LARGE AREA MOOSE CENSUS IN NORTHERN MANITOBA

D.C.M. Elliott,
Manitoba Department of Natural Resources, Thompson, Manitoba, R8N 1X4

ABSTRACT: A moose census for the 152000 km^2 Northern Flood Agreement area was designed and flown. Expeditious completion of the census within fiscal limitations was fundamental to the survey design. Satellite multispectral scanning data were used to classify and map winter moose habitat. Stratification was based on the habitat maps and the previous 30 years' fire history. A random selection procedure was used to select variable size sample plots within 5 habitat types. Plot shapes were irregular and followed geographic features for easy definition. Plot boundaries did not cross habitat boundaries. Between November 1983 and December 1987 two censuses of the area were completed. Study areas in a given year ranged between 14000 and 78000 km^2. Moose densities were greatest in young mixed wood habitat. Moose per plot were poorly correlated with plot size. Degree of homogeneity of age of early successional growth and hunting affected distribution of moose groups in young mixed wood habitat.

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Major hydro-electric projects were undertaken in northern Manitoba in the 1970's. These projects had impacts on the resources of the area and the residents whose livelihood depended upon these resources. A forum for mitigation and compensation was established with the signing of the Northern Flood Agreement (NFA). The NFA defined an area which totalled some 152000 km^2. A Wildlife Advisory and Planning Board was established as set out in the NFA. In 1982 this Board requested the Department of Natural Resources to carry out a moose monitoring program for the purpose of planning moose management for the NFA area. The monitoring was to be done expeditiously and with reasonable cost.

In 1982 there was very little information relevant to the area on which to plan a moose census. The previous assessment of the status of moose in the area had been completed in 1954 (Bryant 1955). Habitat information was limited to forest inventory data. This data set did not cover the entire area and was unsuitable for planning a census of this scale (Bowles *et al.* 1984). Problems with the forest inventory data related to habitat definitions reflecting merchantable timber. Unproductive forest from a timber utilization standpoint was lumped and included both productive and unproductive moose habitats.

The purpose of this report is to describe the methods used to map habitat, stratify the census area, and census moose in a very large area. An analysis of the mapping and census results is discussed.

STUDY AREA

The NFA area lies between 53°15' N and 58°15' N latitude and 94°00' W and 101°00' W longitude. Within the NFA area the study area was defined in 2 parts (Fig. 1). The southern area followed the NFA boundary. The northern area included only the area of productive moose habitat. Unproductive habitats within the Boreal Forest - Tundra transition zone were excluded as a block. These two areas were further subdivided into 5 census areas.

The area lies mostly within the Canadian Shield. Silty and clayey soils predominate. Soil depth ranges from shallow to moderately deep. Bedrock is mainly Precambrian granite with Paleozoic limestone in the northeast and southwest. Organic soils, muskeg and string bogs are scattered throughout the area. Rock outcrops are present throughout the area but are not the dominant landform. Most of the study area falls within the discontinuous permafrost zone (Lockery 1984). Permafrost is more widespread in the northern portion of the study area.

Vegetation is typical of the boreal forest and is consistent throughout the area except in the extreme northeast section. Here there is the transition to stunted spruce forest and tundra of the Hudson Bay Low lands. Black spruce (*Picea mariana*) is the dominant forest species. White spruce (*P. glauca*), jackpine (*Pinus banksiana*) and larch (*Larix laricina*) are common throughout the area. Balsam fir (*Abies balsamea*) is found only in the southern portion. Hardwoods consist of poplar (*Populus tremuloides* and *P. balsamifera*) and birch (*Betula papyrifera*). These mainly occur interspersed with conifers as mixed wood stands. Pure hardwood stands are limited in size and usually found near or along the major rivers. Sites in early post-fire successional stages of growth commonly have a mix of alder (*Alnus spp.*), willow (*Salix spp.*), poplar, birch and one or more conifer species.

There is very limited logging activity in the NFA area. Forest harvesting is mainly for fuelwood. Some communities have small sawmills but the forestry operations suppling the mills are limited to a few tens of hectares.

Hunting is concentrated on the limited road network and major rivers. Remote areas are hunted where there is access by float plane. Only Census Area 2 (Fig. 1) has significant hunting pressure. Hunting in the balance of the NFA area is concentrated in relatively few locations which offer good access and abundant moose. About 80% of the known kill occurs in the months of September and October. Total known kill for licenced hunters and Treaty Indians combined averages about 350 moose per year. The total estimated kill is double the known kill.

METHODS

Habitat Inventory

A winter moose habitat inventory was conducted for the entire NFA area. Criteria for the inventory included:1) habitat classification as closed conifer (> 40% crown closure), open conifer, mixed wood-deciduous (> 10% hardwood in stand), bog, marsh, and water; 2) capability to produce colour coded habitat maps; 3) area summaries for each habitat class; and 4) project completion within fiscal and time limitations.

LANDSAT multispectral scanner data were used for this phase of the project. Resolution was 0.25 ha. The basis of the analysis was an unsupervised cluster analysis employing a maximum likelihood algorithm.This analysis was described by Bowles *et al.* (1984). This classification produced computer-compatible data which were transcribed as color coded habitat maps on an inkjet plotter.

A sample of 1492 km^2 within the first 4 map sheets produced (14025 km^2) was evaluated for classification accuracy by ground truthing and comparison with forest inventory maps (Bowles *et al.* 1989). Sampling units were 16.2 ha.

The habitat inventory and mapping did not differentiate stand age. The fire history for the previous 30 years was overlaid on the habitat maps in order to separate young successional mixed wood from mixed wood stands of mature trees. These areas were separated into 0- to 5-year post-fire growth as Burn habitat, and 6- to 30-year post-fire growth as Young Mixed Wood habitat. The balance of the Mixed Wood-Deciduous habitat was called Mature Mixed Wood.

Stratification and Sampling Procedures

Initial stratification recognized each habitat classification as a stratum. However, because there were no preliminary estimates of variance, sample allocation was determined by progressively evaluating the estimated number of moose and variance in each stratum (Knudsen and Didiuk1985). An optimum allocation was determined as outlined in Snedecor and Cochran (1967:523) and adjusted every few days as more plots were censused.

A post-census evaluation of the southern area based on observed densities and habitat

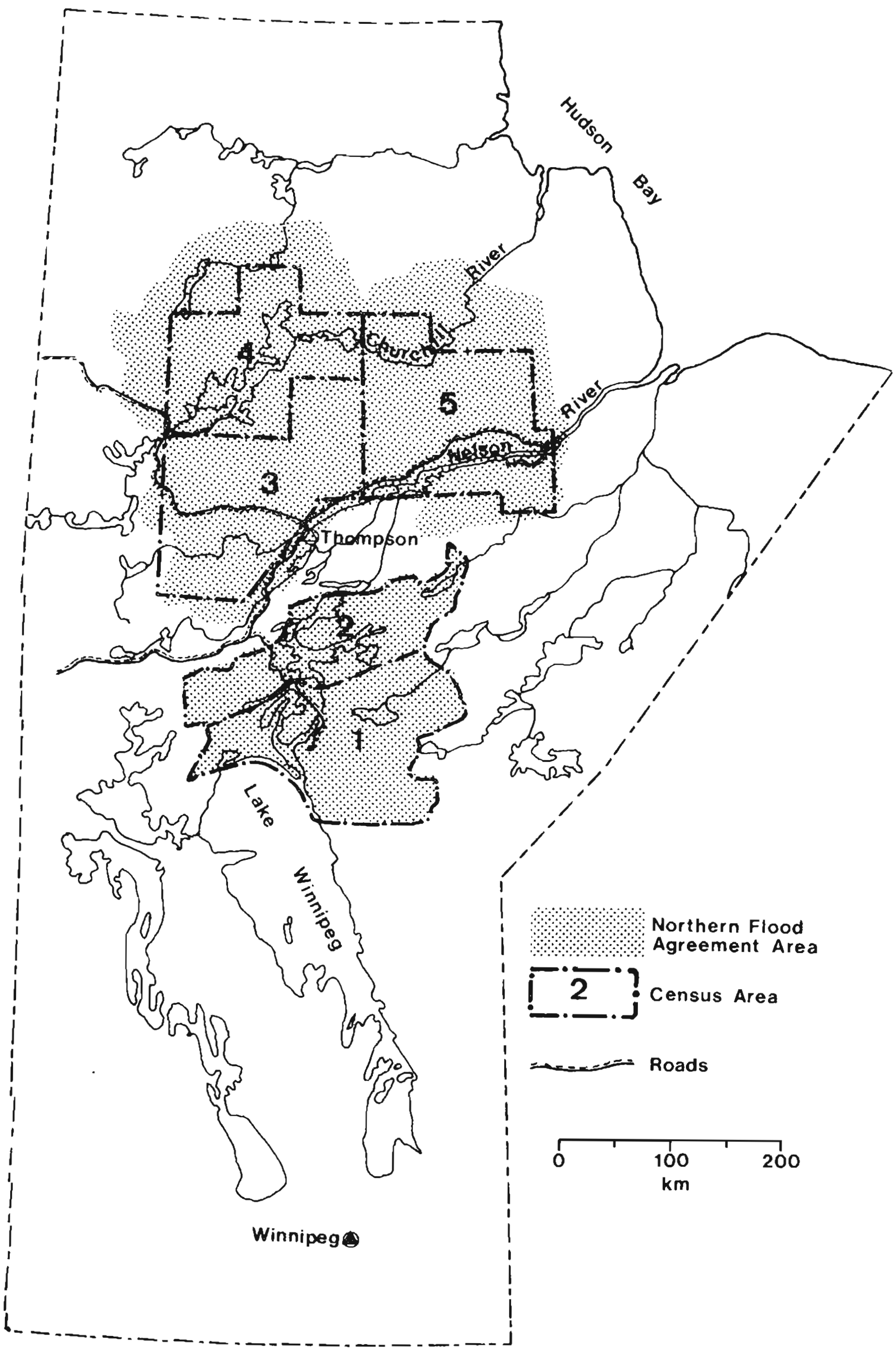

Fig. 1. The Northern Flood Agreement area showing the 5 Census Areas.

use by moose was used to restratify the entire NFA area and allocate sampling effort using standard procedures (Snedecor and Cochran 1967:523). This stratification included an unproductive habitat type to which a moose density of 0 was assigned. No sampling was allocated in this stratum. Prior to surveying the northern 3 Census Areas a reconnaissance flight was made to delineate the boundary of the unproductive habitat in the northeast sector. This consisted of the Taiga-Tundra transition and was excluded as a block. A random selection procedure was used for selecting sample plots. The plot location was determined by randomly selecting a 10 km by 10 km block (UTM grid). The plot was then outlined within the available habitat. Plot boundaries followed habitat boundaries and geographic features for easy definition. Plot boundaries did not cross habitat boundaries. Plots were irregular in shape and of variable size. They averaged about 25 km^2 (range 2.8 - 55.9 km^2).

Census Procedures

With one exception single engine gas turbine helicopters were used for all censuses. In the the 1983/84 census of the southern 2 areas a fixed-wing aircraft was used for some plots with an open cover type. Flight paths within the sample plots were spaced for 100% coverage of the plot. A double search was effected by the flight path coinciding with the outer edge of the previous search strip. Each strip was searched by each observer or by the same observer twice depending on whether the flight pattern was an inward spiral or a series of transects. This search pattern also exchanged the inner and outer boundaries of the search strip between searches. Moose were recorded on 1:50000 maps to avoid double counts. Airspeeds varied between 75 and 100 km/h with the helicopters and were about 160 km/h with the fixed-wing aircraft. Altitudes ranged between 125 and 175 m.

Tracks were not always useful in locating moose. They were not used to adjust estimates for moose not seen. This region often has long periods of little or no snowfall. For example during the 1984/85 censuses there was a period of almost 4 weeks between significant snowfalls (> 2cm). As a result it was very difficult to estimate track age especially where tracks are sheltered from wind. The absence of tracks was a good indicator that moose were not missed on a plot. Another problem associated with tracks was sympatric woodland caribou. Single caribou tracks were almost indistinguishable from moose tracks.

Statistical Procedures

Cochran's method for an unbiased estimate of true variance for unequal sized plots was used (Seber 1982:23). This estimate of variance was used in calculating the confidence interval. Chi square test was used to determine habitat selection. Distribution within a habitat type was tested for randomness with Poisson distribution.

RESULTS AND DISCUSSION

Habitat

In total 114932 km^2 of the NFA area were included in the moose censuses. Approximately 37000 km^2 in the northern and northeastern sectors were excluded as unproductive moose habitat. Within the censused area 70763 km^2 were productive moose habitats. The balance was either water or unproductive habitat (Table 1). Accuracy of the mapping ranged from 67% for mixed woods to 99% for water (Table 2). Inaccuracies in classification were due mainly (60%) to the way this project differed from the Forest Inventory in classifying bog. The former classification method separated bog, open conifer, closed conifer, and mixed wood habitats based on species composition and crown closure. These unproductive forest lands could be classed as various moose habitat types. The Forest Inventory combined all bog types as a single classification. For example willow flats were

Table 1. Summary of moose habitat inventory within the censused portion of the NFA area.

	Habitat	Area (km²)
A. Productive habitats	Closed Conifer	33827
	Open Conifer	25820
	Mature Mixed Wood	2282
	Young Mixed Wood	5723
	Burn	3111
	Total	70763
B. Unproductive habitats	Muskeg, Cultural	26494
	Water	17675
	Total	44169

typed as a bog community by the Forest Inventory but as productive mixed wood-deciduous by the satellite inventory. Muskeg was an unproductive classification in both inventories.

The other major area of classification inaccuracy was some post-fire successional growth. Errors occurred on 2 map sheets in distinguishing between early succession and-bog. This was due to the burn area having similar species composition and spectral reflectance as some muskeg plant communities. This was overcome by plotting fire history on the habitat maps.

A shortcoming of this inventory technique was the lack of sensitivity for stand age. Moose densities differ significantly within mixed wood habitat depending on the maturity of the trees. This becomes a problem in the absence of fire records.

Stratification and Sampling

This inventory and mapping technique had the major advantage of eliminating the series of pre-census stratification flights. Moose densities were accurately predictedby the stratification (Table 3).

The initial census was flown during 2 consecutive winters. In the winter of 1983/84 the southern portion (about 37000 km²) was censused followed by the northern portion (about 78000 km²) in 1984/85. Sampling effort was 18% and 10.5% in the south and north, respectively.

Table 2. Classification accuracy of satellite habitat inventory (source: Bowles *et al.* 1984).

Habitat	Number of Sampling Units	Proportion Correct
Conifer	986	0.849
Mixed Wood	156	0.667
Deciduous	55	0.855
Bog (Muskeg)	731	0.715
Marsh	90	0.889
Water	303	0.993

Table 3. Moose densities (moose/km²) found in sampled strata in NFA moose censuses between 1983 and 1987.

Habitat	Mean Density	Range
Closed Conifer	0.037	0.020 - 0.063
Open Conifer	0.053	0.014 - 0.160
Mature Mixed Wood	0.028	0.003 - 0.056
Young Mixed Wood	0.205	0.152 - 0.285
Burn	0.076	0.025 - 0.169

Following an analysis of the data the area was divided into 5 census areas. In the southern area, division was based on moose distribution and densities within young mixed wood habitat yielding Census Areas 1 and 2. The division of the northern area into 3 Census Areas was based on the cost and budget available for replicate censuses.

Replicate censuses in 4 of these 5 areas were flown over 2 consecutive winters starting in 1986/87. Census areas ranged between 14100 km² and 24100 km². Due to budget reduction sample size was decreased. An optimal allocation of sampling based on variance was first calculated (Snedecor and Cochran 1967). Extra Young Mixed Wood plots were added according to flying hours available (Table 4).

Census Procedures

After assessing the first year's flights the

Table 4. Sampling effort (% of stratum searched) and area in the 2 original and 4 replicate census areas of the NFA area.

	Original		Replicate			
	South	North	Area 1	Area 2	Area 3	Area 4
Effort	18.0	10.5	11.1	5.5	9.4	9.1
Section Area (km²)	36670	78262	14125	22708	24114	23961

NFA moose censuses were done entirely with helicopter. Fixed-wing aircraft crews operating only in open habitats failed to determine sex or age categories of 10% of moose observed. Helicopter crews recorded no unknowns. Moreover, sexing of antlerless moose was less time consuming and safer in helicopters than in fixed-wing aircraft. Flight crews reported being less fatigued after a day in the helicopter than after the same time in a fixed wing aircraft.

Census

Moose densities were greatest in young mixed wood habitat in all census areas in all cenus years (Table 5). The small sample size had an effect on variance. When replicate sampling was less than the original, confidence intervals increased. Variable plot size increases variance when moose per plot are proportional to plot size (Seber1982). The third major contributer to variance is contagious distribution of the moose. In census area 2 even though 86.6% and 93.3% of the mature mixed wood habitat was sampled confidence intervals were 100%. In each of the censuses only 1 plot in this habitat was found to have moose.

Young mixed wood habitat was the only one with moose densities exceeding 0.1 moose/km^2 and it had the greatest sampling effort. Plot size and dispersal was examined only within this habitat. Correlation of number of moose on plot and plot size was generally poor except for 2 cases (Table 6). The Census Area 2 replicate moose and plot size were positivley correlated and in the original Area 4 census moose and plot size were negatively correlated. Plot size in most cases therefore, contributed little to the variance.

Contagious distribution likely contributed most to variance in these censuses. With more empty plots and more plots with many moose than random distribution expects, the variance of moose per plot will be greater than the mean(Seber 1982). In all cases, in young mixed wood habitat, sample variance was greater than the square of the mean.

The distribution of groups of moose in young mixedwood habitat was fitted to Poisson distribution. In 3 of 4 censuses illustrated, distribution was found to be contagious at the 90% confidence interval. The fourth case had just slightly less than 90% chance of difference from Poisson distribution (Fig.2). The distrubtion of groups of moose in this habitat had 3 general shapes. First, in Areas1 and 4 there existed prior to the censuses, low to moderate hunting levels. The young mixedwood habitat was relatively homogenous in terms of age (years since burn). Second, Area 3 had low to moderate hunting levels but the young mixed wood habitat was variable. Plots noted as mature were excluded from this area for this analysis, (See note onTable 5). This area had some plots in very productive habitat that were unhunted due to lack of access and had many groups of moose on plot. There was a large amount of 6- and 7-year post-fire habitat (> 1000 km^2). Moose densities within these areas were greatest around the periphery and decreased toward the centre of the burn area. These 2 factors produced the "4+" peak and the "0" group peak in this distribution pattern. The third distribution (Area 2) was in an area with homogenous young

Table 5. Sampling effort and observed moose density ± 95% confidence interval (%) in original and replicate (in parentheses) censuses.

Census/habitat	Sampling effort		
	Plots	% of Habitat	Moose density (moose/km^2)
AREA 1			
Closed Conifer	56 (16)	10.2 (2.9)	0.020 ± 6.5 (0.063 ± 18.0)
Open Conifer	46 (7)	24.0 (3.6)	0.018 ± 8.0 (0.036 ± 47.5)
Mature Mixed Wood	5 (6)	12.5 (15.0)	0.011 ± 38.9 (0.010 ± 85.7)
Young Mixed Wood	29 (14)	28.1 (13.6)	0.189 ± 10.0 (0.238 ± 11.2)
Burn	3 (5)	15.8 (26.3	0.025 (0.160 ± 54.4)
AREA 2			
Closed Conifer	37 (8)	16.7 (3.6)	0.029 ± 8.4 (0.035 ± 44.3)
Open Conifer	19 (5)	13.2 (3.5)	0.014 ± 18.9 (0.030 ± 57.4)
Mature Mixed Wood	13 (14)	86.6 (93.3)	0.017 ± 100.0 (0.003 ±100.0)
Young Mixed Wood	22 (19)	48.8 (42.2)	0.165 ± 9.5 (0.152 ± 14.7)
Burn	3 (3)	33.3 (33.3)	0.128 (0.029)
AREA 3			
Closed Conifer	47 (16)	13.7 (4.5)	0.046 ± 5.6 (0.024 ± 23.2)
Open Conifer	14 (3)	9.0 (1.9)	0.022 ± 28.1 (0.102)
Mature Mixed Wood	*	*	*
Young Mixed Wood	51 (24)	33.1 (15.6)	0.232 ± 4.2 (0.285 ± 8.8)
Burn	26 (15)	43.3 (25.0)	0.051 ± 7.8 (0.126 ± 11.5)
AREA 4			
Closed Conifer	17 (9)	7.2 (3.8)	0.027 ± 44.1 (0.049 ± 32.8)
Open Conifer	20 (8)	10.2 (4.1)	0.024 ± 18.2 (0.047 ± 40.6)
Mature Mixed Wood	18 (20)	29.5 (32.2)	0.056 ± 12.7 (0.055 ± 13.6)
Young Mixed Wood	9 (13)	11.5 (16.7)	0.198 ± 27.0 (0.182 ± 18.6)
Burn	2 (1)	40.0 (20.0)	0.169 (0.000)

* Mixed woods were not separated due to incomplete fire records prior to 1970.

Table 6. Correlation coefficients (r^2) between moose per plot and plot size in young mixed wood habitat for original and replicate censuses in the NFA area.

Census area	Correlation coefficient	
	Original	Replicate
1	0.0421	0.1298
2	0.0316	0.2418
3	0.0132	0.0085
4	0.3510	0.0509

mixed wood habitat and a high rate of exploitation by hunting. Moose densities increase with increasing distance from human population centres and with decreasing ease of access. This pattern indicates over-exploitation of the moose herd has occurred.

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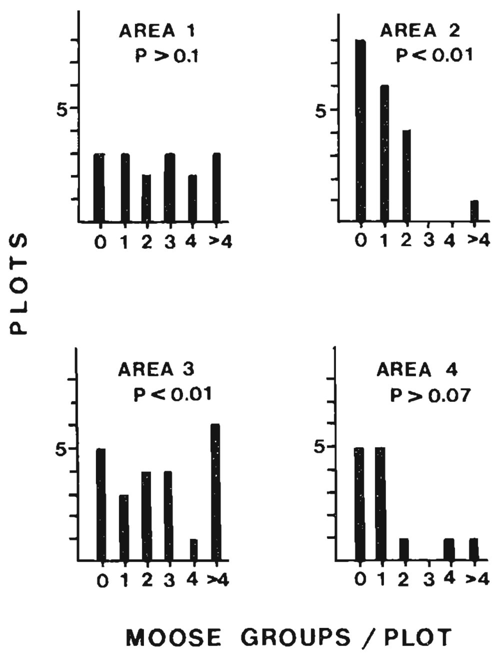

Fig. 2. Distribution of moose groups per plot in young, mixed-wood habitat. P value is level of significance of deviation from Poisson by actual distribution.

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