Using thermal infrared sensing to count elk in the southwestern United States

William C. Dunn, J. Patrick Donnelly, and William J. Krausmann

Aerial surveys are a common method for counting elk (Cervus elaphus) populations during winter in the mountainous areas of the southwestern United States, but not all animals are counted regardless of how intensively an area is flown. The difference between number of animals seen and true population size is the visibility bias, which may be affected by vegetation type, group size, snow cover, and cold temperatures (Gasaway et al. 1985, Samuel et al. 1987, Otten et al. 1993, Bodie et al. 1995).

Increasing the proportion of the population observed is one way to reduce bias in estimating numbers (Lancia et al. 1994). Forward-looking infrared thermal sensors (FLIR) that detect heat emitted by animals might help increase accuracy of population counts (Havens and Sharp 1998). Animals not observed because they are partially hidden by vegetation or are in dark shadows may give off enough heat to be detected by FLIR. Animals might be more easily detected from higher altitudes with FLIR than by visual observation (Wiggers and Beckerman 1993, Naugle et al. 1996), so more area can be surveyed per unit time. Also, animals observed during visual surveys are the final count, whereas FLIR recordings can be digitally enhanced and intensively analyzed with computer image-processing software afterward to detect animals that might have been missed during the survey.

Four recent tests have been conducted using thermal infrared sensors on aircraft to count white-tailed deer (Odocoileus virginianus). Wiggers and Beckerman (1993) located and identified sex and age (fawn vs. adult) of penned deer from up to 450 m above ground level (AGL). Garner et al (1995) detected 52% fewer deer with the aid of FLIR than by drive counts in a mosaic of old fields and woodlands, but Naugle et al. (1996) counted more deer with the aid of airborne FLIR than by spotlight surveys from the ground in an area with open vegetation types. Havens and Sharp (1998) counted more deer with the aid of a handheld thermal infrared sensor than an observer on the same aircraft, although they experienced thermal interference from background sources an hour after sunrise. Despite some limitations, these studies suggested that FLIR might be a useful tool for counting elk.

In this paper we describe the use of FLIR to count elk in New Mexico and Arizona. Our objective was to determine whether FLIR would be more effective than standard aerial survey techniques in detecting elk during winter.

We surveyed 2 areas in eastern Arizona (Dry Lake and Timber Mesa), 1 in southwestern New Mexico (Reserve), and 2 in northern New Mexico (Chama and Dulce) to compare FLIR and visual counts of elk. The Dry Lake survey area was located 16 km northwest of Show Low, Arizona and encompassed 228 km² of flat terrain at 1,830 m elevation. Vegetation consisted of widely spaced one-seed juniper (Juniperus monosperma) and alligator juniper (J. deppeana) in heavily grazed grasslands. Snow was not present during the surveys.

The Timber Mesa survey area, located 1.6 km southeast of Show Low, Arizona, encompassed 111 km² of gently rolling terrain dissected by several small draws. Elevations ranged from 1,980–2,200 m. Vegetation consisted mostly of pinyon pine (Pinus edulis) and one-seed juniper woodlands of moderate (40–50% canopy cover) density with about 20% of the site covered by dense (75% canopy cover) ponderosa pine (P. ponderosa) at the upper elevations. Snow cover was present only in the ponderosa pine stands during the surveys.

The Reserve survey area was located 16 km northwest of Apache Creek, New Mexico and encompassed 67 km² of gently rolling plateaus at elevations of 1,980–2,290 m. Vegetation consisted of a mosaic of pinyon-juniper woodlands of moderate (40–50% canopy cover) to high (>75% canopy cover) densities interspersed with areas of open grassland. Snow was not present during the survey.

The Chama survey area, located 8 km southeast of Chama, New Mexico, was a 21-km² game park surrounded by a 2.5-m-high game-proof fence.
eastern two-thirds of the site were on a steep west-facing slope covered by a dense (>60% canopy cover) blue spruce (Picea pungens) forest. The remaining third was on a gentle west-facing slope covered by open grassland interspersed with small patches of pinyon and ponderosa pine. Snow cover was continuous except for south-facing ridges on the lower third of the site.

The Dulce survey area, located 5 km south of Dulce, New Mexico, encompassed 21 km² of gently rolling terrain except for a steep ridge along the western edge. Elevations ranged from 1,980–2,290 m. Lower elevations were covered with low densities (<25% canopy cover) of pinyon pine and Rocky Mountain juniper (Juniperus scopulorum), with gambel oak (Quercus gambelii) on south-facing slopes. Patches of ponderosa pine occurred from 2,100–2,250 m with patches of blue spruce at the ridgetop. Snow covered 80% of the area.

We conducted surveys at the Dry Lake, Timber Mesa, and Reserve areas in December 1996 and January 1997 and at the Chama and Dulce areas in early March 1997. We conducted 1 FLIR and 1 visual survey in each area. We conducted all FLIR and visual surveys from 0630 to 0900 hrs on mornings with calm winds (<16 km/h) and clear skies. Elk were active during this time period, thermal contrast between elk and their background environment was assumed to be maximal for daylight hours, and environmental conditions (i.e., wind, solar radiation) were likely to have the least adverse effect on thermal detection. Beginning and ending ambient temperatures were 2 and 10°C at Dry Lake, -3 and -1°C at Timber Mesa, -4 and 2°C at Reserve, -14 and 0°C at Chama, and -18 and 0°C at Dulce.

We conducted both FLIR and visual surveys along the same predetermined flight lines. Lines were spaced 800 m apart to prevent double counting (Naugle et al. 1996). For navigation, we programmed end points of flight lines into each aircraft’s Global Positioning System (GPS). We used a Cessna 206 fixed-wing aircraft flown at 70 knots for visual surveys at Dry Lake and Timber Mesa, and a Bell 206 helicopter flown at 50–60 knots for visual surveys at Reserve, Chama, and Dulce, in addition to all FLIR surveys. For visual surveys, we used a fixed-wing aircraft in Arizona and a helicopter in New Mexico because these were the aircraft used by the respective agencies for elk surveys and we wanted to compare the use of FLIR against each agency’s standard survey techniques. The fixed-wing aircraft had stall-prevention equipment and therefore flew at speeds and elevations comparable to helicopters. However, helicopter noise can cause animals to move more readily, thereby increasing their visibility (Samuel et al. 1987). Therefore, fixed-wing aircraft may contribute to lower counts compared to surveys done with helicopters.

At each area, we conducted FLIR surveys first and flew at approximately 300 m AGL which was high enough so that elk were not disturbed by the aircraft and yet could be detected with the aid of FLIR. Wiggers and Beckerman (1993), Garner et al. (1995), and Naugle et al. (1996) also flew at this elevation when they surveyed ungulates with FLIR. The aircraft carried a pilot, an operator with over 80 hours of flight experience using FLIR to locate wildlife, and an Inframetrics IRTV-445G MK II FLIR system (Inframetrics, Inc. Billerica, Mass.) to thermally detect elk.

The FLIR system detected thermal infrared emissions in wavelengths from 8–12 μm and was capable of discerning temperature differences as small as 0.3°C. We mounted the FLIR detector to provide a 200–300-m field of view on each side of the flight line and set it at 1.5X magnification during surveys. We confirmed thermal images of animals by zooming to 3X or 6X magnification. A color video camera was also part of the system, and we used it on a limited basis to assist in classification of thermal images.

We scanned groups of elk with FLIR during preliminary flights in January 1996 to obtain thermal images that would aid in image classification. Elk were distinguishable from livestock and mule deer (Odocoileus hemionus) based on thermal and morphologic characteristics (Figure 1). The dense hair of the cape of an elk provided increased insulation of the neck, thereby causing the thermal image to appear broken between the torso and head. Cattle and horses were distinguished from elk by a brighter and more uniform image because their thinner coat provided less insulation. Deer were distinguished from elk by their smaller size and more visible necks.

We analyzed videotapes of each survey on a Panasonic AG-7400 super VHS video player (Panasonic, Inc., Tokyo, Japan). We exported ambiguous images as raster files into Intergraph microstation software (Intergraph, Inc., Huntsville, Ala.). Contrast was intensified among adjacent pixels of different gray-scale values to enhance images thought to be elk. We added additional elk identified in this process to the total counts.
We conducted visual surveys at 60–90 m AGL, the standard elevation at which ungulate surveys have been flown by Arizona Game and Fish Department and New Mexico Department of Game and Fish. Visual surveys started 20–30 min after the beginning of FLIR surveys. No communication occurred between FLIR and visual survey teams. We assumed that the same elk were available to be counted during both FLIR and visual surveys because the flights were close enough that environmental conditions were similar and, except for one group at Timber Mesa, elk detected during FLIR surveys were sedentary. The visual survey aircraft carried a pilot and 2 experienced observers to count elk on each side of the flight line.

Elk counts using FLIR were lower than visual counts, except at Timber Mesa (Figure 2). The Timber Mesa FLIR count was higher because we observed a group of 243 elk during the FLIR but not during the visual survey. These elk were not disturbed by the survey helicopter but were already moving into cover when first observed. Without this group, the FLIR count still would have been 91% of the visual count (552 vs. 606 elk), by far the highest proportion of all areas. On average, we counted only 54.3% as many elk on FLIR surveys as on visual surveys. Less than 10% of the elk counted with the aid of FLIR were detected during post-survey analysis of FLIR videotapes.

Mean group size of elk detected during FLIR surveys was 34.9 (n = 37 groups, SD = 48.4), whereas mean group size of elk observed during visual surveys was 21.1 (n = 88 groups, SD = 29.2). We detected small groups (1–5 individuals) more often during visual surveys than during FLIR surveys (Table 1).
In aerial surveys of 5 elk populations in Arizona and New Mexico, FLIR was not effective in improving counts over standard survey techniques, which can likely be attributed to 3 reasons. First, elk appeared to be well insulated and did not produce a bright thermal image. Consequently, they were more difficult to detect against background thermal emittance. Second, bare ground stored and radiated heat, especially after exposure to direct sun, which inhibited detection of thermal images of elk. Thermal emittance from bare ground probably would be a chronic problem in counting elk with the aid of FLIR in the Southwest because snow cover often is not persistent. Third, the canopy of coniferous vegetation prevented detection of thermal images of elk. The difficulty of detecting thermal images of ungulates through vegetation with the aid of FLIR has been noted in previous studies (Croon et al. 1968, Wiggers and Beckerman 1993, Garner et al. 1995). In our surveys, coniferous vegetation not only blocked thermal images of elk but also masked them with its own thermal radiation. Thermal masking was a problem even in areas where the conifer component of vegetation was limited to widely spaced pinyon and juniper trees. These trees absorbed and re-radiated solar energy quite rapidly. Their thermal signatures changed abruptly on FLIR imagery from medium-gray to bright white with very little solar illumination. Furthermore, heat trapped under tree canopies produced a bright signature around the bases of trees large enough to mask elk standing near them.

Sampling at the 3–5 μm instead of the 8–12 μm wavelength region has been suggested as one way to increase the effectiveness of FLIR in detecting wildlife (Havens and Sharp 1998). Objects with high temperatures (≤700°C) are readily detected when sampling at 3–5 μm, but objects near ambient temperatures, especially when exposed to solar radiation, are much easier to detect when sampling at 8–12 μm (Campbell 1996). The positive results reported by Havens and Sharp (1998) using 3–5 μm wavelength range may have been the result of flying during pre-dawn hours.

Others have suggested that FLIR might be more effective if used during summer (Graves et al. 1972, Havens and Sharp 1998) or at night (Garner et al. 1995). During summer elk are less insulated and would be radiating rather than conserving heat, so they should produce a brighter thermal signature, which could make them more detectable (Havens and Sharp 1998). However, this advantage most likely would be offset by the occurrence of elk in lower densities and at high elevations, where dense canopies of mixed conifer and spruce-fir forests would block or mask their thermal emittance. At night, thermal emittance from the canopy would be less than during the day, there would be a higher probability that elk would be more active and in open habitats, and the difference between ambient and animal temperatures would be high. Wiggers and Beckerman (1993) detected deer at night even from 300 m AGL during August when ambient temperatures were >20°C. Also, thermal imagery obtained by Graves et al. (1972) at night was superior to what they obtained during the day. Nevertheless, flying in mountainous terrain at night, even at ≥300 m AGL and with the light of a full moon, would be dangerous and imprudent.

Use of FLIR to detect large ungulates from the air
has been most successful in controlled environments (Croon et al. 1968, Wiggers and Becker-ram, 1993) where habitat variability was low (Graves et al. 1972, Naugle et al. 1996) and most of the area was covered with open vegetation types (Naugle et al. 1996), or at dawn when background thermal emittance was low (Havens and Sharp 1998). The results of this study suggest that FLIR currently is inadequate for improving aerial surveys of elk in wildland settings where there is variability in topography and vegetation.

Acknowledgments. We thank D. Cagle, Arizona Department of Game and Fish, P. Snyder and N. Smith, New Mexico Department of Game and Fish, and T. Watts, Jicarilla Game and Fish Department, for assisting in aerial surveys. Chama Land and Cattle Co. allowed us to survey elk in their game parks. P. R. Krausman, University of Arizona, reviewed an earlier draft of this manuscript. This project was partially funded by a grant from the Federal Aid for Wildlife Restoration Project W-93-R-38.

Literature cited


Address for William C. Dunn: New Mexico Department of Game and Fish, P.O. Box 25112, Santa Fe, NM 87504, USA; e-mail: wcdunn@state.nm.us. Address for J. Patrick Donnelly: Remote Sensing Lab, United States Forest Service, 333 Broadway SE, Albuquerque, NM 87102, USA; present address: United States Fish and Wildlife Service, 500 Gold Ave. SW, Albuquerque, NM 87102, USA. Address for William J. Krausmann: Remote Sensing Lab, United States Forest Service, 333 Broadway SE, Albuquerque, NM 87102, USA.

Bill Dunn (left) is supervising biologist for the Predator and Gamebird Management section of New Mexico Department of Game and Fish. He received his B.S. in wildlife biology from the University of Montana and his M.S. in biology from the University of Nevada, Las Vegas. He currently is involved in conservation of the imperiled lesser prairie-chicken and in applying a recently completed long-term study of New Mexico's black bears to progressive management. Pat Donnelly (center) is the remote-sensing scientist for the Southwest Region of the U.S. Fish and Wildlife Service. He received both his B.A. and M.A. in geography from the University of New Mexico. Donnelly is active throughout the Fish and Wildlife Service promoting and developing the use of remote sensing as a tool to monitor wildlife populations and their habitats. Bill Krausmann (right) is the geometronics group leader for the Southwestern Region of the U.S. Forest Service, where he is responsible for managing regional programs in remote sensing, cartography, GIS, photogrammetry, and infrastructure databases. He received his B.A. and M.A. from San Diego State University and Ph.D. from the University of Utah, all in geography. Bill's principal professional interests lie in remote-sensing applications to natural resource management with special emphasis in thermal infrared applications.

This content downloaded from 64.106.42.43 on Tue, 4 Jun 2013 21:55:22 PM
All use subject to JSTOR Terms and Conditions