USING HUNTING STATISTICS TO ESTIMATE DENSITY, COW-CALF RATIO AND HARVEST RATE OF MOOSE IN QUÉBEC

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Abstract: Moose (*Alces alces*) density, estimated from eleven aerial surveys, was inversely related to harvest effort (hunter-days per moose killed), and positively related to moose harvest per 10 km^2. A positive linear relationship was found between the number of calves per 100 females counted in eleven helicopter surveys and the number of calves per 100 females in the harvest. This last hunting statistic was positively related to the percentage of yearlings and milking females in the harvest; the relationship was negative with the mean age of females. Harvest rate was positively related to the three hunting statistics associated with recruitment *i.e.* number of calves per 100 females, percentage of milking females and percentage of yearlings. Harvest rate was negatively related to adult sex ratio and mean age of males in the harvest. Assessment of moose density, recruitment and harvest rate through hunting statistics is possible, but confidence intervals of single predictions are wide.

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Caughley (1976) suggested a harvest model for ungulates, which is based on the concepts of carrying capacity (*KCC*: MacNab 1985) and maximum sustained yield (X_{msy}). The highest point of the bell shaped yield curve in Caughley's model is *msy* and the population density at which this occurs is X_{msy}. Field studies on moose (*Alces alces*) (Crête et al. 1981) and white-tailed deer (*Odocoileus virginianus*) (McCullough 1979) supported the model; X_{msy} was estimated at 0.6 *KCC* for both species. At this value, a harvest rate of approximately 20% of the moose population can be sustained (Crête et al 1981). In Québec, X_{msy} was estimated at one moose per km^2 when only black bears (*Ursus americanus*) are present, and at 0.26 moose per km^2 in the presence of both black bears and wolves (*Canis lupus*) (Crête, In press).

In any population, *msy* and X_{msy} can vary according to productivity and to the relative importance of non-hunting mortality. Consequently, wildlife managers are interested in maximizing productivity [and minimizing non-hunting mortality] to maximize moose yields. For example, it was suggested that an unbalanced sex ratio in moose could lower productivity in areas of low density and forested habitat (Markgren 1973; Babcock *et al*. 1982; Crête 1982). For this reason, Crête et al. (1981) recommended keeping 40% males among adult moose after the hunting season. Similarly, predation has been shown to limit some moose populations (Gasaway *et al*. 1983) and predator harvest may increase recruitment of moose in some cases (Crête and Messier 1984).

Québec represents the North-American jurisdiction with the highest hunting pressure (Crête in press). In 1984, 140 000 hunting licences were sold, 11 000 animals were harvested (Roy 1985), and hunter expenses exceeded $ 60 000 000. With this high demand, moose should be managed for msy, which requires information on density, recruitment and harvest rate. Aerial surveys have been useful to measure density and recruitment but they are costly (Crête and St-Hilaire 1979; Crête et al. 1986). On the other hand, hunting statistics are available annually, inexpensive and easy to obtain. In this article, we relate data from aerial surveys to hunting statistics in an attempt to determine indices of density, recruitment and harvest rate for moose in Québec. We also relate hunting statistics to each other.

STUDY AREA AND METHODS

The study area included sixteen hunting zones (C, D, F_1, F3, F4, G, H1, H2, J1, J2, J3, K1, K2, K3, M, N) of Québec (Figure 1) whose moose harvests were considered between 1976 and 1985. According to areas, the hunting season lasted between 9 and 30 days and opened between early September and late October. Total moose harvest increased from 7000 to 11000 animals (Bouchard and Gauthier 1977; Roy 1986) during the period. Thirty-two aerial surveys using random sampling were conducted in the hunting zones to assess moose density (Figure 1). A helicopter was employed on eleven occasions in accordance with Crête and St-Hilaire (1979) guidelines. First, two observers in a fixed-wing aircraft surveyed each sample plot to map recent and old tracks in the snow.

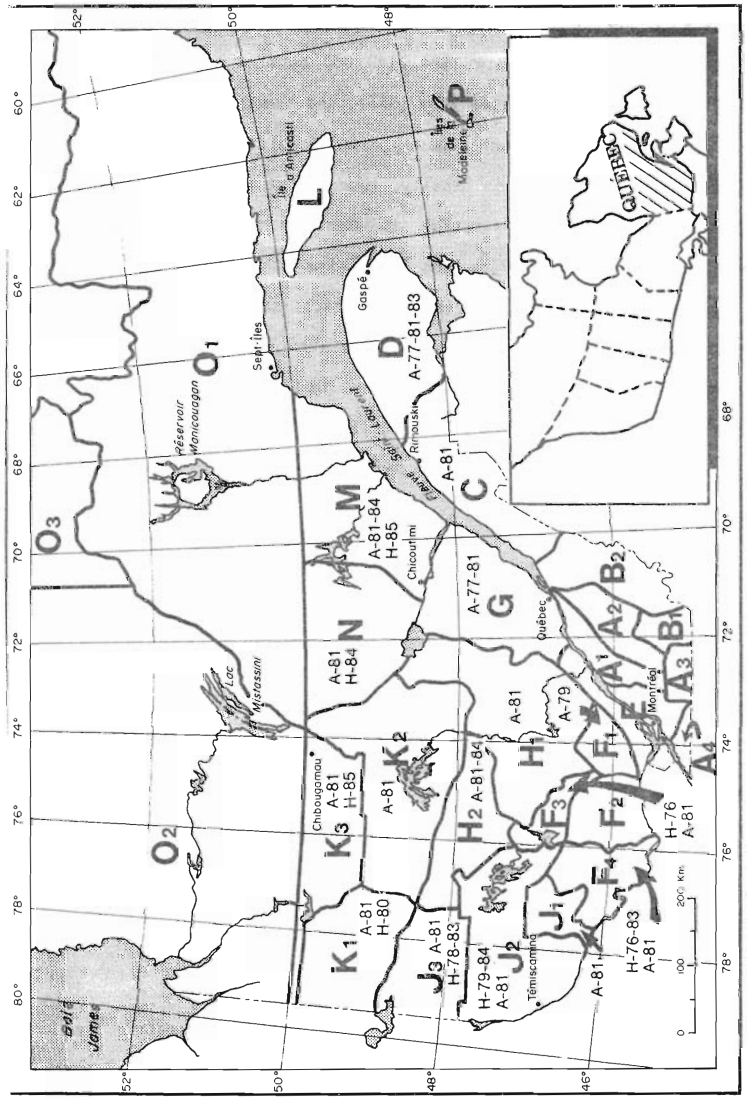

Fig. 1 Study area, showing hunting zones of southern Québec where moose aerial censuses were carried out by means of fixed-wing aircraft (A) and helicopter (H); numbers indicate the year of the aerial survey.

Within 24 hours of mapping, the areas with tracks were intensively searched by two observers in a helicopter, in an effort to count all moose. Sex of adults was ascertained from vulval patch and antler criteria, and calves were identified by relative size (Roussel 1975; Crête and Goudreault 1980). Fixed-wing aircraft were only used in twenty-one cases (Crête and Joly 1981); density was then predicted with multiple regressions in which the independant variables were the number of moose seen from the aeroplane and the area covered by track networks (Crête et al. 1986). A visibility rate of 0.73 was applied to density estimates derived from helicopter counts, to take into account unobserved animals (Crête et al. 1986). Density ranged between 0.04 and 0.29 moose per km^2. Recruitment was evaluated using the cow-calf ratios (CCR= number of calves per 100 females) obtained from the helicopter surveys.

Moose harvest per 10 km^2 was compiled annually, for each hunting zone, from compulsory big game registration data. Harvest rate (HR) was computed as following:

$$HR = \frac{H}{H + D}$$

where H represented harvest per 10 km^2 and D, post-hunting density, estimated from aerial surveys. This formula assumes no post-hunt to aerial survey date mortality, which may slightly overestimate HR. Harvest effort (HE) (number of hunter-days per moose killed) was derived from five mail surveys conducted in 1973, 1976, 1978, 1981 and 1984.

Hunting statistics were computed from samples of annual harvests of each hunting zone; they included:

(1) Sex ratio, expressed as the proportion of males in the harvest (excluding calves) (MH),

(2) percentage of yearlings in the harvest (excluding calves) (YH),

(3) number of calves per 100 females over two years old, (CH),

(4) percentage of milking females among females over two years old (MF),

(5) mean age of bulls and cows (excluding calves) (MAM and MAF), determined with cementum annuli of the first incisor (Sergeant and Pimlott 1959).

Either-sex seasons prevailed everywhere without licence quota; in most cases, the bag limit was one animal for two hunters.

The shape and strength of the relationships between the variables were evaluated with regression analyses using the SPSS package (Nie et al. 1975); linear, logarithm, square root, raise at power 2, and inverse relationships were tested. Confidence intervals for a single prediction were computed for the best estimators of density, recruitment and harvest rate according to Neter and Wasserman (1974).

RESULTS

Moose density (D) was inversely related (R^2=0.72; $P < 0.001$) to harvest effort (HE) and positively related (R^2= 0.80; $P < 0.001$) to harvest per 10 km^2 (H) (Table 1); a decrease in the harvest effort and an increase in the harvest per 10 km^2 were both associated with an

TABLE 1. Regressions relating density (D) (moose per km^2), cow-calf ratio in aerial surveys (CCR) and harvest rate of moose (HR), to selected hunting statistics. (CH= Cow-calf ratio in the harvest, H= Harvest per 10 km^2, HE= Harvest effort, MAF= Mean age of females, MAM= Mean age of males, MF= Percentage of milking females, MH= Sex ratio in harvest, YH= Percentage of yearlings in harvest).

	R^2	P	Standard error of estimate	n
(1) Indices of density				
1/D = (0.12 X HE) - 1.18	0.72	<0.001	2.88	11
D = (0.32 X H) + 0.04	0.80	<0.001	0.04	11
(2) Indices of recruitment				
CCR = (0.92 X CH) - 2.32	0.47	=0.02	17.69	11
YH = (0.21 X CH) + 29.66	0.35	<0.001	5.79	160
YH = (0.25 X MF) + 24.51	0.22	<0.001	6.40	160
MF = (1.37 X CH) - 28.63	0.24	<0.001	17.55	162
MAF = (-0.05 X YH) + 6.13	0.22	<0.001	0.62	144
MAF = (-0.01 X MF) + 4.98	0.06	=0.001	0.68	144
MAF = (-0.02 X CH) + 5.45	0.32	<0.001	0.58	144
(3) Indices of harvest rate				
ln (HR) = 0.22 X ln (CH) - 2.50	0.57	<0.001	0.29	30
ln (HR) = 0.22 X ln (MF) - 2.45	0.49	<0.001	0.31	30
HR = (0.004 X YH) + 0.05	0.13	=0.05	0.07	29
HR = (-0.007 X MH) + 0.56	0.23	=0.006	7.0	30
HR = (-0.09 X MAM) + 0.49	0.30	=0.002	0.06	30

increase in density. No additional hunting statistics were related to density.

Three indices of recruitment were disclosed. First, the cow-calf ratio (CCR) in aerial surveys showed a significant positive relationship (R^2 = 0.47; P= 0.02) with the number of calves per 100 females in the harvest (CH) (Table 1). Second, the percentage of yearlings (YH) (R^2=0.35; $P < 0.001$) and of milking females (MF) (R^2= 0.24; $P < 0.001$) were positively related to the number of calves per 100 females in the harvest (Table 1), without being related directly ($P > 0.05$) to cow-calf ratio in aerial survey. These three indices were negatively related ($P <$ 0.001) with the mean age of females (MAF).

Harvest rate (HR) was also related to the above indices of recruitment. A positive logarithmic relationship occurred between this hunting statistic and the number of calves per 100 females in the harvest (R^2=0.57; $P < 0.001$), and with the percentage of milking females (R^2=0.49; $P < 0.001$). The relationship was positive and linear (R^2=0.13; P=0.05) with the percentage of yearlings (Table 1). Finally, the harvest rate was negatively related to the sex ratio (MH) in the harvest (R^2=0.23; P=0.006) and the mean age of males (MAM) (R^2=0.30; P=0.002) (Table 1).

DISCUSSION

A decrease in density was associated with an increase in harvest effort. This relationship was previously observed by Crête et al.

(1981) in a small sample. These authors proposed a target density of 0.26 moose per km^2 as $\underline{X_{msy}}$ for southwestern Québec. To keep density at this level, harvest effort should reach approximately 42 hunter-days per kill, according to our regression of table 1. This target harvest effort differs considerably from the 23 hunter-days per moose recommended by Crête et al. (1981), from a previous regression. The difference between these two regressions probably originates from the two data sets: in the 1981 study, half of the data were collected in game reserves where moose density is high, but where hunting trips last only four days (Crête and Jolicoeur 1985). This leads to more intensive searching for moose in game reserves, as compared to the rest of hunting zones where the season lasts longer. For this reason, the equation developed here is useful for general areas, while the 1981 equation is more suitable for game reserves.

Harvest per 10 km^2 showed a strong relationship with density: harvest was higher when density was higher, which is logical. However, if Caughley's (1976) model is correct, sustainable harvest should be inversely related to density over $\underline{X_{msy}}$. Our results suggest that most moose populations in Québec are kept close to, or below $\underline{X_{msy}}$ by hunting. Under these conditions, both harvest effort and harvest per 10 km^2 may be used to assess moose density.

The significant correspondence between aerial surveys and hunting statistics indicates that the cow-calf ratio in the harvest can be used as an index of recruitment. Three other hunting statistics seemed to be associated with recruitment, although their value appeared more

limited. The large sample size provided by hunting statistics suggests that the percentages of yearlings and of milking females could also be related to recruitment. These results are logical because females that keep a calf until fall are still in lactation during the hunting season. Moreover, because mortality rate is low after the age of six months (Crête and Messier 1984), numerous yearlings can be expected in areas where cow-calf ratios are high in the fall.

The cow-calf ratio in the harvest was inversely related to the mean age of females. Bouchard and Moisan (1974) found that the introduction of hunting in an unharvested moose population lowered mean age, while Crête and Beaumont (1986) found, for Québec, that younger females were less productive than older ones. Younger, and hence less productive females, should then be expected in heavily hunted areas. This apparent contradiction of young and productive populations can be explained by compensatory mechanisms between natural and hunting mortality. When moose densities are lowered by heavy hunting, natural mortality of calves, mainly caused by predation, can be reduced because, in particular, wolf populations may have problems subsisting when moose density drops below 0.2 km^{-2} (Messier 1984). Therefore, high productivity of young populations probably results from an increase in survival rate of the young rather than from an improved calf production.

Highest harvest rates were generally associated with highest recruitment indices, which illustrates the consistency of our data set inspite of its frequent lack of precision. These results fit Caughley's

(1976) model and the logistic growth curve: highest harvest rates are reached when density is lowered close to X_{msy}, where productivity is stimulated. On the other hand, the negative relationship found between mean age of males and harvest rate can be explained by the younger age structure of newly harvested population (Bouchard et Moisan 1974). When harvesting starts, life expectancy diminishes, particularly for males (Paloheimo and Fraser 1981; Crête et al. 1981).

Crête et al. (1981) in Québec, and Babcock et al. (1982) in Utah, suggested that unbalanced sex ratios could decrease productivity. Because the sex ratio in the harvest after peak of rut is almost balanced, due to lowered vulnerability of males (Crête et al. 1981; Dussault and Huot 1986), hunting seasons were held later in October (Crête 1982). Changes in the hunting seasons have affected sex ratios in the harvest and mean age of males in particular; even if these two hunting statistics were related to harvest rate, they cannot serve as indices because they were biased by hunting regulations.

We propose the use of harvest effort, harvest per $10 km^2$ and calves per 100 females in the harvest to predict density, cow-calf ratios and harvest rates: confidence intervals however must be calculated (Table 2). These intervals are wide, even at $\bar{X}$ and for this reason, caution must be exercised when using our regressions for predictions. In Québec, our experience since 1972 supports the use of hunting statistics, particularly to monitor trends over a long period.

TABLE 2. Parameters necessary for computation of confidence intervals on single predictions (Neter and Wasserman 1974) for the best regression models estimating density, cow-calf ratio and harvest rate. Also confidence intervals (expressed as percentage of y) of single predictions at $\bar{X}$ (α=0.10). (CCR = Cow-calf ratio in aerial surveys; CH= Cow-calf ratio in the harvest; D= Density (moose per km^2); H= Harvest per km^2; HE= Harvest effort; HR= Harvest rate).

Regression model	S_e^2	n	$\bar{X}$	$\sum(X_i - \bar{X})^2$	C.I.
1/D= (0.12 X HE) - 1.18	8.303	11	77.10	12918	68
D = (0.32 X H) + 0.04	0.002	11	0.37	0.461	54
CCR= (0.92 X CH) - 2.32	312.954	11	53.50	2965	72
ln(HR) = 0.22 X ln (CH) - 2.50	0.084	30	3.52	59.476	24

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