MODELLING THE SELECTIVE MOOSE HARVEST PROGRAM IN ONTARIO

Chris Heydon[1], Dave Euler[2], Howard Smith[1], and Alan Bisset[3]
[1]Ontario Ministry of Natural Resources, Wildlife Policy Branch, 90 Sheppard Ave. E., North York, Ont. M2N 3A1, [2]Ontario Ministry of Natural Resources, Comprehensive Forest Policy Framework, 1 St. Clair Ave. E., Toronto, Ont. M4T 2V7, [3]Ontario Ministry of Natural Resources, Regional Wildlife Specialist, 810 Robertson St., Kenora, Ont. P9N 3X9

ABSTRACT: Information from adult tag quotas submitted by Districts, aerial moose inventories and District and Provincial Hunter mail surveys were used to evaluate the response of moose herds in selected WMUs to the implementation of the Selective Moose Harvest System. This paper evaluates both the effectiveness of using provincial data to plan harvests at the WMU level and the effectiveness with which the Guidelines were implemented to regulate the harvest in order to meet specific population objectives. There were significant differences between the modelled and surveyed population trends. The model accurately emulated the population trend in 4 of 16 WMUs. In 8 cases the modelled and actual population trends moved in opposite directions and in 4 cases the observed population trend was in the same direction but at a lower or higher rate than that modelled. This suggests that harvest planning using data and assumptions based on provincially averaged population parameters is not appropriate. In addition to a model which was not appropriate in many cases, management decisions were not sufficiently responsive to meet stated objectives. Planned moose harvest quotas were usually calculated correctly to meet the objective. However, cow harvests were excessive in 87 of 117 harvests where it was estimated.

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The Selective Harvest Program for moose was introduced in Ontario for the 1983 hunting season. One objective of the program was to increase the province's moose population from approximately 92,000 (1982) to 160,000 animals by the year 2000. Population targets for each Wildlife Management Unit (WMU) were established through the Strategic Land Use Planning (SLUP) process. A quota system on the numbers of adult male and female moose licence validation tags in each WMU was initiated to regulate the harvest. Harvests are planned according to the "Standards and Guidelines for Moose Harvest in Ontario" (the Guidelines)(Greenwood, *et al.* 1982). The Guidelines are based on a simulation model which incorporates information about moose biology and ecology from Ontario and elsewhere. Managers use them to establish harvest targets to achieve identified population goals.

The harvest quota for each WMU is based on the difference between the current population estimate and that required to achieve the desired population goal for year 2000. Quotas can be calculated simply as a percentage of the mid-winter population or, if adequate sex and age surveys are available, through a more complex method based on a percentage of cows in the herd.

The Guidelines and model embody four concepts of moose biology which are important for planning the harvest. The assumptions are i) that the optimal herd structure contains about 40 bulls per 60 cows; ii) harvests exceeding 12% of the total (or 8% - 9% of the cows in the mid-winter population) will result in population decline; iii) productivity equals about thirty six percent of the adult herd or 157 calves per 100 females in the population at birth; and iv) ideal harvest ratios should be about 61% bulls, 16% cows, and 23% calves.

Little has been done to evaluate how effectively the guidelines have been applied, or to determine how well the provincial model applies to local conditions. In this study, data regarding moose harvest quotas, harvest levels and population trends were compiled to permit analysis of both the management approach and results for sixteen WMUs. A comparison was made between surveyed population trends and those predicted by the population model. In addition a comparison was undertaken of how well the assumptions of the model regarding harvest level and composition were implemented in actual management decisions.

METHODS

Four WMUs in each of four Ontario Ministry of Natural Resources regions were selected for assessment on the basis of adequate aerial survey data being available. Information for calculating moose harvest quotas was obtained from records submitted by District offices. Prior to 1986, these submissions were made in a non-standardized fashion. In some cases, the original calculations used to set quotas had been lost, and data were acquired from summaries provided by District offices.

Estimates of herd size and composition were obtained from the reports of moose aerial inventories conducted between 1982-83 and 1990-91 and compiled by Wildlife Surveys and Records Section. The reports include a full range of survey information including estimates of total and huntable herd size, population density, number of moose observed, and the age and sex composition of the herd.

In Ontario, "Standards and Guidelines for Moose Population Inventory In Ontario" (O.M.N.R. 1981, Bisset 1991a) were developed to minimize variation in technique among Districts and thereby increase the precision (repeatability) necessary to compile population trend information for moose herds. Adjusted population estimates were used as the "best" estimate of the moose population. The adjusted population estimate includes all observed animals plus an additional estimate of "missed moose" based on track aggregations where no animals were seen. This method has been used since the inception of the standard aerial inventory program and is the basis of harvest quota calculation.

Aerial surveys have been flown to determine population size with both fixed wing aircraft and helicopters. While Novak and Gardner (1975) reported biases introduced by aircraft type, Bisset and Remple (1992) reviewed Ontario's moose aerial survey data and suggest that visibility bias is similar for both fixed and rotary wing aircraft, and may be in the order of 15 percent of the observed population. Snyder (1984) summarized eleven moose survey accuracy studies and found that between 30 and 70 percent of moose were missed ($\bar{x}$=58%). Estimates of age and sex classes of populations were also obtained using both fixed-wing aircraft and helicopters. Age/sex estimates from fixed-wing aircraft are likely of variable quality (Bisset unpubl. data) but have been used in this study where necessary.

Harvest data were obtained from two different sources. District Moose Hunter Survey Questionnaires are generally sent to over 50 percent of adult validation tag holders and frequently to calf hunters. Sample size and survey composition are decided by District staff. Where possible the results of these surveys were used because they have larger sample sizes than provincial estimates. The Provincial Moose Hunter Survey which samples only 10 to 20 percent of licence purchasers was designed to survey provincial level trends, and may under-sample at the WMU level. Where necessary the results of the Provincial Survey were used.

Information used to plan the moose harvest includes an estimate of the size of the herd, the target population and a strategy statement (ie. to increase, maintain or decrease the herd). This information was compiled for each WMU in the study. An example of this information for one of the study units, along with estimates of actual harvest, is presented in Table 1. Table 2 consolidates the data and results for each of the 16 WMUs studied.

Modelling was conducted using the POP-II application on an IBM compatible personal computer. The model is an accounting model which does not consider the probability of random events. The biological information for simulation was derived from values given in Greenwood *et al.* (1982). The main input variables (estimates of herd composition, mortality, natality and harvest data), are presented in Table 3. Thus, the model simulations as based on an initial estimate of population size based on aerial inventories (but uses the Guidelines values for initial sex ratios), Guidelines values for reproduction, non-hunting mortality and wounding loss, and District and Provincial Survey estimates of hunting mortality.

The model uses 'bio-years' as the annual units to account for population change. Initial population estimates at the outset of the simulations were those obtained from the 1982-83 aerial survey (if conducted), or from the interpolated population estimates presented by Bisset (1991b). The first population increment begins with the birth of the young of the year, which in Ontario occurs in late May or early June. Over the year, mortality (estimated for summer, hunting and post-hunting periods) reduces the population. Post-harvest population estimates generated by the model should be comparable to populations estimated in the aerial population surveys conducted from mid-December to February (i.e. the predicted 1983 post-harvest population compares with the 1983-84 aerial survey estimate). Fig. 1 presents an example of the model versus observed population trends, as well as observed harvest levels.

Summary statistics were produced for

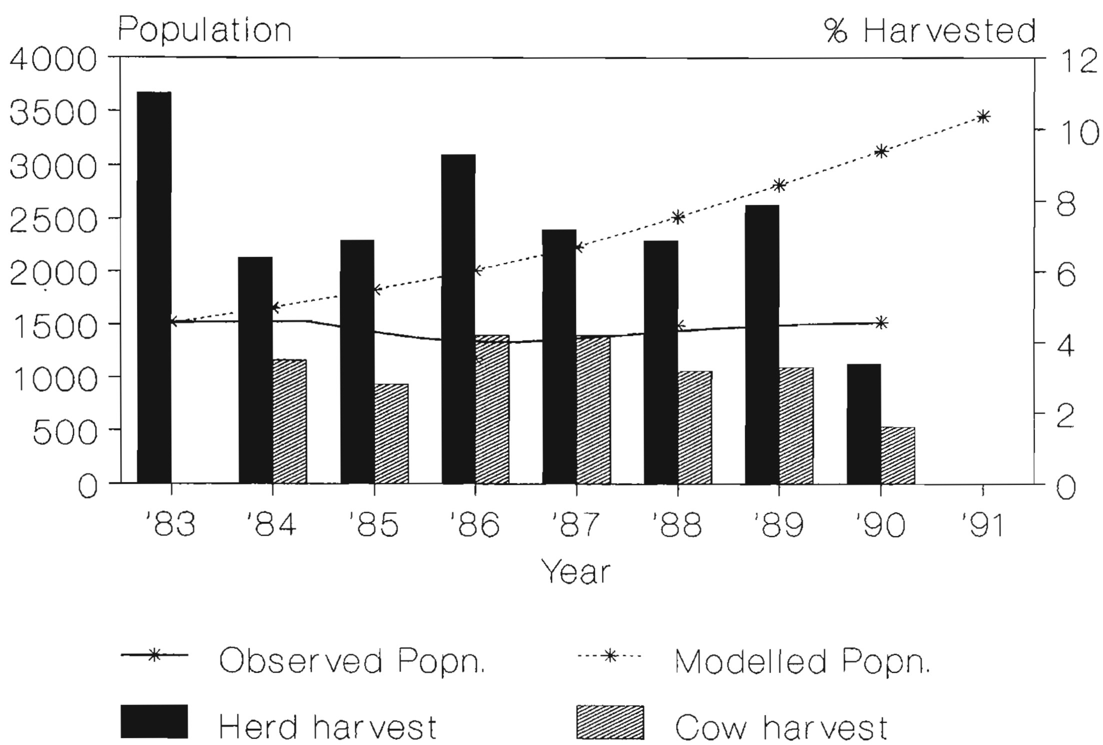


Fig. 1 WMU 27 observed and modelled moose population trends; annual herd and cow harvest. Data derived from Provincial Moose Hunter Surveys, District Moose Hunter Card Surveys and aerial moose inventories.

Table 1. WMU 27 moose harvest quota summary. Information is based on District Moose Hunter Questionnaires, harvest quota submissions, and aerial inventory results.

Planned										Actual								
Background Information				Harvest						Huntable Herd			Harvest					
Year	Popn. Estimate (used in calculation)[a]	Popn. Goal	Mgmt. Approach	Bull	Cow	Calf	Level %	Cow %	B:C Ratio	Bull	Cow	Calf	Bull	Cow	Calf	Level %	Cow %	B:C Ratio
1983		3112	Increase	101[b]	3[b]				unkn.	1246 Total Pop. (1981)			74	42	22	11.0		3.3:1
1984		"	"	110[b]	3[b]				unkn.	557	795	303	55	28	24	6.4	3.5	2:1
1985	1512 (1984)	"	"	96	28	26[b]	10.0	(3.9)[c]	3.4:1	"	"	"	67	22	26	6.9	2.8	3:1
1986	" "	"	"	99	29	55	12.0	(4.0)	3.4:1	478	575	217	55	24	39[d]	9.3	4.2	2.3:1
1987	1416 (Regression)	"	"	80	23	38	10.0		3.5:1	"	"	"	49	24	18	7.2	4.2	2:1
1988	" "	"	"	95	27	45	(11.8)	4.0	3.5:1	425	777	272	60	25	16	6.9	3.2	2.4:1
1989	1490 (1988)	"	"	75	30	45	(10.0)	4.0	2.5:1	"	"	"	62	26	28	7.9	3.3	2.4:1
1990	1578 (1990)	"	"	80	27	51	10.0		3:1	437	773	312	19	12	25[b]	3.4	1.6	1.6:1
1991	" "	"	"	80	27	51	10.0		3:1	"	"	"						

[a]Bracketed value indicates year aerial survey was flown, or other source of estimate.
[b]Quota estimated.
[c]Bracketed values not implicit in quota calculation.
[d]Provincial survey data.

Table 2. Planned and actual harvest levels and strategies, population trends compared to provincial model for selected WMUs in Ontario, 1983-1990.

			Mean planned harvest level, 1983-1990		Mean actual harvest level, 1983-1990				
WMU	Starting population density (moose/km^2)	Population trend	% herd	% cows	% herd	% cows	Trend relative to model	F, P[a]	Actual harvest ratio
5	0.31	static	12.4		14.9	8.8	<	57.5, <0.001	52:20:28
6	0.16	increasing	10.0		8.1	5.8	>	142.2, <0.001	57:18:25
8	0.34	increasing	11.6		15.9	10.0	=	1.2, 0.31	55:19:26
12A	0.35	static/decreasing	12.8	7.8	12.4	6.0	<	76.7, <0.001	60:12:28
13	0.29	increasing?	15.9	6.5	20.1	11.8	>	22.3, <0.01	58:12:30
16A	0.05	static/increasing	8.1		3.8	1.0	<	46.9, <0.001	69:18:13†
16C	0.12	static?	12.4	9.0	6.0	3.2	<	144.1, <0.001	62:10:28
21A	0.27	static/decreasing	10.2		11.8	9.6	<	28.9, <0.001	58:11:31
23	0.18	static	10.0	4.4	9.8	5.2	<	5.4, 0.045	62:11:27
27	0.19	static	10.5	4.0	7.4	3.3	<	69.9, <0.001	53:23:24
28	0.29	static/decreasing	13.2	7.7	15.9	10.1	<	0.0, 0.95	56:17:27
31	0.21	increasing?	10.9	7.0	10.4	4.8	=	0.01, 0.91	50:25:25†
35	0.31	static	12.3	7.4	12.6	7.4	<	68.8, <0.001	58:17:25
36	0.15	increasing	8.2	4.3	13.6	6.8	=	0.1, 0.83	41:34:25†
37	0.26	decreasing	12.6	6.8	16.6	10.2	<	14.4, <0.01	49:26:25†
40	0.27	static	12.2	7.3	14.4	9.9	<	6.0, 0.03	53:20:28

[a]Analysis of covariance homogeneity of slopes probability of a greater value of F.

†Indicates significant difference from recommended bull:cow:calf harvest composition of 61:16:23 (@ 95% CI).

Table 3. Input Variables Required for POP-II.*

I) Initial Population Proportions:

Age	% Male	% Female
Calves	18.0	18.0
1	9.0	9.0
2	5.52	6.48
3	3.78	5.22
4	2.66	4.34
5	1.70	3.30
6	0.90	2.10
7	0.54	1.46
8	0.48	1.52
9	0.40	1.60
10	0.20	0.80
11	0.20	0.80
12	0.10	0.40
13	0.10	0.40
14	0.10	0.40
15	0.10	0.40

II) Non-hunting Mortality:

Age	% Female	% Male
Calves	46	46
1	18	16
2	13	12
3	13	12
4	13	12
6	13	12
7	13	12
8	13	12
9	21	13
10	21	13
11	21	13
12	21	13
13	29	14
14	39	16
15	100	100

III) Wounding Loss: 15% of Harvested Animals

IV) Reproductive Rates:

Age	Calves/100 Cows
Calves	0
1	30
2	157
3	157
4	157
5	157
6	157
7	157
8	157
9	157
10	157
11	157
12	157
13	157
14	157
15	157

V) Harvest Level:
-District Moose Hunter Card Survey used wherever possible; else provincial survey results are used

VI) Mortality Severity Index: 0 (all years)

VII) Effort Values: 0 (all years)

*All values are derived from *Standards and Guidelines for the Determination of Allowable Moose Harvest in Ontario* (Greenwood *et al.* 1982, except V)

each WMU. Performance of the model and therefore the biological assumptions of the Guidelines was assessed through an analysis of covariance homogeneity of slopes model testing for differences in the slopes of the modelled and actual regression lines (SAS, 1982). A chi-square goodness-of-fit analysis was used to compare the average sex ratio of the harvest with the intrinsic values assumed most desirable in the Guidelines. Significance was determined at the 1- α = 0.05 level. Estimated annual harvests were compared to the calculated allowable harvest as a measure of how effectively planned harvests were realized.

RESULTS

The performance of the Guidelines were quantified in each WMU through the homogeneity of slopes analysis between the surveyed and modelled populations (Table 2). The modelled and surveyed population trends were essentially random, differing significantly in 12 of the 16 WMUs assessed.

As a means of illustrating this random response, WMUs were grouped into classes based on the surveyed versus modelled population trend and mean harvest level (Fig. 2). The results show a random response of population trend to harvest level.

A Chi-square test of goodness-of-fit was performed on the sex ratios of moose in the harvest within each WMU. In 4 of the 16 WMUs the average harvest sex ratios were found to differ from those assumed as optimal under the Guidelines. Of the years for which data are available, actual harvest level exceeded the plan in 64 of 124 or 51.6% of all annual harvests, and the cow component of the harvest exceeded that planned in 87 of 117, or 74.4% of all annual harvests.

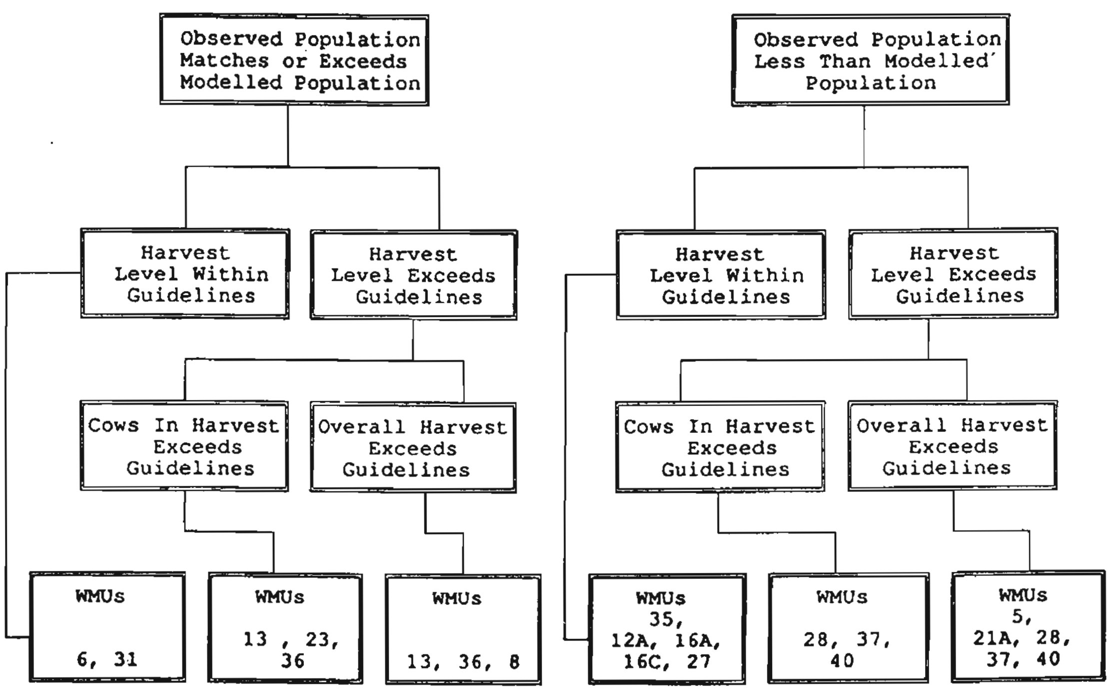
DISCUSSION

There are two separate aspects of this review. The first is to consider the ability of the provincial model to predict population trends at the individual WMU level. The second is to evaluate the effectiveness with which the Guidelines were implemented to regulate the harvest in order to meet specific population objectives.

Clearly the data input variables and assumptions of the provincial model were not accurate for many of the WMUs examined. The modelled versus observed population trends are essentially random. This suggests that provincial data and assumptions are not generally useful for planning moose harvests in individual WMUs. For this reason individual WMU models are essential.

There are a number of reasons why a model may fail. Some of these reasons are very practical in nature while others are more theoretical. In either case, both problems must

Fig. 2. Flowchart listing of WMUs grouped by harvest level and observed population trend, depicting random assocation of harvest level with population response. Harvest levels are an average of the period 1983 - 1990.



be addressed in developing functional models which facilitate appropriate management decisions.

Practical Problems

The practical problems relate to data collection and interpretation. For modelling harvest plans, two key pieces of information are required. These are reliable estimates of population and harvest. Moose population trend information is perhaps most important both for management and for modelling because they are the yardsticks against which management success and the utility of a model are measured. The guidelines for moose population surveys recommend that they be conducted at least every three years (OMNR 1981, Bisset 1991a). Both population size and structure information are required. Although population surveys have generally been done for most WMUs over the period of the study, the numbers of surveys has declined considerably in recent years (Bisset 1991b) and fewer WMUs have adequate population data. If modelling is going to be used to facilitate effective management decisions then at least the minimum level of surveys must be achieved, and in situations when poor survey conditions occur, additional surveys are required.

Relatively few WMUs have adequate age/sex structure information. While age/sex information is obtained in all surveys (OMNR 1981, Bisset 1991a), most surveys are conducted with fixed wing aircraft which may introduce greater variability in age/sex composition due to regional differences in topography affecting observability, as well as their relatively high minimum flight speed and the need for continuous circling. Aerial surveys done in the old Northwest Region by both helicopter and fixed wing craft show significant differences in herd age/sex composition (Bisset pers. commun.). More, and perhaps more effective helicopter surveys are required to assess the age and sex structure of the populations in each WMU.

One potential problem with the use of population survey information in a model is the visibility bias inherent within aerial surveys. Ontario adjusts for visibility bias by estimating missed moose from the number of aggregates believed missed on the basis of tracks (OMNR 1981). The technique is probably subject to error due to the high degree of subjectivity on the part of the surveyors and adjusted population estimates may fluctuate much more widely over time than the observed estimate alone, indicating that sightability is a major source of error. In some cases the adjusted and observed population trends move in opposite directions. The adjusted population estimate was used in the modelling exercise and may account for some of the lack of agreement between the modelled and the surveyed population trends. A less subjective method of adjusting visibility bias, such as that proposed by Bisset and Remple (1992), and estimated for each WMU, would be more appropriate for modelling.

Harvest assessment is generally conducted at an appropriate level, at least for the adult component of the herd, through the District Mail Survey of moose hunters. In many WMUs, however, no estimate of calf harvest is done. A Provincial Mail Survey of moose hunters does provide an estimate of calf harvest but this survey is believed to be less accurate at the WMU level based on the assumption that hunters are less likely to report shooting a calf. More effective modelling could be achieved by including an assessment of calf harvest in District Surveys and perhaps by modifying the Provincial Survey to provide better information at the WMU level.

Theoretical Problems

There are several theoretical limitations of the specific model which are extremely difficult to incorporate at the provincial level. This does not mean that the model cannot be effective, only that it must be executed within a framework which recognizes the limitations. For example, the model does not easily incorporate density dependent factors or habitat quality. It only crudely recognizes that productivity may change as population density or habitat quality changes. This can be overcome by constructing WMU specific models which adjust productivity to local conditions.

The provincial model assumes optimistic levels of natality and mortality. It is impractical to determine such factors for each WMU. They can, however, be incorporated into a WMU specific model so that they reflect what is known about productivity and mortality in a manner that allows the model to reasonably predict population trends. This should permit more effective management decisions, but more importantly, a local basis for testing them. If harvest decisions are made consistent with the local model and the population does not follow projections, then estimates about other influences on the population, such as predation or subsistence hunting, may be challenged.

If useful local models are constructed and tested, then provincial guidelines become less important in determining the level of local harvest. Local models result in better management decisions and this should be one of the considerations in resource management. However, even with perfectly accurate models, population objectives may not be achieved if the information is not used effectively. With current models this simply implies effective response to known conditions. For example, if there is evidence that a population is declining then effective management action must be taken, whether an understanding of the cause is supported by a formal model or the manager's personal knowledge.

Guideline Implementation

In several respects the Guidelines for determining moose harvests have not been effectively implemented. Of the 128 harvest years for which data are available, actual harvest level has exceeded the plan in 51.6% of all annual harvests, and the cow component of the harvest has exceeded that planned in 74.4% of all annual harvests. There are a number of reasons for this, the most common of which is under-estimation of hunter success rates.

The process of selecting a success rate (tag filling rate) to apply to a harvest has proved to be a daunting task. One source of error is the use of a three year average of harvest success to predict future tag filling rates. If hunting success is increasing then this method will result in an underestimate of success, too many adult validation tags issued, and overharvest. The employment of a simple polynomial equation to model the trend of previous hunter success rates in each WMU would result in a greater probability of accurately predicting tag filling rates.

Another problem in the setting of harvest quotas in some WMUs is the use of the total moose population as the basis for quota calculations, when only a portion of the herd is accessible or can legally be hunted. The result can be overharvest of the hunted population. Boer (1990) observed that 92% of moose kills in a New Brunswick study area occurred within 1 kilometre of an access route (road). Throughout most of Ontario access within WMUs by road, water and air is probably sufficiently distributed that this should not present a practical problem. However, where large areas are inaccessible it would be prudent to exclude the population within these areas from calculations of the planned harvest.

Of greater influence on herd size is the setting of quotas based on out-of-date aerial inventories of declining herds. When an incorrect inventory estimate is used to make quota calculations and remains the same year after year, the harvest quota may actually comprise an increasing portion of the herd each year. This can lead to a cycle of exponential negative growth, such as is suggested by Boer and Keppie (1988), and this may have happened in some Ontario management units. Errors in harvest quota calculation have, in many cases, added to the problem, but the contribution is secondary compared to the difference between desired and actual harvest rates.

While technical errors have occurred in the setting of adult harvest quotas, another source of harvest pressure has been the allocation of validation tags in excess of District and regional recommendations. These actions, evident in 1983 and 1984, were made to fulfil an obligation to provide a fair distribution of tags in the aftermath of a computer error during the tag draw. More adult validation tags were issued than was biologically desirable and subsequently, insufficient effort was taken to compensate for possible excessive harvests during this period. Prior to the 1983 hunt, Northern Region, for example, recommended the issuance of 6639 adult validation tags, while 10,706 tags were actually issued (a 61.3% excess). The recommended quota in 1984 for this region was 6672 tags but this was increased to 7664. Similar observations can be made throughout much of the province in these years.

SUMMARY

A general conclusion from this exercise is that the management levers built into the present Selective Harvest Program for moose may mislead managers to unknowingly issue too many adult validation tags. Developing an iterative management approach, in which data such as actual harvest level and composition can be fed back into the process to ensure that subsequent harvests are in keeping with population goals has been difficult, and this should be improved. An increase in the frequency and precision of aerial inventories will make the evaluation of a selected approach a more worthwhile endeavour. Recent Federal and Provincial policy directives towards developing accountability in integrated and sustainable resource management will provide direction in this area.

The use of a locally constructed computer model would help managers to assess the effects of a given level or composition of harvest in a much shorter time frame than a "wait and see" approach which mainly uses aerial survey population estimates to set quotas two to four years down the road. In addition, efforts should be made to use a calculation which better predicts future hunter success rates so that harvests might be more in line with planned quotas.

The "Standards and Guidelines for Moose Harvest in Ontario" have been in use for about 10 years. They are based on a model which uses provincial averages for basic assumptions. Such a model will lead to overharvest in WMUs with below average natality and above average mortality and will lead to under harvest in those WMUs with the reverse set of conditions. The next step in moose management should be to 'fine-tune' the biological assumptions implicit in quota calculations to more accurately reflect the variety of habitat types and quality in Ontario. The use of ecoregions as the basis for developing refined natality and mortality schedules, in the context of the current WMU structure, would increase the precision with which appropriate harvest levels could be determined. Equally important is the need to better anticipate success (tag filling) rates, and to quantify native harvest of moose, effects of predation and weather, as well as illegal hunting and poaching.

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