POTVIN DOUBLE-COUNT AERIAL SURVEYS IN NEW BRUNSWICK: ARE RESULTS RELIABLE FOR MOOSE?

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ABSTRACT: Following the rapid decline of deer (*Odocoileus virginianus*) across northern New Brunswick in the late 1980s, the New Brunswick Department of Natural Resources began to utilize a double-count helicopter survey to estimate deer numbers. Although the survey was designed for deer, moose (*Alces alces*) sightings were also recorded; however, no analysis was conducted on the accuracy or usefulness of these data to estimate moose numbers. The survey design was a modification of the Potvin double-count survey method for deer which accounts for most caveats to aerial surveys. This double-count (mark-recapture) technique allows calculation of bias for both observers, for single and groups of moose, and individual flights. Moose population estimates calculated from 79 flights ranged from 0.17-3.49 moose/km^2 and were similar to a variety of estimates throughout North America. Population estimates from 2004-2009 correlated well with corresponding 2009 population indices for moose based on number of moose seen by deer hunters (Corr. = 0.725, P <0.001). The Potvin estimates in Wildlife Management Zone 2 were highly correlated (0.82-0.93, P <0.05) with other indices based on road kill moose, moose sightings, and harvest success rates; moose sightings and hunter success were also correlated in several other zones. This analysis indicates that Potvin surveys produce reliable population density estimates of moose in boreal/Acadian forests, given that the sighting probability is >0.4 and flights occur before mid-February when moose may occupy denser canopy cover.

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Sustainable and effective management of large ungulates requires a reliable estimate of population size by management unit. Gauging the success of annual management actions and harvest prescriptions hinges upon the ability to obtain cost-effective density estimates with precision that allows detection of annual changes. Following a rapid decline of deer (*Odocoileus virginianus*) numbers across northern New Brunswick, the New Brunswick Department of Natural Resources (NBDNR) initiated the use of a double-count aerial survey in 1996 that was developed in Quebec to estimate deer densities (Rice and Harder 1977, Potvin et al. 1992, Hardy 1994, Potvin and Breton 1995). Although the survey was designed and modified specifically for the observation of deer in boreal forests, observers also recorded sightings of moose (*Alces alces*). However, no further analysis was conducted on the reliability of this survey or how precise or accurate it was to estimate moose numbers.

Various survey methods have been used to determine ungulate densities including line transects, distance sampling, spotlight surveys, and variable plot surveys (Kie 1988, Rabe et al. 2002). Other methods include track counts, pellet group surveys, and measure of browse abundance that provide indirect counts or indices (Kendall et al. 1992, Witmer 2005), and although cost-effective, are not without their challenges and inaccuracies (Storm et al. 1992, Fritzen et al. 1995, Focardi et al. 2002, Freddy et al. 2004, Collier et al. 2007). Some of these methods have low power to detect population change of 20-50% (Strayer 1999) or produce estimates with large confidence limits (Jordan et al. 1993). Although more expensive, aerial surveys can provide quick, reliable estimates of ungulate density (Freddy et. al. 2004); however, aerial surveys have their own set of bias and problems.

Early in the evolution of aerial surveys, Caughley (1974) and Caughley et al. (1976) outlined deficiencies that included width of transect surveyed, cruising speed, altitude, height above ground, observer experience, and habitat cover type. While quadrat flights had the advantages of counting a higher percentage of animals and removing the need for strip width, transects were more robust and allowed for ease in calculating observer bias and were more economical (Caughley 1977). Nearly all of these biases result in fewer sightings and less precise estimates.

Estimates obtained from aerial surveys improved as these problems were addressed (Peterson and Page 1993). The use of helicopters addressed aircraft speed (Peterson and Page 1993) and improved the accuracy of moose estimates by 78%, on average, over fixed winged aircraft (Gosse et al. 2002). Beasom et al. (1981) tested sightability within the survey strip and found that observers saw 34-73% fewer deer in the outer 50 m of a 100 m survey strip compared to the first 50 m of the strip. DeYoung et al. (1989) found that they could improve density estimates with little or no loss in precision by reducing their strip width from 200 to 40 m. In Wyoming, 42% of moose missed occurred >50 m from the transect path (Anderson and Lindzey 1996), evidence that the search area not exceed this width.

Aerial surveys are typically flown over open habitat types because dense overstories combined with oblique angles of view hide ungulates from observers (Anderson and Lidnzey 1996). However, Floyd et al. (1978) found that modifying search methodology greatly improved observability of deer in coniferous forests, such as altering the viewing angle (Potvin et al. 1992, Gauthier and Cumberland 2000). In addition, background snow greatly improved sightability to as high as 78% in an oak-hickory forest (Beringer et al. 1998).

Because not all animals are observed in aerial surveys, several methods are used to correct for this bias, including calculating correction factors by habitat type (Anderson and Lindzey 1996) or incorporating some form of mark-recapture using 2 observers, which has proved the simplest and most efficient means (Pollock and Kendall 1987). A double-count procedure is essentially a mark-recapture technique that improves estimates by accounting for missed animals (Magnusson et. al. 1978, Eberhardt and Simmons 1987, Borchers et al. 1998). DeYoung et al. (1989) used correction factors to improve their population under-estimate (42.3% less than their Bailey's estimate) to within 6% of the estimated population size. Further improvement to precision is possible by calculating visibility bias for both observers, and for both single and groups of deer (Samuel and Pollock 1981, Rivest et al. 1995). With such modifications, double-count aerial surveys that address these issues arguably hold promise for estimating ungulate density in coniferous-deciduous forests.

Potvin deer estimates are considered reliable in New Brunswick. Deer densities estimated in WMZ 22 from 2000-2009 were strongly correlated to estimates derived from population reconstruction with the Provincial deer model. Estimated rates of increase and decrease for Potvin estimates, the deer model, and actual harvest changes in WMZ 22 were strongly correlated throughout the 2000s (NBDNR unpublished data). The objective of this study was to evaluate the reliability of Potvin estimates of moose population density in New Brunswick by using >10 years of aerial survey data from multiple Wildlife Management Zones (WMZ) of variable moose density across New Brunswick.

METHODS

Study Area

New Brunswick is located on the east coast of Canada at 46.00° N and 66.54° W. Over half of it borders the Atlantic Ocean along the Chaleur Bay, Northumberland Strait, and the Bay of Fundy. The majority (>80%) of the landbase is forested, and elevation varies from lowlands at sea level with little relief along the eastern coast, to highlands of the Appalachian Mountains in the north to elevations of 764 m. Woodlands are characterized by Acadian forest, with spruce (*Picea* spp.), balsam fir (*Abies balsamea*), hemlock (*Tsuga canadensis*), and white cedar (*Thuja occidentalis*) as climax species on softwood sites, and sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), and yellow birch (*Betula alleghaniensis*) characterizing mature hardwood sites. Early successional forests are predominated by poplars (*Populus* spp.), birches (*Betula* spp.), willows (*Salix* spp.), and cherry (*Prunus* spp.). New Brunswick is divided into 27 WMZs (Fig. 1) to facilitate localized and site-specific management through seasonal and zone-specific quotas for antlerless deer and all sexes of moose.

Field Techniques

Our survey method (hereafter referred to as Potvin) was modified slightly (Gauthier and Cumberland 2000) from the double-count aerial survey used to estimate deer numbers by Potvin et al. (1992). We flew a 4-seat, Bell 206 Jet Ranger helicopter with a GPS (Global Positioning System) navigation unit. The aircraft was equipped with side bubble windows on the left (port) side that allowed for a wide field of view to reduce parallax, and greatly reduced the effect of dense conifer cover on sightability of moose by reducing parallax angles <45° in the survey strip. The survey strip itself was limited to a 60 m swath and a flight altimeter was installed to maintain consistent height above undulating topography. Flight speeds did not exceed 60 knots and aircraft height above the canopy was kept constant at 60 m. We found that slow speeds and low altitude of the survey aircraft usually initiated some form of movement of deer and moose below the helicopter and greatly assisted with observability. The flight crew consisted of the pilot, a navigator-recorder, and 2 observers seated on the left side of the helicopter. Two observers were employed for the double-count estimator; observability bias was calculated for both observers, for single and groups of deer, and for each individual flight. Every effort was made to ensure that observers were experienced and remained the same within

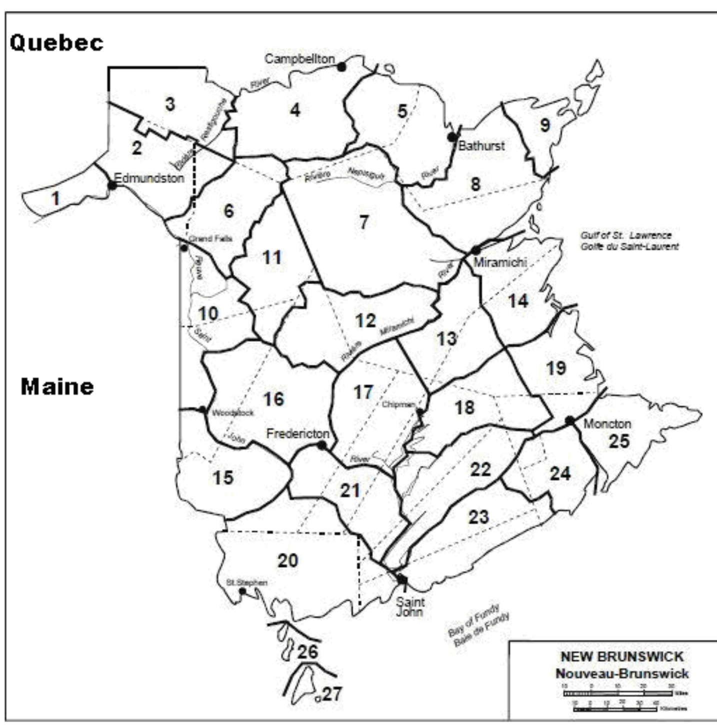

Fig. 1. Distribution of Wildlife Management Zones (WMZ) in New Brunswick; WMZs 1-3, 6, and 10 were used to compare with moose population estimates in adjacent Maine.

each annual survey.

To approximate a true mark-recapture study, observers must be isolated from audio to prevent overhearing conversation that might bias sightings. The helicopter was equipped with a modified intercom system designed to allow the navigator-recorder to hear the observers while controlling their access to audio with a toggle switch. Although snow is not necessary for the survey, the color contrast created between deer, moose, and snow greatly assists observers and increases sightability. Therefore, we only conducted aerial surveys following snowfall that completely covered the ground. Because both deer and moose were counted, surveys were flown as long as snow occurred, but this was altered as we experienced behavioral change of both deer (yarding) and moose (restricted movement).

Survey Block Selection

Ballard et al. (1997) conducted flights of the Potvin double-count survey and suggested that the survey block size should be >200 km^2 with transect lines spaced 1 km apart and of equal length to address spatial distribution of deer, and to meet statistical requirements. Therefore, we selected large survey blocks with gross habitat characteristics that matched the WMZ as a whole. Although the spatial distribution of habitat types could not be evaluated, proportions of habitat types were summarized for each WMZ using a GIS database. To make selection of survey blocks easier, GIS map tiles were used as components to define survey blocks and their boundaries. Because GIS tiles were 43 km^2, combinations of 6 tiles (approximately 258 km^2) in a matrix were selected in each zone (n = 20-40 per WMZ) as potential survey blocks; each was summarized by the 9 habitat types. Survey blocks which most closely matched the total zone habitat characteristics based on simple linear regression analysis were selected (adjusted r^2 values >85%) and subsequently evaluated for topographic characteristics. The block with topographical characteristics with the fewest obstructions (i.e., large lakes, dense housing, suburban areas) and that was most consistent with the habitat in the WMZ as a whole was selected. Transect lines were flown systematically beginning at the edge of the block and spaced 1 km apart and oriented either N-S or E-W. Transects were approximately 40 km long to encompass as much of the variation in habitat as possible to ensure variation between transects was minimized and precision maximized (Caughley et al. 1976).

Moose in New Brunswick are currently managed by tracking various indices of population change through time. Indices across and within WMZs include the number of moose seen per hour by moose hunters, the number of moose seen by deer hunters, annual road kill in each WMZ, and success rate of moose hunters. Density estimates were compared to the relative index of moose seen per deer hunter in each zone to determine if these relative values were comparable. Changes in population and indices were determined by the slope of a regression line fitted to each index, and by measuring *r* by regressing log *e* of the estimated population size (Caughley and Birch 1971). These rates were compared between estimated population change by the aerial survey and other indices of change. Index values were correlated to Potvin estimates over time to determine if changes in moose indices were reflected by related changes in the Potvin estimates. Our estimated moose densities were also compared to estimates from surrounding jurisdictions and others in the literature.

RESULTS

The NBDNR flew 154 individual flights over various habitat types and in nearly all WMZs since 1996. Thirty-five (22.5%) were flown as test flights in February and March 1996 and 1997 to determine appropriate block size, alignment, and location to calibrate the survey and to form sight images for deer and moose; therefore, these test flights were not included in the analysis. Since 1997, several flights were flown in February or later to estimate deer numbers, and several others had sighting probabilities <0.40. These additional 14 flights were also excluded from the analysis because moose typically move into more coniferous cover in mid-late winter thereby reducing sightability; simulations indicate a loss of robustness when sighting probability is <0.45 (Magnusson et al. 1978, Potvin et al. 1992).

Of the remaining 105 flights, 26 flights were excluded from analysis because they did not produce a population estimate due to too few moose. Our 1996-1997 test flights suggested that densities <0.5 per km² resulted in >80% of survey lines without sightings. As expected, central and southern WMZs with lower moose densities and harvests accounted for 17 of these 26 flights.

Population estimates (unpublished data, NBDNR) from the remaining 79 flights indicated high moose density in northern WMZs where deer populations are substantially lower, and lower moose density in southern WMZs. Significant within-zone variability was only evident in 4 (5%) flights. Estimated moose densities varied from 3.49 moose/km² in northern zones (Table 1) to as low as 0.17 moose/km² in southern zones (Table 2). Average sightability for front and rear observers was 0.85 and 0.83, respectively.

Fewer than 8 WMZs were flown yearly due to financial and weather limitations; therefore, few zones have continuous data. Because Potvin estimates were never obtained in all zones in one year, the most recent Potvin estimate in each from 2004-2009 was compared with the 2009 index of moose seen by deer hunters. These two values correlated well (corr 0.725, P <0.001), and better than most other indices with each other except the 2 moose sighting indices that were correlated (corr. 0.80, P <0.001).

WMZ 2 was flown most consistently (1996-1998, 2000, 2003-2004, 2006, and 2008-2009) and provided the best data set for temporal comparisons of the Potvin estimates. The observed rate of increase (r) for Potvin estimates and all other moose indices in WMZ 2 were positive and of similar magnitude (Table 3).

Potvin estimates were highly correlated (0.82-0.93; all P <0.05) with all other popula-

Table 1. Potvin estimates of moose population density (moose/km²) in northern WMZs (higher density WMZs) in New Brunswick, 2006-2009; WMZs 1-3, 6, and 10 border Maine. A WMZ was measured in November or December (see Methods).

WMZ	Year	# Moose	Density ± SD
1	2008	24	1.39 ± 0.42
2	2009	52	3.49 ± 1.14
3	2006	16	1.18 ± 0.32
4	2008	10	0.62 ± 0.18
5	2008	42	2.66 ± 0.77
6	2009	27	1.70 ± 0.83
7	2007	20	1.28 ± 0.44
8	2008	13	0.82 ± 0.23
10	2009	11	0.69 ± 0.36
12	2009	9	0.54 ± NA

Table 2. Potvin estimates of moose population density (moose/km²) in southern WMZs (lower moose density WMZs) in New Brunswick, 2003-2009. A WMZ was measured in December or January (see Methods).

WMZ	Year	Moose	Density ± SD
13	2004	18	1.07 ± 0.32
14	2006	17	1.13 ± 0.34
15	2004	29	1.79 ± 0.44
16	2007	7	0.48 ± 0.15
17	2003	9	0.66 ± NA
18	2007	21	1.37 ± NA
20	2007	11	0.68 ± 0.29
21	2009	43	1.29 ± 0.23
22	2009	3	0.17 ± NA
23	1999	4	0.25 ± 0.13
25	2009	10	0.72 ± 0.26

tion indices in WMZ 2 (i.e., road kill, moose sightings, and harvest success rate; Fig. 2). Potvin estimates were also highly correlated to moose sightings (corr. 0.90, P <0.001) and hunter success (corr. 0.79, P <0.011) in WMZ 8. Although fewer data points were available for Potvin estimates in WMZ 4 and 5, they were strongly correlated with moose sightings (corr. 0.84, P <0.001) and hunter success (corr. 0.75, P <0.001) in WMZ 4, and to a lesser extent in WMZ 5 (corr. 0.61, P <0.082 and corr. 0.46, P <0.21, respectively).

DISCUSSION

Thirteen years of deer and moose population estimates have been done with the Potvin double-count survey in New Brunswick. The survey was designed to address limitations of aerial surveys by flying at slow speed (60 kph) and at low altitude (60 m) to increase the likelihood of deer and moose movement that, in turn, increases the likelihood of sightability. Specifically, bubble windows reduced parallax and vastly improved the ability to sight ungulates under closed coniferous canopies. The flight altimeter allowed the pilot to maintain survey height and reduce fluctuations in survey width that can affect population estimates. Use of a survey transect width of 60 m also reduced parallax, providing easier observation of a narrower strip, including the portion most likely to have observable animals. Using 2 observers in the double-count allowed use of the mark-recapture technique that vastly improves estimates, and calculation of observer bias for each flight as well as singles and groups of animals from which the population estimate is corrected.

Behavioral and ecological differences of ungulate species may introduce bias and affect the accuracy and use of aerial surveys. For example, McCorquodale (2001) found that the spatial distribution of male and female elk during winter was a potential source of bias in helicopter surveys because females were 9 times more likely to be observed than males. However, Anderson and Lindzey (1996) successfully observed 59% of moose groups over a wide range of habitat types with strip widths of 150-250 m (3-5 x larger than here). Given the size and color of moose, and that Potvin estimates were found reliable for deer under similar protocols and conditions, it was presumed that moose had equal or higher sightability than deer, and that bias was negligible.

Table 3. The estimated rate of increase (r) and the corresponding doubling time for the population (Caughley and Birch 1971) for moose population indices in WMZ 2, New Brunswick.

Metric	Estimated r	r^2 adj.	doubling time
Potvin	0.176	84.9	3.9 Years
Harvest	0.226	70.8	3.1 Years
Road kill	0.276	77.3	2.5 Years
Success	0.358	82.0	1.9 Years
Sightings by MH	0.364	65.9	1.9 Years

Because moose shift from deciduous to conifer habitats as snow depth increases (Coady 1974, Peek et al. 1976), some caution against flying in late winter (February-April) when moose tend to occupy denser vegetation (Lynch 1975, Karns 1982, Gasaway et al. 1985, Crete et al. 1986, Anderson and Lindzey 1996, Ballard et al. 1997). The most optimal time to survey moose is when they occupy more open habitat types (Anderson and Lindzey 1996); thus, most aerial surveys are flown late fall and into early winter when snow covers the ground and moose occupy relatively open habitat types (Coady 1974, Lynch 1975, Peek et al. 1976, Karns 1982, Gasaway et al. 1985, Crete et al. 1986, Anderson and Lindzey 1996, Quayle et al. 2001). Quayle et al. (2001) found that % vegetative cover and snow cover, as well as temperature, affected sightability of moose in British Columbia.

Our estimates of moose density are comparable with those in adjacent Maine (L. Kantar, Maine Department of Inland Fisheries and Wildlife, pers. comm.) where the range of density estimates along the New Brunswick border is 1.24-3.05 moose/km²; density in bordering WMZs 1, 2, and 6 were 1.39-3.49 (Table 1). In nearby New Hampshire, the density estimate was 1.19 moose/km² using the FLIR method (Bontaites et al. 2000). Population density of heavily harvested populations or those in poor habitat are typically <1.0 moose/km², but in less-exploited situations, density can approach 3.0/km², and in extreme cases be as high as 5-10/km². Collectively, these other estimates indicate that the Potvin estimates reported in this study (0.17-3.49 moose/km²) are reasonable.

Due to cost and weather conditions, <10 of 25 WMZs were flown in any given year. Further, consecutive flights within WMZs were sporadic due to the need for specific data from other zones in successive years. While this limits the continuous nature of the data set, sufficient data existed in several zones to make comparisons to other moose population indices in New Brunswick. I compared the 2006-2009 Potvin estimates to the number of moose observed by deer hunters because this index was more robust than the observation rate by moose hunters. Moose observations by 3,500 moose hunters during the 3-day season was low in some WMZs, versus the number of moose observed

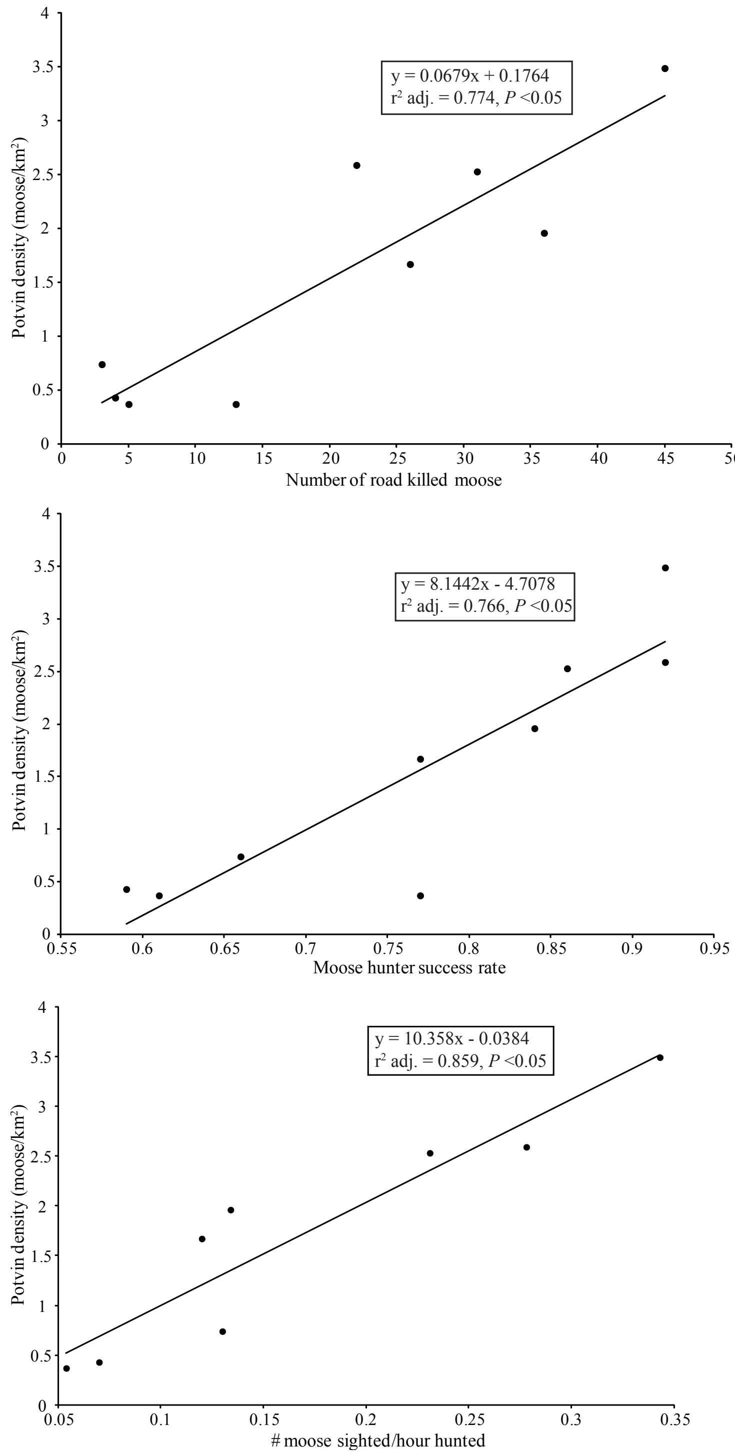

Fig. 2. Relationships between Potvin estimates (moose/km²) and 3 indices of moose population density in WMZ 2 in New Brunswick, 1996-2009: a) road kill, b) moose hunter success rate, and c) moose sightings per hour by moose hunters. Each index was positively correlated (P <0.05) with the Potvin estimates.

by 50,000 deer hunters over 4 weeks. The Potvin estimates correlated well with the relative number of moose observed by deer hunters across WMZs.

Although the absolute change in the Potvin estimates for WMZ 2 increased over the course of our study from 1077 to 8731, the estimated rate of increase was less than that calculated for the other indices of population change (i.e., roadkill, hunter sightings, hunter success, and harvest; Table 3). The Potvin estimates were highly correlated to changes in hunter success and moose sightings in northern zones where a sufficient number of flights allowed for this analysis.

Although the Potvin estimates correlated well with the other indices of moose density, 9 flights did not produce a density estimate in areas where the moose population was presumably high enough to provide an estimate. Further, 4 of the 79 flights where estimates were obtained had a fluctuation >50% from the previous or consecutive estimate. Preliminary analysis shows little evidence that this was attributed to weather or temperature anomalies. The question remains whether such estimates should be excluded from an annual population analysis, or be treated as a low population and managed accordingly; current analysis has not formed the basis for management decisions.

Rivest et al. (1995) analyzed visibility bias of the Potvin survey and found that double-count estimates were superior to those derived from independent sightability studies such as Gasaway and other single survey types. Potvin estimators also have the advantage of reflecting the prevailing conditions during the actual survey. Potvin and Breton (2005) tested the double-count method simultaneously with infrared surveys and found that the thermal infrared technique provided more variable results; accuracy was 54-89% and was mostly influenced by forest canopy. Conversely, 4 of 6 Potvin surveys yielded reliable results and the density estimates were within 64-83% of the assumed densities based on population reconstruction. Provided sighting probabilities are >0.45, the double count method provides valid estimates of deer density for management purposes; however, if sighting probabilities are <0.40 it might underestimate density (Potvin et al. 2004).

Moose in New Brunswick are currently managed by tracking various indices of population change through time, although none have been tested or validated with actual population sizes or rates of change. The Potvin method could be a valuable tool in producing more reliable moose population estimates in boreal/Acadian forests provided sighting probability is >0.40 and flights occur prior to February. Because unreported harvest of moose by First Nation's people in New Brunswick creates a void in age data which limits the ability to implement population reconstruction (e.g., Paloheimo and Fraser model [1981]), early winter Potvin estimates might provide both a population estimate and a basis for understanding any population response associated with unreported harvest.

In New Brunswick, deer and moose data were collected simultaneously and such an approach could be more cost-effective than traditional, single species surveys in jurisdictions with multiple species of ungulates. However, at northern latitudes where deer tend to occupy closed-canopy mature coniferous forest in winter, the timing of favorable weather, presence of snow, and yarding migration greatly narrows the window when combined surveys could occur. Although the Potvin estimates were limited to <10 WMZs flown annually and few zones had continuous annual data, the population estimates were reasonable and correlated with other population indices. Annual flights may not be necessary to calibrate other modeling and population reconstruction efforts, and this technique may also prove advantageous in high density areas requiring local management strategies.

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