A MOOSE SURVEY STRATIFIED BY USING LANDSAT TM DATA, NORTH OF GREAT SLAVE LAKE, NWT, NOVEMBER 1989

RAY CASE

AND

RON GRAF

DEPARTMENT OF RENEWABLE RESOURCES

GOVERNMENT OF THE NORTHWEST TERRITORIES

YELLOWKNIFE, NWT

1992

Manuscript Report No. 59

ABSTRACT

In 1989 the Northwest Territories Department of Renewable Resources undertook an investigation into the use of LANDSAT thematic mapper data for the stratification of moose (*Alces alces*) surveys. The study area on the precambrian shield north of Yellowknife, NWT was stratified using both vegetation maps produced from LANDSAT TM data and from aerial reconnaissance flights. Neither stratification technique was particularly accurate in predicting moose densities. The problems arose mainly from the very low densities of moose in the study area and the LANDSAT classification used did not reflect stand age and thus old burns were not differentiated well.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The currently accepted method of determining moose (*Alces alces*) abundance is to use a stratified block survey (Gasaway *et al*. 1986). Briefly, this technique consists of dividing an area into sample units of about 25-30 km^2 using geographical features; stratifying these sample units using reconnaissance flights in a fixed wing aircraft; then censusing a random sample of the sample units in each stratum using a helicopter.

The stratified block survey technique has proved to be effective for relatively contiguous, moderate density, moose distributions. In such areas sample units which are not "high" or "medium" density are generally assumed to be "low" rather than "zero" density as there is often a chance that moose will be located in these sample units.

On the precambrian shield country north of Great Slave Lake, moose habitat tends to be discontinuous with areas of good moose habitat separated by areas of bedrock, open coniferous forest on bedrock or black spruce bog. There is an extremely low chance that these latter areas will contain moose, thus they need not be included in a survey, even in a low density stratum.

The identification of the "zero" density areas using the conventional technique of reconnaissance in a fixed wing aircraft is both expensive and coarse. It is almost impossible to accurately map the areas of good moose habitat from a fixed wing aircraft. The reconnaissance would only provide an indication of which sample units would likely be in the zero area. Some of these sample units could, however, contain some excellent moose habitat and thus should not be considered part of the "zero" stratum.

Previous investigations into the use of LANDSAT imagery for the identification of moose habitat have been conducted in parts of the continuous boreal forest (Laperriere *et al.* 1980; Bowles *et al.* 1984; Polson 1987; Oosenburg *et al.* 1988). These studies have focused on the ability of LANDSAT imagery to determine the difference between various species compositions in the forest. This information was then to be related to the moose "potential" for the area based on the proportion of the various habitat types. Elliot (1988) used moose habitat maps prepared from LANDSAT multispectral scanner data to stratify a moose census in northern Manitoba.

The objective of this study was to use LANDSAT thematic mapper (TM) imagery to discern areas of potential moose habitat and areas unsuitable for moose. This information would then be used to assist with the determination of distribution and abundance of moose in the study area using a stratified block survey technique.

STUDY AREA

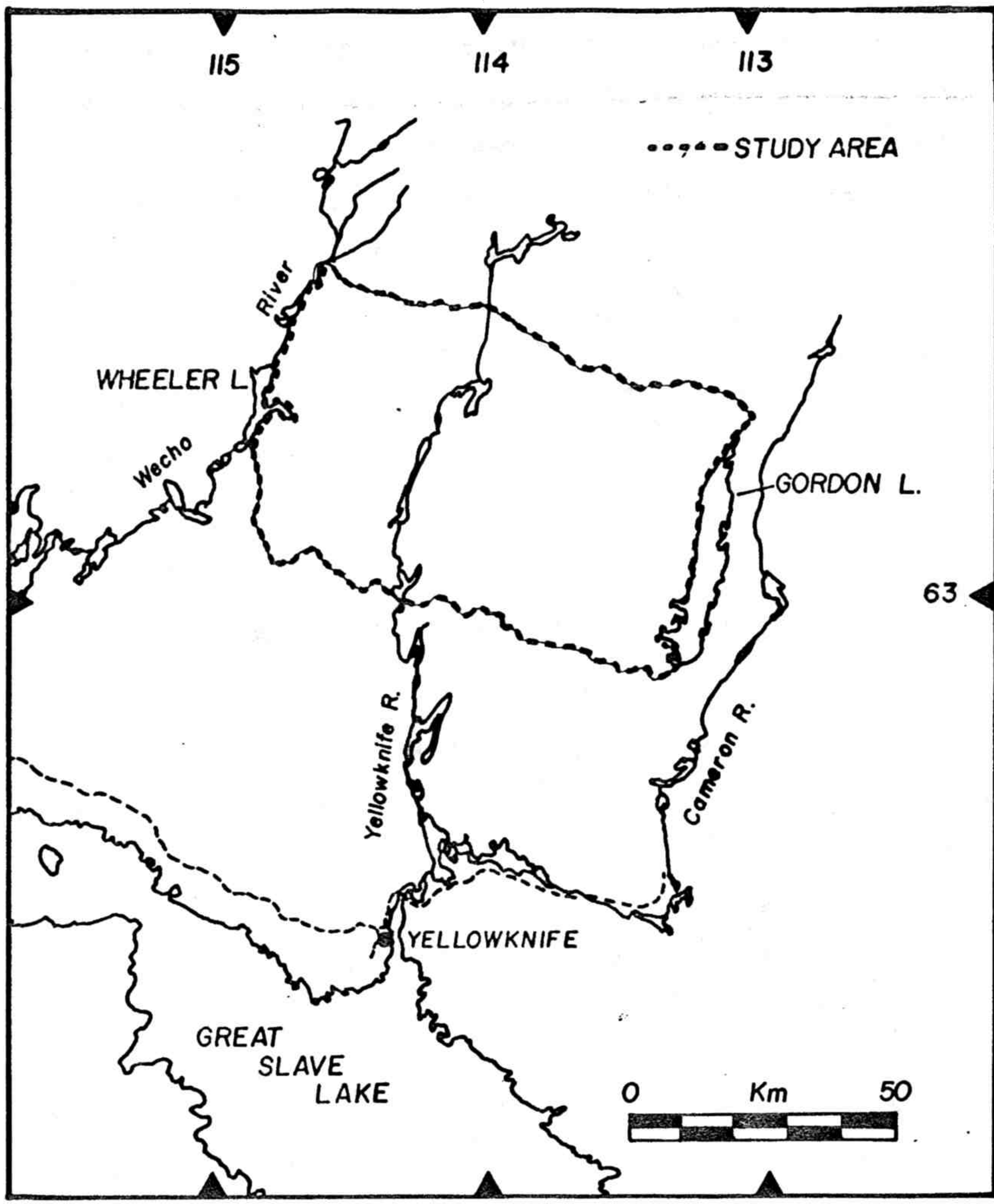
The study area was located directly north of Yellowknife, Northwest Territories. The eastern boundary was formed by Gordon Lake and the Cameron River system with the western boundary formed by Wheeler Lake and the Wecho River system (Figure 1). The study area is within the precambrian shield region. It is characterized by numerous small lakes joined by shallow creeks and rivers. Areas between the lakes are primarily rock outcrop with widely spaced jack pine (*Pinus banksiana*) and birch (*Betula papyrifera*) interspersed with low wet areas of black spruce (*Picea mariana*), white spruce (*P. glauca*) and willow (*Salix spp.*).

Major fires occurred in the study area in 1973 and in 1979. These fires covered one third of the study area and most of the southern half. Revegetation of the 1973 burns has progressed well with jack pine and birch on dry outcrop areas reaching 3-3.5 meters. Willow regeneration in moist areas was extensive. Few standing dead trees remained in these burns.

The 1979 burns had numerous standing dead trees with jack pine and birch only reaching 2-2.5 meters. Willow regeneration was moderate except for scattered areas along creeks and lakes where it was extensive.

The dry, rocky outcrops in unburnt areas were forested mainly by jack pine. Birch remained only in scattered clumps. Birch were also found in moist areas along with dense willow thickets.

Figure 1. North Great Slave Lake moose study area, November 1989.



METHODS

An unsupervised habitat classification map of the study area was produced using LANDSAT Thematic Mapper (TM) data recorded on 12 July 1987. Image data were transformed to enhance contrast. The best contrasts were obtained using the following transformations:

CHN1 - POWER STRETCH
CHN2 - LINEAR STRETCH
CHN3 - HISTOGRAM STRETCH
CHN4 - POWER STRETCH
CHN5 - POWER STRETCH
CHN7 - POWER STRETCH

Combinations of these transformed data were then experimented with to determine which pair would provide the best resolution between deciduous vegetation, coniferous vegetation and sparsely vegetated rocky areas. A fast parallelepiped classification, based on the senior author's knowledge of the area, was then conducted using CHN4 (Power stretched) and CHN2 (Linear stretched).

The following habitat classes were used:

a) sandy/rock outcrop
b) black spruce/lichen
c) open water
d) deciduous
e) open coniferous
f) mixed - coniferous dominant
g) mixed - deciduous dominant
h) bog/organics

The fast parallelepiped classification was ground truthed during 11-14 August 1989 to determine the level of correspondence between the imagery and species composition on the ground. A second fast parallelepiped classification was then conducted using CHN4 (Power stretched) and CHN2 (Histogram stretched). This classification incorporated the information from the ground truthing. Insufficient time was available to ground truth this second image to ensure accuracy, however, the level of correspondence was high in the initial unsupervised classification so it was felt that the second classification would accurately reflect the vegetation.

The classification was not sensitive to stand age so fire boundaries were transferred to the image from fire maps. These maps were produced from reconnaissance flights flown after the fires were extinguished. The boundaries were therefore approximate.

The moose survey area was laid out on 1:50,000 scale topographical maps. Sample units were laid out on these maps, based on habitat data and geographic features. Based on the LANDSAT maps and fire maps each sample unit was stratified as to the probability of locating moose within the block. The stratification was based on the proportion of deciduous vegetation i.e. the higher the proportion of deciduous vegetation the higher the density of moose should be found. Four categories were used: High (H), Medium (M), Low (L) and Zero (0).

On November 20 and 21, 1989 we flew a reconnaisance of the entire study area in a Cessna 206 to determine the relative densities of moose in the area. This initial survey was flown at an altitude of 100-150m above ground level (agl) at a speed of approximately 130 Kph. In both the fixed-wing aircraft and the helicopter used subsequently, the navigator (RG) was seated in a front seat while two observers were seated in the back seats. During the reconniassance, we flew transects in a north/south direction approximately 4 km apart in an attempt to cross each SU twice. Each time a moose was observed we circled the animal to determine if it was accompanied by other moose and to obtain sex and age data. We also recorded moose tracks and other animal sightings.

The survey area was stratified into zero, low and medium density areas based on the tracks and moose observed during the reconnaisance flights. There was insufficient sign or numbers of moose to declare any area a high density zone. Using a Bell 206 JetRanger helicopter from November 22-25, we counted all of the moose in 21 randomly-chosen SU's.

We would totally search a particular SU for all of the moose and other wildlife in it. This was usually accomplished by flying the helicopter back and forth across the SU so that no portion was missed. When a moose was located the animal would be circled to check for other animals and to determine its sex and age. Sex determination was based on antlers and vulva patches, with some reference to facial colours (Oswald 1982). Yearling bulls were identified on the basis of antler development and size (Oswald 1982). Certain broad habitat characteristics of the area in which the animals were found were also recorded and the location recorded on the 1:50,000 map.

Once we began searching low and medium density areas we checked the precision of our estimates by analyzing the data on a microcomputer each evening. In this way we were able to determine our current Coefficient of Variation (CV). We then added our best guess of the next day's results to predict its effect on the CV. In this way we decided whether to expend further effort on medium or low density areas, or to terminate the survey entirely.

Our estimates were calculated using the program "Moosepop" (Reid 1989) which is based on Gasaway et al. (1986) and follows Jolly's Method 2 for unequal sample sizes (Jolly 1969). Before using Moosepop in the field, we compared results from it with results from a program prepared by the senior author which had been used for several years by our Department on Apple microcomputers. The test data came from three separate previous surveys. There were only minor differences.

A statistical comparison (X^2) was made between the stratification based on the LANDSAT map and the aerial stratification (Zar 1974). The accuracy of the two stratifications were then compared based on the sample units censused.

RESULTS

The initial image produced using the fast parallelepiped classification provided excellent differentiation between deciduous and coniferous forests. Areas classified as black spruce swamp and rock outcrop were not as well differentiated. Areas initially classified as sparse vegetation were found to be open coniferous forests with rock or lichen understories. These discrepancies were adjusted in the second fast parallelepiped classification.

A total of 11.5 hours was flown for reconnaisance in the fixed-wing aircraft and then a further 17.5 hours were flown in the helicopter counting the moose within the chosen sample units. Mean SU size was 20.5 km^2. There was approximately 50cm of snow on the ground. During the aerial survey the temperatures ranged from -20 to -33 degrees Celsius. Most of the survey occurred under 50-100% cloud cover but the winds were light.

Based on the reconnaisance flights we stratified the area into 84 zero, 103 low and 10 medium density moose areas. We counted all the moose in 20 SU's (17.7%) and calculated an estimate of 99 $\pm$56 (S.E.) moose with a CV of 0.56. This estimate includes sightability factors of 1.02 and 1.15 (Gasaway et al. 1986) Densities ranged from 0.03 to 0.10 moose per km^2 in the low and medium density areas respectively and averaged 0.02 moose per km^2 for the 4,332 km^2 study area (including the zero areas). We found that 40% of the adult cows were accompanied by calves. A ratio of 60 calves per 100 cows was observed for the whole area with a twinning rate of 50% (the proportion of cows with twins compared to the total number of cows with calves). The number of bulls (including yearlings) found per 100 cows was 50. We also observed 10 wolves (Canis lupus), six foxes (Vulpes fulva) and many hundreds of barren-ground caribou of the Bathurst herd (*Rangifer tarandus groenlandicus*).

Table 1. Moose population characteristics found in the north Great Slave Lake area in November 1989.

Characteristic	**Stratum** Medium	Low	Zero	Total	Non-zero Total
Area (km^2)-	216.0	2,109	2,017	4,332	2,325
# of SU's-	10	103	84	197	113
# of SU's Sampled-	6	14	0	20	20
% of SU's Sampled-	60.0	13.6	0	-	17.7
Search Intensity- (min/km2)	1.2	1.6	0	-	1.4
Pop'n. Est.-	28.7	70.2	-	98.9	
Variance	*15.8	*2.240	-	3,117	
S.E.	*3.97	*47.3	-	55.8	
C.V.	*0.16	*0.79		0.56	
Density (moose/km^2)	0.13	0.03		0.02	
Bulls per 100 cows-	28.6	100.0		50.0	
Calves per 100 cows-	71.4	33.3		60.0	
Twinning Rate- (sets of twins)	66.7 (2)	0.0 (0)		50.0 (2)	

NOTES: Estimates, densities and variances have been adjusted for sightability except where indicated by "*". Age and sex ratios are based only on animals observed, not estimated. Number of bulls includes yearling bulls. Twinning rate is the proportion of cows with twins to total cows with calves.

Based on our aerial reconnaissance we concluded that there were no moose in the northern half of the study area as no moose or moose tracks were observed. The 84 sample units in this area were stratified as "zero" and were not included in the survey. In the northern half the LANDSAT map suggested that two sample units had a high probability of moose, five had a medium probability, 35 had a low probability while the remaining 42 had zero probability.

The stratification of the southern half of the study area divided the sample units into high (3 or more moose expected) and low (less than 3 moose expected). The classification given by the LANDSAT map was independent of the stratification by the aerial survey (X^2 = 2.878 $0.25 \leq P \leq 0.50$). Even after combining the High and Medium, and Low and Zero classifications from the LANDSAT classification the two were independent (X^2 = .138 $0.50 \leq P \leq 0.75$).

An assessment of the accuracy of the two stratifications was conducted by comparing the stratifications with what was actually found in the 20 sample units surveyed by helicopter. The LANDSAT stratification correctly predicted the densities in 8 sample units (Table 2). Six of those correct predictions were for zero density SU's. The major source of error was not finding any moose in units stratified as low. Only one unit stratified as zero by LANDSAT contained moose. The aerial stratification predicted the correct density only four times but none of those SU's predicted as zero density were ever checked. The major source of error also resulted from units stratified as low having no moose (Table 2.). Of the six sample units stratified as medium by the aerial stratification only three were actually medium density (>3 moose) and one had no moose.

Table 2. Comparison of the accuracy of the LANDSAT and aerial reconnaissance stratifications.

LANDSAT Stratification	Observed Density Med	Low	Zero
High/Med	0	1	0
Low	3	2	7
Zero	1	0	6

Aerial Stratification	Observed Density Med	Low	Zero
Medium	3	2	1
Low	1	1	12

To further evaluate the LANDSAT stratification, the number of moose observed in both the reconnaisance survey and the helicopter survey and a description of the habitat (from aerial survey) in each of the sample units where moose or moose tracks were observed were summarized (Table 3). Of these 18 units, four were stratified as zero areas and would not have been included in the survey under the LANDSAT stratification. Only one of the four were actually included in the helicopter survey based on the aerial stratification and were thus thoroughly searched.

Table 3. Summary of LANDSAT classification (CLS) and habitat types in sample units where moose or moose tracks were observed.

SU#	CLS	MOOSE	HABITAT DESCRIPTION
109	L	T	1973 burn - predominantly mixed/deciduous dominant and deciduous
132	L	4	1973 burn - predominantly deciduous with mixed/conifer dominant on outcrops
184	0	3	1979 burn - predominantly bare outcrop with willows along the edges of lakes and creeks.
193	0	1	Mature open coniferous and mixed/coniferous dominant with a few willows along creeks.
7	M	T	1979 burn - predominantly early regeneration mixed/deciduous dominant and deciduous.
17	0	3	1979 burn - predominantly bare outcrop and open coniferous with willows along the edges of lakes and creeks.
18	L	1	1979 burn - predominantly bare outcrop and open coniferous with willows along the edges of lakes and creeks.
38	L	4	1973 burn - predominantly young mixed/coniferous dominant on outcrops with willow regeneration in lower areas and along creeks and lakes.
56	L	2	Mature mixed/deciduous dominant with open conifer on outcrops.
57	M	1	1973 burn - predominantly young mixed/coniferous dominant on outcrops with willow regeneration in lower areas and along creeks and lakes.
66	L	6	1973 burn - predominantly open coniferous regeneration on outcrops with willows along creeks and lakes.
86	L	1	1973 burn - predominantly deciduous (birch) regeneration with willows along creeks and lakes.
87	L	2	1973 burn - predominantly young mixed/coniferous dominant on outcrops with willow regeneration in lower areas and along creeks and lakes.
80	H	4	1973 burn - predominantly young mixed/coniferous dominant on outcrops with willow regeneration in lower areas and along creeks and lakes.
153	L	1	Predominantly mature black spruce with deciduous along lake shores and creeks.
107	L	4	Predominantly mature open coniferous with bands of deciduous along shores of lakes and creeks.
111	0	2	Predominantly mature open coniferous with mine site and tailings ponds. Some willow along shore of ponds.
58	L	2	1973 burn - predominantly open coniferous regeneration on outcrops with willows along creeks and lakes.

DISCUSSION

Moose Population Information

The population estimate was 98.9±55.8(S.E.), an extremely low density of 0.02 moose per km^2. The coefficient of variation of 0.56 is high and indicates a lack of precision, probably due to the low densities and increased effect of a relatively contagious distribution at this time of the year. This density is considered low even for the Northwest Territories (Graf 1992) but Lines (1968), Baker (1974) and Jacobsen (1982) all found similarly low densities in this same general area in the past 25 years.

This area is not prime moose habitat. It is the western edge of the Canadian Shield with little topsoil over the bedrock. Much of the habitat is coniferous, either jack pine or black spruce and only the areas along the small streams and some edges of lakes and ponds support moose browse species. Old burns may provide more palatable browse species for the moose depending upon which coniferous tree species populated the area before the fire.

In addition to not being prime moose habitat, the hunting pressure in the area has continued to be high for many years. Both native and resident hunters harvest moose from this area either opportunistically while hunting caribou or while specifically on moose hunts (Treseder and Graf 1985). We are unaware of any decrease in hunting pressure in the last five years.

Predation rates are not known for moose in this area but predator density is probably quite high. Wolves associated with the Bathurst caribou herd would prey upon moose during the winter and some wolves are known to summer in the area. Black bears (*Ursus americanus*) are quite prevalent in the area and probably take numerous calves each spring and summer as occurs in other areas (Schwartz and Franzmann 1989).

The sex and age ratios are based on such small sample sizes that no conclusions should be drawn from them except to note that calves (including two sets of twins) are still being born.

We have no management recommendations to make at this time based on this survey of a portion of the area north of Great Slave Lake. The density of the moose population is likely being held down by a combination of high predation rates, high hunting pressure and only poor to fair habitat.

Our search intensity of 1.4 minutes per km^2 (Table 1) is similar to the 1.6 of Jingfors et al. (1987) in their helicopter portion near Norman Wells and to the 1.5 to 1.9 recommended by Gasaway et al. (1986). Gasaway et al. (1986) suggests that determining a good sightability correction factor (SCF) for low density areas is generally not worth the expense as the probability of moose occurring in an intensively searched area of about 5 km^2 is quite low. Instead they suggest using the mean from other surveys which have occurred in similar habitat. We have therefore chosen data from Tanana Flats and Lower Nowitna which are both described as lowland flats with large areas of shrubs (Gasaway et al. 1986:p35). These data result in an mean observed SCF of 1.15 times a constant SCF of 1.02, yielding a final population estimate SCF of 1.175.

The LANDSAT Experiment

Over 50% of the moose observed were located in two large 1973 burns with a further 17% of the moose located in 1979 burns (Table 3). Unfortunately the LANDSAT classification used did not clearly show the fire boundaries or the age of stands. The emphasis for the enhancement was to clearly distinguish between coniferous and deciduous forests. The fire boundaries were obscured as the post fire regeneration reflected the unburnt forest in species composition.

Two dominant factors appeared to account for the distribution of moose in the study area; species composition and age of stand. The image produced by the fast parallelepiped classification appeared to accurately describe the species composition, however, the age of the stands could not be determined. Although approximate fire boundaries were used insufficient weight was given to the age of the stands when the LANDSAT stratification was conducted.

The low density of moose in the study area made the assessment of the technique ambiguous. At the densities observed, sample units of excellent moose habitat were unoccupied while, by chance, several moose were located in sample units that were predominantly conifers. This brings the major assumption of this experiment to light- we assumed that habitat quality was the main factor determining moose density. This experiment is probably rigorous enough to withstand some level of bias but in order to account for any bias caused by hunting it does require the secondary assumption that harvest pressure is applied equally across the moose distribution. The resulting distribution must then be a good index, at all densities, of what would have been there without harvesting. We could not test for this error but it is our opinion that the level of hunting probably biased the results significantly by creating such low densities in the study area that the correlation between good moose habitat and moose densities may not be evident.

The stratification of the study area by LANDSAT TM imagery and aerial reconnaissance was not consistent between techniques as only 50.3% (99/197) of the sample units were stratified the same by both techniques. However, LANDSAT was as accurate as the reconnaissance flight technique in predicting the number of moose found in a sample unit.

Although the results from this study have not demonstrated that the use of LANDSAT TM data to stratify moose surveys on the precambrian shield is an effective and efficient technique, they do suggest that the technique is as least as accurate as the aerial stratification. With improvements, such as: a) accounting for stand age, b) accounting for the effects of hunting on distribution and abundance and c) increasing the SU size to $30km^2$ to lower the number of zero SU's, the technique could be more even more effective and efficient.

ACKNOWLEDGMENTS

We would like to thank Helmut Epp, Remote Sensing Specialist, for his assistance with the LANDSAT image analysis and John Lee, Wildlife Technician for his assistance with ground truthing the initial image. Laurie Buckland (Ren.Res., HQ) and Joe Mackenzie (Ren. Res., Fort Rae) were efficient and cheerful observers in the airplane and helicopter and we would like to thank them for their efforts.

LITERATURE CITED

Bowles, L., R. Dixon and B.Knudsen. 1984. Moose habitat analysis in north-cental Manitoba from LANDSAT data. Manitoba Natural Resources.

Elliot, D.C.M. 1988. Large area moose census in northern Manitoba. Alces. 24:48-55.

Gasaway, W.C., S.D.Dubois, D.J.Reed and S.J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the Univ. of Alaska No. 22. 108pp.

Graf, R.P. 1992. Status and management of moose in the Northwest Territories, Canada. Proceedings 3rd Int'l. Moose Symp., Syktyvkar, U.S.S.R.- In Press.

Jingfors, K., R.Bullion and R.Case. 1987. Abundance and population composition of moose along the Mackenzie River, November 1984. Gov't. of NWT File Rept. No. 5. 39pp.

Jolly, G.M. 1969. Sampling methods for aerial census of wildlife populations. East Afr. Agric. For. J. 34:46-49.

Laperriere, A.J., P.C.Lent, W.C.Gasaway and F.A.Nodler. 1980. Use of LANDSAT data for moose-habitat analysis in Alaska. J. Wildl. Manage. 44(4):881-887.

Oosenburg, S.M., T.H. Perrott and C.E. Butler. 1988. Moose habitat mapping in central Newfoundland using digital LANDSAT thematic mapper data. Alces 24:164-177.

Oswald, K. 1982. A manual for aerial observers of moose. Ont. Min. of Nat. Res. Publ. 103pp.

Polson, J. 1987. Cover type mapping in the commercial forest region of Saskatchewan for moose habitat. Saskatchewan Research Council Tech. Rep. No. 207.

Reid, D.J. 1991. MOOSEPOP. Alaska Dept. Fish & Game Rep. In Press.

Schwartz, C.C. and A.W. Franzmann. 1989. Bears, wolves, moose, and forest succession, some management considerations on the Kenai Peninsula, Alaska. Alces 25:1-10.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc., N.J., USA.