Performance of Aerial Forward-Looking Infrared Surveys on Cattle, Elk, and Turkey in Northern Arizona

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Abstract. We conducted performance tests of aerial forward-looking infrared (FLIR) technology to assess its capability to survey cattle, elk (*Cervus elaphus*), and Merriam's turkey (*Meleagris gallapavo merriami*) in forested habitat. Fixed-wing FLIR surveys of known numbers of cattle were inaccurate, but linear correlations explained 86% of the variation, and initial estimates could be corrected to provide accurate estimates. We observed no relationship among fixed-wing FLIR, helicopter FLIR, and visual fixed-wing surveys for elk. In three attempts, we were unable to detect roosting turkeys in night-time aerial, fixed-wing FLIR overflights. FLIR surveys seem to be capable of quantifying large-bodied wildlife, but corrections for sightability need to be developed for each species, season, and habitat that will be surveyed. This correction will probably require several populations of known number to evaluate. Small-bodied wildlife may prove problematic. We recommend against the use of aerial FLIR surveys as the sole estimate of large-bodied wildlife species until correction factors can be developed.

Key words: Arizona, cattle, *Cervus elaphus*, elk, FLIR, infrared, *Meleagris gallopavo merriami*, Merriam's turkey, survey

Game management agencies typically survey many wildlife species by direct observation using visual ground, fixed-wing aircraft, and helicopter surveys (Davis and Winstead 1980). Resource managers and resource user groups have questioned the accuracy and precision of visual surveys because observers cannot quantify the number of undetected animals with these survey protocols or may not be able to ensure that the proportion of undetected animals remains constant (Shupe and Beasom 1987, White et al. 1989). Because contemporary resource management requires increasingly precise and accurate information for guidance, we investigated the performance of aerial forward-looking infrared (FLIR) technology to determine if it could objectively survey specific wildlife species or indicate necessary improvements to existing survey protocols.

Aerial FLIR surveys have become popular in the scientific literature because they seem to standardize and objectively survey large wildlife species with acceptable bias (Adams et al. 1997, Garner et al. 1995, Naugle et al. 1996, Wiggers and Beckerman 1993). Hansen and Beringer (1997) summarized the limitations of aerial FLIR surveys as the (1) inability to consistently differentiate between the radiation of target wildlife and the background, (2) inability to differentiate among species, (3) presence of forest canopy that retards the detection of infrared radiation, and (4) high cost. Recent literature (Garner et al. 1995, Naugle et al. 1996, Wiggers and Beckerman 1993) suggests that advances in FLIR technology have overcome some of the limitations that historically reduced the effectiveness of FLIR in conducting wildlife surveys.

We tested the performance of aerial FLIR to detect free-ranging ungulates and roosting turkeys in forested habitat in northern Arizona. Our objectives were to (1) evaluate the efficacy of aerial fixed-wing FLIR surveys to count cattle in pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) woodlands, (2) contrast observations of elk (*Cervus elaphus*) among standard aerial fixed-wing visual, aerial fixed-wing FLIR, and helicopter FLIR surveys, and (3) determine if aerial fixed-wing FLIR could detect Merriam's turkeys (*Meleagris gallopavo merriami*) on night-time roosts in ponderosa pine (*P. ponderosa*) habitat.

Study Areas

Cattle Surveys

We selected four fenced livestock allotments on the Prescott National Forest to evaluate the ability of FLIR to detect a known number ungulates. The allotments were on four ranches located 40-80 km northwest of Prescott, Yavapai County, Arizona. The Hitt allotment encompassed 1,024 ha, the South allotment 1,536 ha, the Juniper allotment 2,560 ha, and the K-4 allotment encompassed 12,544 ha. The predominant plant community on each allotment was Great Basin conifer woodland (pinyon pine-juniper [*Juniperus scopulorum*]). These woodlands are broken with interstitial areas comprised of plains grasslands, interior chaparral, ponderosa pine, and interior deciduous riparian communities (Brown 1994). Elevations range from 914 to 1,524 m.

Elk Surveys

We addressed our second objective in two study sites within the Apache-Sitgreaves National Forests in Navajo County, Arizona. The first study site is located about 16 km northeast of Heber, Arizona. It encompassed 250 km^2 of primarily open canopy pinyon-juniper grassland. About 1,500 ha is in agricultural production. Mean elevation is 1,830 m with relatively level topography except for bluffs along the northern portion and two washes in the southwest corner.

The second study site is located about 5 km east of Show Low, Arizona. This site encompassed about 110 km^2 of ponderosa pine and pinyon-juniper woodland. Open meadows as large as 500 ha are present. Elevation averages 2,075 m with little topographical relief except for seven wooded knolls composing less than 5% of the area.

Turkey Surveys

Our final objective was studied at three turkey roost sites about 16 km south of Flagstaff, Coconino County, Arizona, within the Coconino National Forest. These roosts were located within predominantly ponderosa pine forest stands. We followed radio-marked Merriam's turkeys to locate the roost sites.

Methods

Aerial fixed-wing surveys were flown using a Cessna 337G twin-engine aircraft (operated by AirScan, Inc., Titusville, FL). We used a Bell Jet Ranger 206 helicopter (operated by the USDA Forest Service) to conduct our helicopter FLIR surveys. FLIR surveys were conducted using FLIR High Performance Infrared Imaging 2000 A/B units, with a temperature sensitivity of ±0.2°C. These units had a 10 power zoom lens that could be used to identify wildlife after detection. Standard fixed-wing visual surveys were conducted from a Cessna 182 single-engine aircraft. FLIR surveys were conducted with a pilot and a scanner operator-observer. FLIR surveys were recorded on VHS video tape and were reviewed after the survey. Visual fixed-wing surveys were conducted with a pilot and two trained observers familiar with the area.

Cattle Surveys

Although our primary interest in aerial FLIR technology involved wildlife surveys, we surveyed cattle to meet our first objective because they approximated the body size of elk and the number of adult cattle within each allotment was known. Cattle were the main ungulates within the allotments, but elk, mule deer (*Odocoileus hemionus*), and domestic horses were present in lower numbers. In addition, cattle were calving during the survey period on three of the four allotments and the exact number of young was unknown.

We conducted two replicate blind surveys on consecutive days, 21 and 22 February 1997. During the first survey flight, wind speeds aloft were 20-75 km/hr, but decreased during the next flight. Winds during the first survey affected the pilot's ability to maintain the aircraft on transects and produced ground speeds that varied depending on flight direction. We planned to move cattle between survey efforts to change the number of target animals within several allotments. We informed the observers that cattle numbers would change between survey efforts. However, we chose not to change cattle numbers because of complex logistic requirements and a short time period between survey efforts. The observers were unaware that cattle numbers within each allotment were not altered between survey efforts.

We provided the pilot with the perimeter coordinates of each allotment. The K-4 allotment is comprised of two allotments that were combined to include a common area of private land between them. The pilot was directed to select the optimal time, flight altitude, and airspeed to produce the highest detection rate. The first survey began at 0730 hrs. To provide better detection contrast, the pilot initiated the second survey at 0620 hrs. Flight altitudes varied from 610-760 m AGL, and airspeed was selected at 150-165 km per hour. The pilot flew non-overlapping survey transects defined by the aircraft on-board global positioning system. The pilot flew orbits over animals that surveyors detected. The aircraft returned on transect when the surveyor was satisfied that all animals detected were enumerated.

We used a paired t-test (Zar 1984) to test for differences between surveyed cattle and known numbers. We also used linear regression to test for a linear relationship between known and surveyed numbers of cattle. We used the regression equation to adjust surveyed numbers and again tested the adjusted numbers with minimum known numbers using a paired t-test.

Elk Surveys

We conducted comparative aerial surveys for elk on two study sites during 18 and 19 February 1997. We selected early winter mornings for this survey because of low thermal loading of the landscape and the greatest potential temperature differential between survey targets and the background landscape. The first study site had three separate surveys flown the morning of 18 February 1997. All observers and pilots were supplied with maps of the survey area and perimeter coordinates. The helicopter FLIR and the visual fixed-wing surveys each flew 18 transect lines in this study area, which were approximately 0.8 km apart. Fixed-wing FLIR surveys were conducted on 14 transects and were about 1.1 km apart. The observations from this latter survey were adjusted to correspond to the transect lines for the other two survey methods. The three aircraft flew the transect lines sequentially so that animal detection availability would remain similar among flights. Parallel north-south transects were flown beginning on the east side. Transect lines were about 750 m apart. Animal observations were recorded by transect line. We flew surveys sequentially, beginning with the survey at the highest altitude. We flew aerial fixed-wing FLIR surveys at 610 m AGL, helicopter FLIR surveys at 155 m AGL, and visual fixed-wing surveys at 60 m AGL. We believed that the chance for animal disturbance would increase as AGL of surveying aircraft decreased. The fixed-wing FLIR survey began about 0500 hrs, the helicopter FLIR survey began at 0715, and the visual fixed-wing survey began at 0740. The surveys required about two hours to complete.

The second study site was surveyed on the morning of 19 February 1997, using the same protocol. We used only the helicopter FLIR and visual fixed-wing surveys in this area. The helicopter FLIR survey began at 0710 hrs and the visual fixed-wing survey followed at 0730 hrs. The surveys were again completed within two hours.

Because we could not ensure that we were surveying the same animals with each subsequent survey, we did not attempt to statistically test for differences among survey methods. We did, however, use linear regression to test for a linear relationship among survey methods.

Turkey Surveys

We followed radio-marked Merriam's turkeys to their night-time roosting sites. These turkeys had been marked as part of another study (see Wakeling and Rogers 1998 for a description of capture and marking details). We recorded the coordinates of two roosts that we had visual confirmation of turkey use and one that we had radio-triangulated the approximate location. These coordinates were provided to the pilot to locate the roost sites.

We placed ground observers within 100 m of the two visually confirmed roost sites during the survey. The ground observers maintained radio communications with the aerial observers and provided a thermal reference point during the survey efforts. Survey efforts began at 0400 hrs and 610 m AGL. When the flight arrived at the roost site location, the aircraft made concentric orbits of <1 km around the roost site. Concentric orbits reduced in altitude until the final orbit was flown at 305 m AGL. Survey efforts alternated among the three roost sites until the turkeys left their roosts at about 0700 hrs.

RESULTS

Cattle Surveys

Aerial fixed-wing FLIR surveys did not accurately measure the number of cattle in the four allotments (t=3.283, 7 df, P=0.013; Table 1). The surveys had a strong linear relationship with minimum cattle numbers (Y=65.21+1.79X, r^2=0.865, P=0.001). Adjusted surveyed cattle numbers did not differ from minimum known numbers (t=0.004, 7 df, P=0.992; Table 2).

Table 1. Allotments, size, minimum cattle present, and number surveyed with aerial fixed-wing FLIR during two survey efforts on the Prescott National Forest, Yavapai County, Arizona, during February 1997.

Allotment	Allotment Size (Ha)	Cattle Numbers	Survey 1	Survey 2
Hitt	2,560	150	0	2
South	3,840	28	0	5
Juniper	6,400	25	0	7
K-4	31,360	394	201	161
Total	44,160	597	201	175

Table 2. Allotments, size, minimum cattle present, and adjusted (Y=65.21+1.79X, r^2=0.865, P=0.001) number surveyed with aerial fixed-wing FLIR during two survey efforts on the Prescott National Forest, Yavapai County, Arizona, during February 1997.

Allotment	Allotment Size (Ha)	Cattle Numbers	Adjusted Survey 1	Adjusted Survey 2
Hitt	2,560	150	65	69
South	3,840	28	65	74
Juniper	6,400	25	65	78
K-4	31,360	394	425	353
Total	44,160	597	620	574

Elk Surveys

The surveys of the first study site were variable in the number and species of wildlife observed among survey methods (Table 3). Fixed-wing FLIR observers detected 37 elk in three herds and one group of seven pronghorn (*Antilocapra americana*). Helicopter FLIR observers detected 18 elk in two herds. Visual fixed-wing survey observers detected 77 elk in 11 herds, approximately 100 pronghorn in 10 herds, eight mule deer in three herds, and three coyotes. No linear relationship explained more than 35% of the variation in elk observations between any two survey methods.

The second study site produced similar variable results, except that the helicopter FLIR observers detected more elk than the visual fixed-wing observers (Table 4). The visual fixed-wing survey noted 24 mule deer, 45 pronghorn, and a flock of turkeys not recorded by the helicopter FLIR survey. A linear relationship explained less than 6% of the variation in elk observations between the two survey methods.

Turkey Surveys

The turkey surveys did not successfully detect the target wildlife. No turkeys were detected with the fixed-wing FLIR at the three roost sites. The ground observers were detected at the two roost sites where they were placed, and non-target elk were also observed.

DISCUSSION

Although the fixed-wing FLIR cattle surveys did not provide accurate results, the adjusted survey numbers did not differ from the mini-

Table 3. Wildlife observed by transect line with fixed-wing FLIR, helicopter FLIR, and visual fixed-wing surveys on 18 February 1997, near Heber, Arizona.

	Wildlife Observed by Survey Method		
Transect Number	Fixed-wing FLIR	Helicopter FLIR	Visual Fixed-wing
1	0	0	10 elk, 10 pronghorn, 3 coyotes
2	0	0	12 pronghorn, 3 mule deer
3	0	0	2 pronghorn, 1 coyote
4	0	0	4 elk, 8 pronghorn, 1 mule deer
5	0	10 elk	15 elk
6	36 elk	8 elk	15 elk, 11 pronghorn
7	0	0	4 elk
8	0	0	23 pronghorn
9	1 elk	0	12 pronghorn
10	0	0	20 elk
11	0	0	4 mule deer
12	0	0	0
13	0	0	0
14	0	0	9 elk, 22 pronghorn
15	0	0	0
16	7 pronghorn	0	0
17	0	0	0
18	0	0	0
TOTAL	37 elk, 7 pronghorn	18 elk	77 elk, 8 mule deer, 4 coyotes, 100 pronghorn

Table 4. Wildlife observed by transect line with helicopter FLIR and visual fixed-wing surveys on 19 February 1997, near Show Low, Arizona.

	Wildlife Observed by Survey Method	
Transect Number	Helicopter FLIR	Visual Fixed-wing
1	0	0
2	0	0
3	0	0
4	0	0
5	74 elk	22 elk
6	0	20 mule deer
7	0	72 elk, 2 antelope, flock turkeys
8	91 elk	69 elk
9	182 elk	10 elk
10	114 elk	139 elk
11	0	34 elk, 9 antelope
12	0	71 elk, 22 antelope
13	0	0
14	0	0
15	0	6 elk
16	243 elk	0
17	0	0
18	0	0
19	0	2 elk
20	91 elk	91 elk, 4 mule deer
21	0	0
22	0	0
23	0	0
24	0	21 antelope
25	0	0
26	0	95 elk
TOTAL	795 elk	611 elk, 24 mule deer, 54 antelope, 1 flock turkeys

mum numbers of adult cattle. A linear relationship explained 86% of the variation between cattle observations by the fixed-wing FLIR surveys and known minimum adult cattle numbers. Because cattle in three of the four allotments were calving during the survey effort, the results of the survey are less precise than they appear. Although the difference in size between adults and calves was sometimes detected, such differences could not be consistently assessed for each observation.

When comparing elk observations among the three survey methods, neither FLIR survey seemed to detect more elk than conventional visual fixed-wing surveys. The one exception was the number of elk observed on 19 February, when 795 elk were detected by the helicopter FLIR versus 611 elk during the visual fixed-wing survey. A group of 243 elk was detected by the helicopter FLIR, but was not seen by the visual observers approximately 20 minutes later. The FLIR scanner operator stated that the elk herd was moving out of a meadow into dense canopy cover. When the visual fixed-wing observers flew that transect the herd may have been undetected because they had moved into the tree canopy.

Another apparent difficulty with FLIR surveys was the apparent inability of the FLIR to detect smaller wildlife such as pronghorn and mule deer. The fixed-wing FLIR survey detected a herd of seven pronghorn, but no others were detected. The visual surveys detected approximately 100 pronghorn in the same area, and the helicopter FLIR did not detect any smaller wildlife.

The inability of FLIR technology to document smaller wildlife is further supported by the lack of detection of roosting turkeys. Turkeys may have been obscured by dense ponderosa pine tree canopies, but their thermal images were too small to detect with current technology. Despite some early success in detecting turkeys in other studies (Garner et al. 1995), free-ranging turkeys seem to be difficult to detect with aerial FLIR efforts.

Aerial FLIR surveys promise to be valuable wildlife management tools. However, further research and technological advances are needed to identify the accuracy and precision of estimates from those surveys. Our experience suggests that the limitations of aerial FLIR surveys noted by Hansen and Beringer (1997) are still prevalent. We believe that the ability to correct for the cattle surveys with a simple linear relationship is encouraging, but this strongly suggests that any survey of a wildlife population of interest would need to be adjusted. This adjustment should be conducted for each species, habitat, and season when FLIR surveys were of interest. Further, this adjustment would require several populations of known numbers to develop sound relationships.

Despite its appeal, we recommend that aerial FLIR surveys should not be relied upon to provide sole population monitoring information on wildlife species. Aerial FLIR may be valuable in documenting occurrence of free-ranging, large-bodied wildlife, but the accuracy and precision of those surveys are unknown. Until such time as these factors are documented, FLIR is of little value beyond documenting the presence of large-bodied wildlife.

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