Field Test Evaluation of White-tailed deer (*Odocoileus virginanus*) Surveying Methods at Wild Basin Nature Preserve

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Abstract

The effective management of any species involves making decisions based on a clear understanding of their population abundance and distribution, and trends in their spatial and temporal movements. Our research aim is to determine the population density of white-tailed deer (*Odocoileus virginanus*) of Wild Basin Nature Preserve; to improve upon previous white-tailed deer surveying techniques with novel instrumentation, and ultimately to compare the efficiency of each through collection and observation methods. Wild Basin is a 227 acre urban nature preserve located in Austin, TX with an open deer population known size and composition. The three methods we evaluated include 1) camera trap surveys, 2) driving spot-count surveys, and 3) performing line-transects surveys using an unmanned aerial vehicle equipped with a standard camera and infrared camera. Results showed the white-tailed deer population estimate are 0.1365, 0.1275, and 0.0000 deer/acre respectively. Camera traps captured a total of 8 mammals. Apart from white-tailed deer, coyote were the most abundant. Camera trapping and driving spotlight surveys yielded accurate results and proved to be successful methods. Camera traps seem to be the most efficient tool as they were the least invasive, continuously gathered data, and required minimal labor to achieve results. The UAV results suggest that further conditions need to be met in order to achieve better results. The infrared camera has the potential to be more useful with lower temperatures and can achieve precise results when coupled with the standard camera. With recommendations for a standard protocol, this will help future UAV use reducing time and expertise for such technology (Chretien et. al, 2015) Our research facilitates future UAV studies at Wild Basin, as technology is becoming increasingly popular in scientific research and can prove to be a valuable tool for conservation management.

Introduction:

Establishing a protected area alone is often not enough for protecting species to take care of itself. Protected areas as such as wilderness preserves and national parks require monitoring of wildlife and vegetation to ensure that. The effective management of any species involves making decisions based on a clear understanding of their population abundance and distribution, and trends in their spatial and temporal movements. Wildlife managers often perform population counts to estimate these parameters and assess the health of the ecosystem.

The selection of a specific method for estimating mammal populations depends upon the monitoring goals, species characteristics (body size, home range/habitat, activity patterns, and level of gregariousness), spatial scale of monitoring required, and resources of the agencies responsible for monitoring (Storm et. al, 2011). The first step for wildlife managers is to identify a reliable method to monitor a particular species given certain budgetary, logistical, and time constraints. Having the option of which technique to use for performing wildlife counts can be useful, as monitoring and management components often involve certain objectives, (such as controlling a nuisance species) with limited resources (Jacobson et. al, 1997). Wildlife is inherently challenging to study and manage, as wild animals tend to be elusive, wide-ranging, sensitive to human disturbance, and dangerous to approach. In many cases the habitats may be otherwise challenging or impossible to assess or navigate at the ground level (Drake et. al, 2005).

Traditional methods such as spotlight surveys, walking line transects, camera trapping, and aerial helicopter counts can be expensive, labor intensive, and may have limited visibility in certain habitats. These factors may in turn skew the data and give an inaccurate representation of the biodiversity within an area (Roberts et. al, 2006). However, the use of a camera-equipped unmanned aerial vehicle (UAV) may add a new perspective for collecting wildlife density counts and complementary behavioral data. A UAV can offer thermal imaging to perform nocturnal population surveys, further insights into heavily covered vegetation, and conduct surveying in sensitive areas without too much disturbance, thus offering additional data on the abundance and distribution of wildlife within an area. Few studies have tested the combined use of UAV, dual standard digital and thermal infrared cameras to detect single or multiple species (Chretien et. al, 2015)

Calculation of white tailed deer (*Odocoileus virginianus*) density is important at Wild Basin Wilderness Preserve as it is an urban preserve, where deer interact with their natural habitat, but are able to roam to the surrounding areas including residential areas, highway/roads, and trails. In a managed ecosystem such as Wild Basin, it is also important to understand the effects these large mammals have on vegetation, and their potential to alter the ecosystem. Here, we compare and evaluate the use of different survey techniques to determine white-tailed deer density and to record environmental and behavioral factors to show spatial movement patterns and behavior.

The objectives of our research are: 1) to examine White-Tailed Deer population density across Wild Basin Nature Preserve, and 2) to compare deer population data collected with a UAV to that of two traditional approaches, camera traps and driving spot counts. We evaluated and compared the overall efficiency of the three approaches by estimating the labor, time, cost, and accuracy associated with each method. The deer management strategies requires finesse because there are multiple stakeholders involved. Our evaluation of approaches will play a part of comprehension of determining an appropriate deer management strategy for Wild Basin.

Study species:

Distribution of White-Tailed Deer (Odocoileus virginianus)

White-tailed deer populations are very widely distributed across the United States and are able to live in variety of ecosystems, from rural settings to urban settings with sufficient foraging areas and cover (Storm et al, 2007, Dawe et al, 2014 and Ambriz-Morales et al 2015). Generally, deer survivorship and density in suburban areas are high due to lack of predation, abundance of cover, and foraging opportunities (Kilpatrick and Spohr, 2000, Grund et al, 2002, and Storm et al, 2007). As long the land-use development is expanding, the population of white-tailed deer will continue to increase (Dawe et al., 2014). Both Wild Basin and the surrounding suburbia have different habitats, and yet white-tailed deer occupy both habitats. This study will explore distribution of deer in kind of land development and provide a better strategy of deer management.

Impact on the ecosystem

It is possible to consider white-tailed deer as "keystone herbivores", as they are a species that greatly affects the distribution and abundance of plants. The increase in deer populations has led to changes in forest composition, facilitating growth of nonnative plants, and created browsing lines in forests (Rooney and Waller, 2008 and Batzli and DeJaco, 2013). Due to overabundance of the deer, there are no young trees or any other understory plants filling in gaps where older trees fell in the forest as shown in Figure 1 (Rawinski, 2008). A healthy forest will have some shrubs and young trees growing in gaps between adult trees and form an understory community.



Figure 1: Oak forest at Suffolk County, NY with no understory due to deer overabundance (Rawinski,



Figure 2: Left: plot with deer overabundance, right: plot with deer exclusion (Rawinski, 2008)

White-tailed deer alternating vegetation structure also affect other herbivores that are living in the same habitat (Rooney and Waller, 2003). Wild Basin is home to Golden-cheeked Warblers, and the environment there is precious. Preferred population of deer is 1 deer per 20 acres for oak recruitment and songbirds nesting. The impact of white-tailed deer changing the vegetation structure in Wild Basin could be a threat to Golden-cheeked warblers and other inhabitants of Wild Basin.

Impact on the economy

Overpopulation of white-tailed deer increases the probability of encounters and conflicts with humans. By 2011-2012, Deer-Vehicle Collisions (DVCs) cost the United States $4 billion annually, and vehicular collisions are more likely to occur in suburban areas than exurbia, due to more roads (Storm et al, 2007 and Blackwell et al, 2014). Deer also cause damages on residential yards, as such as eating their ornamental plants which causing property values to go down, and as well crops depredation on agricultural lands (Drake et al, 2005, Butfiloski, 2006, and Taggart and Long, 2015). Unfortunately, the proximity of urban and residential areas to Wild Basin is very close, and many deer are hit by cars- and are seen as pests foraging in residential gardens. It is important to consider the relationship between humans and deer as part of Wild Basin management strategy.

UAV Applications:

The use of UAVs, or unmanned aerial vehicles, is a rapidly growing trend in research today. UAVs, also referred to as remote sensing systems or drones, are expanding to many different fields such as carbon accounting, fire spread and risk modeling, forestry, and ecosystem modeling. Studies are finding more uses for UAV research every day. The ability to mount an array of sensors to these drones enables such diverse applications (Dandois and Ellis, 2013). This feature is especially important for ecological studies because it allows the UAV to map multiple physical and biological characteristics of the environment simultaneously (Nishar et al, 2016). Another positive aspect UAVs provide is a temporal factor. For instance, the ability to map invasive species at a specific phenological stage is extremely important when developing invasive management strategies (Michez et al, 2016). Drones can do more than gather observational data and map physical characteristics. They can retrieve test samples from infected areas and even map transmission of infectious diseases. Drones have also been outfitted to collect radiation and pollution data (Fornace et al, 2014).

Advantageous factors of UAVs related to our study are maneuvering in dense canopies (McNeil et al, 2016), up-scaling forest studies to a regional or even global scale (Masek et al, 2015), and eliminating safety concerns in harsh weather conditions (Bhardwaj et al, 2016). Using manned aerial vehicles to conduct population surveys for whitetail deer is common, but UAVs are making this method obsolete. The use of drones is becoming invaluable in an array of

disciplines. Studies show promising results for habitat suitability, biodiversity and ecosystem functioning, and understanding ecosystem dynamics and forests (Dandois and Ellis, 2013).

Materials and Methods:

Table 1: UAV specifications and flight limitations

Vehicle Type:	Phantom 3 Advanced
Vehicle Diagonal Size	350 mm
Weight	1280g
Max Speed	16 m/s
Max Ascent	5 m/s
Max Descent	3 m/s
Max Flight Time	Approx. 23 min
Battery Type	LiPo 4S
GPS Mode	GPS/GLONASS

Study Site:

The study was conducted at the Wild Basin Nature Preserve located in Austin, TX. Wild Basin is a 91.8 ha Nature Preserve, part of the larger expanse of the Balcones Canyonlands Preserve (BCP) System, situated off Texas State Highway Loop 360 and 20 minutes from downtown Austin. The BCP is home to several species of mammal, birds, and reptiles; and is managed jointly by the county and city of Austin (BCP, 2014). Austin is growing at an exponential rate, which brings an increase in development. Urbanization can be seen close to the preserve along Texas State Highway Loop 360, which may increase the probability of human -wildlife interactions..

Consistent with much of the Texas Hill Country, the typical habitat found in Wild Basin is characterized by scrubby Oak and Juniper woodlands. The endangered Golden-cheeked Warbler (*Setophaga chrysoparia*) and Black-capped Vireo (*Vireo atricapilla*) occupy the preserve and breed throughout the spring and early summer seasons. Our research was conducted after the breeding season to avoid any possibility of disturbing the Golden-Cheeked Warbler.

Study Design and Data Collection:

Our main goal was to compare traditional and novel survey methods for estimating deer density, including driving spot-counts, camera traps, and using a UAV outfitted with both a standard and

infrared camera (for diurnal/nocturnal surveys). UAV's may be able to offer safer, convenient, and minimally invasive means of acquiring high-resolution imagery of wildlife, particularly in locations difficult to access/assess or survey from the ground or habitats sensitive to disturbance. These findings will provide a better understanding and hopefully deeper insights into what wildlife species can be seen in the preserve, and may yield information such as predator/herbivore ratios and nesting bird populations, as well as vegetation type and cover.

The surveys, both camera traps and UAV, were conducted within the southern section of Wild Basin Nature Preserve, close in proximity to the area where the driving survey had taken place in previous years. Once the data from camera traps and UAV were analyzed we input data into a database accessible to the Wild Basin Creative Research Team and Travis County to assist in determining the biological integrity of the preserve, adding to a biological index from the data collected during the deer census surveys.

Driving survey

Surveys were conducted twice a week over a month from mid-October 2016 to mid-November 2016. The driving spot-count technique has been the standard method used by the Wild Basin Research Center and Travis County for estimating the deer population within Wild Basin and the surrounding areas since 2007. The driving survey took place along eight roads, as shown in Figure 3, surrounding the preserve totaling a distance of 6,160 yards (5632.7 meters), and covering an area of 56.12 acres (observed). The start and finish points were the same for each survey conducted. Three trained observers drove along the designated route at an average of 10 mph and recorded the location, number of individuals, sex, age (fawn, yearling, adult), behavior, and distance from the vehicle. The survey data were entered into an ArcGIS database (McShea, 1993).

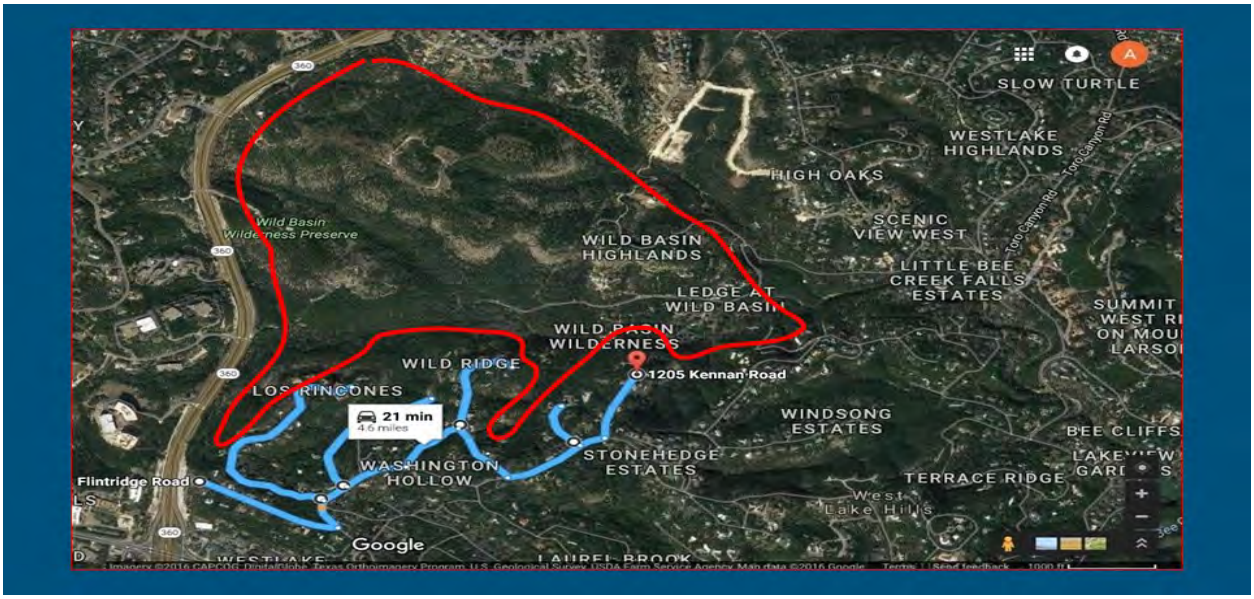


Figure 3: The red outlines Wild Basin and the blue outlines the driving spot count survey route.

Motion-Triggered IR Camera Traps

The second technique used was motion sensor camera traps. The camera traps, as shown in Figure 4, were set up along a previously-established grid system generated by the Wild Basin Creative Research team and used for long-term data collection. With the substantial number of camera traps available, we were able to cover larger target areas within the preserve than in previous years, which may have improved the probability of obtaining deer density accurately within the Wild Basin. However, to ensure that our research focused on comparing the techniques, we chose to not use utilize all camera traps that the Wild Basin had to offer. We instead chose those already set up within southern part of the preserve to gather deer density to compare to the deer density we obtained from the driving survey with relevant location and size of survey areas. We focused data collected from those five southern camera traps in order to compare with other two methods. Then we added data from other seven camera traps to dataset of those five camera traps to calculate the estimation of Wild Basin's total deer population.

As used by previous research teams at Wild Basin, we chose to use the method/technique explained by Rowcliffe (2008 and 2013) to accurately analyze and determine deer density with camera traps. This method is known to be a newer and less invasive technique than other methods. We calculated the trapping rate, or the number of encounters between the camera and deer, which we then used to accurately estimate the density of deer in the area. To perform this technique, we measured certain parameters to have significant density calculations without duplicating counts. These parameters included detection distance, detection arc, velocity and average group size of deer (Rowcliffe et. al, 2013).

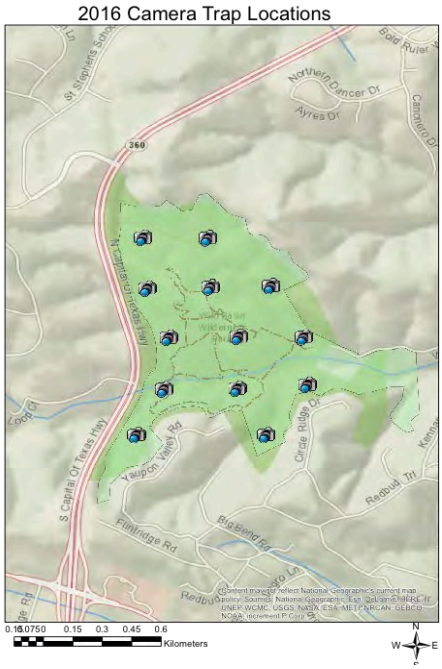


Figure 4: The shaded green region is Wild Basin and the camera icons represent the locations of the camera traps.

Unmanned Aerial Vehicle (UAV) and infrared camera

The third method incorporated a novel surveying technique: utilizing a UAV equipped with a standard and an infrared camera to estimate the deer population and to gather behavioral data within the Wild Basin. We established the line transect method using an unmanned aerial vehicle (DJI Phantom 3 Standard Advanced Craft), to determine the resolution and visibility the camera provides in a variety of habitats, and to examine the presence and abundance of species (biodiversity) within the preserve. UAV surveys were conducted within the same time frame as the driving surveys. 10 transects were performed across the southern half of Wild Basin using the standard UAV camera and a *Flir* Vue Pro infrared camera simultaneously. An example of the flight path can be seen in Figure 5.

We coupled the UAV's standard digital camera with an infrared camera to perform line transect surveys. Wanting to be consistent with previous year deer census surveys, each method began 30 minutes before sunset. The thermal IR camera will enhance the probability of sighting deer as it can detect wildlife found under tree canopy.The drone offers 12-15 minutes of fly time per the battery, which allowed us to conduct a line-transect zigzag pattern of equal distance. The line-transects were produced and executed using ArcGIS and using a handheld GPS. We conducted repetitive surveys within each plot. The surveys took place through November, two times per week.

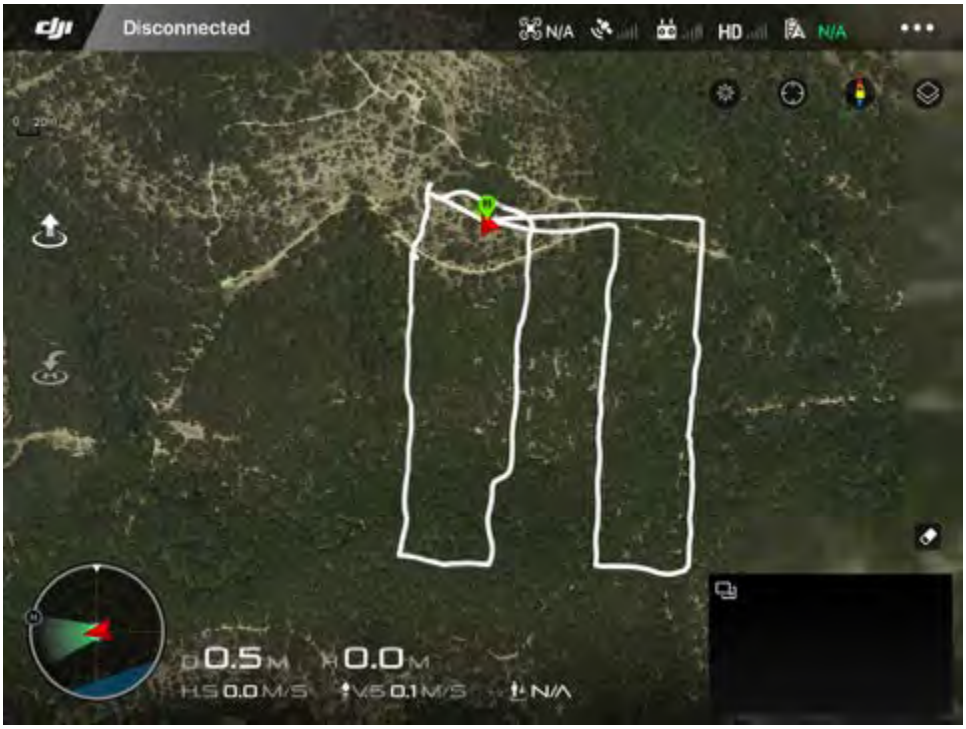


Figure 5: An example of an UAV flight path used during a survey.

ArcGIS analysis

ArcGIS was incorporated into our research by illustrating a map of the density of deer at each camera trap. An ideal comparison of each survey method involved replicated surveys of closed populations (i.e., no immigration, emigration, births, or deaths) of meaningful size so that detection rates accounted for differences in counts. Although closed populations were not possible in our study area, we attempted to design our study to amend the lack of population closure (Mace et. al, 1994). Additionally, we attempted to minimize the time between each survey to avoid large changes of deer abundance and distribution between surveys during our study (Storm et. al, 2011).

Results

Camera Traps Estimates:

We observed a total of 18 does, 7 bucks, and 6 deer that we were unable to classify. From this information we calculated the deer population to be 0.3376 deer/ha. The camera traps accumulated 720 hours of data over the 12 sites and observed a total of 91.8 ha. The total cost of using this method totaled $2200, as each camera costs around $200. The camera traps set up across the preserve captured a total of 7 different species including white-tailed deer (*Odocoileus virginianus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), nine-banded armadillo (*Dasypus novemcinctus*), eastern cottontail rabbit (*Sylvilagus floridanus*), opossum (*Didelphimorphia*), common gray squirrel (*Scirius canolinensis*), and the greater road-runner (*Geococcyx californianus*). Apart from white-tailed deer, coyotes were the most abundant species seen by the camera traps.



Figure 6: Photo of *Lynx rufus* on camera traps



Figure 7: Photo of *Canis latrans*

Driving Spot-count Surveys:

We observed a total of 36 does, 8 bucks, and 5 fawns. With the data gathered during the driving surveys we estimate the deer population to be 0.3146 deer/ha. We completed seven driving

surveys were conducted along the southern border of Wild Basin, totaling 244 minutes (4.06h), averaging 35 minutes each. The driving surveys allowed us to observe a total of 22.7 ha. The total cost of performing the surveys was around $47 (depending on the price of gas).

Table 2: Comparison of results from driving spot-count survey and camera trap survey

Variable	Driving	Camera Traps
Buck	8	7
Doe	36	18
Fawn	5	0
Unknown	0	6
Deer/ha	0.3146	0.3376

UAV Line Transect Surveys:

No white-tailed deer were observed while performing line transects with the UAV. The total time performing transects was 112 minutes (1.86 h), averaging 11.2 minutes per transect. The distance that each transect covered was on average of 35 ha. The total cost of the drone and additional IR camera was $3200. Specifications such as speed, time, elevation, camera angle, and IR camera scheme were each evaluated and defined with each survey taken. Standard camera footage had great clarity and resolution whereas the IR camera was less successful. The use of the UAV to conduct wildlife census is still a novel technique and required trial and error to achieve the desired results.

Discussion

Field Technique Efficiencies:

The accurate estimation of wildlife population density is difficult and requires considerable investment of resources and time. With the advance in technology, new techniques have become available to assist natural resource managers to better manage or monitor species. Traditional methods such as helicopter counts and walking line transects can be accurate but can be expensive and require a number of resources and time. The field techniques evaluated each had strengths and weaknesses in achieving management objectives

Camera Trap surveys were successful in estimating deer population of Wild Basin. This non-invasive method is effective for long-term monitoring of one or multiple species, and for achieving multiple management objectives. There is a high first time cost, but is ideal for Wild Basin and similar sized urban preserves.

Driving spot-count surveys were also successful in estimating the deer population. However, this method is mainly effective when only monitoring one species such as deer, that cross the urban/wilderness boundary. It is not very expensive but can labor intensive, as it requires multiple observers and a vehicle. Both the camera traps and driving surveys yielded results comparable to previous year's white-tailed deer population estimate, which may indicate to its accuracy. White-tailed deer management decisions of Travis County seem to be maintaining the population.



Figure 8: Photo of Buck taken during driving surveys

The use of a UAV to perform aerial line transects is still in the beginning stages. The lack of results indicates the need to continue adjusting instrument settings, modifying methods, and determining optimal environmental conditions required to efficiently use a UAV equipped with

an IR camera. Although it has a high initial cost, it has the ability to be an efficient method for performing non-invasive line transects, especially in remote areas or with rugged terrain. Additional surveys implementing methods we developed should yield accurate and plentiful results.

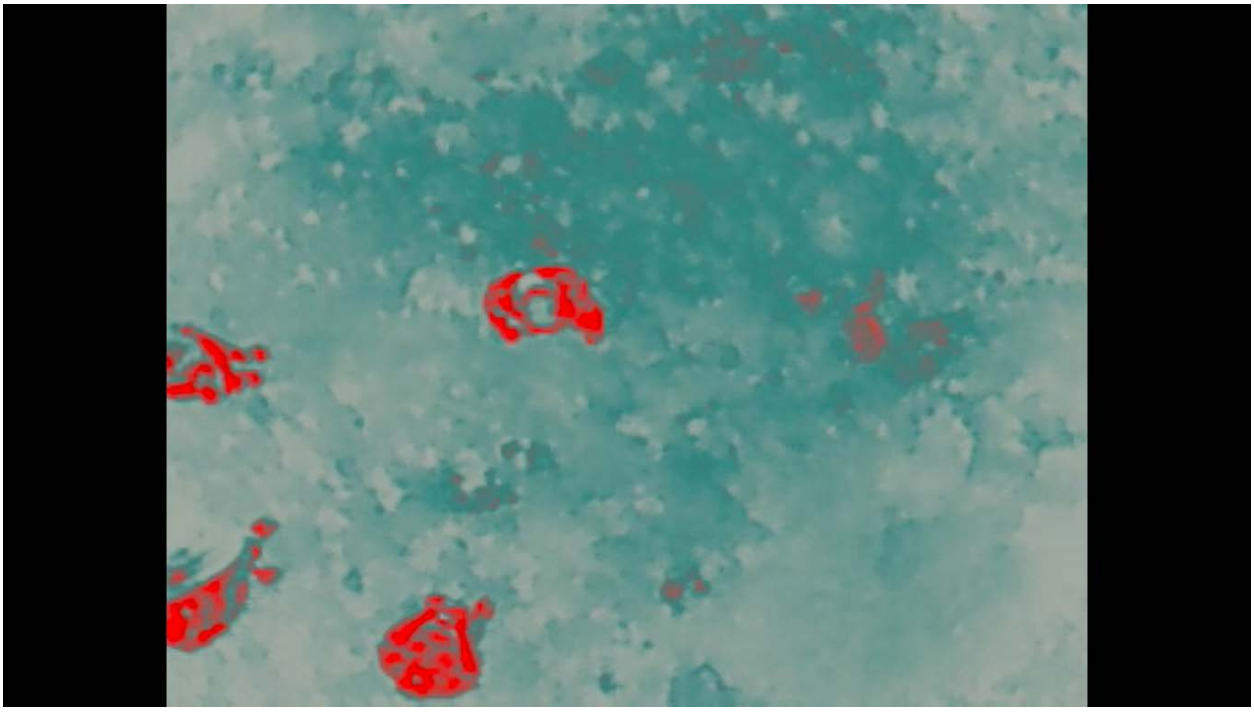


Figure 9: Grey/Red IR Camera Scheme still photo

Table 3: Comparison of three surveying methods

Surveying methods	**Time**	**Cost**	**Area Covered**
Camera Traps	720 hours	$2200	91.8 ha
Driving Survey	4.06 hours	$47	22.7 ha
UAV with IR	1.86 hours	$3200	~35 ha

Deer management strategies implications for Wild Basin

The management should not be designed as a “one-size-fits–all” strategy. It is necessary to consider factors of the surrounding environment and assess each factor and its influence on white-tailed deer populations, including the understanding of deer movements within urban-suburban areas (Kilpatrick and Spohr, 2000, and Grund et al, 2002). There are so many factors

that can affect a management plan; multiple options should be considered for planning a well-formed management plan. One option is using a UAV, as it can be useful for conducting a census survey of white-tailed deer and/or assessing the biodiversity within the ecosystem that white-tailed deer inhabit. This study concluded that it is necessary to have further exploration and sampling with a UAV to count white-tailed deer.

Wild Basin will be able to utilize the knowledge of each field technique efficiency to determine which technique will be more likely to achieve their objective. So far, Camera trap method is most effective in counting the deer density, providing higher confidence in accuracy of the census and least invasive method. Wild Basin should be able to implement all three approaches to gather more accurate census.

Driving surveys will be able to provide further insight of human and deer relationship that other two approaches are unable to, and camera trap will be able to cover much of Wild Basin to gather data of deer within entire area of Wild Basin preserve and on other species simultaneously. Implementing UAV approach as third aspect of the management strategy will continue aiding the management by providing additional information that neither camera traps nor driving survey are able to cover. There are limitations of UAV that hindered us to determine how much we can incorporate the UAV into the management strategy, but we have recommendations to answer those limitations. Our recommendations encourage the continuation of usage of UAV and thus improving the management of white-tailed deer population.

Limitations and Recommendations

One of the reasons we did not yield any results was because of the warm temperatures we experienced this fall. The average temperature during the flights was 26C as we conducted surveys 30 minutes prior to sunset. The the sun warmed the ground throughout the day preventing the camera from being able to distinguish heat signatures of deer below the tree canopy. For this reason, UAV surveys using the IR camera should be performed at sunrise or with low temperatures. In addition, we suggest to take in consideration of the weather during the day before flying the UAV.

The time of the flight is limited due to the battery life of the UAV. The battery can last up to 15 minutes which only allowed us to perform two line transects per battery. The shortened flight time prevented us from maximizing sampling time with the UAV. We recommend purchasing additional UAV batteries to survey more area.

The infrared camera color scheme was something we encountered as a limitation. Since there was no previous experience being done with infrared camera at Wild Basin, we were not familiar with the color scheme that would yield the optimal image. This setting can be manipulated within the Flir Vue UAS app for smartphones before flight. We experimented with several color schemes before determining the gray/red color scheme had the clearest image

The flight itself was also a limitation. As we mentioned earlier, there was no literature or previous experience using a UAV with an infrared camera attached. After examining data from the first surveys we determined that the speed of the drone should average 3 m/s and the elevation should be right above the tree line to maximize the probability of spotting wildlife when reviewing the video.

Future Studies

With this study, we were able to set up flight parameters and instrument setting to efficiently use a UAV coupled with an IR camera to perform line transects and achieve multiple wildlife management objectives. The recommendations of these the flight parameters stated can be used as the baseline for continuing research with a UAV.

Future research could include using the drone with IR camera to conduct multi species surveys. Reviewing the data from the camera traps a pattern of carnivore and herbivore spatial locations were evident. Literature has shown a "space race" between predator and prey (Chretien et. al., 2015). Prey may attempt to maximize spatial overlap with humans to avoid predators and take advantage of increased nutrition from residential gardens, whereas predators may attempt to minimize their overlap with humans but maximize overlap with prey. With continued long-term use of the camera traps in conjunction with UAV surveys may yield significant data to determine the spatial relationships of predator and prey.

The overarching impacts held within this project are to inform the Wild Basin and Austin community on how to efficiently manage and coexist with the white-tailed deer population while maintaining the population of the species through a continuing change in land-use with human activity.. With this data we hope to increase the awareness of how to co-exist with species inhabiting in areas with heightened urbanization to maintain a balance. With the addition of the thermal camera on the UAV, it can be a useful tool for future research at Wild Basin (i.e., monitoring endangered species, conducting surveys in sensitive areas and nocturnal surveys), and may provide exclusive information on biodiversity, species abundance, and habitat quality that we would otherwise be unable to capture from the ground.

Through increased sampling we could aid in creating a biological index of the species that inhabit Wild Basin, and determine whether increased development in the area affects the spatial or temporal movement patterns of deer and other wildlife. This may me integral for a preserve such as wild basin where many species cross the urban/wilderness boundary. Wild Basin. We can use these non-invasive techniques to study these communities and allow us to make better management decisions that can continue to support and preserve the diversity and uniqueness of Wild Basin Wilderness Preserve.

Appendix

Table 4: Raw data of deer counted in each camera traps.

	Buck	Doe	Fawn	Unknown	Total
Camera 1	1	8		2	11
Camera 2	1				1
Camera 3					
Camera 4					
Camera 5	1	5			6
Camera 6	1	2		2	5
Camera 7					
Camera 8					0
Camera 9	1				1
Camera 12		1			1
Camera 13	2	4		2	8

Table 5: Driving Deer Survey Data

Date of Survey	Buck	Doe	Fawn
October 18	2	4	
October 20	0	5	
October 25	1	6	
October 27	2	2	
November 1	1	11	3
November 3	1	2	1
November 15	1	6	1
Totals	9	36	5

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