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THERMAL IMAGERY FOR CENSUS OF UNGULATES

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ABSTRACT

A Daedalus thermal linescanner mounted in a light single engine aircraft was used to image the entire 270 square kilometers within the fenced perimeter of Elk Island Park, Alberta, Canada. The data were collected during winter, 1976 in morning and midday (overcast conditions) processed and analyzed to obtain a number for total ungulates. Five different ungulate species were present during the survey.

Ungulates were easily observed during the analysis of linescanner imagery and the total number of ungulates was established at 2175 compared to figures of 1010 and 1231 for visual method aerial survey results of the same area that year. It was concluded that the scanner was much more accurate and precise for census of ungulates than visual techniques. Advantages over visual survey methods include: no technition effect; no observed fatigue; operation at night, early morning and without snow cover; detection of camouflage or neutral coloured animals; accurate results, repeatable results, and habitat permanently recorded. Disadvantages include: restricted in severe terrain, southern latitudes; sex of animal is not recorded; species separation is limited to different sized animals; and cost is equal to or higher than visual methods. Applications of the thermal scanner include total counts of ungulate concentrations or high densities, sampling programs or animal habitat relationships (both habitat and animal are represented on imagery). Cost is comparable to helicopter census work.

1. INTRODUCTION

The obtaining of reliable census information is one of the major difficulties in the management of wildlife populations. Most methods in use today for counting or estimating ungulate populations rely on visual observations from aircraft. Experiments over the last few years have caused many workers to move to rotary wing aircraft from fixed wing aircraft or to the use of block rather than transect methodology <u>or both</u> (Evans, et al. 1966; 1968; Bergerud, and Manual, 1969; Lynch 1975). Though these changes have given better results, many factors still bias the results of aerial census work. Internal factors (those related to the observer and aircraft, ie. tiredness, nausea, experience, type of aircraft, visibility, and external factors, ie. weather (snow cover, temperature), animal movement and behavioral patterns, coloration and habitat are discussed by Graham and Bell (1969) and Heyland (1976) in relation to their effects on census reliability.

These problems of accuracy and precision in census work have led wildlife managers to experiment with new techniques in an effort to obtain increased reliability. Considerable hope has been expressed regarding the potential of a thermal technique that would detect warm blooded animals in a cold environment (Zanon, 1964; Bartholomew and Hoffer, 1966, and Cain, 1966). Field tests using thermal infrared scanners have been conducted in several areas but few results have been published. Croon, et al. (1968) published the most widely known test; in which it was concluded that scanners could give the most reliable counts of any method available, but that the technique was expensive and did not work well in coniferous habitats.

The potential of the method demonstrated by Croon and the availability of a high resolution scanner in an available, light aircraft prompted the design of a new study in both economics and reliability. Elk Island National Park was selected as an ideal test area for the thermal method because the park is of limited size, fenced, has very few conifers, and has a high density of wild ungulates (hooved animals). Parks Canada was receptive to the idea of applying the technique there and a pilot program was designed. The objectives of the study were; 1) to obtain a reliable estimate of the total number of ungulates, 2) to evaluate the potential of imagery from the thermal linscanner data to provide separate species information and 3) to evaluate the effectiveness of the scanner as a function of different weather conditions, times of day, altitudes and possible unknown parameters. The following text summarizes the project and discusses the results of this pilot program.

2. METHODS

The scanner used for data collection was a quantitative Daedalus thermal linescanner and mounted in a Piper Cherokee Six and later in a Piper Aztec. The scanner was used with an 8-14 micron sensor having a 1.7 milliradian instantaneous field of view (IFV) which results in an IFV of 52 cm. at an altitude of 305 m. above ground level (AGL). The data were collected at an above ground altitude of approximately 300 m. which provided a 12.7 cm. strip of film (when processed) representing a 500 m. width of the ground surface. A total of 862 line km. were flown on three separate surveys.

The imagery was processed by Canada Centre for Remote Sensing and interpreted in 12.7 cm. wide negative format. Interpretation of all imagery was done by two biologists, Keith Baker, Wildlife Resources Manager for Parks Canada and Marc Wride, INTERA. After completely analyzing the imagery individually, both collaborated to reanalyze the data simultaneously and arrive at a mutually acceptable estimate for each strip of film.

Density slicing was experimented with using the facilities at Alberta Remote Sensing Centre in Edmonton to evaluate the technique for more machine-oriented interpretation methods.

3. RESULTS AND DISCUSSION

Comparison of Visual and Thermal Methods

Results from the analysis by interpreters A and B did not diverge more than 9.0 percent and were as low as 2.0 percent (Table I). In most cases, interpreter B returned a larger number; usually the result of locating animals which had not been observed by the first interpretation (all animals were marked by each interpreter). The second time through the data both interpreters analyzed each strip of film simultaneously and arrived at a mutually agreed upon number of animals. Again previously unseen animals were located. The average of the two interpreters first result compared to the combined result for each area (including total) shows that the collective or combined results were larger than the average of the two separate counts by approximately 10 percent. This consistent increase was attributed to the combined effort and additional interpretation time spent on the data. Many of the animals located during the combined effort were characterized by small size or minimal contrast on the film making detection difficult. More thorough analysis by the interpreters coupled with increased experience during a first analysis should reduce this discrepancy and increase precision.

The final estimate of total ungulate numbers was 2175 (Table II). Two visual aerial surveys conducted by Parks Canada the same winter; one in December 1975 and one in March 1976, produced estimates of 1010 and 1231 ungulates respectively. These included 356 bison (*Bison bison*), most of which were collected, penned and counted. The higher March figure of 1231 is 57 percent of the infrared result (2175). Parks usually adds 25 percent to these raw data excepting bison because it is common knowledge that numbers from visual aerial census are consistently below actual population figures. This would raise the estimate to 1450 or 67 percent of the thermal scan number. This large difference between the estimates from the aerial survey and the thermal scan has some basis for explanation.

A recent test on aerial census accuracy of penned moose (*Alces alces*) in Alaska by Le Resche and Rausch (1974) showed the average detection rate for experienced observers to be 68 percent of moose present. Inexperienced observers saw only 43 percent. Habitat and relief were factors, however, and as Elk Island is flat and primarily deciduous, under good snow conditions, experienced observers should see a higher percentage; perhaps 75-85 percent of the moose present. Such a high percentage would be possible only under optimum conditions, and snow conditions were not optimum in the March survey. Le Resche and Rausch (1974) showed poor conditions to cause up to a 50 percent reduction of sightings compared to optimum conditions. In addition to these there is the problem of detectability coefficients for the different species. Moose are easily observed in comparison to elk (*Cervus canadensis*) and especially deer (*Odocoileus* spp.) and a coefficient for this characteristic was not and usually is not included in visual surveys. For these reasons it is concluded that the visual estimate is probably on the order of 60 percent of actual numbers and that the thermal scan figure for total ungulates is a more accurate estimate.

There are sources of potential inflation of the thermal scan number including: solar heated objects, vacant beds and other animals. It is the opinion of both interpreters after viewing the imagery, that counting of solar heated objects could not be responsible for a significant inflation of data in this study. Evaluating the potential for bias from counting vacated beds of animals is more difficult. Marble (1967) reported that the apparent temperature of beds was 1 to 2°C warmer than the animal at the time of vacation, but dropped below animal temperature within one minute of the time the animal left. Driscoll (1976) indicated that tests with thermal scanning of penned deer showed sensing of beds to be no problem. Preliminary studies the temperature change of vacated beds in the Calgary Zoo field pens for moose, deer and bison indicate a more prolonged temperature retention than before suspected. Light snow and warm ground temperatures may have influenced this to a large degree and additional research is necessary.

It is also possible that a number of animals were omitted, as an animal behind a tree might not be "seen" by the scanner. Comparison of areas with overlapping coverage did not show this to be a significant problem, although occasionally additional animals were located in this manner. It was concluded that the thermal scan number for total ungulates may be subject to limited inflation, which would be partially compensated for by a few missed animals, the total effect being not significant. This is, however, a preliminary conclusion and additional research is planned.

Separation of Species

Separation of species using the scanner data was found by both interpreters to be quite difficult. Bison could be separated by their gregarious social patterns and preference for open and lakeshore habitat (Figure 1). Moose could be generally recognized by their non-social spatial orientation (Figure 2). Although this separation approach has merit and utility it is limited in reliability by the potential to identify social groups of elk and deer as bison or single bison and elk as moose.

Studies by Hammel (1956) on emissivity values of different animals have shown most animals to be very similar. Relative size of the "hot spot" on the imagery is often helpful but can be misleading as there is some variance in hot spots due to processing on different filmstrips, metabolic rate (activity of animal) and orientation to scanner. This fact makes machine processing questionable. It is possible that a technique of species separation may be developed and refined which could be adequate for reasonably accurate results, but the data collected in this study were not preceeded by the necessary testing to allow this type of interpretation. In many areas the number of species may be one or perhaps two different sized animals. In cases of this type or if the ratio of animals is known from preliminary sampling, the system can be used for obtaining accurate total numbers and adequate estimates of species. It appears however that visual census methods will for the foreseeable future provide better information on sex and age of ungulates.

Interpretation Techniques

Interpretation of imagery was done visually, although some colour and black and white density slicing was done on a trial basis. Density slicing did not isolate the animals as well as visual interpretation; insensitivity of the slicing caused inclusion of other objects having nearly the same temperature. A number of variables in animal temperature could be more easily accounted for visually than by machine, including: animal orientation and small differences in processing results. Visual methods will probably remain the most effective method of analysis for the foreseeable future.

Operational Constraints

Croon et al. (1968) established a series of optimum conditions for thermal scanning of ungulates which included: open or leafless habitat, snow cover, no wind, high overcast sky, and daytime overflight. He stated that as conditions depart from these optimum conditions the image quality decreases. This was found to be true in this study, but to a lesser degree than expected as imagery collected during less than optimum conditions was still found to be of operational qualtiy. Snow cover was not a necessary requirement nor was a high overcast sky. Absence of wind, cold ground (or snow) and open canopy were, however, determined to be necessary for operational quality imagery. Under these conditions, early morning flights produce good quality imagery and allow census work to be done during the active part of the animals' day. These results indicate thermal scanning is a feasible operational technique under a broader combination of weather conditions than previously thought. This capability offers an important advantage over visual methods because such flexibility offers reliable census numbers in fall and late winter when poor snow conditions or absence of snow render visual methods unreliable. Additional work during these seasons and conditions is required to verify this observation as is work in coniferous habitat and rough terrain conditions.

Cost Effectiveness and Application

The cost of scanning is higher than normal light fixed wing operations because of technical manpower requirements, scanner costs and processing costs, however, most fixed wing census operations have been or are being replaced by helicopter techniques. Some agencies are flying samples and others are making attempts at complete coverage of their game habitat. This variance in platforms and methodology makes a cost comparison difficult, but, generally it can be concluded that thermal census is comparable in cost to helicopter methodology. This cost comparison is made on the basis of total services and data product for the thermal census versus airplane and fuel costs for visual census. Visual census mantime is not included, however, it is recommended that the agency do their own interpretation which equalizes this discrepancy.

Thermal scanning for ugulate census is more accurate than visual techniques for actual counting for numbers, but this accuracy does not always warrant using the thermal technique. Considering cost and benefits it was concluded that thermal scanning methodology has optimum application in three types of roles: 1) total counts of ungulates in wintering areas; 2) statistical sampling in relatively homogenous habitat or stratified habitat; and 3) in research applications of animal-habitat relationships. All of these applications will be most effective if the cover is primarily deciduous, terrain is moderate and if the species of interest is locally predominant in that size category (eg. moose vs. deer). The thermal system will count more effectively than visual means in coniferous habitats but reliability of any census method is suspect in such conditions.

Populations of ungulates often concentrate in wintering areas to obtain food and shelter. Costs of scanning such areas are not excessive and the data collection can be done in early morning when animals are in more open habitat. River valleys would be among the more ideal situations. Elevation changes in river valleys are predictable and can be compensated for.

Quadrat sampling of homogenous or stratified habitat can be done effectively and the area done confirmed as the designated strata and statistically analyzed for precision. This application has merit compared to visual work as precision and accuracy have been lacking in visual work, making results suspect.

Research data requirements for an animal-habitat relationship study could justify instigating a thermal survey, but this type of information is available as a spin-off or by-product from doing a thermal census for census purposes, increasing cost effectiveness. The scanner records vegetation and other environmental features well enough that they are easily correlated with normal aerial photos or good vegetation maps. Also, these data are easily stored and could be used later if a question on use should arise. The flexibility of scanning at different times of the day over a 24 hour period allows documenting the location of entire herds or single animals in relation to vegetation, etc. Animals are generally not disturbed by a fixed wing aircraft flying 300 m. or more above ground level which reduces bias from induced movement. There is currently no radio telemetry technique that can provide such complete or exact information on animal location relative to habitat.

4. CONCLUSIONS

The thermal scan resulted in a total number of ungulates that was higher than both of the aerial census estimates, and more reasonable considering the bias inherent in visual census documented in other studies. The thermal scan did not provide enough information for reliable separation of animal species, however, additional work on this problem (currently underway) could show separation of different sized species. Spacial relationships of bison and moose were easily detected and could be helpful in species separation. Visual interpretation of thermal imagery appears to be the best method available at the present time. The conditions under which the linescanner can be operated are broader than previously thought, enhancing or increasing the potential of the method for operational use, however, wind and extreme terrain are limiting. Although scanning is expensive relative to fixed-wing aerial survey, it is approximately equal to helicopter techniques and the improved accuracy of the method justifies use of the method for statistical sampling, census of winter habitat (ie. river valleys or key winter areas) and for habitat-animal distribution studies.

Additional studies to refine the technique and determine operational limitations are underway and results will be available in the near future.

REFERENCES

Bartholomew, R.M. and R.M. Hoffer. 1966: Investigating the feasibility of censusing deer by remote sensing of thermal infrared radiation. Mid-west Wildl. Conf. Chicago, Illinois 4 pp.

Bergerud, A.T. and F. Manual, 1969: Aerial census of moose in central Newfoundland. J. of Wildlife Management 33(4): 910-916.

Brooks, J.W. 1970: Infrared scanning for polar bear. IUCN Pub. No. 23: 138-141.

Croon, G.W., D.R. McCullough, C.E. Olson, Jr. and L.M. Queal. 1968: Infra-red scanning techniques for big game censusing. J. of Wildlife Management 32(4): 751-759.

Driscoll, R.S. 1976: Personal communication. Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Eberhardt, L.L., 1968: A preliminary appraisal of line transects. J. of Wildlife Management 32(1): 82-88.

Evans, C.D., W.A. Troyer and C.J. Lonsink, 1966: Aerial census of moose by quadrat sampling units. J. of Wildl. Manage. 30(4): 767-776.

Hammel, H.T. 1956: Infrared emissivities of some arctic fauna. J. of Mammal. 37(3): 375-378.

Heyland, J.D. 1976: Remote sensing of wildife. Unpublished paper, 42 pp.

Le Resche, R.E. and R.A. Rausch 1974: Accuracy and precision of aerial moose censusing. J. of Wildl. Manage. 38(2): 1975-182.

Lynch, G., 1975: Personal communication. Region Biologist, Alberta Fish and Wildlife, Edson, Alberta.

Marble, H.P. 1967: Radiation from big game and background: a control study for infrared scanner census. Unpublished Master's Thesis, U. of Mont., Missoula. 86 pp.

McCullough, G.W., C.E. Olson and L.M. Queal. 1968: Progress in large animal census by thermal mapping. In: Remote sensing in ecology. U. of Georgia Press Ed: P.L. Johnson.

Moen, A.M. 1968: Surface temperatures and radiant heat loss from white-tailed deer. J. of Wildl. Manage. 32(2) 338-344.

Parker, H.D. Jr., 1971: Infrared eyes for game management.

Parker, H.D. and R.S. Driscoll, 1972: An experiment in deer detection by thermal scanning, J. of Range Manage. 25(6): 480-481.

Zanon, A.J. 1964: Reconofax for the sake of wildlife. Short Circuit 14(10): 9-11.

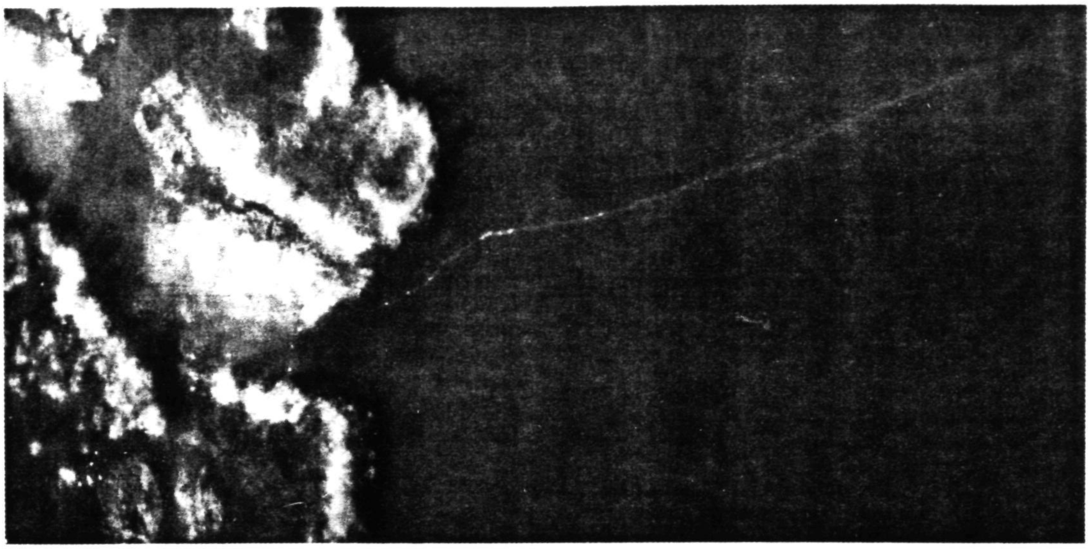

FIGURE 1. Bison on frozen lake. Contact print of infrared imagery showing bison (Bison bison) as white "hot spots" in aspen (Populus tremuloides) (lighter areas) and shrub, grassland (darker areas) communities between two frozen lakes. Note the dense spatial pattern of the bison. Scale 1:4800.

FIGURE 2. Moose in Aspen. Contact print of infrared imagery showing two ungulates (white spots center of photograph), probably moose (Alces alces) in a non social spatial orientation in an aspen community (lighter areas) near a muskeg (darker area).

TABLE I. RESULTS OF INFRARED IMAGERY INTERPRETATION AT ELK ISLAND PARK, 1976.

Section of Park	Interpreter	Number of Animals Certain	Uncertain	Total
Northern	A[1)]	571	63	634
	B	551	38	589
	AVE $\frac{(A+B)}{2}$	561	50.5	611.5
	A,B combined[2)]	659	----	659
Centre	A	968	41	1009
	B	1053	33	1086
	AVE	1010.5	37	1047.5
	A,B combined	1164	----	1164
Total Main Park	A	1539	104	1643
	B	1604	71	1675
	AVE	1571.5	87.5	1659
	A,B combined	1830	----	1830
Isolation	A	288	----	288
	B	297	14	311
	AVE	292.5	14	300
	A,B, combined	345	----	345
Total Park	A	1827	----	1827
	B	1901	85	1986
	AVE	1864	85	1949
	A,B combined	2175	----	2175

1) A - Parks Canada Interpreter
B - INTERA Interpreter

2) A,B combined - both interpreters analyzed each strip of film together and agreed on the number of animals observed.

TABLE II. RESULTS OF AERIAL SURVEYS OF UNGULATES IN ELK ISLAND PARK 1971 - 1976.

Section of Park	Date	Animal Count				
		Moose	Deer	Elk	Bison[1)]	Total
Main Park	Dec. 75	231	27	200	268	726
	Mar. 76	217	16	430	268	931
Isolation	Dec. 75	337	106	211	356	1010
	Mar. 76	349	78	448	356	1231

1) Known number, not estimated.