Results of White-Tailed Deer (*Odocoileus virginianus*) Surveys in Highland Park, Rutgers EcoPreserve, and Johnson Park, NJ, in 2019

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Methods: Infrared surveys for white-tailed deer (*Odocoileus virginiana*) were conducted between 18:30 on 12/6/2019 and 05:10 on 12/7/2019, and 19:00 on 12/7/2019 and 2:30 on 12/8/2019, in order to obtain estimates of local deer population size and density. The search area includes Highland Park, Rutgers EcoPreserve, and Johnson Park and surrounding buffer area of approximately 300 m. Surveys were conducted with a Zenmuse XT thermal imaging camera mounted on a DJI Inspire drone. All flights were conducted with an FAA-certified pilot aided by a visual observer trained and certified in night-time operations. Each mission was flown below 400 feet above ground level in class G airspace, and under an FAA waiver for night-time operations. Flight routes were carefully conducted in order to ensure that all areas were adequately covered (Figure 1). 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 (Figures 2&3). If necessary, the drone was moved to a lower position (≥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.

Figure 1. sUAS flight mission paths indicating extent of spatial coverage in search area in Highland Park, Rutgers EcoPreserve and Johnson Park in 2019

Figure 2. 7 Deer clearly visible in deciduous forest understory in Rutgers Ecopreserve.

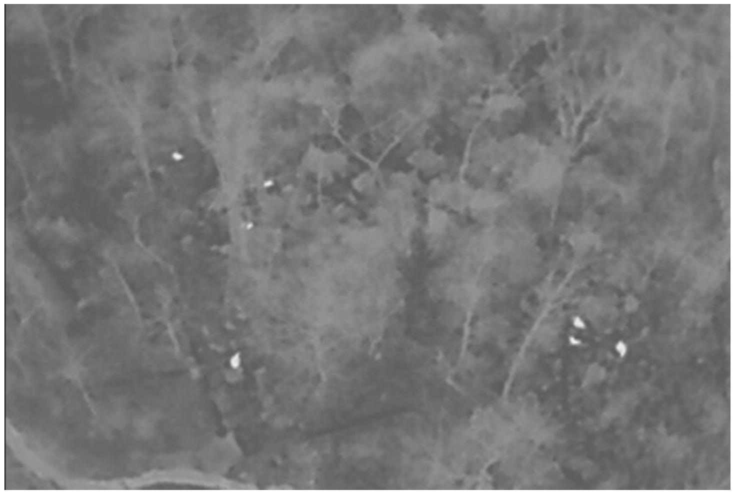
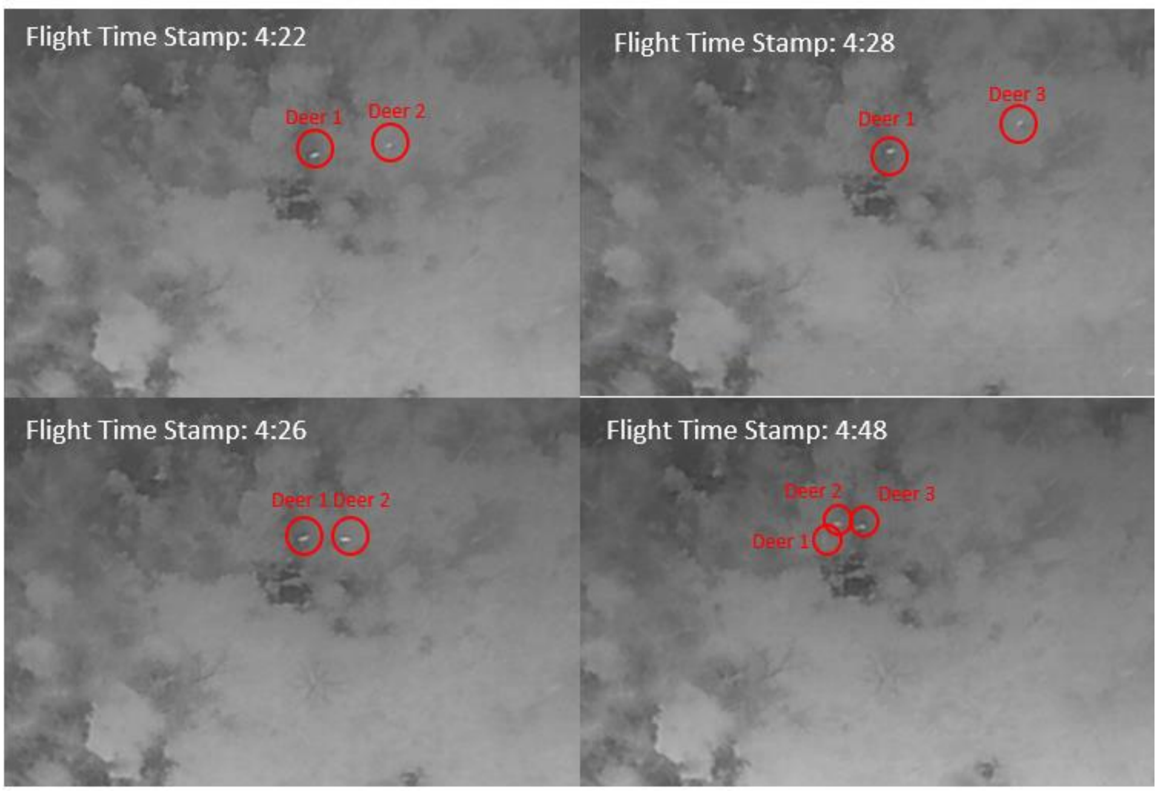


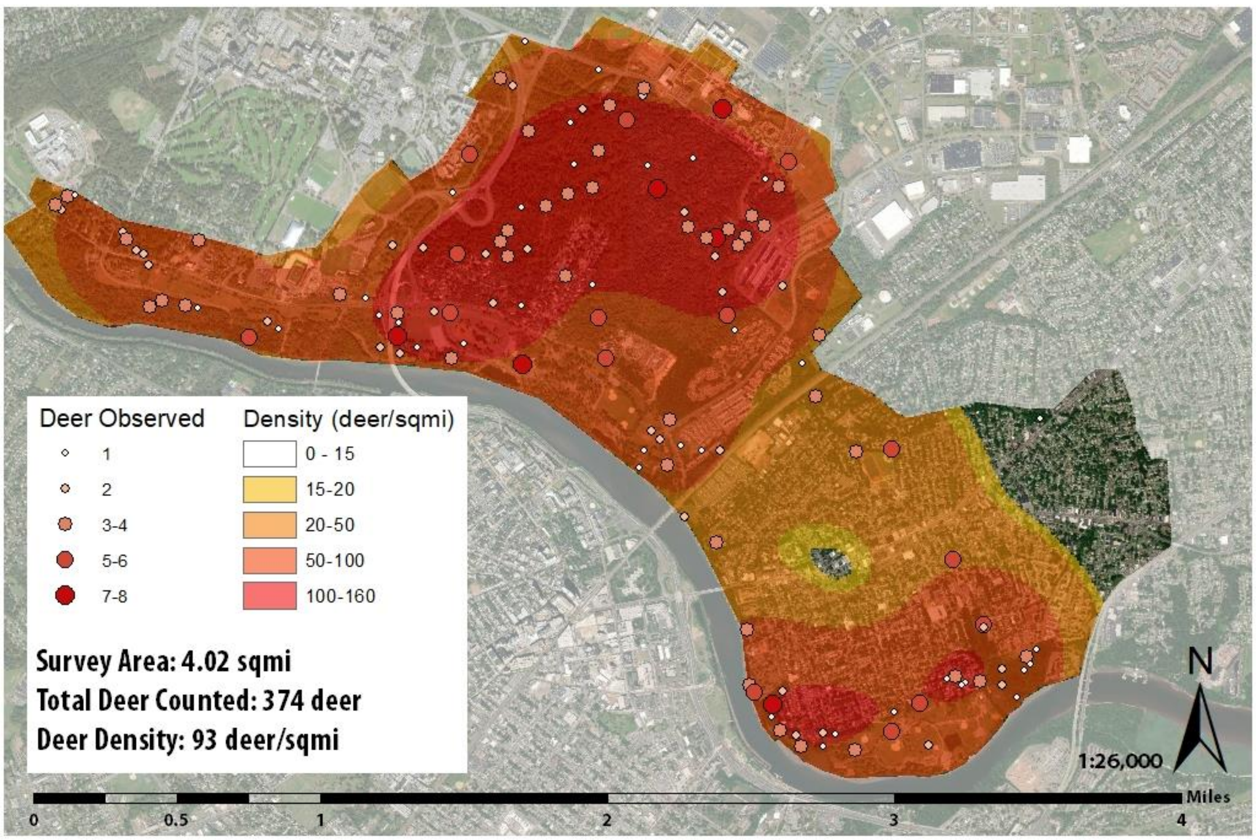
Figure 3. Deer located in a dense coniferous forest in Rutgers Ecopreserve, showing benefits of hovering capabilities for accurate measurements. The drone is held in a hover position to spot and verify three deer. If deer were not moving, identification would be hard or impossible with a coniferous canopy type. As the drone hovers deer 1 and 2 are initially visible, then deer 2 walks under canopy cover, and deer 3 appears behind. Deer 3 then walks under the canopy cover, and deer 2 becomes visible again. Deer 1, 2, and 3 become visible in the last shot, although deer 1 is faint due to canopy cover.



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, 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 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.

Drone Survey Results: A total of 374 deer were counted in the 4.02 mi^2 survey area resulting in a total density of 93 deer/mi^2 (Figure 4). Densities varied between survey areas with highest densities occurring in Johnson Park, and Rutgers EcoPreserve at 121 and 114 deer/mi^2 respectively (Figure 5&6). Highland Park, composed largely of urban land use, had a density of 74 deer/mi^2(Figure 5&6). Donaldson Park, which comprises the largest area of undeveloped land in Highland Park east of the train tracks, had a density of 148 deer/mi^2 (Figure 5).

Figure 4. Total deer observed during drone surveys in Highland Park, Rutgers EcoPreserve, and Johnson Park in 2019.

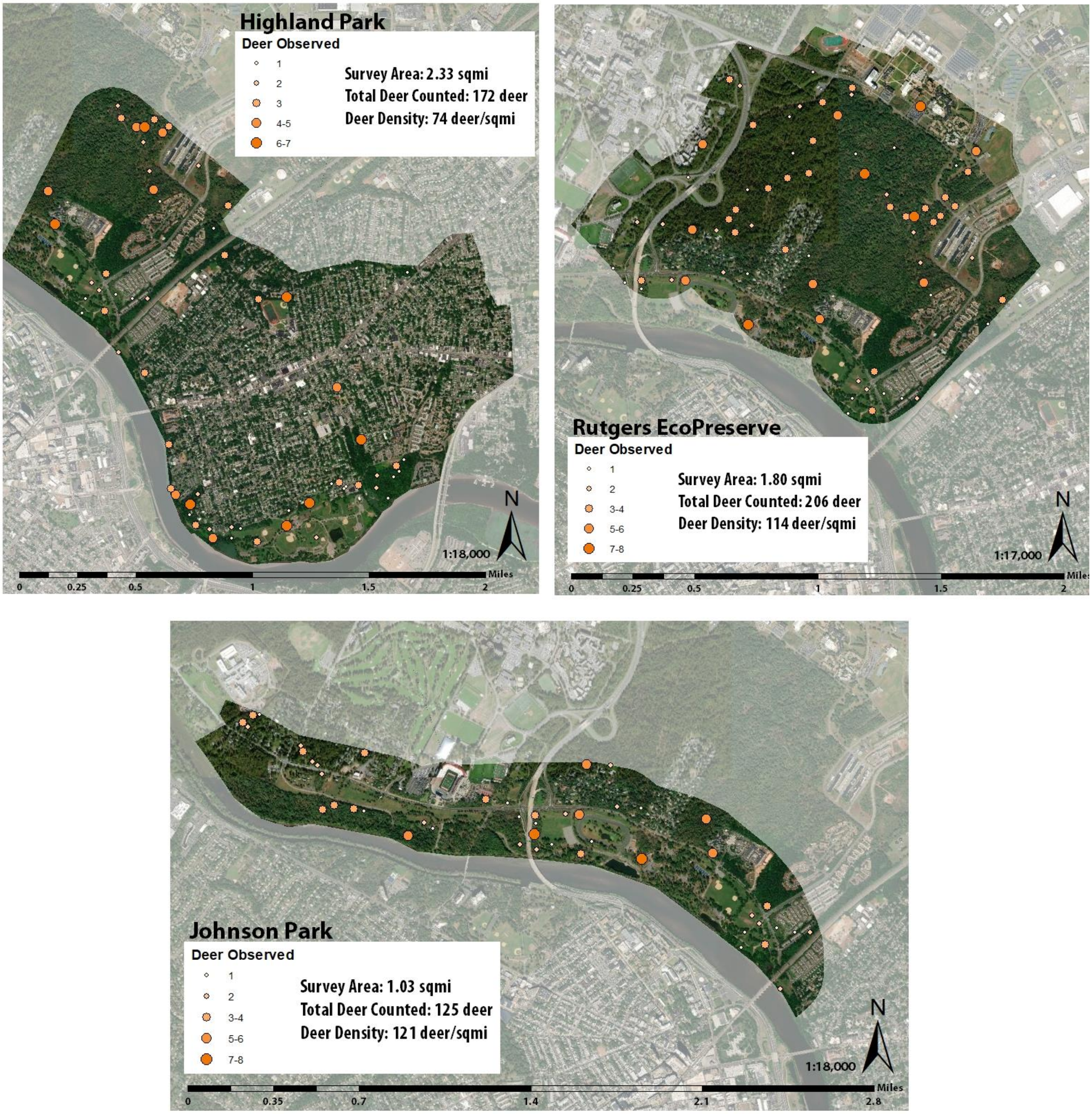


Map created by Raritan Valley Community College (RVCC), Center for Environmental Studies on Decemper 2019. sUAS thermal imaging deer survey data was collected from 12/6/2019 - 12/8/2019 using a DJI Inspire 1 drone and a Zenmuse XT thermal imaging camera. All data was collected by RVCC, Ceter for Environmenal Studes.

Figure 5. Individual deer density in Highland Park, Rutgers EcoPreserve, and Johnson Park in 2019. All Survey areas include a ~300m buffer. Donaldson Park, a portion of Highland Park, is shown separately for perspective.

	Area (sqmi)	# of Deer	Density (deer/sqmi)
Highland Park	2.33	172	74
Donaldson Park	0.31	46	148
Rutgers EcoPreserve	1.80	206	114
Johnson Park	1.03	125	121
Total	**4.02**	**374**	**93**

Figure 6. Deer locations in Highland Park, Rutgers EcoPreserve, and Johnson Park respectively.



Discussion - The densities of deer observed in the surveyed areas are far higher than both historical, biological and social thresholds for sustainable deer management. Historical studies suggest that precolonial deer densities were likely to be approximately 5-11 deer/mi^2 (McCabe and McCabe 1997), and levels higher than these amounts have been shown to impact ecosystem health. Biological impacts to preferred browse species, for example, 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).

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