could have other great effects on other species and ecosystem functions. There are also other limitations that include the amount of accessible open-source data, time limitations, accuracy of data and statistics, and sufficient funding.

Conclusions

The conflict of human-deer interactions is a complicated subject with many sides to argue about. With progressing technology these conflicts can become easier to navigate, especially when accurate and real-life data is put into the mixture. The addition of Agent-based Models to research can help us deal with very complex systems that will give researchers the opportunity to understand systematic levels of adaptive behavior of individuals and how they are affected by their environment (Grimm et al., 2006). The use of models can help municipalities all across the globe predict and prove how management can be implemented for the greater good of human-deer interactions.

References

Stinchcomb, T. R., Ma, Z., & Nyssa, Z. (2022). Complex human-deer interactions challenge conventional management approaches: The need to consider power, trust, and emotion. *Ecology and Society*, *27*(1), art13. https://doi.org/10.5751/ES-12899-270113

Summary: In this article the authors start out by explaining how the management of white-tailed deer has been focused on improving hunting opportunities and mitigating human-deer conflicts. The growth of both humans and deer have implied that human-deer interactions are diversifying and to help understand the two interactions the Integrated Adaptive Behavior Model (IABM) was used. To assess how the public perceived deer populations they used empirical social science to configure what outcomes the public desires and how those could be implemented into Indiana's, where the study was conducted, deer management plans. Once the stakeholders were identified which included: woodland owners, farmers, hunters, and urban area residents they conducted interviews and focus groups and concluded that Indiana citizens hold complex opinions toward the deer population. Factors that influenced the opinions included past experiences, beliefs, responsibilities, and ethics in deer management.

Hernandez, S., Locke, S. L., Cook, M. W., Harveson, L. A., & al, et. (2006). Effects of SpayVac® on Urban Female White-Tailed Deer Movements. *Wildlife Society Bulletin*, *34*(5), 1430–1434.

Summary: In this article the authors explain how high white-tailed deer densities in urban areas result in human-wildlife conflicts. They state that managing deer densities via fertility management is more supported than lethal extermination. Out of all the contraceptive vaccines that are available and safe and humane SpayVac would be used as a contraceptive in this study to determine how it effects female white-tailed deer and their movements and ranges. The information that follows can allow wildlife managers to grasp a better understanding of the effects of the SpayVac contraceptive on urban white-tailed deer. Once the study was conducted on 49 females with 38 of them injected with SpayVac and 11 with a placebo (control) they found that the contraceptive to be 100%. One side effect the did predict though was that the injected females would adopt a side effect of an expanded range and movement due to estrus, and this side effect was not seen in the study. To conclude, the study proved that the use of contraception in female deer in urban areas could be a management tool.

Darlington, S., Ladle, A., Burton, A. C., Volpe, J. P., & Fisher, J. T. (2022). Cumulative effects of human footprint, natural features and predation risk best predict seasonal resource selection by white-tailed deer. *Scientific Reports*, *12*(1), Article 1. https://doi.org/10.1038/s41598-022-05018-z

Summary: Habitat loss and fragmentation is the leading cause of human disturbance and is affecting wildlife populations the most. Biodiversity, community structure, and species distributions can change species behaviors. Land-use change can create suitable conditions for invasive vegetation that can support herbivores that are adaptable to changing landscapes, but herbivores that are not adaptable to change can lead to a change in behavior like range-expanding. This can then lead to negative impacts on biodiversity through increased competition and predation. In this study, the authors assess how human features like highways and buildings, predators, or natural habitat selection explain why range-expanding deer choose their seasonal habitat. They found that across all seasons in deer ranges that human caused disturbance like the changing in boreal forests and the addition of human features contribute to range-expansion of white-tailed deer. They also found that contact with linear features like roads drove the deer to make decisions about movement while also considering how was foraging affected.

Edelblutte, É., Short Gianotti, A. G., & Connors, J. P. C. (2022). Perceptions, concerns, and management of white-tailed deer among municipal officials. *Human Dimensions of Wildlife*, *27*(5), 436–456. https://doi.org/10.1080/10871209.2021.1959963

Summary: In recent years white-tailed deer and been a highly talked about species in terms of how they do very well in urban and suburban areas across the United States. But it has also been talked about how management plans will continue with growing populations of both deer and humans. In order to manage wildlife populations in urban and suburban areas an investigation in how the public view deer management needs to be done. In this paper municipal concerns, municipal-level policies and practices, and how municipal officials view public concerns are evaluated. In order to get the answers a questionnaire was sent out to municipalities in MA asking various questions that relate to different views. Respondents noted that in the east side of MA there was concern about deer populations among municipal officials. The respondents also noted that the concern was in suburban areas where human development patterns shape the interactions between humans and wildlife.

Gamborg, C., Sandøe, P., & Palmer, C. (2020). Ethical management of wildlife. Lethal versus nonlethal control of white-tailed deer. *Conservation Science and Practice*, *2*(4), e171. https://doi.org/10.1111/csp2.171

Summary: In recent years the debate of lethal control of white-tailed deer has been on the rise, with more abundant deer populations in suburban and urban areas this dilemma is a real challenge for city councils and natural resource managers. Lethal control of deer populations traditionally involves sport hunting or sharpshooting to achieve the desired population numbers. This approach can be problematic in higher density urban areas and has been voiced that it is unethical and an alternative like fertility control is more favored. The strategy of fertility control can also have its downsides, one being the cost and the amount of work that has to go into sterilizing or using contraceptives. In this paper the authors want to develop a deeper thinking about what strategies would be ethical in deer population management. They discussed the different welfare outcomes of male and female deer saying that in both cases the use of fertility control could change how mating season plays out as well as risking "positive" experiences that comes along with it. They also discuss the welfare of deer in terms of hunting by addressing the effectiveness of the hunters' execution and can also be seen as robbing the animal of the ability to live out its life. There is also the naturalness argument made about how fertilization is unnaturally intended, same goes for the hunting aspect.

Gulsby, W. D., Stull, D. W., Gallagher, G. R., Osborn, D. A., Warren, R. J., Miller, K. V., & Tannenbaum, L. V. (2011). Movements and home ranges of white-tailed deer in response to roadside fences. *Wildlife Society Bulletin*, *35*(3), 282–290. https://doi.org/10.1002/wsb.38

Summary: Increasing white-tailed deer populations, highway expansion, and road traffic has resulted in a great increase in deer-vehicle collisions across the U.S. Strategies used to reduce collisions include fences, interception feeding, road lighting, reflectors and more. Fences are the most studied and a used, even though it is very costly, it is the most effective and economical option. In this study the authors report on a trial fence design and compare it to a commonly used fence design and compare the two in regard to how they affect deer home ranges and movement. They GPS collared 10 deer right before construction of the roadside fence in Georgia where they would collect the coordinates of deer movement before, during, and after the construction. The results concluded that before fence construction, the home-range deer crossed the fence 124 times and after the construction they crossed it 2 times leading to a 98% reduction of crossing in the most used fence. For the trial fence, which was angled toward the deer and away from the deer, these results were that before the construction deer crossed 228 times and after construction, they crossed 22 times. This study implies that fencing of different kinds is still just as effective and that when using fencing it is more effective to target deer home ranges that relate to highway hotspots.

Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S. K., Huse, G., Huth, A., Jepsen, J. U., Jørgensen, C., Mooij, W. M., Müller, B., Pe'er, G., Piou, C., Railsback, S. F., Robbins, A. M., … DeAngelis, D. L. (2006). A standard protocol for describing individual-based and agent-based models. *Ecological Modelling*, *198*(1), 115–126. https://doi.org/10.1016/j.ecolmodel.2006.04.023

Summary: In the field of ecology and in other disciplines simulation models that describe individual organisms or agents have become a very popular tool that deal with complex systems that are composed up of independent variables. These entities include the social sciences, economics, demography, and political sciences and when there is a need to describe these simulation models there is no standard protocol, and this can make is hard for other people to comprehend. In this paper the authors proposed a standard protocol to address this issue called ODD (Overview, Design concepts, and Details) to help describe IBMs (Individual-based models) and ABMs (Agent-based models). Individual-based models give researchers the opportunity to understand how system level properties grow from the adaptive behavior of individuals and how the system affects those individuals. There are two issues with the context of IBMs, the first one being that the standard protocol for describing them are burly in the sense of being able to describe what all is being used in the model.
The ODD protocol is broken up into seven elements: purpose, state variables and scales, process overview and scheduling, design concepts, initialization, input, and submodels. The purpose of splitting up these elements within each block is so that when the reader is understanding the IBM they can easily follow what is being explained. In this paper a sample application of ODD is presented which follows all elements in order.

Acknowledgements

I would like to acknowledge the CSU Geospatial Centroid, specifically Josh Reyling, for his dedicated help with our ArcGIS learning and struggling. His assistance helped us with transferring our landcover and management layers into NetLogo and without him we couldn't have done it ourselves. I would also like to thank SUPER for giving me the opportunity to participate in this research project along with whatever guidance was needed along the way.

Appendix 1: Methods Outline

Data Collection:

- Data collection done by Allie Kohler and her technicians:
    - Sampled understory woody plants as indices to browsing impacts on understory plant communities.
    - Collected year-round camera trap survey data across study site to estimate local deer dynamics.
    - Gathered land cover data from the National Land Cover Data Base (NLCD)
    - Gathered weather data from Parameter-elevation Regression in Independent Slopes Model (PRISM) Climate Group
    - Gathered harvest and collision data from state agencies in study area.
    - Study relevant literature to fill potential gaps in data.
    - Gathered survey/interview data from state agencies, town officials, large landowners, private landowners, and hunters in study area.

Data Entry and Processing

- Data that was collected by Allie and her technicians were entered into Netlogo model by Allie and Dr. Boone.
    - NLCD
    - PRISM
    - Harvest and collision
- Data that was entered into model by myself and Allie:
    - Geographic Information System (GIS) layers that will show town, forest, open space, development, and water.
    - Deer population data for each town.
- Model structure:
    - Interconnected sectors: environment, management, and population
    - Model is stimulated for 10 years, 1 tick is one week
    - Model globals:
        - Temporal
        - Spatial
        - Deer dynamics
        - Hunter dynamics
        - Harvest dynamics
    - Parameters of the model consist of each town and the data that correlates to the town.
    - Agents consist of female and male adults, yearlings, fawns, and male antlered.
    - Management parameters consist of no harvest, sharpshooter, archery, shotgun, primitive, and archery.
    - Mortality is related to natural and hunting.
    - Model also consists of natural happenings with deer that include male and female yearling dispersal, fawning, birth, the forming of bachelor groups, changing of male group leaders, and new group formations.
    - The interface tab consist of:
        - Town selection
        - Switches to turn on and off deer and hunters
        - Population tracker of deer and hunters (graph)
        - % of land that is open access (slider)
        - Age over time (graph)
        - Birth and growth rate (graph)
        - Deer density for rural, suburban, available and unavailable land

Data Analysis

- Assess Pepperell, Weston, Fenner, and Manlius

- Assess how the agents in the model reacted to the parameters (landcover and management)
- Use the numbers from how the hunters effected the population and how percent of available land to form results when assessing management strategies
- Assess what management implementations are most effective.
- Relate any literature to research.

Data Interpretation

- Relate similar research from literature to my research.
- Explain how the use of AMBs can be useful in future management plans.
- Discuss implications