KDFWR Executive Summary of Services Rendered by VizionAir

Deer and Elk Program staff were overall pleased with the quality of effort put forth by The VizionAir and Eco-Tech Consultants during the recent UAS project. Nearly all project deliverables included in the RFP have been satisfactorily completed, with a few minor exceptions caused by technological limitations.

Despite the contractor's admirable work ethic and obvious desire to provide KDFWR with a satisfactory product, issues highlighted in the project's final report cast doubt as to whether this technology is mature enough to provide a viable option for surveying elk in the near term. The following list details some of the concerns shared by Deer and Elk Program staff about the UAS project, coupled with the citation from the contractor's final report.

1. Page 3, part B: "The steep terrain and the varying height of tree canopy in the Steeltrap sampling grids required manual control of the UAS to keep a safe distance from terrain obstacles and maintain visual line of sight (VLOS). This eliminated the possibility of relatively standard image elevations that is necessary to create imagery mosaics."
    a. Program commentary: Due to difficulties imposed by the terrain, VizionAir was not able to perform the flight in a manner that allowed the creation of a map as requested in the project deliverables.
2. Page 4, part C, second bullet: "the amount of overlap between images is low."
    a. Program commentary: Under typical flight conditions presented on surface mine habitats, the UAS was unable to maintain the designated flight path to sufficiently meet Deer and Elk Program needs for mapping and/or marking animal locations for minimum count or mark-resight purposes. In some cases, there was no overlap at all between images. This will not provide adequate coverage of the sampling area, which may provide lower estimations for future use through missed animals.
3. Page 4, part 5: "...it was impossible to maintain visual line of sight (VLOS) of the aircraft at all times during sampling."
    a. Program commentary: This was a relatively small sampling area (250 acres), but despite the small size the operators were still unable to effectively survey the plot due to VLOS constraints imposed by terrain. This may have serious ramifications for the potential for future UAS work, since VLOS is a current FAA requirement for UAS operation. This obstacle is exacerbated by increasing elk use of timbered and rugged terrain as documented through recent GPS collar data.
4. Page 5, text between tables: "Noise disturbance during UAS ascension may have startled this herd, which may have prompted the elk to move away from the grassland and into heavy forest cover."
    a. Program commentary: UASs have been utilized to haze nuisance animals, including elk. If the UAS disturbs the animals (as was suspected in this instance), this platform will prove to be an ineffective tool for future counts. We were extremely lucky on the night of the survey that the elk eventually stopped

running. Had they not, we would not have been able to get an accurate count of this herd, thus biasing the results.

5. Page 5, below Table 2: "If Eco-Tech was unable to discern white-tailed deer (*Odocoileus virginianus*) from elk, the individual was characterized as an ungulate.."
    a. Program commentary: The thermal technology used by the contractors – which is quantifiably best-of-class – did not provide enough resolution for the contractors to accurately identify ungulates to the species level. Furthermore, at the Starfire site, the contractors failed to detect the GPS-collared bull that was definitively located in S4 during the survey period. See maps.
6. Page 6; Page 7: "Eco-Tech biologists could not verify antler presence... but it was not sufficient to determine gender or age of any elk identified in the images or videos." And "The resolution is too poor at the survey distance/ altitude to determine elk gender and age class."
    a. Program commentary: Without the ability to identify age or gender of the surveyed species, Deer and Elk Program staff can draw very few conclusions of worth from these data. However, it would appear nearly impossible to achieve more precise data given current technological limitations. This lack of precision is especially troubling given that the altitude flown was relatively low (never exceeding than 400 feet above ground level, and sometimes as low as 150 feet above ground level).
7. Page 6, part 6: "VizionAir recommends flying on nights warmer than 59^0 F"
    a. Program commentary: These are not ideal conditions for conducting minimum counts on elk, and we generally do not have many winter evenings where these conditions are present, thus greatly reducing any flight potential. This is especially pertinent because VizionAir later recommends scheduling all flights during leaf-off conditions to increase the ability to identify animals within the timber.
8. Page 6, part 6: "VizionAir recommends choosing a control point with a take-off/landing area close to the center of the sampling grids to yield greatest battery efficiency while minimizing flight time."
    a. Program commentary: It will be difficult to find suitable locations for control points in non-strip-mine habitats, especially given the constraints imposed by VLOS.
9. Page 7: "The relative temperatures of nearby non-biological features were sometimes warm enough to provide a heat signature similar to an endotherm (i.e., an animal that creates its own heat; Image 6)"
    a. Program commentary: It will be impossible to conduct counts at any time of year other than leaf off, but is still difficult under ideal situations with current technology.

Project Parameters of Success

Before sending this project to bid, KDFWR Deer and Elk Program staff identified several key parameters by which this project's success would be determined. These parameters were:

1. Species misidentification rates (e.g mistaking white-tailed deer for elk) may not exceed 5%.
    a. Misidentification rates determined by Deer/Elk Program staff review of all the flight data
2. ≥ 90% of all recorded animal locations in each habitat type (bare ground, grassland, shrubland, and forest) should be identified to the species level (e.g., being able to determine whether a partially obscured animal is a deer or an elk).
3. In survey blocks containing collared elk, the collared individual should be located 100% of the time.
4. All costs (including data analysis and project management) will be analyzed by $/hour flight time for comparison against current costs for conducting minimum counts from the helicopter ($500/hour).
5. Total project time (including data analysis and project management) will be analyzed by minutes/1000 acres surveyed for comparison against current time expenditures for conducting minimum counts from ground counts and helicopter counts.

Evaluations of these parameters follow:

1. Species misidentification rate: Upon review, KDFWR staff felt that the contractors correctly identified all animals that were classified to the species level within the report. This parameter was successful.
2. Species level identification: The contractor was only able to classify 82% of the ungulates documented during the flight. As a result, this parameter was not successful.
3. Successful identification of collared elk: According to GPS collar data, only one collared animal (the Starfire bull) was present in a survey block on the date of the survey. The contractors identified a single animal in that survey block (likely the bull), but they were unable to classify the animal at the species level. As a result, this parameter was not successful.
4. Flight cost/hour: The total project cost was $24,000, and no replicate routes were performed. The UAS in this project was actively surveying (i.e., not counting battery changes) for approximately 4.5 hours. That means this project cost $5,333/hour flight time. Being an order of magnitude more expensive than observed helicopter flight costs on a per hour basis, this parameter was deemed not successful.
5. Flight cost/acre: It is often difficult to obtain an accurate measure of acreage covered during helicopter flights, but KDFWR staff routinely cover 10,000-12,000 acres in the course of a morning flight. This UAS project was bid at 2,000 acres. Given the observed costs for both methods, helicopter minimum counts cost approximately $0.21-0.25/acre, whereas the winning bid for this project cost $12/acre. Given this significant cost differential between these methods, this parameter was not successful.

Program Summary of Project Success:

The goal of this project was to evaluate the feasibility of combined UAS and thermal imaging technology to perform minimum elk counts. The contractors did successfully locate elk during the project using these technologies. However, practical obstacles to further use of these techniques are readily apparent. Technological limitations (especially regarding the

inability to adequately classify ungulates to the species level, and the complete inability to differentiate age and sex categories) severely degrade the usefulness of these data for elk management.

Purchasing a UAS and utilizing KDFWR staff for all operations and analysis activities would likely decrease the cost/unit surveyed relative to using an outside contractor. However, the severe limitations associated with the data specificity would nonetheless increase the real cost of this method, since the data collected through this method will be inherently less informative than data gathered through alternative methods.

As documented in the original RFP, the data used to generate these survey grids was derived from GPS collars placed on free-ranging elk. We took the last 27 days' worth of location data to formulate a "home range" for each individual and conducted the surveys within this area. Despite the fact that we sampled the area that each elk was known to occupy over the past month, we were still unable to definitively locate either animal. The Steel Trap cow was actually outside of her "home range" during the night of the survey. This highlights the unpredictability of daily elk movements, and raises concerns regarding the future applicability of the current technology to conduct further minimum counts with a UAS.

UAS and thermal imaging technology could hold some applicability for targeted elk surveillance where sex and age categorization are unimportant. However, the observed inadequacy of desired data specificity, coupled with the extreme cost of this project relative to alternative minimum count methods, lead us to conclude that this technology is not currently applicable for large-scale elk management activities.

Unmanned Aerial System Elk Survey
Doc ID No: PON2 660 1700001306 1

KNOTT, PERRY, AND HARLAN COUNTIES, KENTUCKY

Prepared for:
Kentucky Department of Fish and Wildlife Resources
Frankfort, KY

Prepared by:
VizionAir & Eco-Tech Consultants, Inc.
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April 2017

UNMANNED AERIAL SYSTEM ELK SURVEY
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KNOTT, PERRY, AND HARLAN COUNTIES, KENTUCKY

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1. INTRODUCTION

VizionAir has been contracted by the Commonwealth of Kentucky, Tourism, Arts, & Heritage Cabinet/Kentucky Department of Fish and Wildlife Resources (KDFWR) to complete Unmanned Aerial System (UAS) monitoring of elk (*Cervus canadensis*) herds in Knott, Perry, and Harlan Counties, Kentucky.

This report outlines UAS elk survey purpose, methodology, results, and conclusions based on field data collection within the survey areas.

2. PROJECT DESCRIPTION

The KDFWR is searching for new ways to survey existing elk herds living in Kentucky. KDFWR hired VizionAir to assess the efficacy of UAS for collecting elk population demographics for Kentucky. VizionAir subcontracted data analysis and report preparation to Eco-Tech Consultants, Inc. (Eco-Tech).

The project goals outlined by KDFWR are to:

1. collect elk herd parameters within a defined survey area in Kentucky,
2. determine the efficacy of UASs for collecting elk population demographics, and
3. determine the effect of cover type on elk sightability.

This document fulfills the project goals by reporting the number and herd sizes, and locations of elk recorded by a thermal-mounted UAS in two survey areas in South-eastern Kentucky.

3. ELK (*CERVUS CANADENSIS*) IN KENTUCKY

Elk were once widespread throughout North America. By 1900, elk populations had declined to less than 100,000 individuals and extirpated from Kentucky due to anthropomorphic pressures of hunting and competition with livestock grazing (Crank et al. 2015, NRCS 2017). Due to the species adaptability and favorable response to management practices, elk have returned to stable populations in several places across North America (NRCS 2017). According to the IUCN Red List, elk are currently considered to have a wide distribution on a global scale, and populations may be increasing (Brook et al. 2016).

Elk population densities average between 2-10 individuals per square kilometer (km^2) throughout their world ranges (NRCS 2017). Elk are generally found in mountainous areas with habitats consisting of open deciduous woodlands, natural grasslands, pastures, and meadows. The elk diet consists mostly of shrub and tree shoots, grasses, and sedges (Brooke et al. 2016).

Elk were reintroduced to Kentucky in 1997 from several western states, after having been extirpated from the region in the 1880s. In the early 2000's, the elk populations were stable without needing additional elk moved into the state. Currently, KDFWR estimates that there are approximately 10,000 elk living in and around the 4.1 million acre elk restoration zone in the Appalachian Highlands of Kentucky (pers comm. KDFWR 2017; KDFWR 2016). An elk-hunting season in Kentucky has been successful in maintaining the elk population in Kentucky while being well participated over the last several years, and populations are now at densities that allow for

translocation of additional individuals or small herds to unoccupied habitat within their historic range within the United States.

4. METHODS

A. SURVEY AREAS

Two survey areas were selected by KDFWR for elk surveys (Figure 1) based on collared elk location data received every 13 hours. The survey areas were delineated by KDFWR using elk collar movement data from about 27 days and a 50-yard buffer. Within each survey area, KDFWR established four 250-acre (~1km^2) sampling grids. Three of the grids were randomly placed by KDFWR within the survey area, and one grid was non-randomly placed to focus on where the collared elk was expected to be, based on the most recent data. All four sampling grid coordinates in each survey area were provided by KDFWR to VizionAir. The three non-random grids were and survey areas were provided to VizionAir prior to surveys for preflight planning.

Both survey areas are located in the Dissected Appalachian Plateau (69d) Level IV Ecoregion (Woods et al. 2002). This ecoregion is more rugged with higher stream gradients than the surrounding ecoregions. Narrow ridges and valleys are abundant, and the ecoregion is mostly forested (Woods et al. 2002).

KDFWR requested the surveys be completed before the end of March, while bull elk still have antlers, there is more size variability among age classes, and vegetation in the area has limited leafy growth to interfere with imagery.

UAS surveys were completed based on two collared elk, which the survey areas are named for: the Starfire Bull (Starfire) and Steeltrap Cow (Steeltrap) survey areas. No data on the specific collared elk or elk herds residing in these survey areas were provided to VizionAir or Eco-Tech. Originally, KDFWR selected Starfire and Redbird Cow for surveying (20 miles northwest of Steeltrap on the border of Clay and Leslie Counties), but after a potential health and safety concern was identified at Redbird Cow, KDFWR and VizionAir decided to complete a different survey area on another night. Steeltrap was selected to replace Redbird Cow and surveys were arranged for the following week. Several KDFWR employees were present at the UAS control points during all flights.

Starfire Bull

The Starfire survey area lies in Knott and Perry Counties (Figure 2). The area in and around Starfire is mostly strip mined, with some grassland, pasture and forested land. Elevations in this survey area range from about 1,400 feet (ft) above mean sea level (MSL) to about 850ft MSL. However, most of the area within Starfire is between 1,200 and 1,400ft MSL. Lick Branch and Kitchen Fork streams flow through this survey area, and a few unnamed ponds are also within the survey area bounds, including one that sprawls approximately 30 acres.

Sampling grids S1, S2, and S3 were randomly placed within the Starfire survey area, while S4 was non-randomly assigned by KDFWR. Unfortunately, there was a large degree of overlap (65%) between sampling grid S2 and the non-random sampling grid S4 provided by KDFWR (Figure 2). Because of this overlap, only three sampling grids should be considered as having been surveyed. VizionAir used a single UAS control point to survey all Starfire sampling grids, located on a high-elevation (i.e., 1,400ft MSL) plateau in the S3 sampling grid. This plateau

provided excellent visibility across the entire survey area, and satisfied the requirement that the remote pilot needs to maintain visual line of sight with the UAS during flight.

Starfire was surveyed the night of March 6th, from about 20:30 to 03:30 on March 7th. VizionAir flew the sampling grids starting with S3, S2, S1, and ending with S4. Weather conditions during the Starfire Bull survey were cloudy with no precipitation, with temperatures consistent around 54° Fahrenheit. Wind speeds the night of the survey were not ideal, blowing from the Southwest at 4 miles per hour (mph), gusting to about 17mph, but were adequate for UAS flight.

Steeltrap Cow

The Steeltrap survey area lies in Harlan County, KY (Figure 3). The area within Steeltrap is almost entirely forested, with some grassland. Elevations in this area vary from 2,430ft MSL to less than 1,600ft MSL. Steeltrap contains very steep terrain, with many peaks and valleys. Laurel Creek, Little Right Fork and Lick Fork streams all flow through the survey area.

Sampling grids S1, S2, and S3 were randomly placed within the Steeltrap survey area, while S4 was non-randomly assigned by KDFWR. Due to the steep terrain and tall trees, each sampling grid had its own UAS control point in a lowland valley area with visibility of the grid where UAS line of sight could be maintained (Figure 3).

Steeltrap was surveyed the night of March 12th, from about 21:16 to 02:19 on March 13th. The sampling grids were flown starting with S4, then S3, S1, and ending with S2. Weather conditions during the Steeltrap Cow survey were mostly clear with no precipitation, with temperatures ranging from about 40°F to 32°Farenheit. Wind speeds during the survey ranged from 2 to 8mph. Although the low temperatures aren't ideal for UAS operation, overall, UAS flying conditions were adequate.

B. UAS TECHNOLOGY & FLIGHT

VizionAir operators hold 14 CFR part 107 remote pilot in command certificates with small UAS ratings, and a 107.29 "night flight" waiver. The operators followed all applicable requirements provided by the FAA for UAS operation under the 107.29 waiver, along with a risk management plan to ensure a safe flight.

VizionAir used a vertical take-off and landing DJI Inspire 1 Pro (cover image) with a DJI Zenmuse XT FLIR camera to complete the elk UAS surveys. The UAS and camera were operated by independent personnel. Both individuals traded off maintaining visual contact with the UAS during flight. The FLIR camera has 640x512 display format, 30 Hz full frame rate, 9mm lens, and 8x digital zoom. VizionAir used multiple infrared (IR) filters throughout the survey to demonstrate the varying abilities of each filter for observing mammalian signatures.

VizionAir was able to set up pre-programmed flight transects using DroneDeploy and DJI GO autopilot IOS application software for the Starfire grids, because of the relatively flat terrain (Image 1). VizionAir created mosaics of the Starfire sampling grid imagery using Pix4D software (Version 3.1). The flight altitude at Starfire was 230ft above ground level (AGL), and the cruising speed was approximately 30mph.

The steep terrain and the varying height of tree canopy in the Steeltrap sampling grids required manual control of the UAS to keep a safe distance from terrain obstacles and maintain visual line of sight (VLOS). This eliminated the possibility of relatively standard image elevations that is necessary to create imagery mosaics. Since mosaic creation would not likely be possible for the

area, VizionAir used video recording on the Steeltrap grids, and only recorded still images to highlight potential mammalian IR signatures. Flight altitudes at Steeltrap varied from 150ft to 400ft AGL, with cruising speeds between 15 and 30 mph.

The flight speeds for each survey area were maintained to attempt to complete all sampling grids in one night to prevent recounting elk.

C. IMAGERY ANALYSIS

After field survey completion, VizionAir provided survey area boundaries, sampling grid boundaries, Steeltrap flight logs, raw thermal images and videos, and mosaic Starfire imagery to Eco-Tech for analysis. Eco-Tech completed manual analysis of all images and video provided, visually searching for IR signatures that could be considered mammalian. All images with potential mammalian signatures were compiled into a list for more rigorous analysis, involving comparison among known elk and cow signatures, evidence of movement, signature shape, and relative size comparisons to nearby landscape features like roads and trees.

VizionAir provided Eco-Tech with mosaics of the Starfire imagery for reference material. When possible, Eco-Tech compared the partial mosaics from Starfire to the individual images to determine if a signature was in fact stationary or moving, since Pix4D attempts to eliminate moving objects from mosaics. However, the construction of the mosaics were incomplete and inaccurate, due to the images not having enough visual key point matches to process complete/accurate 2D mosaic maps in Pix4D (Image 2). Low number of visual key point matches per image can be a result, if;

- visual content is too repetitive or complex (e.g., desert, forest, snow, fog, water),
- the amount of overlap between images is low,
- image quality is too low (over/under exposed, blurry, or noisy), and/or
- there are too many changes in the scene during the image acquisition (e.g., shadows, thermal flares, moving objects).

2D Mosaics from Steeltrap were not created, because the standard resolution of thermal video data is not sufficient to get reasonable results in Pix4D.

All potential mammalian IR signatures identified to a species or group were QA'd by another wildlife biologist to ensure accuracy.

5. RESULTS

Overall, VizionAir recorded a total of 3,074 IR images and 126 minutes and 33 seconds of video at Starfire and Steeltrap (Table 1). On average, each sampling grid took between 45 and 90 minutes to complete, depending on the distance from the UAS control point, terrain, number of suspected mammalian IR signatures, wind, and temperature.

Steeltrap S2 was surveyed notably less than all other sampling grids (Table 1). This grid was in an extremely deep valley that had less than ideal UAS launch points to conduct a full survey safely. Even though the UAS technology is capable enough to complete the entire S2 grid, it was impossible to maintain visual line of sight (VLOS) of the aircraft at all times during sampling. This area required climbing to maximum altitude in order to maintain line of sight, reducing the scanning area and downrange travel. After discussion with KDFWR, they determined that enough of the sampling grid had been covered in one pass for the survey to be considered completed.

Table 1. Remote Sensing Data Collected at Starfire Bull and Steeltrap Cow Survey Areas on March 6 & 12, 2017.

Survey Area	Sampling Grid	Number of Images	Minutes of Video
Starfire Bull	S1	905	0
	S2	747	0
	S3	667	2 min, 40 sec
	S4	722	1 min, 36 sec
Steeltrap Cow	S1	2	28 min, 2 sec
	S2	0	11 min, 17 sec
	S3	29	48 min, 38 sec
	S4	2	34 min, 20 sec
	Total	*3,074*	*126 min, 33 sec*

A total of 14 elk were recorded during all surveys (Table 2). All 14 individuals were recorded in a single herd within Steeltrap S3 moving from a grassland area into a forested valley (Table 2; Image 3). The herd was observed via video footage in three general areas in S3 as they moved Northeast (Figure 3). Noise disturbance during UAS ascension may have startled this herd, which may have prompted the elk to move away from the grassland and into heavy forest cover.

Table 2. Elk Inventory Data recorded during Starfire Bull and Steeltrap Cow Survey Areas on March 6 & 12, 2017 within Knott, Perry, and Harlan Counties, Kentucky.

Sampling Grid	Individual Elk Recorded	Herds Recorded	Unidentified Ungulates Recorded	Cover Type
Starfire S1	0	0	2	Bare ground
Starfire S2	0	0	1	Bare ground
Starfire S3	0	0	0	-
Starfire S4	0	0	0	-
Steeltrap S1	0	0	0	-
Steeltrap S2	0	0	0	-
Steeltrap S3	14	1	0	Open Grassland, Deciduous Forest
Steeltrap S4	0	0	0	-
Total	*14*	*1*	*3*	

If Eco-Tech was unable to discern white-tailed deer (*Odocoileus virginianus*) from elk, the individual was characterized as an ungulate (i.e., hoofed mammal). Comparison of IR signatures among different images taken in the study areas was difficult due to landscape variability as the UAS flight elevation is relative to take-off elevation and not adjusted during flight over irregular terrain. Because the elevation of the UAS was often changing throughout a sampling grid, it is difficult to infer ungulate species by IR signature size.

Three other ungulates were recorded on bare ground during Starfire S1 (two individuals; Image 4) and S2 (one individual; Image 5) flights (Attachment C). Although it is very likely that these three (especially the two individuals recorded in S3) were elk, the captured images were not sufficient to determine if the ungulate was an adult white-tailed deer or an elk. It is likely that the

elk herd known to occupy the Starfire survey area were located within the western portion of the survey area during the night of the survey, which was outside of the four sampled grid boundaries (Figure 2).

The only other mammals identified during surveys were a herd of cattle in Starfire S3 near the Starfire UAS control point. Although a few elk in images and frames of video appear to potentially have antlers, Eco-Tech biologists could not verify antler presence. The resolution of the IR camera used (DJI FLIR Zenmuse XT (640x512 30 Hz) is the highest resolution/quality UAS camera that FLIR has to offer, but it was not sufficient to identify gender or age of any elk identified in the images or videos. All photos or videos with identified mammalian IR signatures are listed in Attachment C.

6. RECOMMENDATIONS FOR FUTURE UAS FLIGHTS

The goal of this project was to deem the feasibility of using a UAS for collecting elk population demographics in Kentucky. In completing the initial test, VizionAir and Eco-Tech has compiled several recommendations for future UAS flights for KDFWR.

Daylight site surveys of the planned survey areas are recommended to mitigate the risk of controlled flight into terrain or obstacles. For example, one of the sites contained numerous small utility lines that would have been imperceptible at night and could have resulted in an impact were they not spotted during daylight.

VizionAir recommends flying on near-full or full moon nights with clear weather conditions for natural illumination of the surroundings and horizon. This additional light helps the remote pilot avoid obstacles, and overall ground operations safety.

Cold temperatures significantly impacts UAS battery life, reducing flight time and increasing charge time. VizionAir recommends flying on nights warmer than 59°F.

Control point selection had a tremendous impact on flight efficiency. Flights that launched outside of a sampling grid could spend over half of the available flight energy in a battery just flying to and from the grid, severely increasing survey time. VizionAir recommends choosing a control point with a take-off/landing area close to the center of the sampling grids to yield greatest battery efficiency while minimizing flight time.

Although the standard external navigation lighting on the Inspire 1 was adequate to see the UAS from over a mile, VizionAir recommends adding an external strobe light to enhance visibility at a distance. The strobe did not have any noticeable effect on the FLIR imagery, and there was no electric interference.

VizionAir recommends following memory card best practices by retrieving the data from the card after each flight. Making a back-up before launching eliminates the potential of losing data should an incident occur.

Having additional personnel available during flights is recommended for help with landing spotting, visual observing, and general control point assistance.

Notification should be provided to nearby residents and local law enforcement prior to surveys. Letters, phone calls, or in-person visitations help mitigate surprises, and are highly recommended by VizionAir well in advance.

Although the FLIR camera used for these surveys is one of the top models, imagery resolution presented several challenges during data analysis including:

- The resolution is too poor at the survey distance/altitude to determine elk gender and age class. Although there were a few individuals that look smaller than the rest, the resolution is too poor to determine if this is an accurate assessment, or if vegetation is obstructing the IR signature. The poor resolution (640x512) also makes it difficult to identify IR signatures to species in some cases.
- The relative temperatures of nearby non-biological features were sometimes warm enough to provide a heat signature similar to an endotherm (i.e., an animal that creates its own heat; Image 6).
- The imagery taken with the FLIR often contained motion blur. The UAS was likely moving too fast while taking photos for the FLIR's slow shutter speed, resulting in blurry images and inaccurate, partial mosaics (Image 2).

IR technology has been rapidly advancing, and hopefully will improve in the near future. For future surveys, the UAS should hover at a complete stop during photo collection and a much higher resolution IR camera (1280x720) should be used to obtain elk age class and gender information.

The multi-rotor Inspire 1 Pro functioned well for this study. By being one of the smaller aircrafts compatible with a FLIR Zenmuse XT camera with a 3-axis gimbal, it allowed quick setup, portability, and increased maneuverability. Other larger multi-rotor platforms available such as DJI's M600 can be used, allowing larger payloads and increased flight time. If batteries continue to improve, longer flight times will increase UAS survey efficiency.

While tracking of a known herd as it migrated from open grassland to forested habitats was feasible, obtaining accurate counts of individuals in the forest was more difficult than in open terrain, as woody vegetation obscured the IR signatures. Review of several different images and videos was required to duplicate accurate counts of the individuals within these forested habitats. Obviously, these counts would've been nearly impossible were the deciduous tree leaves in full growth during summer. VizionAir and Eco-Tech maintains that flying outside of the vegetation growing season was the correct time to complete surveys.

IR cameras offer a number of filters that can be activated for different visual experiences. VizionAir experimented with several filters while collecting imagery and videos (Images 7-10). For elk surveys, ideal filters include those that are scales between two colors alone (e.g., black colors are warmer than white). Using a white hot with isotherms enabled was helpful to spot IR signatures up close during flight, but was not ideal for individual identification during analysis. For future surveys, Eco-Tech recommends using only one filter for the duration of the survey, so the imagery reviewers can easily compare images/videos without needing to alter signature criteria during analysis.

VizionAir mainly took images for the Starfire sampling grids and videos for the Steeltrap grids. After reviewing both imagery and videos for this project, it was determined that video files allowed for easy recognition of moving IR signatures when compared to still images. When recording videos, the digital zoom should not be activated unless the UAS is stationary, as it is disorienting for the data reviewer and helps to disrupt the viewer's analysis. When the UAS is stationary, however, a digital zoom can be beneficial when all individuals are within the view frame. Lowering

the altitude of the UAS would also be beneficial in these times, keeping in mind that the UAV noise could disturb the elk if too close. Eco-Tech recommends the use of video recordings over still imagery. Instead of using the digital zoom, Eco-Tech recommends flying as close as possible to the target IR signature for easier signature identification.

Camera angle can influence identification of IR signatures, with top-down imagery lacking tilt can be beneficial when viewing targets directly through a leaf-off forest canopy, but this lens position provides little information useful for determination of taxa. As found in other wildlife surveys, video footage allows for 360-degree perspective of potential mammalian IR signatures, which is helpful in observation of diagnostic characteristics such as appendages, ears, torsos, and rostrums. When a suspected herd or individual is located during flight, VizionAir and Eco-Tech recommends that the UAS be maneuvered to hover at an angle to the target, while circling slowly and capturing several perspectives of the IR signature.

7. CONCLUSIONS

VizionAir completed elk population UAS surveys under adequate conditions in Knott, Perry, and Harlan Counties, Kentucky. They were able to record one elk herd containing 14 individuals in Steeltrap S3 on March 12, 2017, moving northeast from a grassland into a forested valley. Three individual ungulates of unknown species were captured in still imagery in Starfire S1 and S2 on March 6th, 2017. Eco-Tech could not reliably determine age class or gender from the collected data.

We have determined that UAS can locate elk herds and capture population data with an IR camera, particularly when recent or real-time location data from individuals fitted with geographic positioning systems or radio-tracking collars can limit survey areas to productive locations. These data can then be used to estimate elk herd size and home range. With the relatively low operation costs when compared to other aerial surveys, UAS elk monitoring is a cost-effective and efficient way to monitor nightly movements of elk herds in a given area, when conducted in an appropriate manner with capable technology.

In our study, we were unable to obtain population demographics (i.e., age class and gender) due to the currently low-resolution of the IR camera systems. However, with advancing technology, IR camera resolution will likely increase within the coming years and provide more useful data for calculation of these wildlife population metrics.

For future UAS elk searches, we recommend more video be recorded than imagery, and all potential mammalian signatures be circled during video capture to collect several angles of the subject. If possible, lowering the altitude of the UAS to get closer to the subject is highly desirable, and may help with collected population demographic data.

8. LITERATURE CITED

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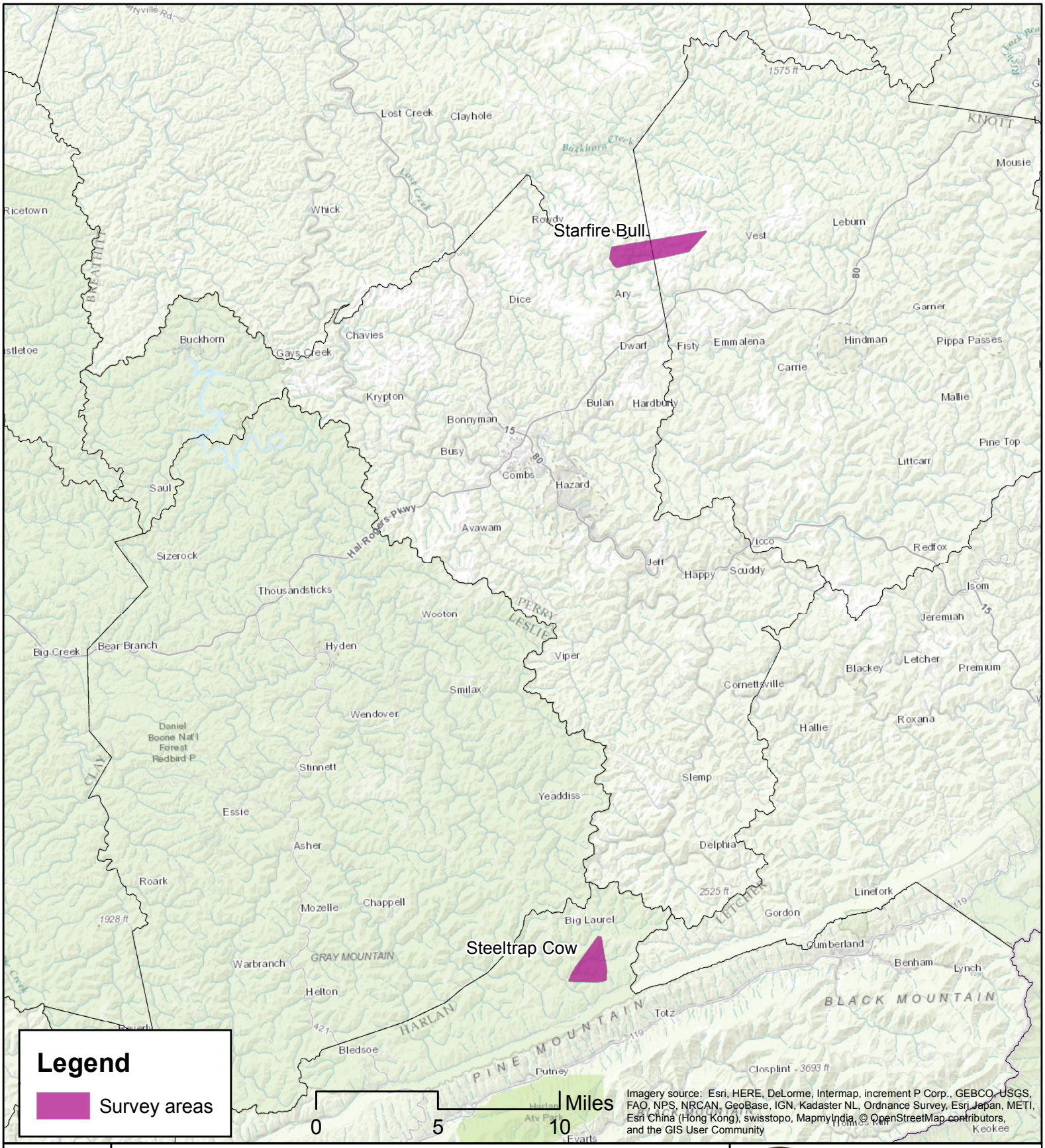
Attachment A
Figures



N

Figure 1

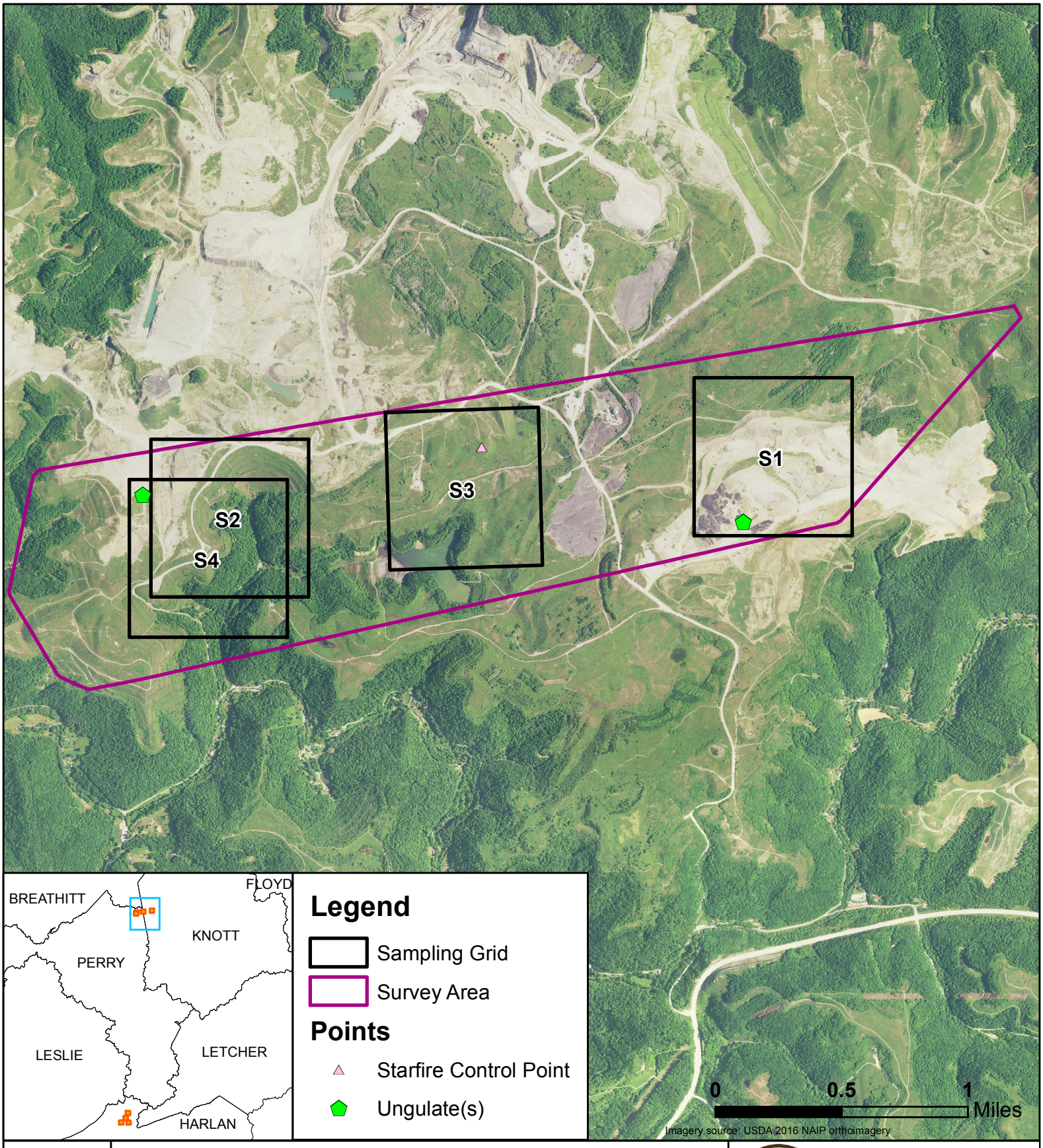
Starfire Bull and Steeltrap Cow Survey Areas

Prepared for: Kentucky Department of Fish and Wildlife Resources

Knott, Perry, and Harlan Counties, Kentucky

Eco-Tech CONSULTANTS

Drawn by: RRN
Print date: 4/17/2017
ETC File: LV2017004



N

Figure 2

Starfire Bull Sampling Grids

Prepared for: Kentucky Department of Fish and Wildlife Resources

Knott and Perry Counties, Kentucky

Eco-Tech CONSULTANTS

Drawn by: RRN
Print date: 4/17/2017
ETC File: LV2017004

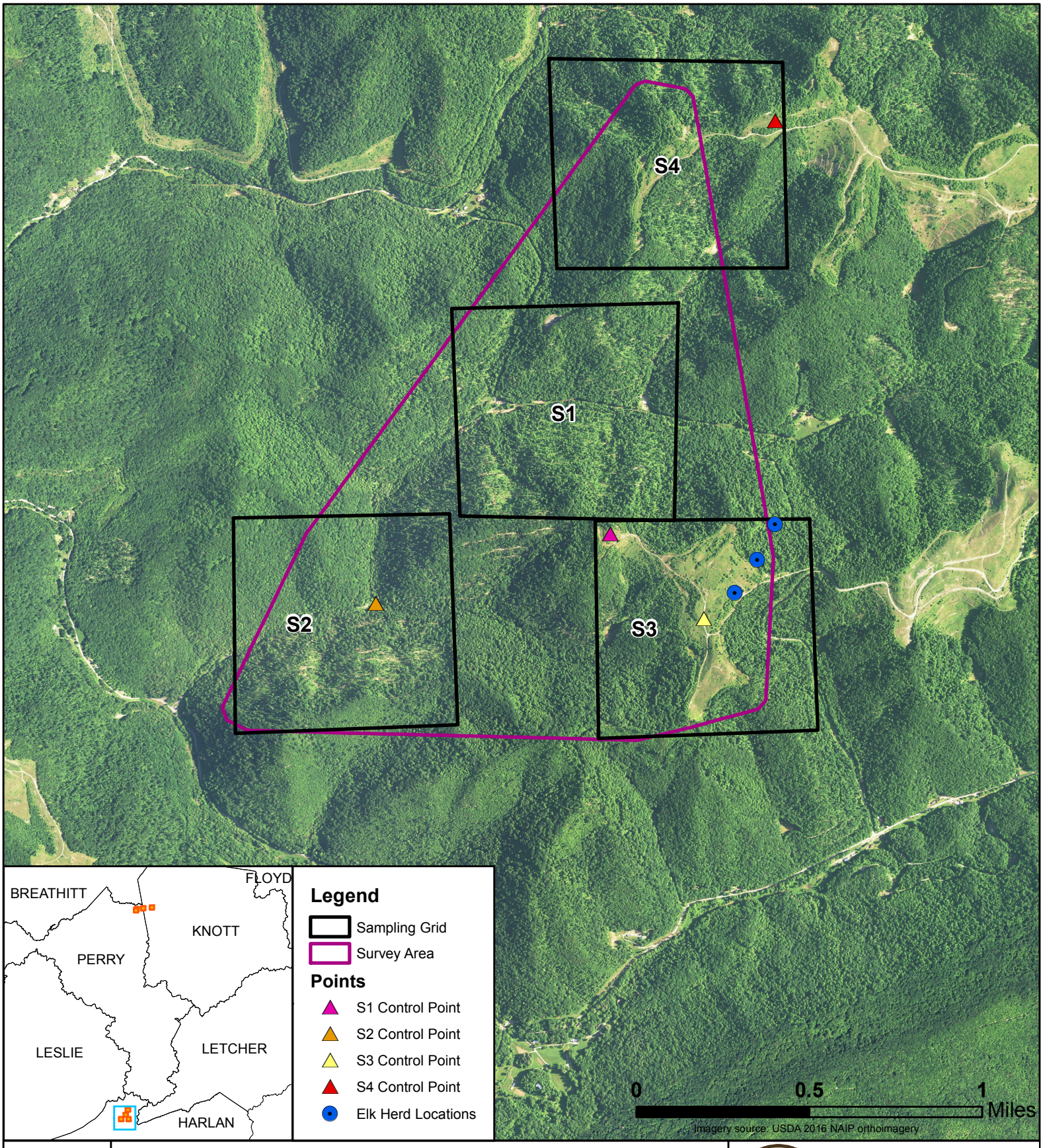


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Figure 3

Steeltrap Cow Sampling Grids

Prepared for: Kentucky Department of Fish and Wildlife Resources

Harlan County, Kentucky

Eco-Tech CONSULTANTS

Drawn by: RRN
Print date: 4/17/2017
ETC File: LV2017004

Attachment B
Imagery Log

Image 1: Starfire Bull grid 2 transect screenshot, March 6, 2017.

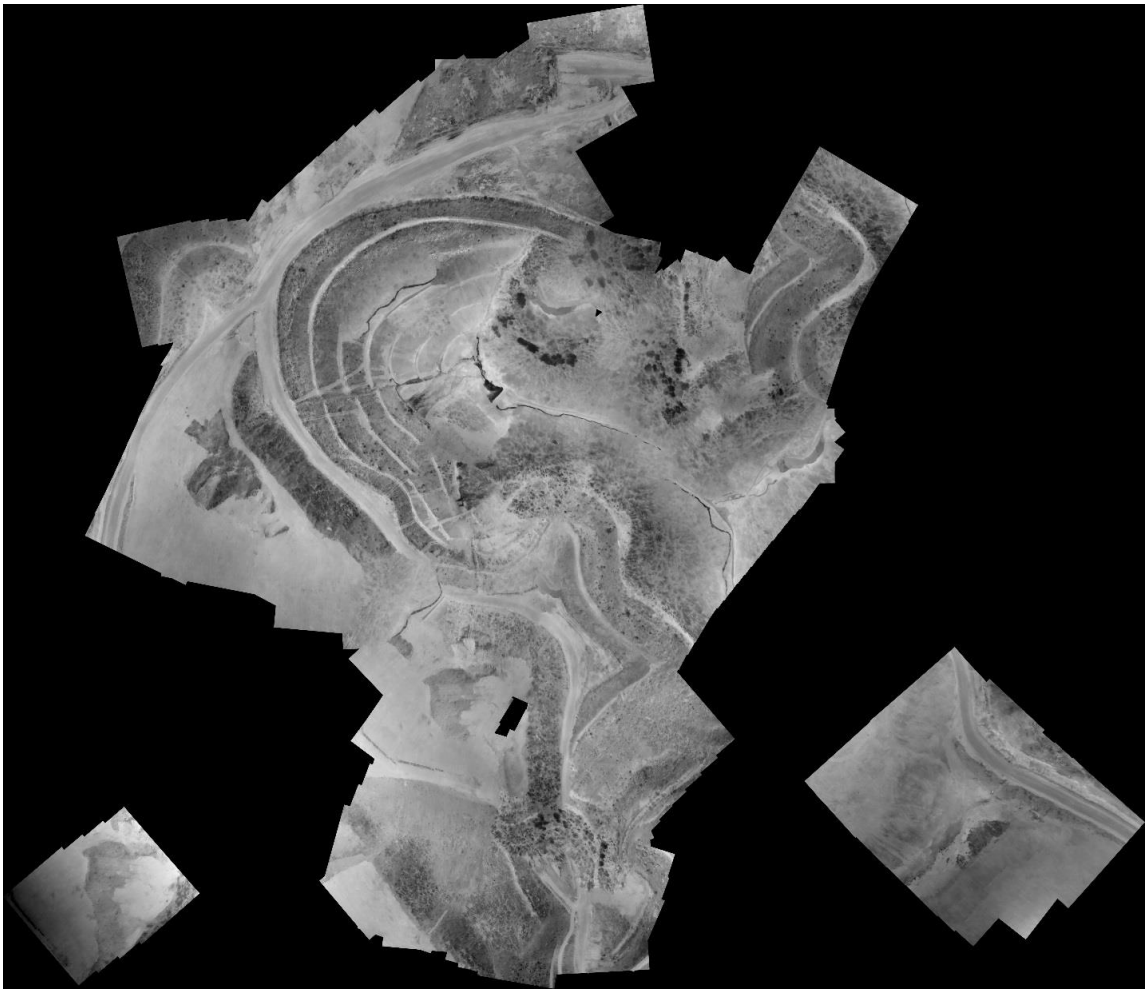

Image 2: Starfire Bull grid 2, March 6, 2017.

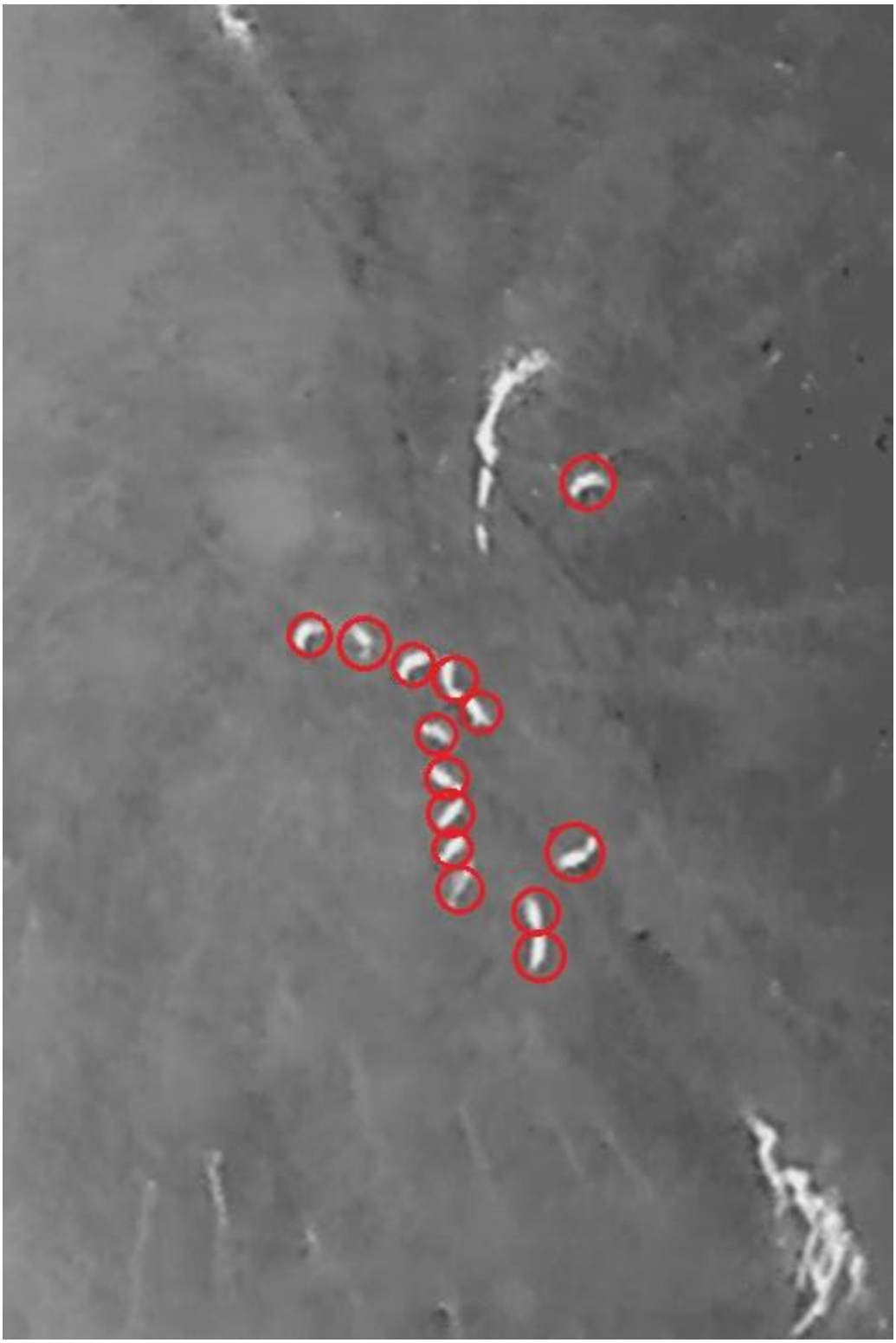

Image 3: Elk herd recorded in Steeltrap Cow grid S3 on March 12, 2017. Identified elk are circled.

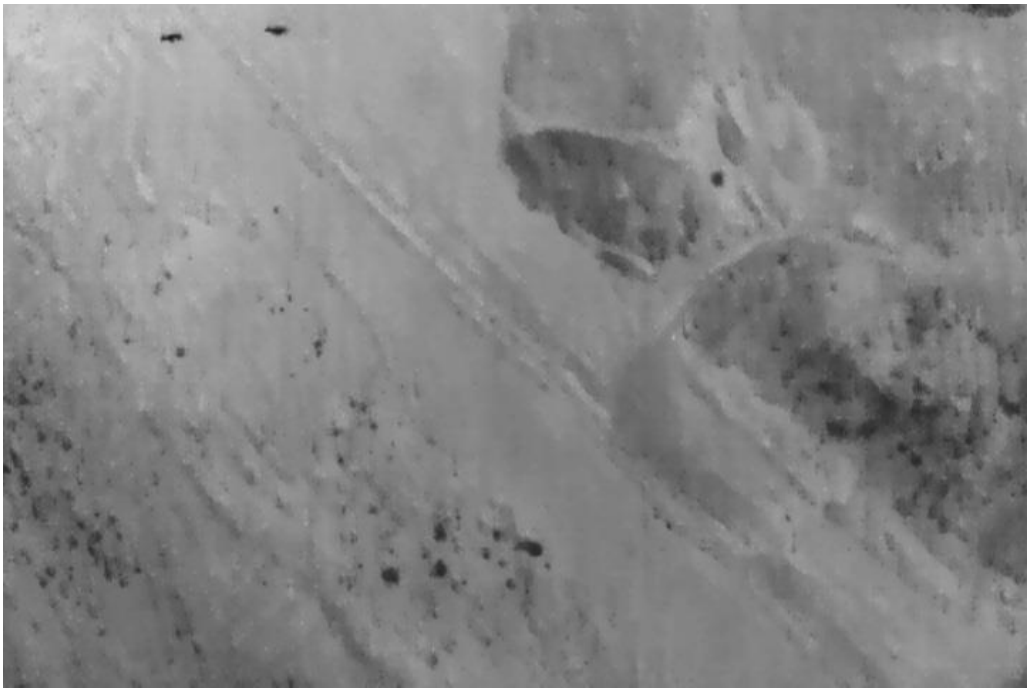

Image 4: Two ungulates recorded in Starfire Bull Grid S1 on March 6, 2017.

Image 5: Unidentified ungulate recorded in Starfire Bull grid S2 on March 6, 2017.

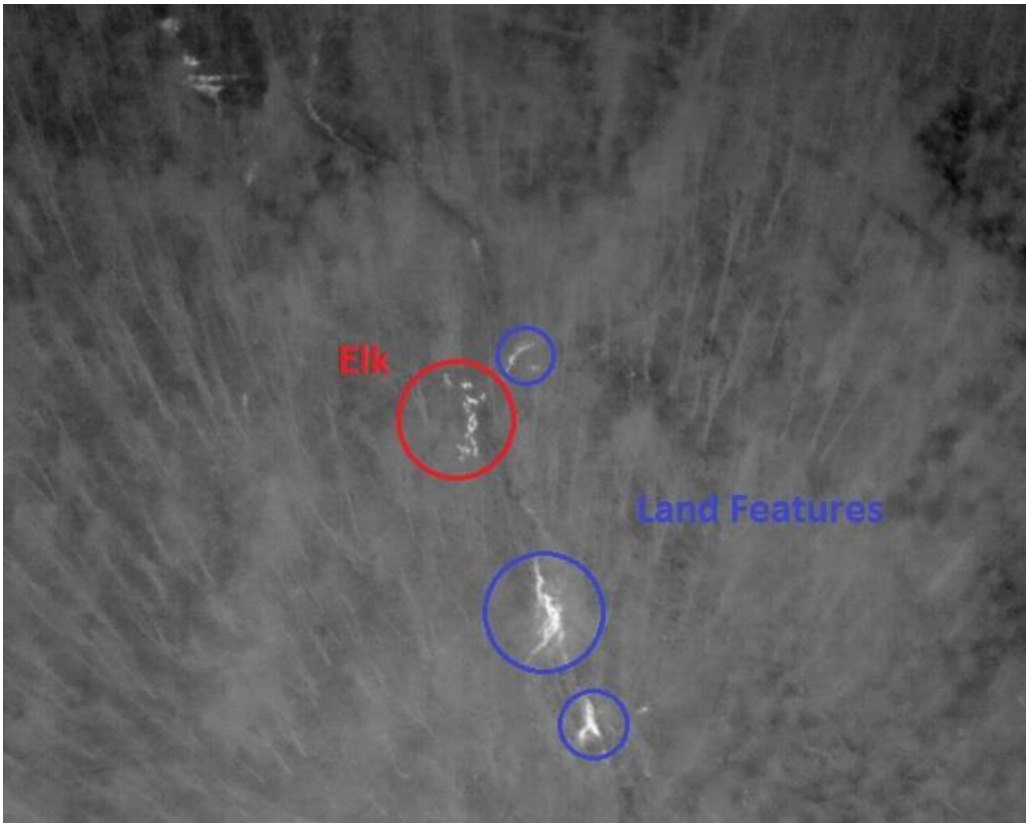

Image 6: IR signatures from elk and landscape features for comparison.

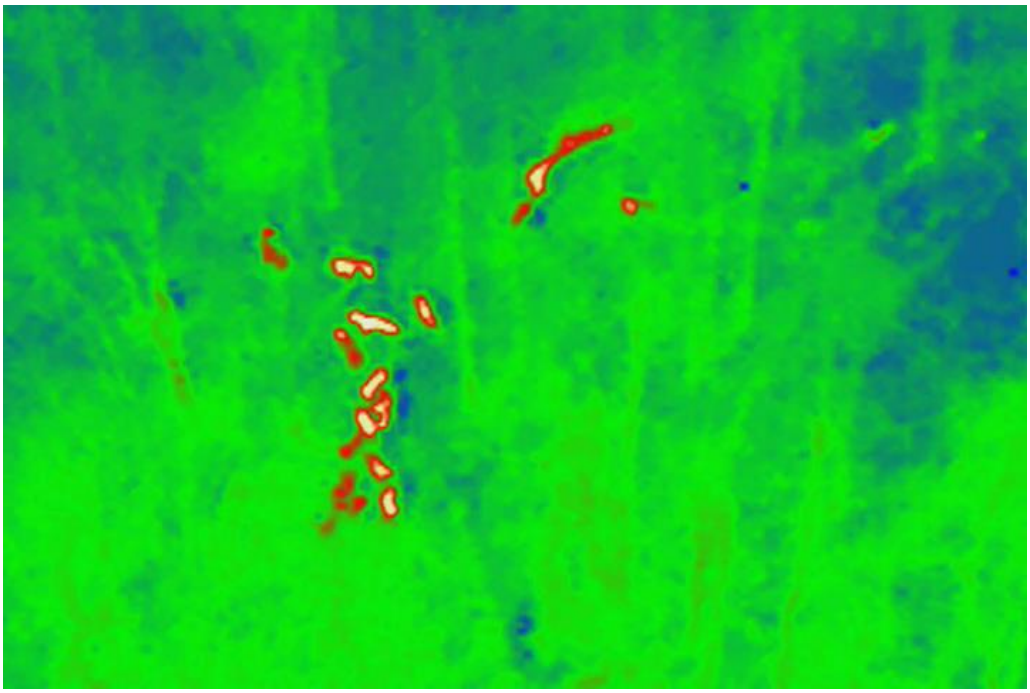
Image 7: Video screenshot of elk using green filter (4x Digital Zoom).

Image 8: Video screenshot of elk using black filter.

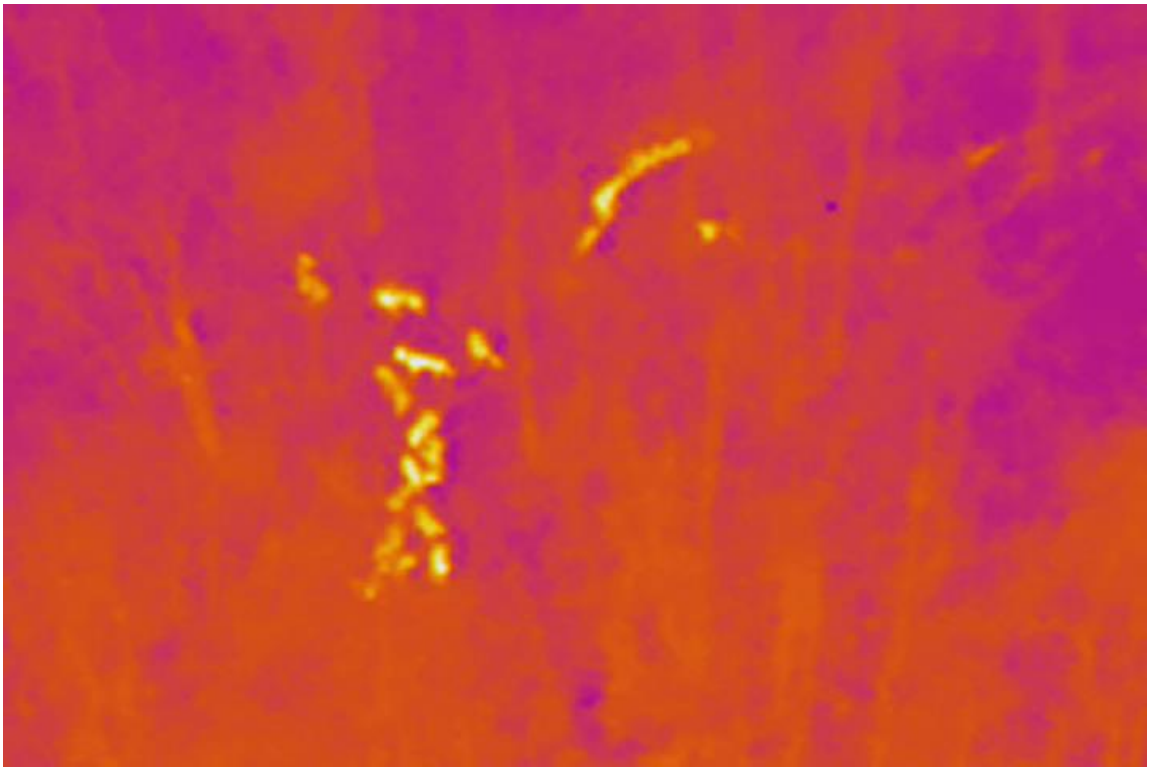

Image 9: Video screenshot of elk using red filter (6x digital zoom).

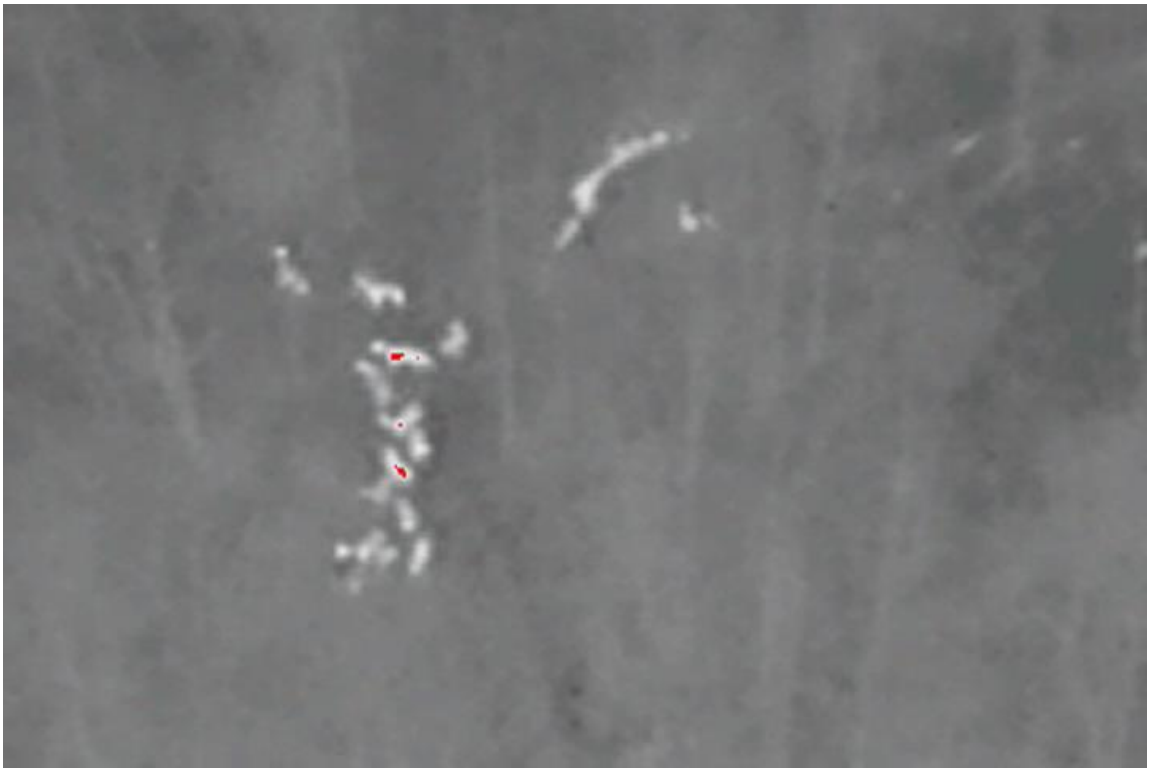

Image 10: Video screenshot of elk using white with heated red filter (6x Digital Zoom).

Attachment A
Imagery Analysis Log

Approximate location of all objects of interest found in imagery and videos from Starfire Bull and Steeltrap Cow survey flights during data analysis.

Sampling Grid Data Folder[a]	Image[b]	Number[c]	Identification[d]	Latitude[e]	Longitude[e]
Starfire 1	67	2	ungulate	37.395411	-83.10199
Starfire 1	68	2	ungulate		
Starfire 2	455	1	ungulate	37.397924	-83.145155
Starfire 2	456	1	ungulate		
Starfire 2	457	1	ungulate		
Starfire 2	458	1	ungulate		
Starfire 2	459	1	ungulate		
Starfire 2	460	1	ungulate		
Starfire 3a	487	18	cows	37.400104	-83.121954
Starfire 3a	488	18	cows		
Starfire 3a	489	4	cows		
Starfire 3a	524	13	cows	37.400627	-83.121711
Starfire 3a	525	18	cows		
Starfire 3a	526	18	cows		
Starfire 3b	NONE	-	-	-	-
Starfire 4	NONE	-	-	-	-
Steeltrap 1	NONE	-	-	-	-
Steeltrap 2	NONE	-	-	-	-
Steeltrap 3 - DJI0002	*00:20*	Multiple	elk	36.967515	-83.173144
Steeltrap 3 - DJI0002	*9:43*	14	elk	36.968867	-83.171923
Steeltrap 3 - DJI0004	*0:35*	Multiple	elk	36.97033	-83.170932
Steeltrap 3 - DJI0004	*2:50*	14	elk		
Steeltrap 3	7	14	elk		
Steeltrap 3	8	14	elk		
Steeltrap 3	11	14	elk		
Steeltrap 3 - DJI0016	*0:01*	14	elk		
Steeltrap 3	17	14	elk		
Steeltrap 3 – DJI0028	*1:15*	14	elk		
Steeltrap 3 – DJI0028	*6:40*	14	elk		
Steeltrap 4	NONE	-	-	-	-

a – sampling grid name is based on VizionAir's survey folder names (see raw data from VizionAir). Survey folder names are important to note, since all survey folder imagery starts with photo 1 for all sampling grids. Starfire 3 was divided into two folders, a & b, which both start with photo 1. When a video contained an object of interest, the video's name is also included in this column.
b – the image number or video time in which object of interest appears. "None" = no objects of interest detected in imagery/videos.
c – the number of objects of interest of type counted in the imagery/video segment. "Multiple" = unknown number; italicized text = time of first occurrence in video footage.
d – identification of the object of interest. Unknown ungulates (i.e., deer, elk) were listed as "ungulate."
e – approximate latitude/longitude taken from the imagery/video. All imagery were georeferenced, and video locations were estimated by data reviewer.