# A GASAWAY-TYPE MOOSE SURVEY IN NEW HAMPSHIRE USING INFRARED THERMAL IMAGERY: PRELIMINARY RESULTS

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ABSTRACT: A Gasaway-type aerial moose survey was conducted in northern New Hampshire using fixed-wing aircraft equipped with a Westinghouse WesCam forward looking infrared (FLIR) sensor in place of human observers. The purposes of the survey were to: (1) provide a more accurate estimate of moose numbers; and (2) to begin to validate the ability of a fall hunter survey to accurately reflect changes in the moose population. Sightability was tested in 1995 by flying a number of survey units (SUs) at survey speed and immediately re-flying these SUs at a more intensive rate. Sightability was estimated to be 88%. Mean population density for the area flown was 1.19 moose/km$^2$ ±27.5% (90% C.I.). The survey will take place annually for 3 - 5 years before validation of the hunter survey is complete. For the state of New Hampshire this survey technique was slightly more expensive but considerably safer than a similar survey using rotary-winged aircraft. In areas with fast changing weather patterns and varied topography this technique can be successfully used in place of the traditional aerial survey which relies on direct visual observation.

ALCES VOL. 36: 69-75 (2000)

**Key words:** aerial survey, *Alces alces*, density estimate, infrared thermal imagery, New Hampshire

The principal population parameters that should be gathered for successful moose management are density, adult sex ratio, recruitment, mortality, and rate of population change (Cumming 1974, Simkin 1974, Gasaway *et al.* 1986). Lack of data on population parameters has been listed as a primary reason for the failure of moose management practices in many North American jurisdictions (Crichton 1987). It has also caused overharvest in the jurisdictions of Alaska, Newfoundland, Manitoba, Saskatchewan, Ontario, and New Brunswick (Timmerman 1987).

New Hampshire has lacked reliable information on moose density, mortality, and rate of population change. In the absence of a direct measure of these parameters the New Hampshire Fish and Game Department based its management on an index to population change that is measured annually. This index was the November deer hunters' observation rate of moose. It was assumed that the observation rate was directly correlated to changes in the moose population. This index has allowed the Department to set limited hunting seasons since 1988.

As moose numbers have increased so too has the complexity of moose management. The recreational value of moose to the state coupled with increasing demands for more diverse and responsive management strategies has heightened the need for more accurate data. In 1986 the Department flew a Gasaway-type survey using fixed-wing aircraft in the northern region of the state where knowledge of moose numbers was most critical. The constantly shifting weather patterns coupled with New Hampshire's rugged terrain made this type of survey too dangerous and unacceptably long. The use of rotary-winged aircraft increased maneuverability in mountainous terrain, but increased costs and continued safety problems proved prohibitive.

In 1993, the Department contracted with the University of New Hampshire to test the use of aerial infrared thermal imagery for moose surveys. In the past, these surveys produced poor results due to an inability to properly identify the target species (Croon *et al.*1968, Graves *et al.*1972, Parker and Driscoll 1972). New technology, however, has greatly increased the level of resolution and allows for accurate identification of many species based on morphology (Wiggers and Beckerman 1993, Adams 1995, Garner *et al.* 1995, Havens and Sharp 1998). This new technology was tested on 2 study sites in northern New Hampshire in the winter of 1995, and was successful at detecting and identifying moose in the area's various terrains and cover types (Adams 1995). Based on this success it was decided to use this technology to develop a more accurate estimate of moose numbers in the northern region, and to begin to determine the relationship between changes in moose population density and moose observation rate from the deer hunter mail survey.

## STUDY AREA

The survey area was the northern most portion of New Hampshire and encompassed 4,236 km$^2$, of which 3,460 km$^2$ was possible moose habitat. The area is characterized by mountainous terrain interspersed with broad to very narrow valleys and wetlands. Elevations range from 357 to 1,360 m above sea level. The vegetation is a mix of northern hardwoods, spruce-northern hardwoods, and spruce-fir. Predominant tree species in these forests include beech (*Fagus grandifolia*), birch (*Betula* spp.), maple (*Acer* spp.), red spruce (*Picea rubens*), and balsam fir (*Abies balsamea*). The climate is cool temperate, and the area is characterized by fast moving weather fronts and very changeable weather patterns. Moose densities are the highest in the state and increase from south to north. The land is owned primarily by either large paper companies or the federal government. Extensive logging takes place in the northern two-thirds of this area while the southern portion is comprised of more mature forest and higher human densities. Tourism and the forest products industry, both of which can be influenced by moose numbers, fuel the economy. The study area was chosen due to the importance of moose to the area's economy and because it had 3 discernible areas where observation rates of moose were significantly different.

## METHODS

In 1998 a stratified random block type survey (Gasaway *et al.* 1986) using aerial infrared thermal imagery was flown over the study area to determine moose densities. The survey was conducted in November to take advantage of leaf drop, utilization of clear cuts by moose (Miller 1985), and to coincide with the deer hunter mail survey.

Prior to the survey, the study area was broken into 3 blocks and stratified based on the average number of moose seen per hundred hunting hours (MSHHH) during the first 2 weeks of the November 1997 deer season. Based on the MSHHH the 3 survey blocks represented high (A1/A2), medium (B/C2), and low (C1/D1) observation rates, and were delineated by wildlife management unit (WMU) boundaries. Within these blocks individual towns (the finest resolution at which the mail survey data could be used) were assigned to high or low strata by subjectively dividing the MSHHH range at an obvious midpoint. This resulted in 3 survey blocks (A1/A2, B/C2, C1/D1) each with high and low strata. This stratification technique is quite different from that recommended by Gasaway *et* *al.* (1986) in 3 substantial ways: (1) the observation rates used for stratification were a year old; (2) the stratification observation rates were acquired using a different methodology from that of the survey; and (3) delineation of the strata was based on political (WMU and township) boundaries.

Using density and variance estimates from Adams (1995) that were felt to be representative of the populations in the survey blocks, simulation analyses were used to estimate the number of sample units (SUs) needed in each strata (Gasaway *et al.* 1986). Location of SUs within each stratum was accomplished by computer generated random number selection using UTM coordinates. The SU was then delineated on or near this coordinate using geographic boundaries. Each SU lay entirely within 1 stratum. Large water bodies, heavy softwood cover, developed areas, agricultural lands, and elevations above 3,000 ft were not considered moose habitat and were not included in the survey. Sixty-one sample units averaging 16.7 (±2.1 SD) km$^2$ in size were delineated. To reduce variance estimates a larger number of SUs were assigned to the high-density strata than to the low-density strata (Gasaway *et al.* 1986).

Sightability was determined in the test flight done by Adams (1995). The infrared equipment and study area used by Adams were the same as for this 1998 survey. The method employed by Adams to estimate sightability in 1995 was similar to that suggested by Gasaway *et al.* (1986). Two study sites representing the 2 major habitat types (hardwood, hardwood/softwood) were flown in a "normal" survey pattern and then 2 subsites of each of these areas, or the entire area, was immediately re-flown in a pattern that allowed for maximum detection of moose. The resulting sightability correction factor was 1.12. Financial considerations precluded the use of collared animals in defining sightability.

The survey took place from 15 November - 12 December 1998. AirScan Incorporated (Titusville, FL) flew the survey using a Cessna 337G aircraft equipped with a Westinghouse WesCam DS infrared sensor with a spectral range of 8-12 microns. The sensor was left-wing mounted and included a 10X zoom lens color television camera. The WesCam could search a distance of up to 5.5 km and had 2 fields of view (FOV); wide FOV covered 400 m$^2$ and narrow FOV covered 75 m$^2$ at 762 m looking straight down. The plane was also equipped with 2 sensor screens, a video recorder, global positioning system (GPS) navigation, and latitude - longitude and date-time generator. One 14.6-cm sensor screen was mounted in front of the co-pilot's seat and the other screen (33 cm) was in the sensor operator's workstation. The pilot had 1,000 hours of experience flying infrared surveys and the sensor operator had 3,000 hours experience with IR use and interpretation. During most flights a third person familiar with the region assisted with navigation and data recording.

Survey flights took place between 0600 and 1630 hrs when the cloud ceiling was at least 667 m above ground level (agl). Night flying was not undertaken due to the mountainous terrain. Flight duration did not exceed 5 hours to reduce sensor operator fatigue. A total of 40 SUs (668 sq. km.), 26 high SUs and 14 low SUs were flown (Fig. 1). To reduce problems associated with moose movements an effort was made to completely fly an entire WMU block before beginning another. The crew flew to each sample unit using pre-programmed GPS coordinates. Flying at 600 - 833 m agl a series of slightly overlapping orbits were used to survey the SU (Adams 1995). The circles or orbits had an average radius of 0.65 nautical miles. Search effort averaged 5.2 min/km$^2$. Search pattern of the IR sensor was a consistent pattern that cov-

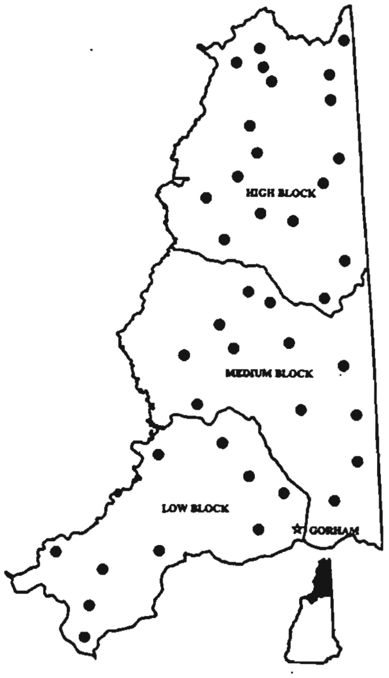

Fig. 1. Block boundaries and location of SUs for northern New Hampshire aerial infrared moose survey.

ered as much as 90% of the area of each orbit. The plane maintained an average bank angle of 10°. Air speed averaged 70 knots and altitude averaged 750 m agl. All infrared and real time imagery and crew communication were automatically recorded on a DVD digital HI 8 tape including latitude, longitude, heading, speed and altitude of the plane, and camera elevation and azimuth.

Animals were initially sighted using the infrared camera wide FOV then checked with the narrow FOV and occasionally rechecked using real time imagery. All sightings were called out with the number of moose sighted, the time of sighting, and the bank angle of the plane. Moose were identified by their morphology, behavior, and luminous intensity. As the survey progressed, the variance around the block population estimates were periodically checked using the optimal allocation methods of Gasaway *et al.* (1986) so that additional SU flights could be assigned where most needed.

Once flights were completed, the sensor operator would review the tapes and eliminate or include sightings that may have been misinterpreted or missed during the flight. All animals were then plotted on 1:24,000 USGS maps using the information which appears on the tape (latitude, longitude, flight speed, elevation and azimuth of the camera, and heading and bank angle of the aircraft). The digital tapes were then converted to standard VHS tapes. These tapes, maps, total numbers of moose detected per SU, and daily flight logs were provided to the Department.

## DATA ANALYSIS

Data analysis procedures for estimating strata and block densities, population estimates, and confidence limits followed those of Gasaway *et al.* (1986). A population estimate was derived for each block and then summed to get the population estimate for the whole study area. A regression analysis (Freund and Little 1981) was then run between the estimated moose densities for each block and strata and the associated 1998 MSHHH rates.

## RESULTS

AirScan Inc. was in New Hampshire from 15 November through 12 December. There were 12 flight days and 12 bad weather days, 3 days for meetings and transport, and 2 down days due to technical problems. Total flight time was 57.5 hours with each survey flight averaging 4.75 hours including travel time to the SU. The infrared interpreter indicated that surveys which took place after 1330 were hampered by high levels of background emmisivity so all flights after 24 November took place in the AM. The flight planning, tape review, plotting, and report writing took approximately 6 hours per flight hour or 342 total hours.

The 40 SUs surveyed represented 19%, or 668 km$^2$, of available moose habitat. Moose densities varied from a high of 2.01 moose/km$^2$ in the A1/A2 block to a low of 0.49 moose/km$^2$ in the B/C2 block. Confidence intervals for the combined block data are better than for the strata data (Table 1). Density for the moose habitat within the entire study area was estimated to be 1.19moose/km$^2$, resulting in a population estimate of 4,100 ± 1,127 animals (90% CI).

The 1998 mean observation rates for the 6 strata (Table 1) ranged from 2.77 MSHHH in WMUs C1/D to 16.22 MSHHH in A1/A2. Regression of the density estimates with the 6 strata observation rates had an $r^2 = 0.87$, $P = 0.0152$, and 4 df (Fig 2).

Total cost of this survey was US $52,780.00. Flight time was $530.00/hr compared with $650.00/hr for a helicopter. Cost for bad weather days when the crew was grounded was $670.00 per day. During this time the crew would work on tape review and plotting. An additional 5 days ($670.00/day) were needed to complete the plotting. The final product (all tapes, maps, and written documentation) was delivered to the Department 5 weeks after the last flight day.

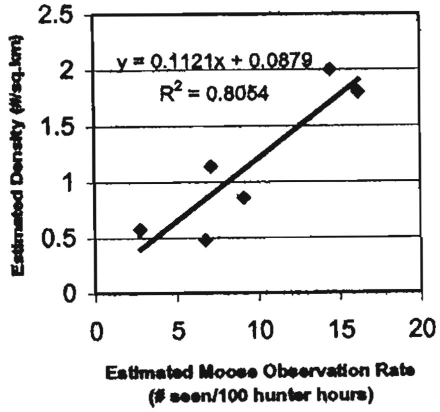

Fig. 2. Estimated relationship between moose observation rate and moose density based on block and strata data.

## DISCUSSION

We feel this infrared technique has or will achieve both of the outlined objectives. The 1998 population estimate did not achieve the minimum precision recommended by Gasaway *et al.* 1986 (± 25% with 90% confidence) but it wasn't far off (± 27.5% with 90% confidence). Improvements would include: (1) refining sightability using collared animals; (2) surveying later in the fall when moose are more dispersed across the landscape (Miller1985); (3) re-stratifying based both on MSHHH and habitat types in

Table 1. Block observation rates (MSHHH) and density estimates (moose/km$^2$) for northern New Hampshire infrared survey.

| Survey Block | Number and Strata of SUs | | Percent of Area Searched | Observation Rate (MSHHH ±90% CI) | Density Estimate (moose/km$^2$ ±90% CI) |
|---|---|---|---|---|---|
| A1/A2 | 14 High | | 26 | 14.47 1.56 | 2.01 0.90 |
| | 4 Low | | 21 | 9.14 2.67 | 0.86 0.59 |
| B/C2 | 7 High | | 30 | 16.22 4.30 | 1.77 0.36 |
| | 5 Low | | 8 | 6.76 1.01 | 0.49 0.26 |
| C1/D1 | 5 High | | 21 | 7.13 1.71 | 1.14 0.85 |
| | 5 Low | | 24 | 2.77 0.78 | 0.59 0.98 |
| Combined Strata | | | | | |
| A1/A2 | 14 High | 4 Low | 25 | 13.58 1.36 | 1.75 0.74 |
| B/C2 | 7 High | 5 Low | 14 | 8.14 1.01 | 0.85 0.29 |
| C1/D1 | 5 High | 5 Low | 18 | 4.24 0.78 | 0.79 0.71 |

the GIS data set; (4) increasing the number of SUs surveyed; and (5) homogenizing the size of the SUs.

The regression analysis will take several more years to fully develop. Observation rates are influenced by a variety of factors including moose numbers, weather, timber harvest, and accessibility (Crichton 1993). Additional data points gathered during other years under varying conditions will better define the true relationship between observation rate and population levels. The regression pertains only to the study area and may not be applicable to other areas (Zar 1984). However, by covering many variables and a wide range of values, we believe it will increase our understanding of how observation rates may be influenced by changing population levels, even in areas with different values.

Croon *et al.* (1968) suggest that infrared is comparable to fixed-wing for accuracy in identification of the target animal. Based on our experience we feel it is better. Animals that are partially concealed by trees or difficult to see due to cryptic coloration are revealed with the use of infrared. We feel this will work well for those jurisdictions that cannot utilize traditional fixed-wing or helicopter surveys. While we used this survey for a population estimate only, spring flights may increase the amount of information obtained. When performed prior to leaf out, and after some antler growth has occurred, sex ratio information could also be obtained. Airscan Inc. interpreters were able to correctly identify the sex and age of white-tailed deer in an enclosed compound during an August survey (Wiggers and Beckerman 1993). It seems logical to conclude that they could correctly sex adult moose and distinguish calves from adults.

For our jurisdictions, costs were similar to those of a helicopter survey of the same area. Although there are additional costs in this method which do not occur with traditional surveys (tape review and plotting of locations), they are somewhat offset by the increased land coverage this method provides over that of traditional surveys (Adams 1995). To save money biological staff not trained in IR could do tape review. In a study done with known targets, biologists were able to accurately identify 76% of all targets by species after only a few hours of practice compared to 100% accuracy by the IR scanner operator (Wiggers and Beckerman 1993). However, we feel the resultant reduction in accuracy of the estimate due to inexperience would probably not offset the savings. Additional changes that could be made to reduce costs would be to reduce search effort while improving sightability estimates. The slight increase in costs associated with this technique was offset by the significant increase in safety and a good end product.

## ACKNOWLEDGEMENTS

The authors wish to thank Bill Hastings of Shelburne, NH, for providing the AirScan crew with better navigational advice than could be obtained from the GPS unit, and for being the data recorder. We thank the crew from AirScan for their high level of professionalism and dedication to this project. Finally, a special thanks to Sue Bernadis and John Piowaty for help with manuscript preparation.

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