GPS AND GIS ASSISTED MOOSE SURVEYS

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ABSTRACT: Wildlife managers in Alberta are using Global Positioning System (GPS) and Geographical Information System (GIS) technologies to aid in aerial surveys of moose (*Alces alces*). GPS performed well for locating lines of stratification and SU boundaries, flying lines of latitude during stratification, flying overlapping survey lines within SU's, and recording moose locations during stratification and the detailed census. GIS worked well for map preparation and plotting moose locations. GPS and GIS contributed to reduced aircraft and manpower costs for moose surveys.

ALCES VOL. 31 (1995) pp.145-151

Global Positioning System (GPS) is a satellite radio positioning network that provides accurate position, velocity and time information (Clark 1994). The three segments of GPS are space (the satellites), control and user. Space consists of 24 satellites in semi-synchronous orbits at an altitude of 20,200 km. Control includes a master station at Colorado Springs, Colorado and five monitoring stations around the world. Control monitors the health of the satellites, determines their orbits and the behaviour of their atomic clocks, and injects broadcast messages into the satellites (Wells 1986).

User consists of all military and civilian users. User employs special GPS receivers that track the coded signals from a minimum of four satellites and extract the navigation messages. A receiver makes numerous calculations and corrections and computes the position fix as coordinates of latitude, longitude, and altitude.

GPS positioning uses the concept of time of arrival (TOA) ranging — travel time of a radio signal from transmission to reception. GPS satellites are broadcast beacons which transmit coded signals that provide exact transmit times, correction data for clock errors and ionospheric signal delays, and send navigation messages originating from control.

Geographical Information System (GIS) is a computerized system that analyzes data to give it graphic form so it can be seen on a map (Mapinfo 1994). It "is an integrated set of hardware and software tools used for the manipulation and management of digital, spatial and thematic data" (Buckley 1989). A GIS is made up of four main subsystems: 1) data input; 2) data storage and retrieval; 3) data manipulation and analysis; and 4) data reporting/output. Since the advent of powerful desk-top computers, a variety of GIS systems have become available for desk-top mapping applications.

In Alberta, Natural Resources Service patterned its moose survey after the technique by Gasaway *et al.* (1986). The Alaska technique involves sampling randomly selected subunits of a stratified survey area. The main components include: 1) the survey area, called a Wildlife Management Unit (WMU) in Alberta; 2) survey units (SU's), which are subunits of a WMU; 3) stratification, the preliminary survey that uses moose observations to assign a strata to a SU, either low (L), medium (M), or high (H); 4) the detailed survey of randomly selected SU's to capture the data used to compute population parameters; and 5) the intensive search that provides a correction for animals missed during the detailed census. Beginning in 1993, GPS and GIS technologies were incorporated to help improve the efficiency of moose surveys. The objective was to minimize labour and aircraft inputs while maintaining statistical precision. During the winter of 1993/94, GPS and GIS applications were tested during moose surveys in 25 WMU's with a total area of 138,059 km^2. During 1994/95, GPS and GIS were incorporated into all moose surveys in 9 WMU's that encompassed 39,299.0 km^2. This paper explains how wildlife managers in Alberta use GPS and GIS to assist with the moose survey technique and reports the strengths and weaknesses of methods and equipment.

METHODS

Equipment

Fixed wing aircraft (Cessna 185 on skis or Cessna 210) were used for the stratification portion of moose surveys. SU's were flown using helicopters, either Bell 206B, Robinson R44, or Eurocopter A-stars. All aircraft were equipped with GPS receivers. Crew leaders on each aircraft used Garmin GPS 55 (GARMIN International, Inc., Lenexa, KS) portable GPS receivers to record animal locations. GPS antennas were mounted on suction cups that adhered to the windshield of the aircraft.

A Toshiba T6600C (Toshiba of Canada Limited, Markham, Ont.) portable computer was used to analyze positional data and generate maps. Maps were printed using a Hewlett-Packard Paintjet XL300 (Hewlett-Packard Company, San Diego, CA) colour inkjet printer. Software included ARKLINK (Mapinfo Corporation, Troy, NY) for translating base maps, Mapinfo (Version 3.0, Mapinfo Corporation, Troy, NY) for GIS, POLYGRID (Version 2.0 Global Media Systems, Sudbury, MA) to generate SU boundaries on maps, and QUATTRO PRO FOR WINDOWS (Version 5.0, Borland International, Inc., Scotts Valley, CA) for randomizing SU's and completing the equations. Garmin PCX5 (Version 2.00, GARMIN International, Inc., Lenexa, KS) was used to download moose locations from the Garmin 55's. Purchase costs (1993) of the Garmin 55, Toshiba T6600C, and XL300 printer were $975.00, $8,487.00 and $2,917.00 (Canadian) respectively. Software costs (1993) were: MAPINFO $1,836.00; ARKLINK $635.00; POLYGRID $250.00; QUATTRO PRO $450.00; and Garmin PCX5 $130.00.

Pre-survey

Prior to the moose survey, GIS was used to import base maps, and print maps of the WMU. Digital base maps were imported into Mapinfo using the Arklink software. In preparation for a survey of a WMU, Mapinfo and Polygrid were used to generate SU boundaries as a grid over the WMU. SU boundaries consisted of lines of latitude and longitude at 5 minute intervals each. This produced columns and rows of SU's of approximate equal size (about 51 km^2). The lat./long. SU's were rectangular in shape, approximately 5.50 km wide by 9.26 km long. They were slightly narrower on their north end and SU's became progressively smaller to the north due to the curvature of the earth's surface. Polygrid automatically numbered survey units with a column-row designation. Coloured SU maps were printed on 27.9 x 43.2 cm paper that was later laminated for use in the field. The Mapinfo browser (database) was adjusted to automatically truncate SU's at the WMU boundary.

Stratification

GPS was used during stratification to navigate lines of latitude and for recording the locations of individual moose. GIS was used at the end of the day to plot moose locations, analyze moose positional data, and assign strata to SU's. Stratification involved flying four lines at one minute (1.9 km) intervals of latitude across each tier of SU's. There were two observers plus the pilot in the aircraft during stratification. Crew leaders kept notes on direction of flight, observability and habitat and they used Garmin 55 receivers to record locations of individual moose along the lines. At the end of the day, the moose locations were electronically downloaded into a computer.

Mapinfo was then used to plot moose locations on a WMU map and complete a series of data transformations. Plotted animal positions that fell on SU boundaries were shifted back against the direction of flight to place them into the correct SU. Figure 1 shows a WMU with the moose from stratification plotted within lat./long. grid boundaries.

Mapinfo was used to perform a series of functions that resulted in final assignment of SU's to strata. Strata assignments of irregularly shaped SU's along WMU boundaries were made manually. Irregular SU's were considered flyable if their areas were greater than 50 percent of a whole SU. Irregular SU's were often combined to make flyable units if they were of the same strata and occurred near to each other. Mapinfo was used to calculate the areas of SU's and WMU's.

Moose Census

Moose surveys were flown during December and January after the hunting season and when snow conditions were adequate. Surveys were only flown when visibility was good (no limiting fog or snowfall) and temperatures were above -30°C (for reasons of safety). Helicopters flying at 120-160 km/hr. searched 300-500 m wide strips along lines of latitude .15 - .25 minutes apart. Helicopter height above ground varied depending on the density of cover (higher over dense cover), but was usually about 150-200 m. Survey lines were close enough so deviation from a line usually only occurred when a moose group was located. Helicopters circled all groups so sex and age could be determined for each animal. Females were separated from antlerless males by a combination of criteria including: presence or absence of a vulva patch (Mitchell 1970), colour of the snout and side profile. Males were classified as antlerless, yearling, medium or large.

The number of SU's flown in a WMU depended on the accuracy of stratification and the statistical precision goal. Additional SU's were flown until 90 percent confidence limits were + or - 20 percent of the mean estimate.

During the detailed moose count of SU's, GPS was used to locate SU's, help navigate straight lines of latitude in a helicopter, determine if moose were within SU boundaries, and record positions of moose groups. GIS

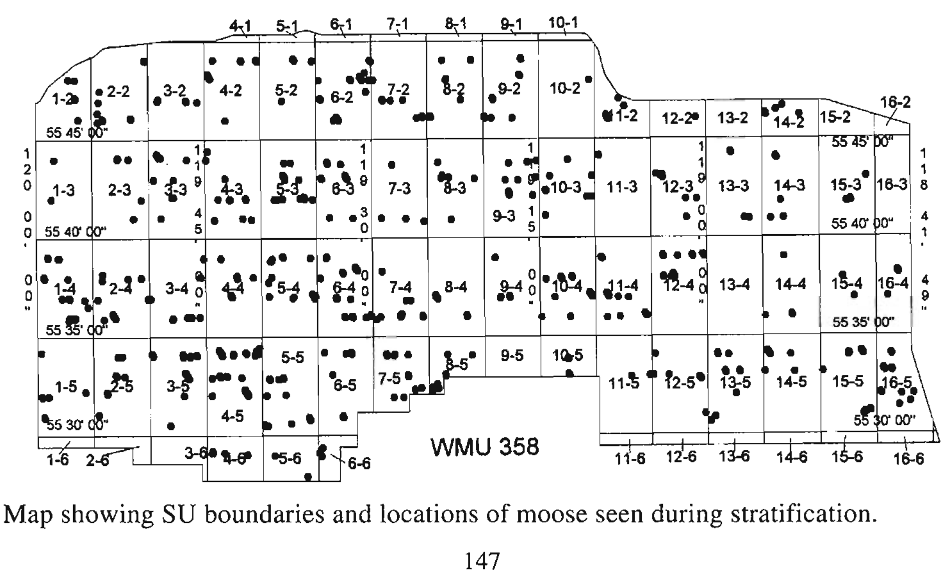

Fig. 1 Map showing SU boundaries and locations of moose seen during stratification.

was used after the survey to plot locations of individual moose and to produce maps showing locations of moose within SU's. Helicopter pilots used GPS to locate one corner of a SU to be flown. This enabled the total count of moose to begin immediately upon arrival at the SU, without having to establish SU boundaries. Helicopters were manned by the pilot, a navigator/recorder (next to the pilot), and two observers in the rear seats. The navigator used a Garmin 55 to record the locations of moose groups. Waypoint names, along with other data, were recorded on data sheets. Intensive searches were accomplished by intensively re-flying the strip along a line of latitude on which six or more moose were observed during the standard search.

At the end of the day, moose group locations were downloaded and later plotted (Figure 2). Results of the helicopter counts in SU's were entered into a laptop computer for analysis using the equations described by Gasaway *et al.* (1986). Four WMU's that were surveyed using the original technique (irregular SU boundaries) in 1993/94 were surveyed again in 1994/95 but using the lat./long. technique we describe.

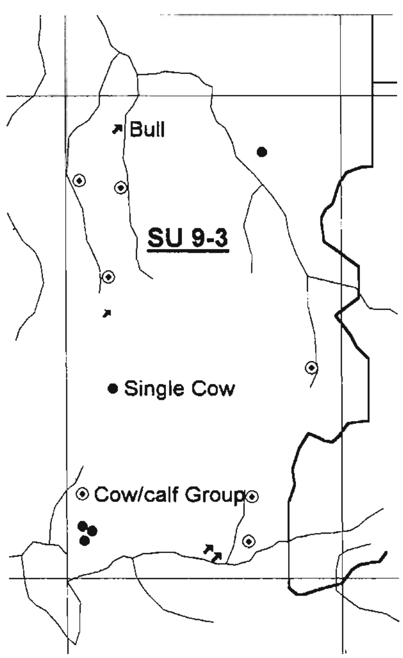

Fig. 2. Map of one SU showing locations of moose observed during the helicopter portion of the moose survey.

RESULTS

Table 1 summarizes fixed and rotary wing costs to census nine WMU's for moose during 1994/95. A total of 39,299.0 km^2 were flown at a total aircraft cost of $258,672.00. Stratification was responsible for 9.1% of the aircraft cost, compared to 90.9% for helicopter hours. It cost $0.62 per km^2 for stratification and 5.96 for the helicopter portion. The total cost per km^2 was $6.58.

A total of 182 SU's were flown requiring 365.6 helicopter hours at an average cost of $640.66 per hour. It took two hours to census a SU, including ferry time. Additional SU's were always flown until the statistical precision goal was reached. When stratification was accurate a minimal number of SU's could be flown during the detailed survey. Every additional SU flown added $1,281.32 to aircraft costs. A minimum of 15 SU's were flown in each WMU (five each of L, M, and H strata). The minimum helicopter cost per WMU was therefore $19,219.80. The quality of the stratification process was essential to minimizing the costs for helicopters hours.

There were other costs associated with the moose survey, including manpower and travel expenses. We usually used two Cessna's to stratify a WMU in one day. Staff requirements for stratification were two paid employees, plus two volunteers. Three helicopters were usually used for the detailed survey of SU's. This required six paid staff and three volunteers for two days.

GPS and GIS performed extremely well for both stratification and the detailed census of SU's. We were able to generate custom made maps that included the features we required. Moose sightings were easily plotted. GPS worked well for locating SU's for

Table 1. Aircraft charter costs to survey nine WMUs for moose in 1994/95.

WMU	Stratification			Helicopter Survey		Total
	Area (km^2)	FW Hours	Cost*	RW Hours	Cost*	Aircraft Cost
346	5,205.3	16.6	$3,158	59.8	$29,870	$33,028
348	3,045.0	11.3	$2,140	36.9	$26,477	$28,616
350	5,992.0	19.0	$3,515	39.2	$27,832	$31,347
354	7,111.8	20.2	$3,945	42.8	$28,633	$32,578
358**	2,886.5	9.9	$1,930	40.2	$26,894	$28,823
358	2,886.5	10.7	$2,797	29.9	$18,239	$21,036
360	4,270.2	12.2	$2,257	38.7	$27,477	$29,734
521	4,645.7	15.6	$3,028	43.1	$28,431	$31,459
522	3,258.0	12.8	$1,679	35.0	$20,372	$22,050
Totals	39,299.0	128.3	$24,448	365.6	$234,225	$258,672

* Fixed wing costs ranged from $185 to $205 per hour. Helicopter costs ranged from $495 to $710 per hour (fuel included). ** WMU 358 was surveyed Dec. 6-7, 1994 and again Feb. 8-9, 1995.

the helicopter phase of the survey. SU's could be flown with no maps by simply flying to the coordinates of one corner of a SU, then flying lines of latitude until the next boundary was reached. The percentage of the moose population seen during stratification was not critical. It was more important that stratification treated the entire WMU equally.

The percentage of population means seen during stratification averaged 16 percent, but ranged from 9.5 to 32.9 percent. Stratifying aircraft could fly straight lines, with no need of circling or other special manoeuvres to spot animals. The number of moose seen during stratification was largely dependent on visibility. Best conditions seemed to be when snowcover was complete and the sky had a high overcast. Conditions that impeded visibility included poor snow conditions (stumps, banks, and low vegetation exposed), low light conditions associated with heavy overcast, and bright sunlight that produced deep shadows and excessive glare. During December and January when moose surveys are flown, the sun was low on the horizon, producing visibility problems for stratifiers.

We were able to replicate the survey in one WMU (WMU 358, 2,886.5 km^2). It was flown December 6-7, 1994 when 21 SU's were flown and the population mean was 2,478 moose (+/- 14.9 percent). This WMU was surveyed again Feb. 7-8, 1995 when 14 SU's were flown and the population mean was 2,429 moose (+/- 19.7 percent). The difference between the two population means was only 49.

In four WMU's that were surveyed using irregular SU boundaries in 1993/94 and lat./long. boundaries in 1994/95, twelve percent fewer SU's had to be flown by helicopter the second year when the lat./long. technique was used. The aircraft savings in flying 10 fewer SU's was approximately $12,813.00. There were additional manpower savings in 1994/95 because SU boundaries did not have to be manually drawn on maps. In 1993/94 it required nine man-months to draw SU boundaries for 46 WMU's. In 1994/95 it took less than .25 man-month to produce survey maps for eight WMU's.

SU's that used lat./long. boundaries were easier to locate and fly, hence contributed to lower aircraft costs. However, differences in costs between years may have been more a function of moose distribution and/or better stratification.

DISCUSSION

There is always concern of losing data when a recording device is used to store field data. We found the Garmin 55 to be reliable and were able to use it with little difficulty. We did not lose any data but had to resort to recording lat./long.'s on paper when batteries ran low or problems with the antenna wire occurred. Seven hours of battery life could be expected with the Garmin 55 when the battery saver option was selected. The Garmin 55 stores 250 waypoints and in some WMU's greater than 250 were required. When large numbers of moose are expected during stratification it is necessary to carry two Garmin 55's or to download the waypoints and reset the unit while in flight. The Garmin 55 normally deletes waypoints one at a time. We found we could delete all waypoints in a three step procedure: 1) download the almanac to save the satellite orientation data; 2) do a master reset; and 3) upload the almanac. This procedure is not explained by the Garmin manual. A few times the survey could continue using the Garmin 55 GPS for navigation when there was failure of the onboard aircraft unit. Failure of both the Garmin 55 and onboard unit rarely occurred. A helicopter and a fixed-wing pilot not familiar with their GPS had to be trained in its use. Ensuring that pilots are well trained in the use of GPS is important to the success of the technique.

We found the accuracy of the Garmin 55 to be sufficient for our purposes. Accuracy of GPS depends on the category of use, PPS (Precise Positioning Service) or SPS (Standard Positioning Service) (Clarke 1994). PPS is extremely accurate, but is available only to those authorized by the U.S. military; we did not use PPS. SPS is used for civilian purposes; its accuracy specifications are: horizontal — 100 m; vertical — 300 m; and time — 170 nanoseconds. Differential GPS (DGPS) requires that a local positioning signal is transmitted and added to the mix of calculations made by the GPS receiver. DGPS increases the accuracy of SPS to 10 m (Clarke 1994). We were able to check the accuracy of our Garmin 55 SPS receiver against a DGPS unit. The average difference between 42 simultaneous reading was 35.3 m (range 3.6 -101.4, S.D. 21.95).

We found all software packages to be satisfactory. The PCX5 worked well, QUATTRO PRO was well suited to converting waypoint data, preparing and randomizing seed lists, and producing final survey results. MAPINFO was reasonably easy to use and included all of the features we required. One disadvantage was having to use several different software packages to complete all activities associated with the survey technique. User manuals for the software packages were notoriously difficult to understand, except that for QUATTRO PRO.

The lat./long. grid replaced the traditional irregular SU boundaries that use landforms (Gasaway *et al.* 1986). One advantage of the lat./long. system is that SU's are of equal area which improves statistical precision. If lines of latitude and longitude rather than land features are also used for WMU boundaries, then all SU's within the survey area will be approximately the same area. However, WMU's usually have boundaries that follow natural land features, as is the case in Alberta. The result is a group of partial SU's around the periphery of the survey area. We dealt with that complication by combining pieces of the same strata into flyable sized SU's. Those not combined were included in the total areas of respective strata.

Lat./long SU boundaries minimize the potential bias that can occur when riparian features such as creeks and rivers, are used as boundaries. During winter moose often congregate in these habitats, making it difficult to handle boundary areas during moose surveys. Similarly, handling moose along WMU boundaries is simplified when lat./long's rather than rivers and streams are used for boundaries. However, lat./long. WMU boundaries would not be compatible with some other wildlife management needs. We found that stratifying by flying lines of latitude to be fast, efficient and cost effective. Pilots had little difficulty staying on lines of latitude and SU boundaries were quickly located. The survey could always be started with no time wasted on boundary orientation. We found all aspects of aircraft navigation to be enhanced with GPS.

Our intensive search procedure to correct for missed animals did not adhere to the recommendations of Gasaway *et al.* (1986) and may not correct well for undercounting bias. The advantage of our system is that it occurs immediately after a strip is searched, making it easier for observers to identify missed animals. Often animals in dense cover are missed on the first pass, but seen during the intensive search because they were disturbed from their beds by the low flying helicopter.

ACKNOWLEDGEMENTS

We thank the Natural Resources Service staff who participated in the development and testing of the technique, especially Gordon Carr, Carmen Pollock, and Cynthia Schaff. Della Clish provided digital base maps, Angela Turlione typed and Arlen Todd reviewed the manuscript. This project was sponsored by the Alberta Government through the Wildlife Management Enhancement Fund.

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