Results of White-Tailed Deer Surveys at Pennington Borough, NJ, in 2023

May 4, 2023

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Summary

The Center for Environmental Studies at Raritan Valley Community College (RVCC-CES) conducted surveys to document the local abundance and densities of white-tailed deer at Pennington Borough, NJ, on April 14, 2023. The surveys spanned the entire municipality and were conducted with a thermal imaging camera mounted on a small-unmanned aerial vehicle (sUAS). A total of 47 deer were observed across the 1.06 mi^2 survey area, resulting in a density of 44 deer/mi^2. A detailed discussion of survey methods and results is provided below, along with an interpretation of results in relation to deer impacts and management.

Methods

We conducted infrared surveys for white-tailed deer (*Odocoileus virginianus*) by drone or sUAS (small unmanned aerial system) to obtain estimates of local deer population size and density in Pennington Borough, NJ. We used an Autel EVO II Dual drone with FLIR 640 Thermal Sensor, which was flown at night when greater contrast between ground and deer body temperatures enabled enhanced visibility. All flights were conducted with an FAA-certified pilot aided by a visual observer trained and certified for night-time operations. Each mission was flown in public airspace (Class G) at ≤400 feet above ground level, in compliance with federal regulations.

Surveys were conducted on April 14, 2023. This is within a seasonal window that provides the most conservative estimates of annual deer densities; i.e., after the fall/winter season when deer numbers are driven to their lowest numbers in the year from hunting, vehicle collisions, harsh winter conditions, and prior to the birth of fawns in May. The survey area totaled 1.06 mi^2. Preflight planning included identification of suitable launch points, flight hazards, access, and airspace regulations via aerial photography, aeronautical maps, and field visits to each site. Sufficient launch points were identified to ensure that all areas were adequately covered based on the range limitations of the drone.

Flights were conducted in transects to ensure proper coverage of the entire search area (**Figure 1**). Transects were spaced an average of roughly 500 feet apart in forested and residential areas and were wider in open fields where the field of view was unobstructed by structures such as buildings and trees. All observations of deer and search areas were recorded and mapped in real-time using the Autel Explorer and ArcCollector App. When deer were spotted, the drone was kept in a hover position until an accurate count was obtained. This procedure was repeated until the entire study area was surveyed. Densities from the drone surveys were later calculated by dividing the total deer found by the search area covered by the drone.

To obtain the most accurate estimate possible, we also implemented several additional quality control measures. If herds of deer were found close to a prior location where deer were previously observed, the drone was flown back to the vicinity of the first observation to see if they were still present. If absent from the original location, then the second observed herd was not counted in order to avoid double-counting (i.e., to account for the fact that the first herd observed may have moved to the new position). Secondly, when deer herds were noted to be moving in a certain direction during the observation, then the area of habitat that they were moving towards was surveyed next in order to ensure that deer were not double-counted. In rare circumstances, ground-truthing of observations was necessary to confirm whether an unknown object was, in fact, a deer, especially if the deer was still or in a sleeping position, and/or in areas where captive farm or other animals of similar size were present. If observed objects could not be positively identified, the data was excluded from our analysis. All of these controls ensured the results to be as robust and conservative as possible.

Results and Discussion

Surveys were conducted at Pennington Borough. A total of 47 deer were observed across the 1.06 mi^2 survey area, resulting in a density of 44 deer/mi^2. The density decreased by 46% when compared to the same spatial area surveyed in 2020, when 81 deer/mi^2 were observed **(Table 1)**.

Table 1. Deer densities observed during sUAS thermal imaging deer surveys in Pennington Borough in 2020 and 2023

Date	Year	Location	Area (mi)	# of Deer Observed	Density (deer/mi)
17-Mar	2020	Pennington Borough	0.97	79	81
22-Apr	2023	Pennington Borough	1.06	47	44

Deer observations were spatially plotted in ArcMap, and density ranges within Watchung Reservation were determined using a kernel density tool, which creates heat maps of local deer densities based on the densities of points within predetermined search radius. Home range sizes, or the extent to which deer will move throughout the year, are dependent on various factors, including, but not limited to sex, food availability, weather conditions, hunting pressures, land cover (forested, suburban, urban, exurban, rural, etc.), and breeding patterns (Etter et al. 2018, Innes 2013, Kilpatrick et al. 2001, Williams et al. 2008). Studies on home range sizes of whitetail deer show major variation throughout their range, from between 0.14 – 11.7 square miles (Innes 2013). However, in the Mid-Atlantic and New England regions, deer home ranges tend to be much smaller, including approximately 1.0 mi^2 in agricultural and heavily forested land covers (Sparrowe and Springer 1970, Tierson et al. 1985), 0.4 mi^2 in exurban areas (Storm et al. 2007), and 0.17 mi^2 in suburban areas (Kilpatrick and Spohr 2000).

Because Pennington Borough is a largely suburban landscape, surrounded by surrounded by agriculture, we formulated heat maps using a search radius that represented 1 mi^2 home range size in order to be conservative. However, it is important to keep in mind that some densities may be underestimated as some deer within this area may have smaller, more localized home range sizes more typical of suburban environments. Based on these estimations, 0% of the survey area had low deer densities (<10 deer/mi^2), 6% had moderate levels of deer (10-20 deer/mi^2), and 94% had high (>20 deer/mi^2) deer densities (**Table 2, Figure 2**).

Table 2. Areas of Pennington Borough occupied by different deer densities based on a 1.0 mi^2 home range size in 2023.

Density Range (deer/ mi^2)	Area (mi^2)	% Area Covering the Twp.
0-10	0.00	0%
10-20	0.06	6%
20-50	0.84	79%
50-100	0.16	15%

In order to interpret these results, it is important to understand the social and environmental impacts of different deer densities. Biologists estimate precolonial deer densities to be approximately 8-11 deer/mi^2 (McCabe and McCabe 1997). This is supported by the negative impacts from deer browse that tend to occur at densities above these levels for preferred browse species and forest structure (Almendinger et al. 2020, deCalesta and Stout 1997; Alverson et al. 1988; Frelich and Lorimer 1985; Behrend et al. 1970). Additional indirect or "cascade" effects on food webs and other ecosystem properties tend to occur at densities above 15-20/mi^2 (McWilliams et al. 2018, Russell et al. 2017, Chips et al. 2015, Nuttle et al. 2011, Horsley et al. 2003, Drake et al. 2002, de Calesta 1994). These densities, therefore, provide useful benchmarks for deer management to achieve ecological goals, with ~10 deer/mi^2 being the optimal target for supporting the greatest biodiversity and ecosystem structure and function.

The effects of overabundant deer are not limited to natural areas, however, but to human populations as well, costing millions of dollars a year from deer-vehicle collisions, damage to agricultural crops and landscaping, and impacts of Lyme's disease and other tick-borne diseases (Patton et al. 2018, Conover 2011). Increased deer-vehicle collisions are associated with higher deer density, among other factors (Kelly and Ray 2019ab), and deer management practices that have successfully reduced deer populations have resulted in significant decreases in deer-vehicle collisions in New Jersey and other areas (Williams et al. 2013). Effective deer management is, therefore, likely to yield significant benefits not only for environmental integrity, but for social and economic goals as well (Kelly 2019).

With these ecological and social goals in mind, the densities observed across the survey area as a whole were 4.4x higher than those needed to maintain ecosystem health and public safety (**Table 1**) with none of the survey area having deer densities ≤10 deer/mi^2 (**Table 2**). Surveys did show a 46% decrease in population when compared to the same survey extent in 2020. The decreasing densities observed in the Pennington Borough are likely a factor of increased pressure from hunting. Surrounding areas in NJ regularly allow for deer densities of 40->100 deer/mi^2 (**Figure 3**). Exceptions include areas with aggressive deer management (hunting or exclosures) and/or where large areas of intact forests remain in the state. Duke Farms, for example, has been able to maintain their deer populations at 33 deer/mi^2 outside their exclosure (Almendinger et al. 2020, Kelly and Ray unpublished data). Mahlon Dickerson Reservation in the NJ Highlands also currently has lower deer densities of 21 deer/mi^2, due to the combination of deer management and the large areas of mature, intact forest in the surrounding landscape, which provide less supplemental food resources or refugia from hunting for deer (Kelly and Ray 2020).

General concerns about the ecological impacts of excessive deer densities are supported by several recent studies in NJ, which reported negative impacts that current deer densities are having on forest conditions in the central and northern parts of the state. One study found 70-85% declines in understory plant communities when compared to historic studies in 1948-1973, when statewide deer densities averaged <10 deer/mi^2 (Kelly 2019). The numbers of young trees at browse height, in particular, were closely associated with local deer densities, and removal of deer by aggressive hunting and exclosures allowed the forests to return to historic levels of tree regeneration after 10-20 years (Kelly 2019). Other elements of understory plant communities respond well to exclosures and intensive hunting as well, including native grasses, herbs, and the ratio of native to non-native species (Almendinger et al. 2020). These results are consistent with other studies of deer impacts in the broader region by the U.S. Forest Service, which found the mid-Atlantic (including NJ) to have the highest levels of deer browse in the northern states, with 79% of forests experiencing moderate to severe levels of browse (McWilliams et al. 2018).

These data suggest that deer management is still needed in Pennington Borough to improve ecosystem integrity in the future. In interpreting these results or setting harvest goals for deer management based on them, it is important to remember that the deer densities observed in this study occurred at the lowest point in the year for deer population sizes (i.e., after winter mortality and prior to birthing). The densities are likely to be much higher during the growing season and by the time of fall hunting. In order to estimate deer populations at those times, the reproductive and mortality rates must be taken into account. Reproductive rates are generally 2-3 fawns/doe per year in this area (estimated by counting prenatal fawns within does harvested during the hunting season), with 1.9 fawns/doe being the average in the Midwest (Green et al. 2017) and 2.25 fawns/doe reported locally in neighboring NJ (Juette pers. comm. 2018). The effective deer densities from late May through September are therefore likely to be ≥50-100% higher than the densities observed during this survey period, as mortality from vehicle collisions and freezing temperatures are not typically significant until October or later (Kelly and Ray unpublished data). Lastly, we recommend repeated deer surveys in combination with harvest data, deer-vehicle collision data, and forest monitoring plots (ideally including exclosures) in order to gauge the effectiveness of any hunting programs being implemented in the future.

Figure 1. sUAS flight paths showing complete coverage of Pennington Borough in 2023

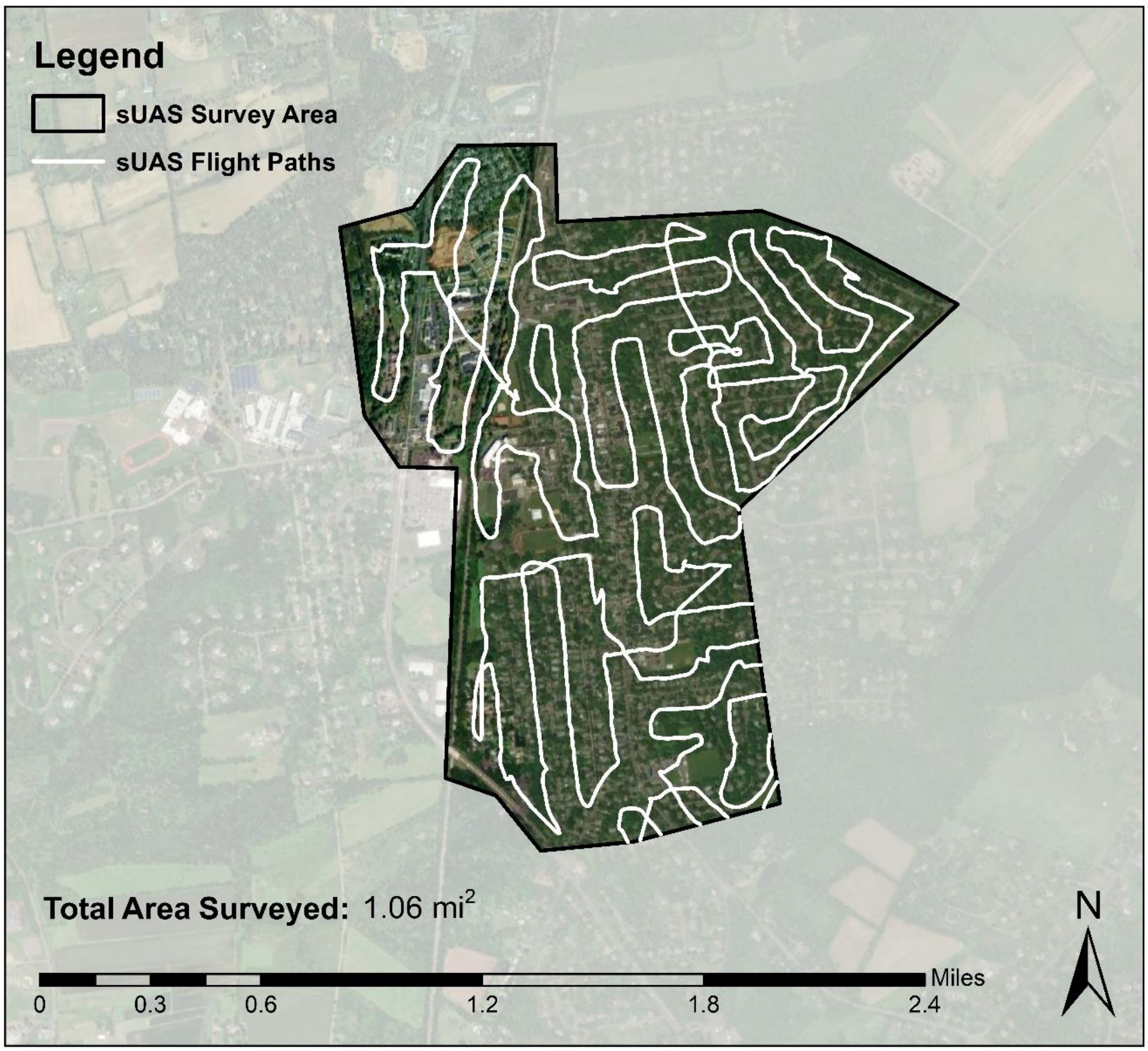


Figure 2. Local deer densities at Pennington Borough in 2023 based on a 1.0 mi^2 home range size. Heat maps created in ArcMap using the kernel density tool.

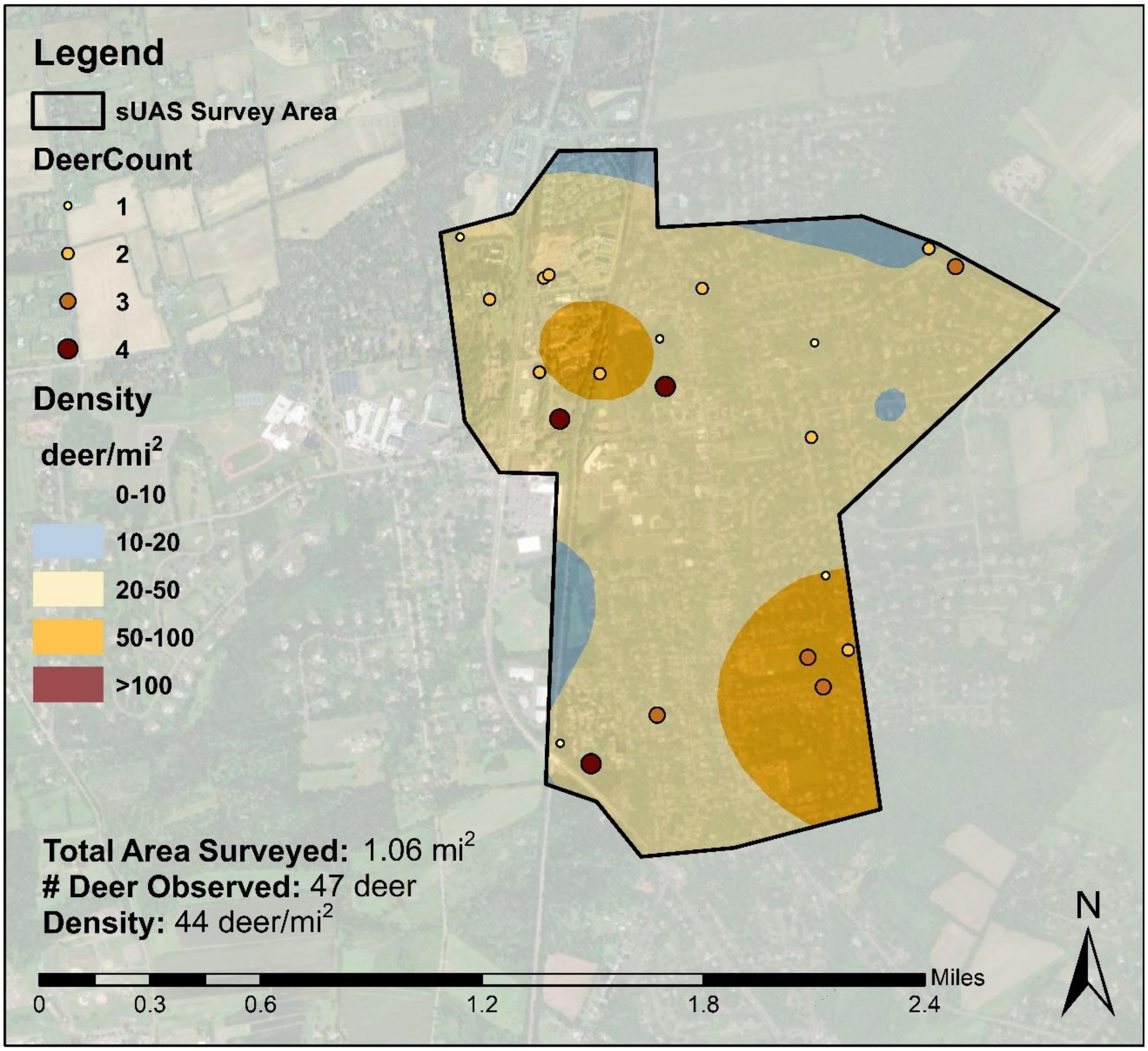
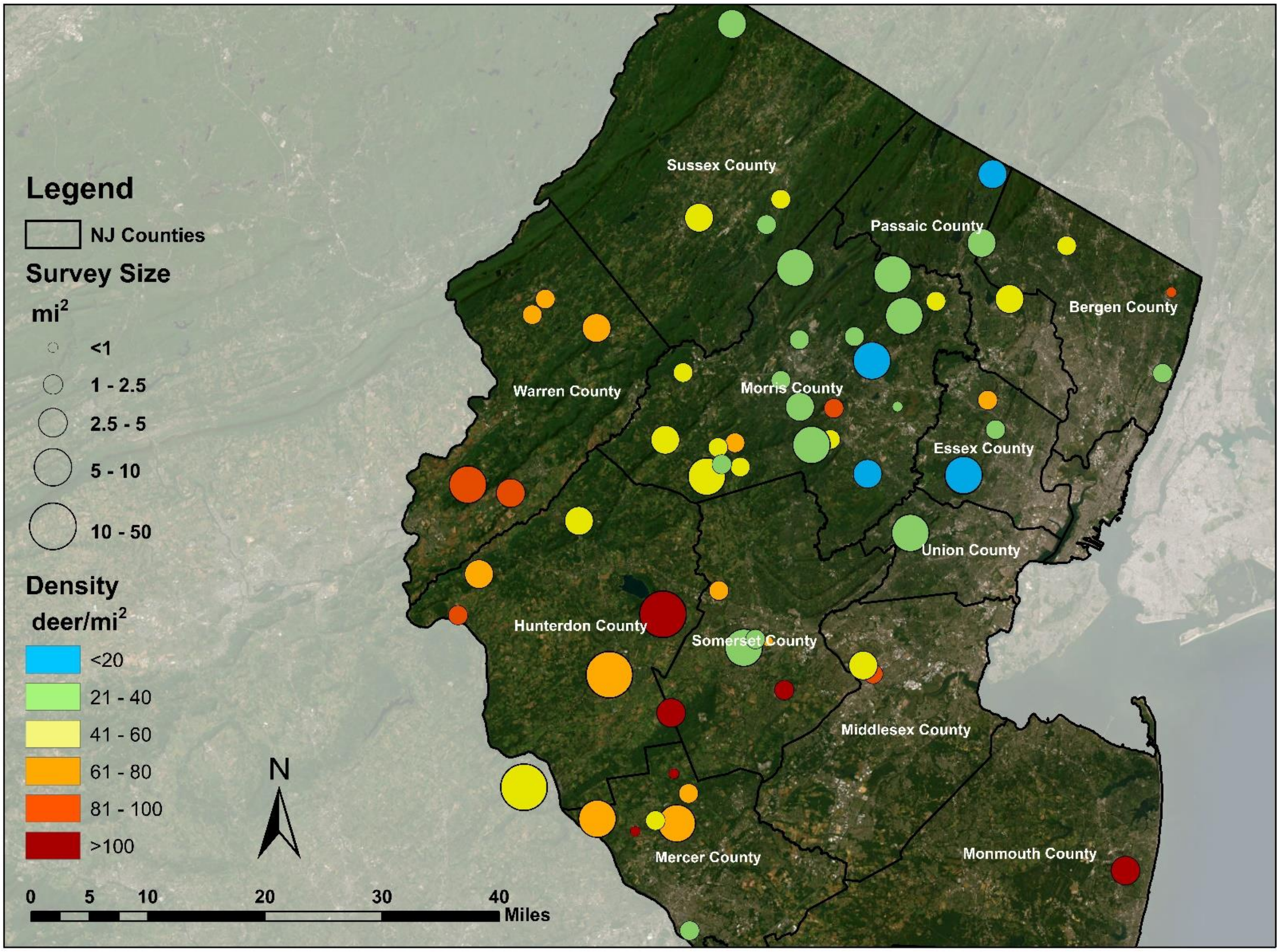


Figure 5. Results of RVCC infrared sUAS surveys of white-tailed deer in northern NJ in 2019-2023



Literature Cited

Almendinger T, Van Clef M, Kelly JF, Allen M, Barreca C. 2020. Restoring forests in central New Jersey through effective deer management. Ecological Restoration 38: 246-256.

Alverson WS, Waller DM, Solheim SL. 1988. Forests to deer: edge effects in northern Wisconsin. Conservation Biology 2: 348-358.

Behrend DF, Mattfeld GF, Tierson WC, Wiley III JE. 1970. Deer density control for comprehensive forest management. Journal of Forestry 68: 695–700.

deCalesta DS. 1994. Impact of white-tailed deer on songbirds within managed forests in Pennsylvania. Journal of Wildlife Management 58:711-718.

Chips MJ, Yerger EH, Hervanek A, Nuttle T, Royo AA, Pruitt JN, McGlynn TP, Riggall CL, Carson WP. 2015. The Indirect Impact of Long-Term Overbrowsing on Insects in the Allegheny National Forest Region of Pennsylvania. Northeastern Naturalist 22(4):782-797.

Conover MR. 2011. Impacts of deer on society, In Hewitt DG (ed.) Biology and management of white-tailed deer. CRC Press, Boca Raton, FL.

Drake D, Lock M and Kelly J. 2002. Managing New Jersey's Deer Population. Rutgers Agricultural Experiment Station, Rutgers University Press.

Etter, DR, Hollis KM, Van Deelen TR, Ludwig DR, Chelsvig JE, Anchor CL, Warner RE. 2002. Survival and movements of White-tailed Deer in suburban Chicago, Illinois. Journal of Wildlife Management 66(2): 500-510.

Frelich LE, Lorimer CG. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, USA. Biological Conservation 34: 99–120.

Green ML, Kelly AC, Satterthwaite-Phillips D, Manjerovic MB, Shelton P, Novakofski J, Mateus-Pinilla N. 2017. Reproductive characteristics of female white-tailed deer (*Odocoileus virginianus*) in the Midwestern USA. Theriogenology 94:71-78.

Horsley SB, Stout SL, deCalesta DS. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13: 98-118.

Innes, RJ. 2013. *Odocoileus virginianus*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: www.fs.fed.us/database/feis/animals/mammal/odvi/all.html [2021, April 22]

Juette H. 2018. Winter 2017 Birthing rates per female. Personal Communication. Watchung Borough Wildlife Advisory Board, Borough of Watchung, NJ.

Kelly JF. 2019. Regional changes to forest understories since the mid-Twentieth Century: Effects of overabundant deer and other factors in northern New Jersey. Forest Ecology and Management 444:151-162.

Kelly JF, Ray J. 2019. The Effects of Prescribed Burning on Forest Understories in Northern New Jersey: Preliminary Results. Center for Environmental Studies, Raritan Valley Community College, 10 p.

Kelly JF. 2018. Effects of White-tailed Deer on Forests in Watchung Borough in October 2018. Report Prepared for the Borough of Watchung, NJ. Raritan Valley Community College, 7 p.

Kelly JF, Ray J. 2019a. Results of Deer Population Studies in Raritan Township in 2019. Report Prepared for the Township of Raritan, NJ. Raritan Valley Community College, 7 p.

Kelly JF, Ray J. 2019b. Results of Deer Population Studies in River Vale Township in 2019. Report Prepared for the Township of River Vale, NJ. Raritan Valley Community College, 4 p.

Kilpatrick HJ, Spohr SM, Lima KK. 2001. Effects of population reduction on home ranges of female white-tailed deer at high densities. Canadian Journal of Zoology 79: 949–954.

Kilpatrick HJ, Spohr SM. 2000. Spatial and temporal use of a suburban landscape by female White-tailed Deer. Wildlife Society Bulletin 28 (4): 1023-1029.

McCabe RE, McCabe TR. 1997. Recounting whitetails past. In: McShea WJ, Underwood HB, Rappole JH (Eds.), The Science of Overabundance: Deer Ecology and Population Management. Smithsonian Books, Washington, pp. 11–26.

McWilliams WH, Westfall JA, Brose PH, Dey DC, D'Amato AW, Dickinson YL, Fajvan MA, Kenefic LS, Kern CC, Laustsen KM, Lehman SL, Morin RS, Ristau TE, Royo AA, Stoltman AM, Stout SL. 2018. Subcontinental-scale patterns of large-ungulate herbivory and synoptic review of restoration management implications for midwestern and northeastern forests. Gen. Tech. Rep. NRS-182. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 24 p.

Nuttle T, Yerger EH, Stoleson SH, Ristau TE. 2011. Legacy of topdown herbivore pressure ricochets back up multiple trophic levels in forest canopies over 30 years. Ecosphere 2:1–11.

Patton SR, Russell MB, Windmuller-Campione MA, Frelich LE. 2018. Quantifying impacts of white-tailed deer (*Odocoileus virginianus* Zimmerman) browse using forest inventory and socio-environmental datasets. PLoSONE 13(8): e0201334. https://doi.org/10.1371/journal.pone.0201334

Russell MB, Woodall CW, Potter KM, Walters BF, Domke GM, Oswalt CM. 2017. Interactions between white-tailed deer density and the composition of forest understories in the northern United States. Forest Ecology and Management 384: 26–33.

Sparrowe RD, Springer PF. 1970. Seasonal activity patterns of white-tailed deer in eastern South Dakota. Journal of Wildlife Management 34: 420-431.

Storm DJ, Neilsen CK, Schauber EM, Woolf A. 2007. Space use and survival of White-tailed Deer in an exurban landscape. Journal of Wildlife Management 71(4): 1170-1176.

Tierson WC, Mattfeld GF, Sage Jr RW, Behrend DF. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49: 760–769.

Williams SC, deNicola AJ, Almendinger T, Maddock J. 2013. Evaluation of organized hunting as a management technique for overabundant white-tailed deer in suburban landscapes. Wildlife Society Bulletin 37: 137–145.

Williams SC, deNicola AJ, Ortega IM. 2008. Behavioral responses of white-tailed deer subjected to lethal management. Canadian Journal of Zoology 86: 1358–1366.