Results of White-Tailed Deer (*Odocoileus virginianus*) Surveys in Watchung Borough in 2019

Final Report

September 6, 2019

Jay F. Kelly, Ph.D., and Jessica Ray
Center for Environmental Studies
Raritan Valley Community College
118 Lamington Rd.
North Branch, NJ 08876

Objective: We documented densities of white-tailed deer (*Odocoileus virginianus*) in Watchung Borough in early spring of 2019 using a combination of roadside spotlight survey and infrared drone techniques.

Methods: For spotlight surveys, the Borough was divided into three sections (Figure 1), which were surveyed simultaneously by two different teams of Raritan Valley Community College wildlife research interns, on 4/2/2018 (Section 1, 2, and 3), 4/20/2018 (Section 1,2, and 3). Surveys were conducted on clear nights from 9:30 PM to 2:00 AM, counting the number of deer for each 0.2 mile segment of road using high-powered flashlights (600 yard max. range), and measuring search area using laser rangefinders. Deer and search area data were entered in real-time in ArcCollector. Density was calculated by dividing the total number of deer observed by the total search area, and was determined for both the first and second round of surveys for the Borough as a whole, as well as for each individual segment. The average density was then calculated for each in order to estimate town-wide densities. The total deer population in the town was calculated by extrapolating the average number of deer observed per survey across the area of the town.

Because survey results may be biased by landscape and other factors, densities were also obtained from infrared drone surveys for quality control. Drone surveys were performed with a Zenmuse XT thermal imaging camera mounted on a DJI Inspire drone on three separate nights, with a minimum of one survey located within each road survey section. Surveys were conducted at night to allow for adequate thermal contrast between the landscape and deer, and only when conditions were suitable, with low/no winds or precipitation. All flights were conducted with an FAA-certified pilot aided by a visual observer. Each mission was flown below 400 feet above ground level in class G airspace, and under a night waiver as required by FAA regulations. Flight routes were carefully conducted in order to ensure that all areas were adequately covered (Figure 2). All observations of deer and search areas were counted and mapped in real time using DJI Go and ArcCollector software. When deer were spotted, the drone was kept in a hover position until an accurate count was obtained (Figure 3). If necessary, the drone was moved to a lower position (as low as ~200') or a different angle to get better vantage for accurate counting or positive identification. A data point was then recorded on a map in the ArcCollector App (5-15 seconds) before the census was continued. This allowed us to track where and how many deer were found in real-time. This method 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.

In order to obtain the most accurate estimate possible, a number of other quality control measures were also taken. If herds of deer were found close to a prior location where deer were previously observed, then the drone was flown back to the vicinity of the first observation to see if the herd were still present. If it was absent from the original location, then the second observed herd was not counted in order to avoid double counting, as it may be that the first herd simply 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 weren't 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. Ground-truthing was done using high-powered flashlights from the ground. If observed objects could not be positively identified as deer, the data was excluded from our analysis, thus providing the most robust and conservative data set possible. All of these controls ensured the results to be as robust and conservative as possible.

Figure 1. Road-based spotlight survey sections in Watchung Borough

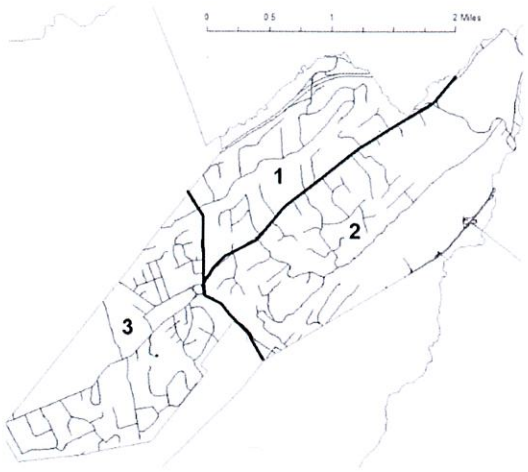


Figure 2. Drone survey routes from Watchung in 2019 indicating comprehensive spatial coverage of sample areas. The image below shows drone routes from 2019 surveys, indicating comprehensive spatial coverage of all survey areas. NOTE: Intersecting lines indicate return trips to the launch site (i.e., after survey completion or for battery replacement), not repeated survey of same sample areas.

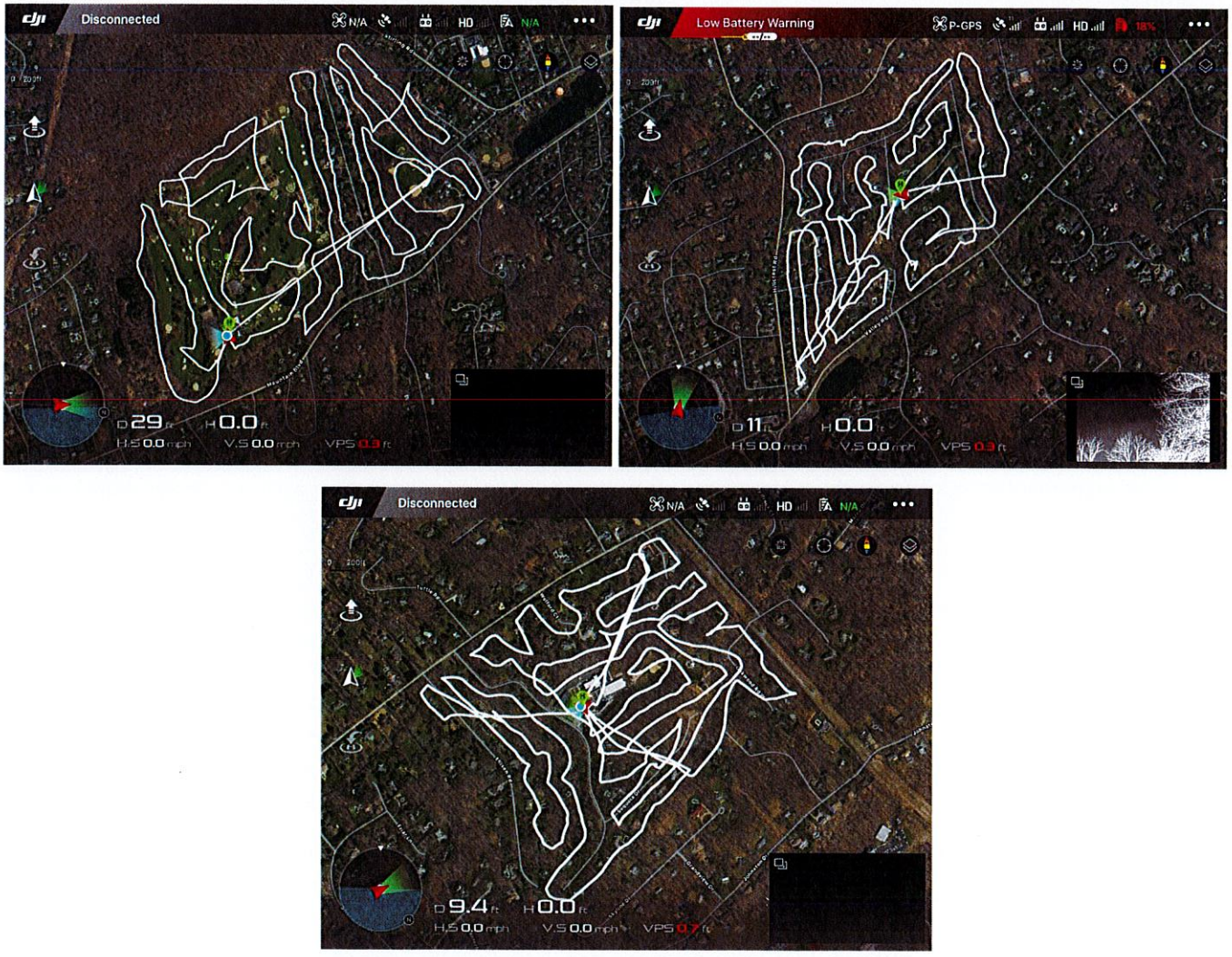
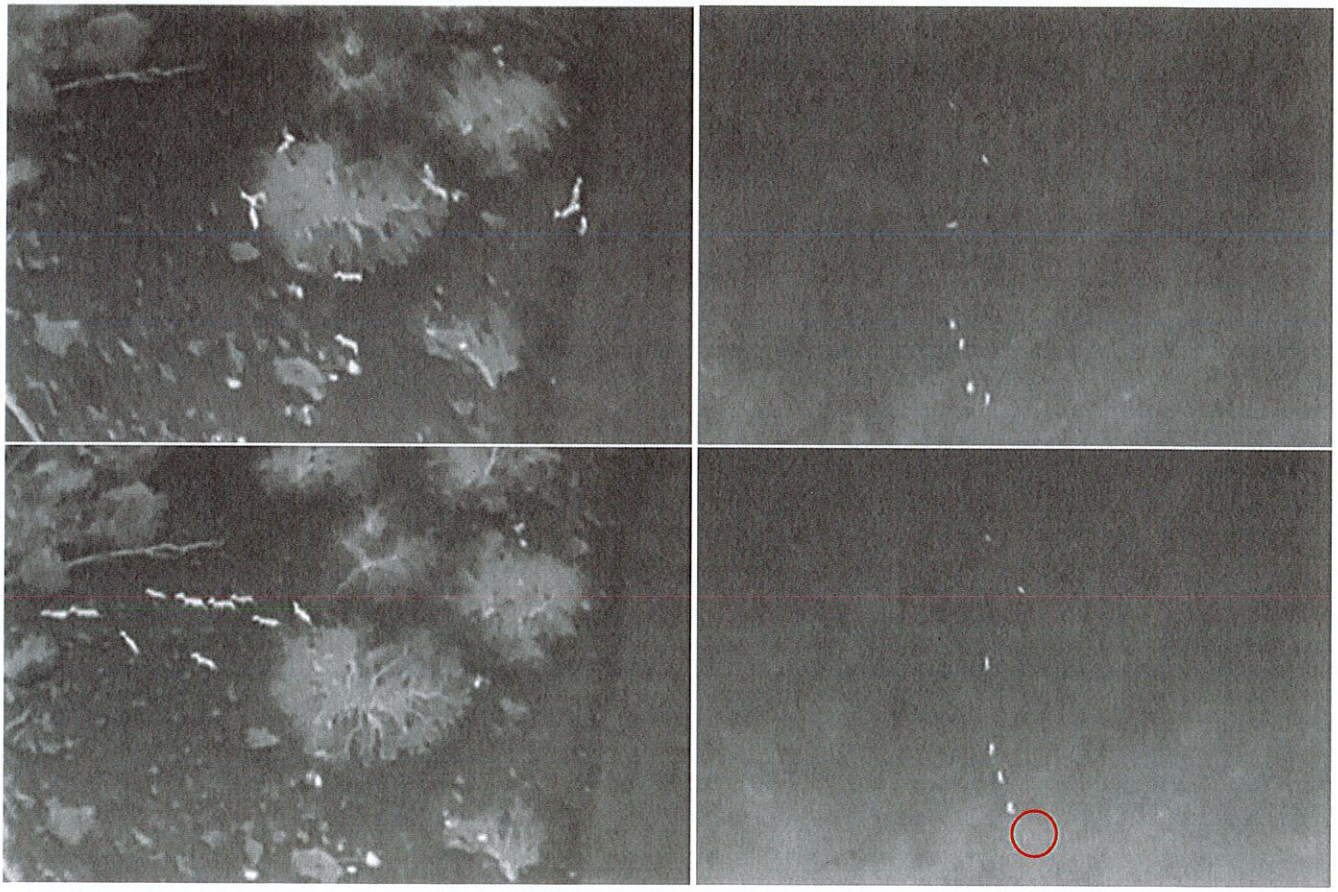


Figure 3. Sample of RVCC Infrared Drone Imagery, Indicating Benefits of Hovering Capability. Snapshots of infrared images taken from video footage of deer herds in two different locations, indicating benefits of hovering capabilities of drones compared to single-pass flyovers from fixed-wing aircraft. Continuous footage of each herd allows for more accurate counts than single snapshots of deer, when individuals may be temporarily hidden by vegetation or other difficult to discern due to close proximity or other factors.

LEFT SIDE: The top left photo shows a herd of deer (in white) from 200' altitude above ground level, with the exact number being difficult to discern at that moment because of the close proximity of some individuals. The lower left picture was taken of the same deer 15 seconds later, showing the ten individuals to be easily discernible. Continuous video footage can be seen at: https://youtu.be/2H_JUae06ho

RIGHT SIDE: The top right photo was taken of a different herd walking through a forest, observed from 400' altitude above ground level. This image shows seven deer (white) in the herd. The bottom right image shows the same deer 5 second later, in which one of the deer walked under more dense vegetation and is no longer visible. The red circle shows the approximate location of the deer obscured by vegetation. Continuous video footage can be seen at: https://youtu.be/x9wMLP59NTs0



Spotlight Survey Results:

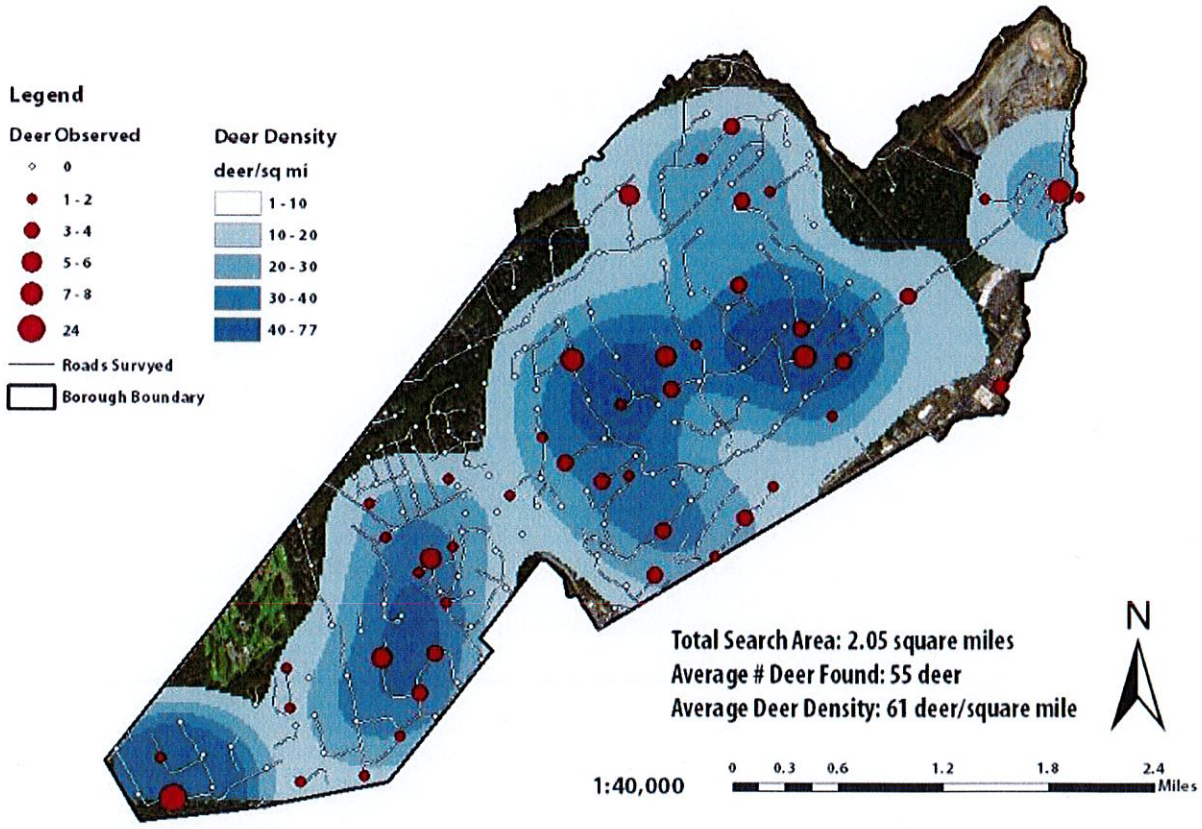
A total search area of 2.05 mi^2 was covered during each spotlight road-based survey, or 33.9% of the approximately 6.05 mi^2 in the Borough as a whole. A total of 155 deer were observed during the first census, resulting in a total density of 75.5 deer/mi^2. A total of 97 deer were observed during the second round of surveys, resulting in a density of 47.2 deer/mi^2. The average density of deer for the Borough as a whole was 61.4 deer/mi^2. Groups of deer numbered from 1 to 24 individuals (average = 3). Numbers of deer and associated densities varied greatly between individual Borough sections

and between surveys, from 27-66 deer per section, and densities of 45.5 to 96.9 deer/mi^2. Variation in maximum observed numbers and densities are displayed in Figure 4.

Table 1. Results of individual surveys for each section of Watchung Borough including search area (mi^2), number of deer observed, and density (deer/mi^2).

		1st Survey		2nd Survey		
	Search Area	# Deer	Density	# Deer	Density	
Section 1	0.58	28	48	27	47	
Section 2	0.68	66	97	31	46	Average
Section 3	0.78	61	78	39	50	Density
TOTAL	2.05	155	76	97	47	61

Figure 4. Number and density of deer observed during road-based spotlight surveys. Note that the deer density displayed in shades of blue does not show actual deer density per section, but merely density of *observed* deer from the road in order to illustrate spatial variation in deer distribution. The data illustrated is the greater results of the two surveys for each respective section of town.



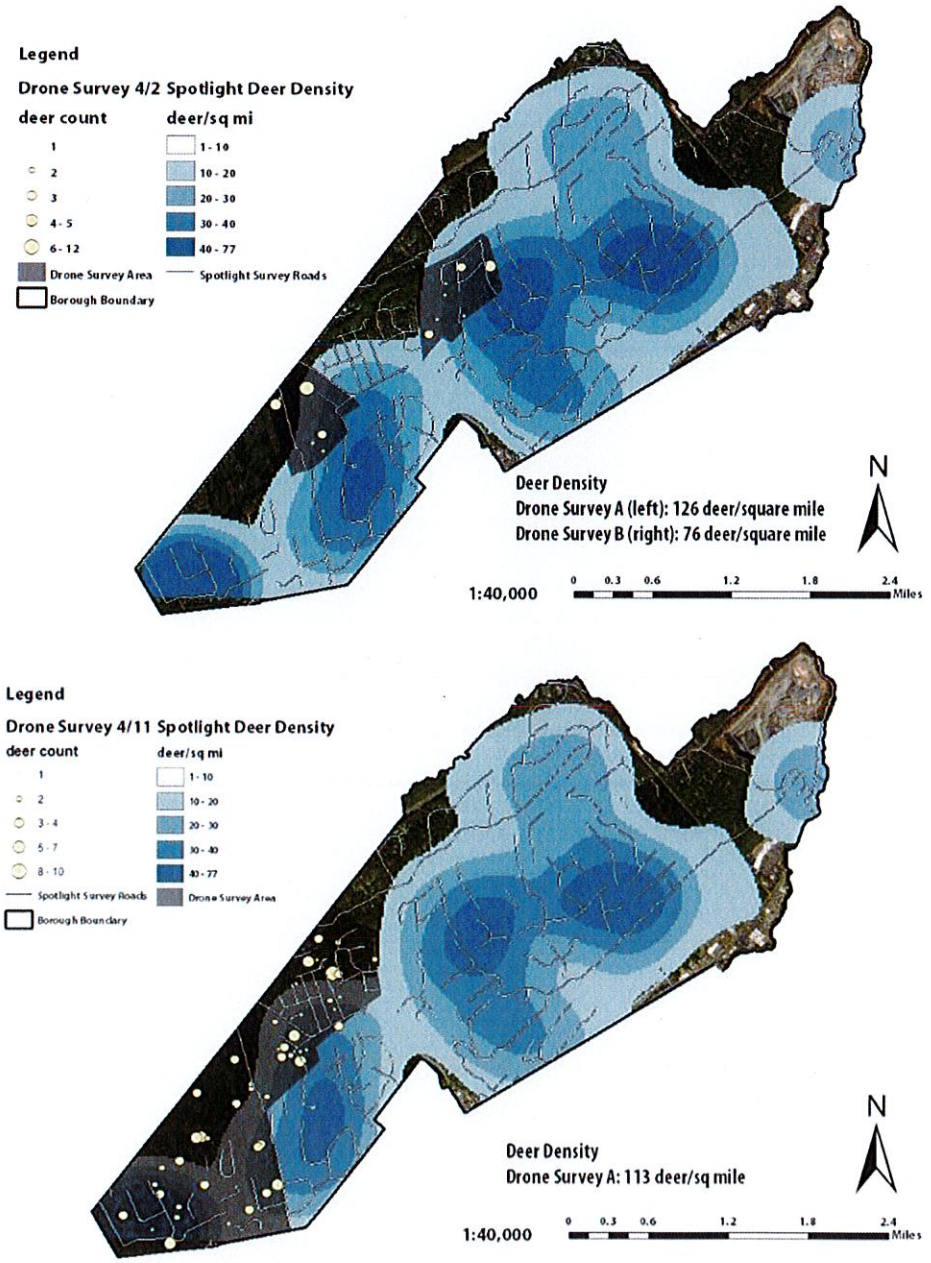
Drone Survey Results:

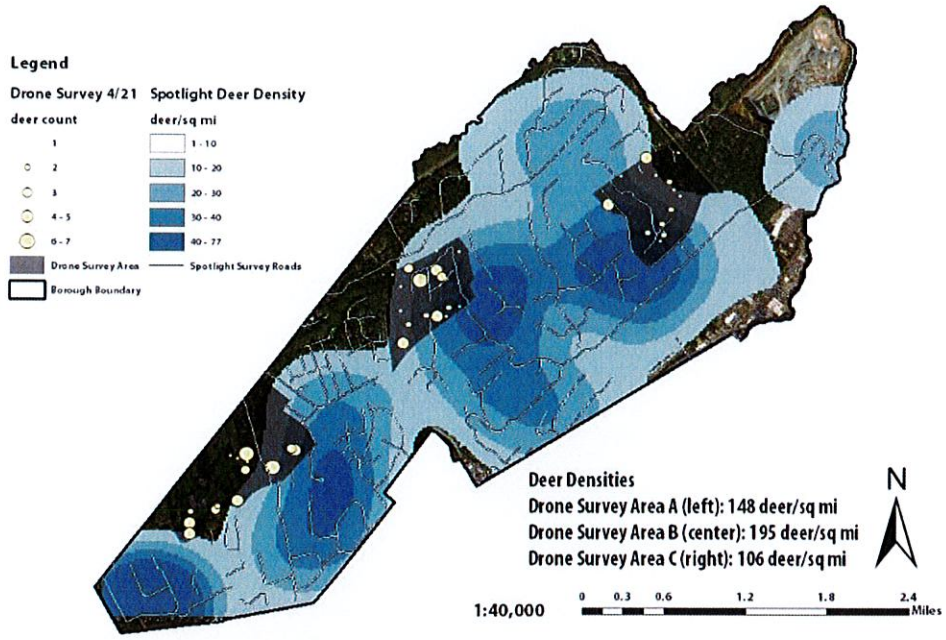
Drone surveys were done on three separate nights. Total search area of non-overlapping surveys resulted in 1.86 mi^2, or 30.7% of the Borough as a whole. Densities from the each drone surveys ranged between 103 deer/mi^2 and 148 deer/mi^2 with an average of 121 deer/mi^2 (Table 2, Figure 5). The greatest continuous survey area extent covered by the drone surveys in a single night was 1.42 mi^2 and resulted in a total of 160 deer for 113 deer/mi^2. Surveys from smaller, individual search areas found densities ranging from 76-195 deer/mi^2.

Table 2. Results of individual drone surveys for Watchung Borough including search area (mi^2), number of deer observed, and density (deer/mi^2).

	4/2/2019			4/11/2019			4/21/2019			
	Search Area	# Deer	Density	Search Area	# Deer	Density	Search Area	# Deer	Density	
Drone Survey A	0.2305	29	126	1.4187	160	113	0.4590	68	148	
Drone Survey B	0.1976	15	76				0.2052	40	195	Average
Drone Survey C							0.2370	25	106	Density
TOTAL	0.4281	44	103	1.4187	160	113	0.9012	133	148	**121**

Figure 5. Number and density of deer observed during drone surveys. Note that the deer density displayed in shades of blue are based on the spotlight deer surveys for comparison.





Average densities of deer of 61-121 deer/mi^2 obtained by spotlight and drone surveys in Watchung Borough in 2019 show an apparent increasing trend from both the 21-22 deer/mi^2 observed in the spring of 2017 using aerial and spotlight surveys (Kelly unpublished data; Vision Air Research 2017), and the 40 deer/mi^2 observed in the spring of 2018 using the same spotlight methodologies (Kelly 2018a). Several possibilities may explain this increase, include a reduction in mortality due to a series of mild winters, increased immigration of deer from surrounding municipalities, limited deer harvest by hunting, increases in fecundity, or observer error. With females in this area regularly birthing 2-3 fawns per year (Watchung unpublished data), for example, it is possible for populations to double in years with low mortality.

The high variation observed within and between individual spotlight and infrared surveys suggest significant spatial and/or temporal variation in deer densities at small scales within Watchung Borough. While deer movement between survey sections may be a factor, potentially leading to double or under-counting, all three sections were surveyed simultaneously by spotlight surveys in our studies, and deer ranges in suburban landscapes are highly local in the winter season after hunting has ended (Williams et al. 2008), suggesting this is not a factor. The discrepancies between the road-based and infrared surveys more likely the result of the physical limitations of the spotlight surveys in general (i.e., observing only deer that are visible from the road) and their consequent susceptibility to spatiotemporal variation in population patterns. Weather conditions that cause deer to seek greater cover, for example, or greater food availability away from roads, may dramatically reduce the likelihood of detection by spotlight surveys. Drones also have an advantage over similar infrared surveys conducted by fixed-wing aircraft, as the hovering capabilities allow for more careful and accurate counting of deer, which may be temporarily obscured by vegetation or otherwise difficult to count. Such limitations may have led, for example, to an underestimate of the Watchung Borough deer population by Vision Air Research in 2017 and thus provide support for the possibility observer error being partly responsible for the differences between infrared surveys conducted in 2017 and 2019.

While detectability is not a significant factor for infrared drones as it is with road-based or fixed-wing aircraft surveys, they are more limited in terms of spatial coverage, at least with the drone and battery technologies currently available. The high variation in local densities observed in Watchung suggests that sample areas greater than the scale of local variation are needed with these methods to accurately estimate densities at large (e.g., town-wide) scales. The largest sample of 1.4 mi^2 collected in this study therefore likely provides the best estimate of current town-wide densities (113 deer/mi^2), compared to the other, much smaller samples collected. Given the increased accuracy and decreasing costs of drone-based aerial infrared surveys, these methods are likely to present more reliable methods for surveying deer populations than road-based surveys or infrared surveys by fixed wing aircraft in Watchung Borough in the future.

Despite the variation observed between survey methods, the results from Watchung Borough in 2019 remain consistently higher than both historical, statewide, and optimal deer densities for sustaining ecosystem health. Actual populations occurring throughout the remainder of the year are likely to be substantially higher. The most recent regional estimates of deer densities available from the New Jersey Department of Environmental Protection indicated minimum average densities to be as high as 78 deer/mi^2 (NJ Division of Fish and Wildlife 1999). However, these estimates are based off of harvest statistics from hunting, which may not be accurate in areas where hunting access is limited, such as the suburban or urban environments that characterize much of central and northeastern NJ (NJ Division of Fish and Wildlife 1999). Local surveys using direct counting methods (spotlight or infrared) have found local deer densities to be in excess of 150-200 deer/mi^2 in some areas of New Jersey (NJDFW 1999, McWilliams et al. 2013). It is also important to note that the number and densities of deer observed in this study were recorded at the most conservative time of year; i.e., after the period of peak mortality from hunting and cold temperatures in the fall and winter months and before the birth of fawns in late spring. Given the high reproductive rates of deer, it is likely that the actual deer population size for the majority of the year is much higher than the survey results indicate.

Historical studies suggest that precolonial deer densities were likely to be approximately 5-11 deer/mi^2 (McCabe and McCabe 1997). Biological impacts to preferred browse species have been observed at densities above 10 deer/mi^2 (Horsley et al., 2003; deCalesta and Stout, 1997; Alverson et al., 1988; Frelich and Lorimer, 1985; Behrend et al., 1970) and impacts to forest regeneration, bird communities, invertebrates, and a host of other ecosystem variables above 15-20/mi^2 (McWilliams et al. 2018, Russell et al. 2017, Nuttle et al. 2011, Horsley et al. 2003, Drake et al. 2002, de Calesta 1994). The effects of overabundant deer are not limited to natural areas, 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). Accordingly, deer management practices that have successfully reduced deer populations have been found to result in significant decreases in deer-vehicle collisions in New Jersey and other areas (Williams et al. 2013). It is therefore advisable that targets for deer management should be set at 10 deer/mi^2 to maintain the greatest benefits for social, economic, and ecosystem integrity as possible (Kelly 2019). Given the high densities and increasing population trends of deer populations in Watchung, along with the limited response of forest regeneration on hunted properties compared to other areas where more aggressive deer management is taking place (Kelly 2018b), modifications to the Borough's deer management practices should be considered in order to achieve greater benefits of these kinds for residents in the future.

Literature Cited

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.

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.

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.

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.

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. 2018a. Results of white-tailed deer (*Odocoileus virginianus*) surveys in Watchung Borough in April 2018. Raritan Valley Community College.

Kelly JF. 2018b. Effects of White-tailed Deer on Forests in Watchung Borough in October 2018. Raritan Valley Community College.

McCabe, R.E., McCabe, T.R., 1997. Recounting whitetails past. In: McShea, W.J., Underwood, H.B., Rappole, J.H. (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.

Vision Air Research, Inc. 2017. Aerial Deer Survey – Watchung, NJ. Final Report.

Williams, S.C., deNicola, A.J., 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.