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Harnessing Drones for Snow Leopard Prey Surveys

Rodney M. Jackson[1*] · Bayaraa Munkhtsog[2] · Bariushaa Munkhtsog[3] · Ben Hunter[4] · Daniel Rice[5] · Don O. Hunter[6]

1 Snow Leopard Conservancy, Sonoma, California, USA.
2 Mongolia Academy of Sciences, Ulaanbaatar, Mongolia; Wildlife Institute, Beijing Forestry University, China
3 Irbis Mongolia, Ulaanbaatar, Mongolia
4 Longshadow Media, Carbondale, Colorado, USA.
5 Geospatial Centroid at Colorado State University, Fort Collins, Colorado, USA.
6 Rocky Mountain Cat Conservancy, Fort Collins, Colorado, USA.
* Corresponding author Rodney M. Jackson Email: rodney@snowleopardconservancy.org

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Abstract

Surveying snow leopard prey species such as argali, ibex or blue sheep through traditional ground-based observations is time-consuming, expensive, and challenging. Aerial drones present a promising alternative. We tested using thermal-sensor-equipped drones to count ungulate populations in Mongolia's Ikh Nart Nature Reserve, surveying ~400km of transects along five fixed routes for forty-three missions. Drones detected 235 prey animals and 209 livestock; 26% of all sightings were in areas that would not have been visible to hypothetical ground-based observers. Our tests reinforced the utility of drones for counting snow leopard prey and highlighted important issues and future advances for supporting largely autonomous prey surveys. We recommend biologists build upon existing technology to attain an inexpensive, easy to

use, and field ready set of equipment and procedures that can reliably improve or replace traditional transect or point count methods for large prey species.

Introduction

Unmanned aerial vehicles (UAVs) or drones are being increasingly employed in wildlife surveys (Corcoran et al. 2020; Mo and Bonatakis, 2022; Wirsing et al. 2022; Elmore et al. 2023). To our knowledge no papers have been published on drone use for counting snow leopard (*Panthera uncia*) prey numbers: rather, these prey are surveyed by humans on foot using traditional transect or fixed observation count methods (Suryawanshi et al. 2012; Thapa et al. 2021). Mongolia's Ikh Nart Nature Reserve staff conduct argali (*Ovis ammon*) and ibex (*Capra sibirica*) counts annually in late summer in predefined 8km^2 survey blocks by walking along 4km transects and tallying sightings within 1km on either side (Wingard et al. 2011). Distance sampling is used to fit empirical "sightability" curves to help account for imperfect detection in subsequent population estimates (Buckland et al. 2001) and double observer techniques further help quantify detectability (Suryawanshi et al. 2012).

Our study originally aimed at assessing aerial counts from drones flown at the same time of year as Ikh Nart's annual surveys. We predicted that an aerial vehicle, moving faster and looking forward/downward from a consistent height would have significantly less obstructed views, and would therefore detect ungulates missed by ground based observers. Even in level terrain, scattered shrubs, rocky outcrops and drainages conceal animals from ground-based observers. However, a drone flying at 60-100m above the ground benefits from unobscured views of the landscape. The drone's ability to detect cryptic ungulates is further enhanced through deploying onboard thermal sensors (Burke et al. 2018).

In this paper, we offer preliminary findings and recommendations for using thermal-equipped drones to enhance surveys of snow leopard ungulate prey.

Methods

The study was conducted in Mongolia's Ikh Nart Nature Reserve (Wingard et al. 2011; Wingard et al. 2023). We deployed three quadcopters: Matrice 210, newer M30T (©SZ DJI Technology Co., Ltd., Shenzhen, China), and the Autel Evo II 640T (©Autel Robotics, Bothell, WA), each fitted with 640 x 512 30Hz thermal sensors. Flights were conducted August 22 – September 4, 2019, and August 23 – September 2, 2022, immediately prior to the annual ground-based counts.

We chose five representative survey-block transects from the Reserve's ten long-term argali and ibex monitoring survey design. In each block, we established two fixed rectangular transect routes, one on either side of the block's centerline, notated as North and South survey sectors (Figures 1 and 2). Each 9-11km transect route comprised an outward 4 km leg, a sharp 90° turn with short 0.75-1.25km leg, ending with 4km homebound leg and was delineated by 4 fixed GPS waypoints. Each sector was flown in quick sequence between batter changes.

We followed standard flight routines (e.g., Hodgson et al. 2016), flying at elevations of 60-75m above take-off location with fixed speeds of 15m/sec (M30T) and 10m/sec (Autel, manufacturer's set maximum). Sensor gimbals were set at -22° below horizon, resulting in a trapezoidal image frame, covering up to 500m in front of

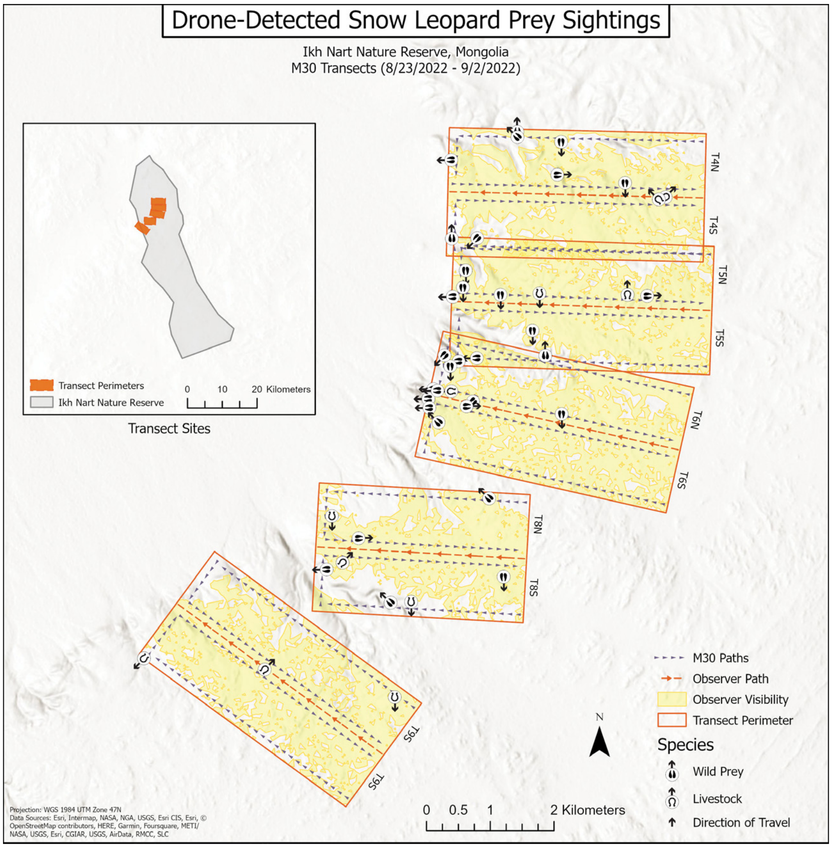

Figure 1: *Five survey blocks and transects sampled via drones in this study, indicating all ungulate sightings and the direction of travel with respect to fixed UAV flight pathways (each consisting of a single outward and return leg of 4km in length).*

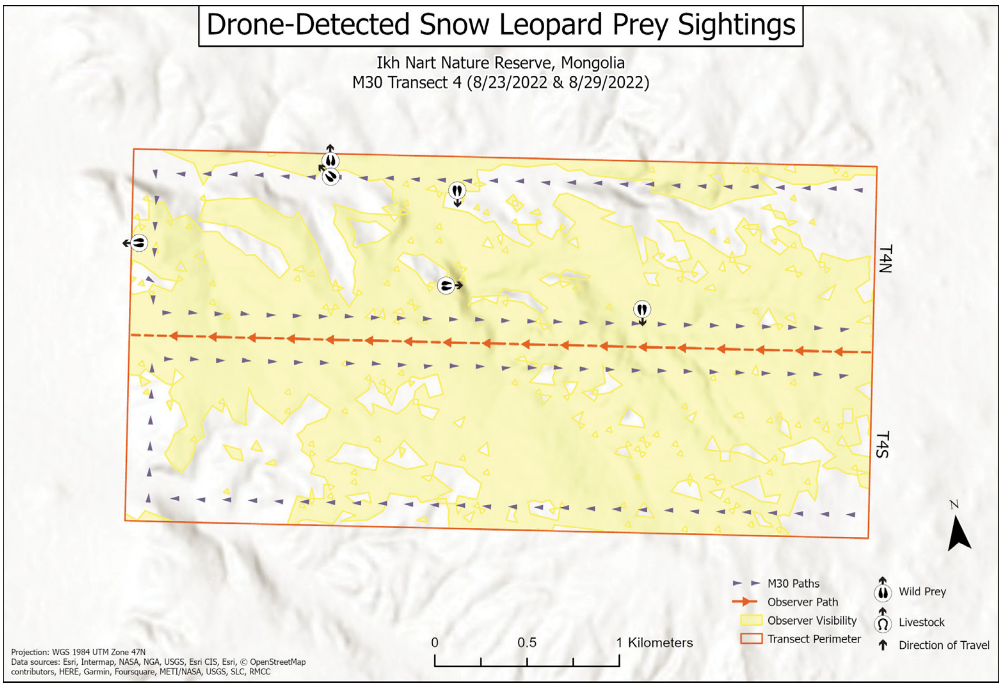

Figure 2: *Viewshed map of Transect # 4 showing flight pathways and prey detections, including UAV travel direction and each animal's direction of flight in response to the approaching drone. Light gray depicts areas judged unlikely to be visible to observers conducting the traditional annual ground-based transect count; yellow areas are deemed visible to ground surveyors.*

the drone. The M30T completed each transect in approximately 9 minutes (depending on wind conditions) compared to Autel's 11-13 minutes. Drones continuously recorded RGB and thermal video, with data collection synchronized to start at each transect's beginning location and ending at its last waypoint, usually with the North sector flown first.

We used manufacturer-supplied software to conduct autonomous missions (see Appendix 1 for protocols, available upon request). All flights were conducted near dawn and were completed prior to thermal crossover – as the sun rises, land surfaces are warmed, thereby increasing difficulties of thermal image differentiation between animals and the surrounding background – but before increasing wind speed impeded flight duration or safety. However, animal movement triggered by the drone's sound and/or movement greatly facilitated separating them from inanimate surfaces.

Footage from each mission flight was briefly reviewed in the field and backed up on hard drives. Later in computer facilities, three observers reviewed all collected imagery, to detect, enumerate and verify animals, using comparable methods including viewing split-screen thermal and RGB imagery with high-resolution monitors, noting animal movement and direction. Animal GPS locations (at the initial sighting) were approximated by comparing drone imagery and Google Earth© imagery.

To determine if the drone-observed animals would have been visible to hypothetical ground observers, we used ArcGIS software (ESRI, Inc, California, USA) to calculate the viewshed visible from human eye-level (about 2m above the ground) along the centerline of each survey block based on a 30m Digital Elevation Model (Figure 1 and 2).

Results & Discussion

We report only the M30T data as this drone flew uninterrupted at constant speed over all waypoints, providing smooth, unbroken video timestamps. By contrast, the Autel paused briefly at each waypoint, which required the pilot-in-charge to manually restart video recording, thus greatly complicating reconstruction of video timestamp records for GIS input and analysis.

We completed 43 missions covering transects from 5 traditional survey blocks for a total flight distance of almost 400km with 2-5 replicates per survey block. Figure 1 shows all sampled transects; Figure 2 illustrates the typical flight pattern with recorded animal detections, in this case survey block #4; Table 1 summarizes wild prey and livestock sightings, including their position within the mapped viewshed.

A total of 235 wild prey and 209 livestock (cattle, horses, goats, and sheep) were detected. Figure 3 is a representative example of a small group of argali sheep captured with regular color and thermal imagery extracted from video recorded during a typical mission. These and other images illustrate how difficult it is to discern wild ungulates when body coloration blends closely with habitat background, shown here with little or no vegetation. Contrast that of the animals' warm body captured using the "WhiteHot" thermal infrared palette with the isotherm set to body temperature (25-31.7°C). While wild and domestic ungulates were relatively easy to detect thermally, especially if they moved, identifying species was more difficult.

Viewshed Analysis

Figure 2 displays the viewshed map for Transect #4 with ungulate sightings and flight transect pathways along with each animal's flight direction in

GROUP/HERD SIGHTINGS							
Transect	Wild Prey in View	Livestock in View	Wild Prey Obscured	Livestock Obscured	Total in View	Total Obscured Detected	Total Drone
4	5	2	1	0	7	1	8
5	8	1	3	1	9	4	13
6	9	0	1	1	9	2	11
8	3	2	2	1	5	3	8
9	0	2	0	1	2	1	3
INDIVIDUAL SIGHTINGS							
Transect	Wild Prey in View	Wild Prey Obscured	Livestock in View	Livestock Obscured	Total in View	Total Obscured Detected	Total Drone
4	38	3	140	0	178	3	181
5	62	14	4	6	66	20	86
6	102	2	0	5	102	7	109
8	7	7	13	10	20	17	37
9	0	0	19	12	19	12	31
Totals	209	26	176	33	385	59	444
	Total Prey: 235				**Total Domestic: 209**		
Species	% of Type in View	% of Type Obscured	% of Total Animals in View	% of Total Obscured Animals	% of Drone Detections	Cumulative	Proportions
Wild Prey	88.9%	11.1%	54.3%	44.1%	52.9%	Total in View:	86.7%
Livestock	84.2%	15.8%	45.7%	55.9%	47.1%	Total Obscured:	13.3%

Table 1: *Total number of prey and domestic animals detected during 43 flights over 5 transects in Ikh Nart Nature Reserve.*

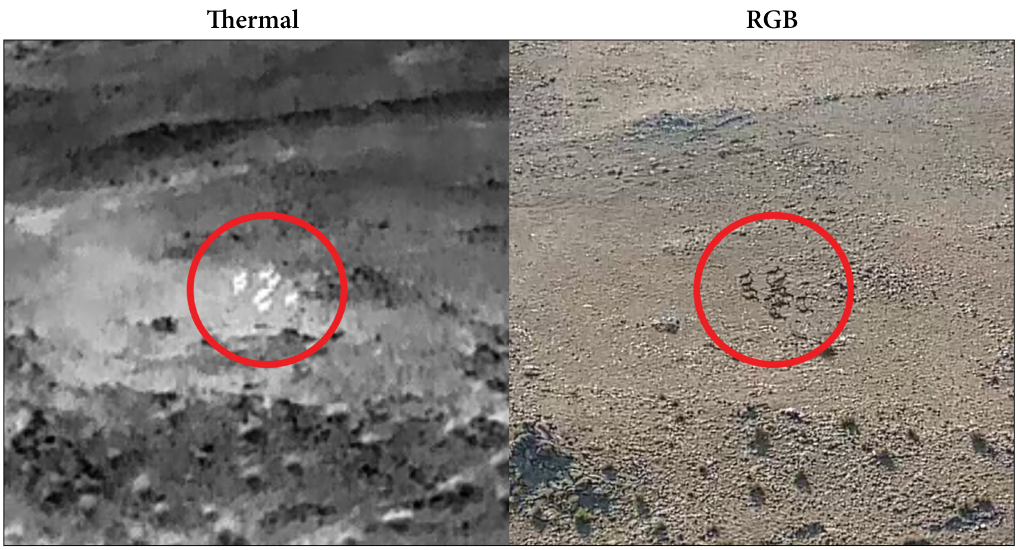

Figure 3: *Visual RGB color image (right) and thermal (left) image of argali sheep group comprised of 9 individuals detected in highly open habitat by the Autel UAV on August 25, 2022, while flying at an elevation of 75meters above ground level (640 x 512 pixels with 13mm focal length lens, abstracted from video clip).*

Transect Number	Total Area (km2)	Percent Within View	Percent Obscured
4	8.11	69.26	30.74
5	8.22	70.38	29.62
6	8.12	70.81	29.19
8	6.67	60.38	39.62
9	8.11	71.39	28.61
Totals	**39.23**	**68.75**	**31.25**

Table 2: *Proportion of each survey block located within view or obscured from human observers conducting ground-based "walking surveys."*

response to the approaching UAV.Lightly shaded gray areas are judged not visible to a human walking the central transect line (in red). Table 2 summarizes numbers of prey and domestic animals detected within and outside of the estimated viewshed for human observers conducting the annual count: on average, 31.3% of the survey land area, 26% of ungulate groups and 13.3% of the total number of animals observed were obscured from traditional ground-based viewsheds.

The thermal sensor has relatively few pixels (640 x 512), and a limited field-of-view (M30T 9mm; Autel 13mm), thus requiring relatively low flight heights of 60-75m resulting in a footprint of thermal-infrared survey coverage strip roughly 178m wide where the leading edge intersects the ground. We estimated about 50% of each survey block was covered by the thermal infrared sensor given flying height and gimbal angle settings, as suggested by Burke et al. (2018).

Figure 4 illustrates team members initiating a typical M30T mission. We found flight mission options sophisticated in this craft, which performed flawlessly except for a near catastrophic first flight forced landing. The incident affirmed concerns about wind resistance negatively impacting battery life and platform stability. A long flight with sudden change in wind velocity activated real-time responses by onboard sensors that directed the craft to "Return to Home," followed shortly afterwards by an automatic, autonomous emergency landing. Fortunately, the only damage affected two rotor-blades which were quickly replaced. We safeguarded against another such landing by eliminating four transect legs which reduced the total transect distance by 50% (i.e., 28km to 16km).

Conclusions & Next Steps

Overall, drones successfully detected large wild and domestic ungulates. Animal detection was facilitated by drones flushing prey for distances ranging from near zero meters (tolerance) to several km (presumably fear of mechanical noise), but more typically several hundred meters, typically halting after the drone has passed by. Transferring the technique to more typical snow leopard habitat will require a drone with better obstacle avoidance capabilities and reliable, robust terrain following flight controls. Given the combination of speed and aerial perspective, drone-based surveys have distinct advantages of being quicker to complete than ground surveys, while potentially enabling surveyors to cover a greater proportion of each survey block.

Going forward, we recommend that future developments in drone use for snow leopard prey surveys should center around refining transect designs, robust terrain following (e.g., Wubben et al 2022), employing Artificial Intelligence (AI) algorithms (e.g., Prakash et al. 2023) and modeling for double-counts and behavioral heterogeneity in detection. Research plans call for continued trial-testing in Colorado prior to resumed Mongolian flights in more rugged, viewshed-complex mountain habitats, comparing transect and point-count methods. Hopefully, these tests

Figure 4: *Photograph of the study team launching the DJI Matrice M30T drone on a typical mission (left to right, Rodney Jackson, Don Hunter & Bayaraa Munkhtsog). Photo by Ben Hunter.*

can include flights over radio-collared ungulates/ snow leopards to assess flushing distance and movement behavior. Our team will also examine advanced fixed-winged drones that can fly for an hour or more, covering greater areas than possible with quadcopter drones. We fully envisage that within the decade wildlife biologists will have access to less expensive craft with greater capabilities. The key lies with continued collaboration, deployment, field testing and refinement among practitioners.

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Conflicts of Interest

No known conflicts of interests

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