USING GIS TO MODIFY A STRATIFIED RANDOM BLOCK SURVEY DESIGN FOR MOOSE

Douglas C. Heard[1], Andrew B. D. Walker[2], Jeremy B. Ayotte[1], and Glen S. Watts[1]

[1]British Columbia Ministry of Environment, 4051 – 18th Ave., Prince George, British Columbia, Canada, V2N 1B3; [2]5657 Simon Fraser Ave., Prince George, B.C., Canada, V2N 2C4

ABSTRACT: We modified the standard, stratified random block design used typically in aerial surveys of moose (*Alces alces*). We laid a grid of approximately 9 km^2 cells over our study area, and GIS was then used to allocate polygons into one of 2 strata within each grid cell. The 2 strata were based upon vegetation attributes that were predicted to have either high or low moose density from previous research. We assumed that polygons of early seral forest stands (<40 yr), shrubs, and meadows would have high moose density relative to other vegetation attributes. Vegetation polygons were often <1 km^2, consequently, single grid cells usually included >1 high and low density polygons. Adjacent cells were amalgamated to produce sample units with >4 km^2 of high density stratum area. Real-time navigation was used and the flight track was recorded over a map of sample units, strata boundaries, and topographic features to accurately identify polygon boundaries and assign each sighted moose to the appropriate strata. We concluded that our approach was efficient and effective in fine-grained environments where the relative selection by moose for vegetation patches is well understood, and those patches are mapped in digital databases.

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Moose population parameters such as density, and age and sex composition are typically gathered from aerial surveys that incorporate a stratified random block design (Boertje et al. 1996, Timmerman and Buss 1998). The often used stratified random block design of Gasaway et al. (1986) was developed to survey moose in the northern boreal forest, the subalpine zone, and the northern coastal shrub zone where vegetation patches are large at the northern range of moose distribution. In this paper we describe a modification of the stratified random block design (Gasaway et al. 1986) for use in central British Columbia where distribution of moose in early winter is predictable, and population density varies substantially among small, discrete, and mapable patches of vegetation (Nielsen et al. 2005).

METHODS

Study Area

Beginning in the late 1960s, clearcut logging superseded fire as the primary landscape disturbance in central British Columbia (Heard et al. 1999, Nielsen et al. 2005). The early seral vegetation communities created by clearcutting were largely responsible for the relatively high abundance of moose throughout much of interior British Columbia (Spalding 1990, Thompson and Stewart 1998, Heard et al. 1999, Shackleton 1999). The resulting landscape contained a mosaic of multi-aged stands (i.e., regenerating cutblocks) ranging from 10-10,000 ha within a mature forest matrix; for a landscape view go to Google Earth maps (<http://earth.google.com>) at 53º 55’ N x 122º 45’ W at an eye altitude of 200 km.

Stratification

Previous research revealed that moose selected low-elevation (<1200 m) cutblocks with a few, specific vegetation attributes during early winter (Thompson and Stewart 1998, Nielsen et al. 2005). Therefore, we developed a stratification design that used 2 strata (S1 and S2) based upon use of different vegetation types by moose. Although potential high population density patches were small compared to the sample unit (SU) size of 30 km^2 suggested by Gasaway et al. (1986), they were usually discernible in the field, and their boundaries were available in digital databases.

Stratum 1 (S1) was the high population density stratum and included young forest (≤40 years), areas with shrub crown closure ≥60%, and Vegetation Resource Inventory descriptors for natural shrubby and open areas including meadow, open range, non-productive brush, non-commercial brush, and not sufficiently restocked. Stratum 2 (S2), the low population density stratum, was classified as forest >40 years old and the remainder of study area polygons not classified as S1 including gravel bars, riparian areas, and cutblocks or burns <5 years old. We obtained forest, cutblock, and other vegetation patch attributes from 3 provincial digital databases (i.e., Vegetation Resources Inventory, Forest Inventory Polygon, and RESULTS) stored in British Columbia's Land and Resource Data Warehouse. Unlike the stratified random block design of Gasaway (1986), we assumed that our stratification process did not require a pre-census stratification flight.

Sample Unit Definition

To determine stratum-specific SU's, a grid of approximately 9 km^2 (3.2 × 2.8 km) cells was laid out over the study area, specifically the grid layer from the Land and Resource Data Warehouse named "A5K Sampling Tiles." All polygons within each grid cell were classified as S1, S2, or outside of the survey zone (land >1200 m elevation and large lakes). To improve the likelihood of observing at least 1 moose in each SU (Bergerud and Manual 1969, Heard et al. 1999), adjacent cells were arbitrarily amalgamated until the sum of all the S1 polygon areas added up to ≥4 km^2 (Fig. 1). The high population density SU was the set of all S1 polygons within that group of cells, and the low population density SU was the set of all S2 polygons within that group of cells. To estimate moose numbers in the high population density stratum, a random sample of SUs was chosen from the entire study area and all moose were counted within all the S1 polygons in each selected SU. To estimate moose numbers in the low popualtion density stratum, a random sub-sample of SUs from the first sample was selected, and moose were counted within all the S2 polygons in those SUs.

Field Techniques

To be certain of locating polygon boundaries within an SU, real-time navigation was used where our flight track was recorded on a map of SU and strata boundaries and topographic features using ArcPad™ 7.0 (Environmental Systems Research Institute 2006) on a Hewlitt-Packard iPAQ™ handheld computer (Hewlitt-Packard Development Company 2006) connected to a Garmin Mobile 10™ wireless GPS unit (Garmin International, Inc. 2006). A comparable system includes the DNR Garmin extension (T. Loesch, Minnesota Department of Natural Resources; <http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html>) used in conjunction with ArcView™ (Environmental Systems Research Institute) and a Garmin GPS receiver (Garmin International, Inc. 2006). Real-time navigation allows the navigator to instantly determine the location of observers and moose relative to strata and SU boundaries and ensure complete sampling of a SU. Poole et al. (1999) suggested that incorporating real-time navigation into moose inventories can reduce flying time by 10-20%.

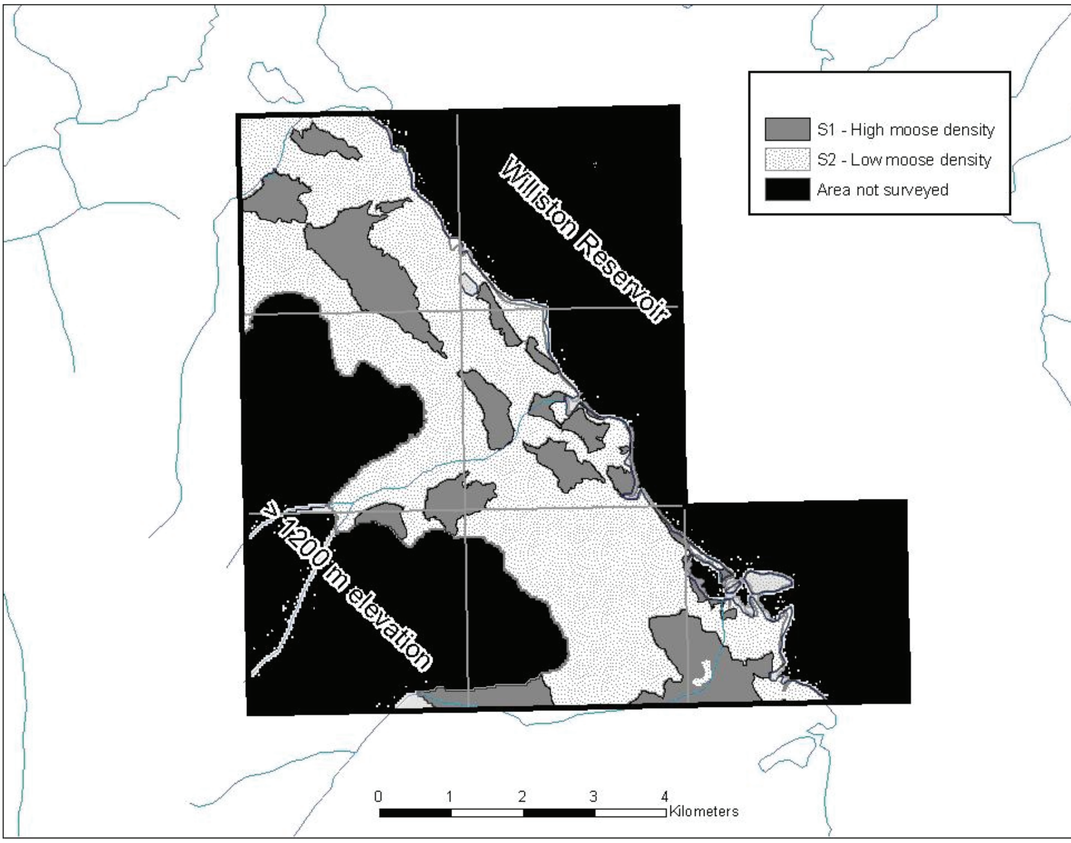

Fig. 1. An example of a high moose population density stratum sample unit (S1; all dark gray polygons combined) and a low moose population density stratum sample unit (S2; all stippled area) where 7 adjacent grid cells were amalgamated to form an area within which the S1 polygons would add to >4 km^2. Both the Williston Reservoir and elevations >1200 m (black area) were excluded from the survey zone.

Moose were counted from a Bell 206B helicopter using a search pattern over the entire SU that consisted of transects spaced 200-400 m apart depending on vegetation cover. Each sighted moose was circled and age (adult or calf) and sex were recorded: calves were distinguished by size, bulls by antlers, and cows by the presence or absence of a white vulva patch, bell length and shape, and facial colouration (Timmermann and Buss 1998). If additional moose were sighted during circling, they were categorized likewise and added to the data.

Sightability Correction

Corrections for sightability bias were made according to Anderson and Lindzey (1996). We estimated vegetation cover visually to the nearest 5% within a 9 m radius of where a moose was first observed according to the standards of Unsworth et al. (1998). Vegetation cover estimates were grouped into 5 classes and we applied the class-specific detection probability and corresponding sightability correction factor (SCF) of Quayle et al. (2001) which includes data from sightability tests carried out in central British Columbia (D. Heard, unpublished data). The recommendations of Gasaway et al. (1986) were followed with respect to conducting surveys during early winter and after a fresh snowfall when there was complete snow cover in the study area.

Data Analysis

For each stratum we calculated a naïve population and sampling variance estimate for unequal sized SUs as in Jolly (1969). We then multiplied the naïve population estimate by the mean stratum-specific SCF (sum of the corrected number of moose/number of moose observed) to obtain the corrected population estimate. The variance of the corrected population estimate was the sum of 1) the naïve sampling variance multiplied by the squared mean SCF (Goodman 1960, Heard 1987), 2) the sightability variance, and 3) the model variance. The sightability and model variance were calculated with the program Aerial Survey (Unsworth et al. 1998) and the detection probabilities from Quayle et al. (2001). We used Jolly (1969) rather than Aerial Survey (Unsworth et al. 1998) to calculate the sampling variance because Aerial Survey calculates a population estimate using a sampling fraction based on the number of censused SUs divided by the total number of SUs in the study area. Our analysis used a sampling fraction equal to the censused area divided by the total stratum area; we were not limited to SUs of equal size with this approach. Aerial Survey calculates variances assuming that all unseen moose are in the same SU as the observed moose. Where there are few moose in each SU, Aerial Survey will overestimate the variance among SUs (i.e., the sampling variance). Our approach assumed that unseen moose were divided among SUs in proportion to the number of moose observed in each SU.

The total population estimate was then calculated as the sum of the corrected stratum-specific population estimates and its variance was the sum of the 2 stratum-specific variances. Overall population density was obtained by dividing the total population estimate by the area of both strata combined.

RESULTS AND DISCUSSION

The methods described in this paper have been used 6 times to estimate moose population density in central British Columbia (e.g., Heard et al. 1999, Walker et al. 2006, 2007). The S1:S2 population density ratios in the 6 estimates were 8.7, 3.1, 2.8, 2.4, 2.3 and 1.7. Overall, the moose population density estimates in S1 sample units averaged 3.5 times higher than those in S2 sample units. The survey coefficients of variation were always <20% of the total population estimate. Thus, we concluded that our stratification design using 2 strata (S1 and S2) based on use of different vegetation characteristics by moose in early winter was effective. We also improved our cost and time efficiency because pre-survey stratification flights were not necessary.

Our approach resulted in relatively high sampling variance in the low population density stratum because many S2 sample units had no moose. The S2 variance would likely be reduced if we constructed larger S2 sample units or counted more S2 sample units; our SUs were only 20-25% as large as the SU size recommended by Gasaway et al. (1986). Our higher variances in the low population density stratum were contrary to the findings of Gasaway et al. (1986) who concluded that high population density strata generally have the greatest variance and require the most sampling effort. An additional source of variation in the population estimates was related to inaccurate stratification resulting from discrepancies between the land cover database and the actual forest attributes. We suspected that both database input errors and out-of-date map attributes contributed to that discrepancy.

Time since logging and silvicultural treatments affect the availability and composition of moose forage (Eschholz et al. 1996, Thompson and Stewart 1998, Rea and Gillingham 2001) hence, the distribution and abundance of moose (Nielsen et al. 2005). The precision of the population estimate might have been improved with a more precise habitat use model. We believe that the design described in this paper should be useful and effective in fine-grained environments where the relative selection for vegetation patches by moose is well understood, and those patches are mapped in digital databases.

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