MOOSE MANAGEMENT SYSTEM

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INTRODUCTION

The purpose of the moose management system is to describe the decision process and the actions needed to meet the goals and objectives established by the public working group. Population objectives (size and structure) were chosen to best meet moose management goals over the long term. Recreational hunting will be the tool used to meet the population objectives in all areas. The population objective will dictate the size of the allowable harvest. In order to fulfill viewing and highway-safety goals, additional measures, other than harvest regulation, will be needed (e.g., public information and education programs, surveys on viewing satisfaction).

MOOSE GOALS AND OBJECTIVES

DEVELOPMENT OF GOALS

The Big Game Public Working Group convened in 1999 to develop goals and objectives that would guide moose management for the next 10 years. The goals are broad statements that describe the "products" wanted from the moose population. The products considered included hunting opportunity, viewing opportunity, road safety, preventing habitat/forest damage, and prey base for wolves. After much discussion, the last 2 concerns were dropped and the remaining products were used to establish goals and objectives for each Wildlife Management District (WMD).

Preventing habitat destruction by moose was one of the “sideboards” the group worked within when establishing goals. The group only identified a few WMDs where they thought forest/habitat damage was a problem, but they agreed that preventing forest/habitat damage would always be a concern. Because it was a sideboard for all areas, it was not specifically stated as a goal for any WMD.

The working group put each WMD into one of three categories based on the management goals they developed; the categories were Recreation Management, Road Safety, and Compromise Management (Figure 1). In the Recreation Management Area, hunting, and usually viewing, opportunities were the most important goals. In the Road Safety Area, reducing the number of moose/vehicle collisions was the only goal. In the Compromise Management Area, the goal was to balance recreation and safety concerns. Population objectives were developed for each management goal.

For WMDs in the Road Safety and Compromise Management Areas, current populations are considered to be unacceptably high, and the public working group recommended those populations be reduced to reduce the number of moose/vehicle collisons. Habitat impacts were expected to be within acceptable limits at the lower

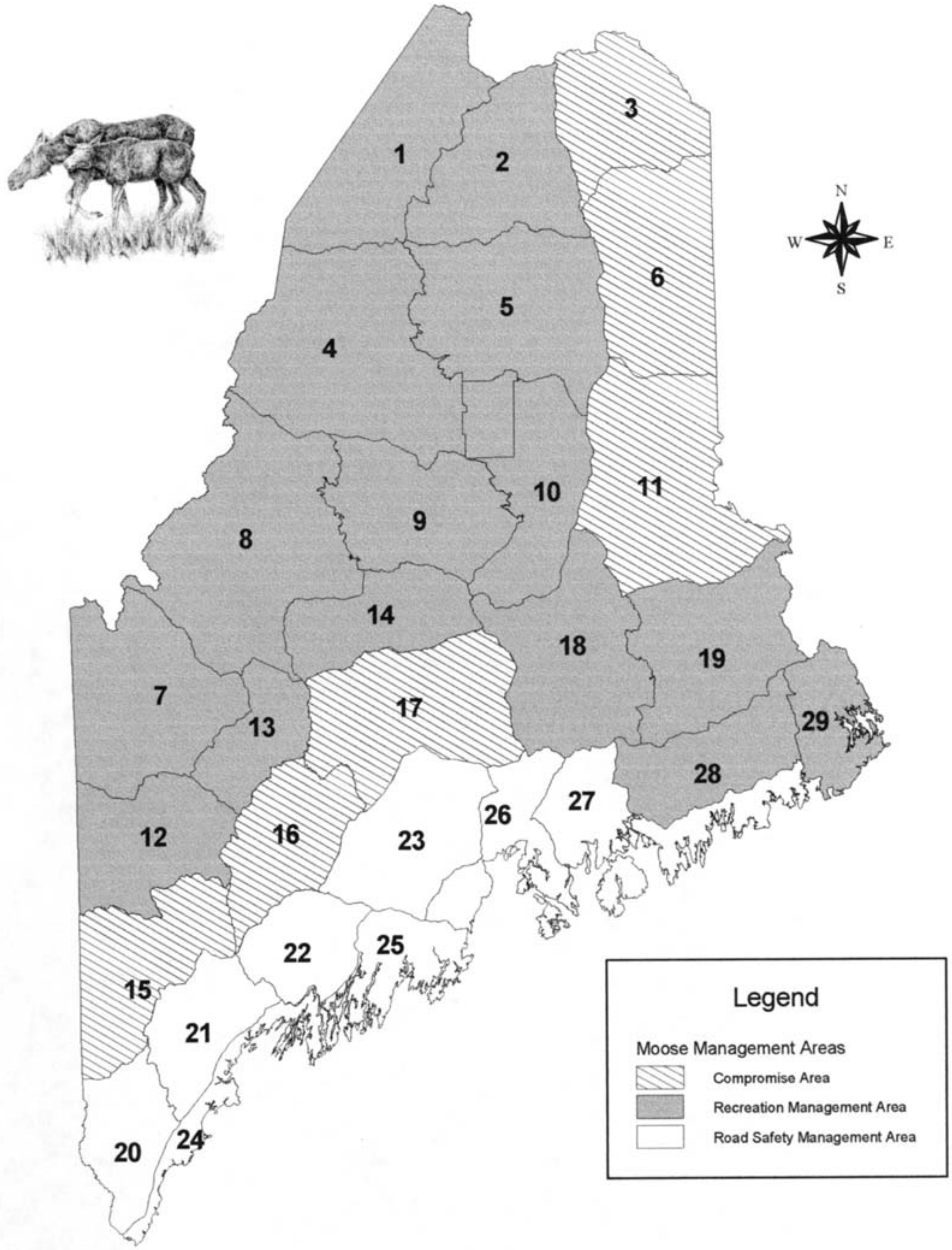


Figure 1: Wildlife Management Districts included in the Three Moose Management Areas

population levels. Population objectives for these two areas were expressed relative to the size of each area's current moose population.

For WMDs in the Recreation Management Area, the working group wanted to have high moose populations, but not so high that habitat would be damaged or animal health would be compromised. Therefore, the desired population size was expressed relative to the carrying capacity (K) of the habitat. The population objective for the Recreation Management Area was set at 55%-65% K. At this level, the allowable harvest would be nearly maximized, and habitat impacts were expected to be within acceptable limits. The target population of 55%-65% K was expected to be similar to or higher than current populations in most WMDs in the Recreation Management Area.

The Department explained that managing at 55%-65% K could result in a reduction in the number of moose if habitat quality declined. The group decided to keep the goal, as stated, rather than recommending to manage the habitat to support a particular density of moose. Reasons for allowing populations to fluctuate with habitat quality were: (1) moose habitat quality is not expected to decline greatly in the next 15 years, and (2) it would be difficult for the state to manage habitat for moose, since most moose habitat in Maine is on privately owned land.

The group considered several “quantity vs. quality” aspects of hunting when formulating population objectives. Although more moose could be harvested if the harvest concentrated on calves, the group did not think this would be desirable. They also considered whether it would be preferable to increase the allowable harvest by permitting the sex ratio to greatly favor cows at the expense of bulls. A population that is skewed toward cows would have a higher recruitment rate than a population that had an even sex ratio. The working group decided it was important to maintain an even sex ratio and have large bulls for both viewing and hunting opportunities.

The group also considered “quantity vs. quality” aspects of viewing. Although increasing the moose population would increase a person’s chance of seeing a moose, it would also reduce the size and productivity of the animals as the population approached K. Thus there would be less chance to see a calf or very large bull, the types of moose that survey respondents said they enjoyed seeing the most. Furthermore, increasing the population above 65% of K would result in habitat damage by moose.

GOALS AND OBJECTIVES

Recreation Management Area

WMDs 1 & 2

Goal: Maximize hunting opportunity while maintaining the availability of mature (over 4 years of age) bulls.

Objective: By 2010, manage the moose population at 55%-65% K[1] while maintaining 17%[2] mature bulls.

WMDs 4, 5, 9 & 14

Goal: Maximize hunting and viewing opportunity while maintaining the availability of mature bulls.

Objective: By 2010, manage the moose population at 55%-65% K while maintaining 17% mature bulls.

WMDs 7, 8, 10, 12, 13,18, 19, 28, & 29

Goal: Balance concerns over moose/vehicle collisions with the desire to provide excellent hunting and viewing opportunity.

Objective: By 2010, manage the moose population at 55%-65% K with 17% mature bulls.

[1] 55%-65% K is the population level which will provide close to the maximum sustained harvest while giving a margin of safety against overharvest, and not result in excessive browsing.
[2] 17% is the highest level that can likely be achieved in a hunted population.

Compromise Management Area

WMDs 3 & 6

Goal: Balance the public's concern about moose/vehicle collisions with the public's desire to hunt moose.

Objective: By 2005, reduce the current (2000) moose population by 1/3 and maintain 17% mature bulls.

WMD 11

Goal: Balance the public's concern about moose/vehicle collisions with the public's desire to hunt moose.

Objective: By 2005, reduce the current (2000) moose population by 1/3 while maintaining the sex ratio of at least 60:100[3] males to females.

WMDs 15, 16, & 17

Goal: Reduce moose/vehicle collisions.

[3] Sex ratios more skewed than this have resulted in some cows being bred late in Quebec.

Objective: By 2005, reduce the current (2000) moose population by 1/3[4].

Road Safety Management Area

WMDs 20 – 27

Goal: Reduce moose/vehicle collisions.

Objective: Reduce the moose population to the extent necessary to minimize the danger to motorists.

MANAGEMENT CONCERNS RELATING TO GOALS

The three types of goals present differing management challenges. The goals and objectives of the Compromise Management Area are clearly stated. The goals and objectives of the Safety Management Area are somewhat less clear. Although the objective for the Safety Management Area calls for a reduction in the number of moose, the magnitude of the reduction needed to achieve the objective is unknown. However, it will be possible to evaluate population trends. There are no conflicting objectives for any WMD in these two areas. The goal of reducing the moose population is expected to be controversial. Several aspects of the goals and objectives for the Recreation Management Area will make meeting the goals difficult.

[4] The working group did not specify a sex or age composition for this population but it is assumed that the sex ratio will be kept at at least 60 bulls: 100 cows as in WMDs 15, 16, and 17.

In 9 of the 15 WMDs in the Recreation Management Area, the Department was directed to address concerns about moose/vehicle collisions while managing the number of moose at 55-65% of K. The target population of 55%-65% K was expected to be similar to or higher than current populations in most WMDs in the Recreation Management Area. Accordingly, there is no known and practical means of reducing collisions over a wide area while stabilizing or increasing the number of moose. Nonetheless, the working group chose to keep the objectives as stated and recommended that road safety be addressed by means other than reducing the number of moose.

Maintaining the population near 55-65% of K is expected to meet long-term recreational demands while keeping browsing damage at acceptable levels. However, there is little experience managing moose populations relative to K anywhere in their range, and no techniques to measure where a moose population is relative to K have been developed. For most of this area, we feel that the moose population is below the objective population. Therefore, the most prudent approach will be to allow the moose population to grow. As the population grows, and we gain more experience with populations near the objective, we will develop measures of population status relative to K.

This management system outlines an approach to managing moose in the Recreation Management Area to be used as we gain experience with populations near the objective level and develop better measurements. It uses two criteria. The first is an estimate of the population density at 60% K based on the experience of other jurisdictions and habitat assessments in Maine. This will serve as a guide to indicate when the population can be allowed to increase with little fear of exceeding the objective and when only slow growth should be allowed. The second is a way of determining when the moose density has become high enough to result in poor nutrition and therefore smaller moose. Both proposed criteria are tentative, as we gain experience with populations at or near the objective level, the criteria will be refined and/or new criteria will be developed.

DECISION PROCESS

OVERVIEW

The decision process is a series of yes and no answers to questions related to criteria A, B, and C (Figure 2) that guide the decision-maker to one of 6 management options (Table 1). These management options are general descriptions of the required harvest, relative to the current harvest, but do not specify the number of bulls and the number of cows that should be killed. An option recommending that the harvest be maintained may include slight adjustments (in either direction) in the harvest to modify the rate of population change, or to maintain a desirable sex composition in the population.

Table 1. Decision matrix of moose management decisions and options.

Population Status Relative to Target CRITERIA A	Population Trend CRITERIA B	Percent Bulls CRITERIA C	Mgmt option	Cow harvest action	Bull harvest action
Above	Increasing	OK	1	Increase	Increase
Above	Increasing	Low	3	Increase	Maintain
Above	Stable	OK	1	Increase	Increase
Above	Stable	Low	2	Increase	Decrease
Above	Decreasing	OK	5	Maintain	Maintain
Above	Decreasing	Low	6	Maintain	Decrease
On	Increasing	OK	1	Increase	Increase
On	Increasing	Low	3	Increase	Maintain
On	Stable	OK	5	Maintain	Maintain
On	Stable	Low	6	Maintain	Decrease
On	Decreasing	OK	4	Decrease	Decrease
On	Decreasing	Low	4	Decrease	Decrease
Below	Increasing	OK	5	Maintain	Maintain
Below	Increasing	Low	6	Maintain	Decrease
Below	Stable	OK	4	Decrease	Decrease
Below	Stable	Low	4	Decrease	Decrease
Below	Decreasing	OK	4	Decrease	Decrease
Below	Decreasing	Low	4	Decrease	Decrease

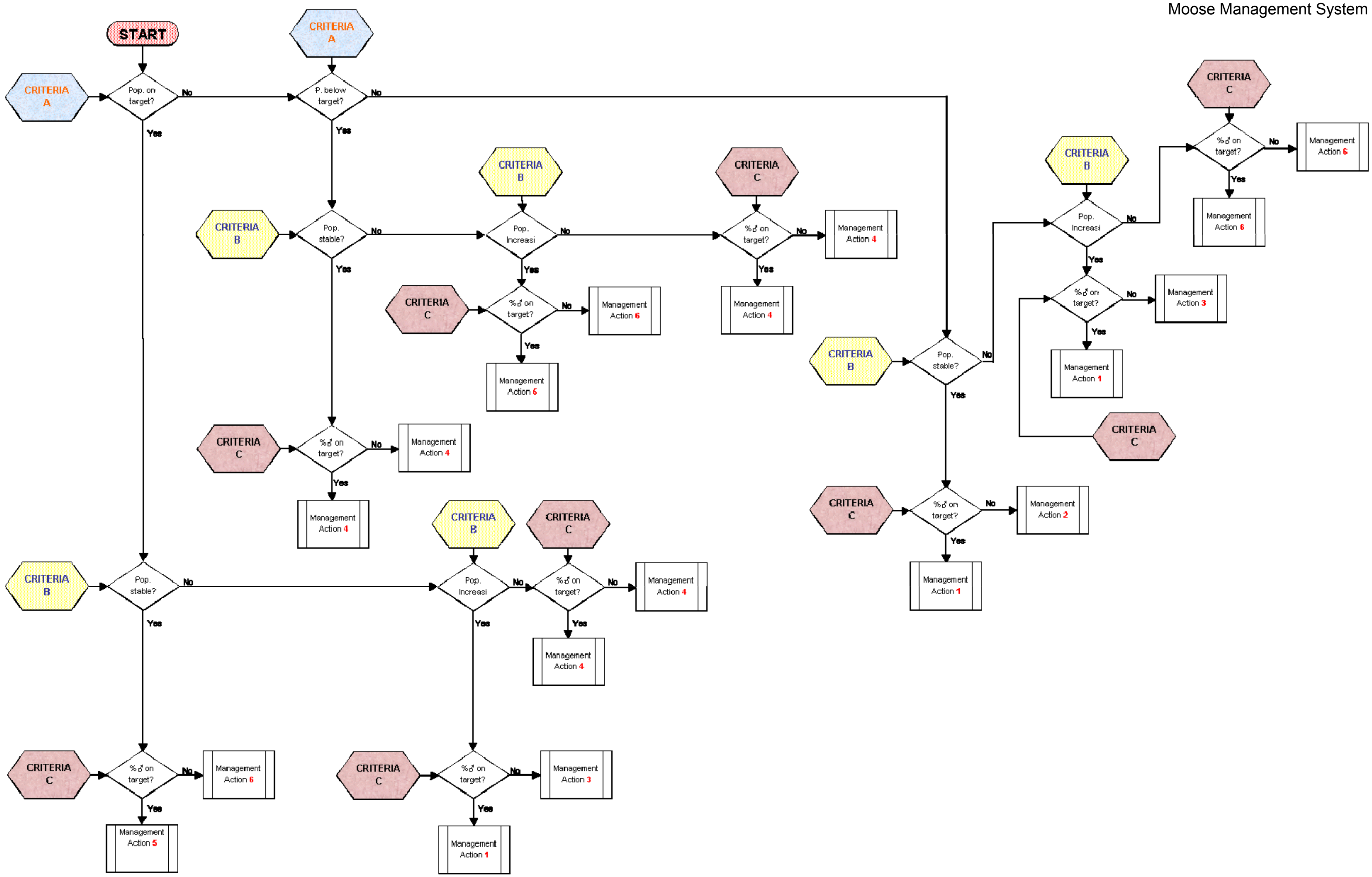


Figure 2. Moose Management System. The management actions are described in Table 1.

CRITERIA A: *Current population vs. population objective*

The first step needed for population management is to determine where the current population is relative to the population objective. In other words, should we increase, decrease, or stabilize the population? Because the population objective is described in 3 different ways for the various WMDs, different methods will be used to determine whether the population is on target. ***Criterion A1*** is used when the objective is to maintain the population at 55-65% of K (Recreation Management Area). ***Criterion A2*** is used when the goal is to maintain the population at around 66% of the current population (Compromise Management Area). ***Criterion A3*** is used when the population is to be reduced to minimize danger to motorists (Safety Management Area).

Criterion A1

For much of the state (WMDs 1, 2, 4, 5, 7 8, 9, 10, 12, 13, 14, 18, 19, 28 and 29) we have been directed to manage moose at the population size that will provide close to the highest harvest without excessive habitat damage, or around 55% - 65% K. This section outlines two criteria that will be used to guide our progress. The first criterion ***($A1_{POP}$)*** compares the current size of the moose population to the estimated size of the moose population at 55% - 65% K. The second criterion ***($A1_{cond}$)*** is based on several antler measurements that change with the physiological condition of the animal. A change in the average physical condition of moose may be indicative of a change in the number of moose relative to K.

Criterion *A1*

Moose population densities at 55% and 65% K are estimated for each WMD using Equations 1-4.

Eq. 1 $D_{M55} = 5.5 \text{ moose mi}^{-2} \bullet H_x$

Eq. 2 $D_{M65} = 6.5 \text{ moose mi}^{-2} \bullet H_x$

For equations 1 and 2,

$\mathbf{D_{M55}}$ and $\mathbf{D_{M65}}$ are the maximum number of moose that can be supported in WMD_x by available browse at 55% and 65% K, respectively;

5.5 and **6.5 moose / mi^2** are estimates of maximum moose densities that can be supported in the southern portion of the moose range at 55% and 65% K, respectively; and

$\mathbf{H_x}$ is a proportion (see Table 2) representing the habitat quality of WMD_x relative to the habitat quality of the WMD with the highest browse production (i.e., WMD 9). This will be updated whenever new data is available from the U.S. Forest Survey.

Assumptions

1. WMD 9 has the highest habitat quality of any WMD. Therefore, if any WMD in Maine could sustain the maximum number of moose for this region, it was assumed it would be WMD 9. The maximum moose density that could be achieved for this region (i.e., 10 moose / mi^2 at K) was estimated from studies of other areas in the southern moose range in North America and Europe that

Table 2. Habitat quality indices for Wildlife Management Districts (WMDs) that are in the moose Recreation Management Area. The habitat quality index compares the browse density in WMD_x to the browse density in WMD 9 as a ratio (i.e., WMD_x : WMD_9). Browse densities were determined from data from the Fourth Forest Inventory of Maine (US Forest Survey 1997), and from a modified version of Allen et al.'s (1987) model.

WMD	Habitat quality index
1	0.81
2	0.94
4	0.88
5	0.71
7	0.88
8	0.88
9	1.00
10	0.73
12	0.73
13	0.62
14	0.77
18	0.44
19	0.62
28	0.50
29	0.44

either sustained a high moose population or experienced a population crash (Angelstam et al. 2000, Connor et al. 2000, Crete 1989, Peterson 1999).

2. It was assumed habitat quality, expressed relative to the habitat quality in WMD 9, would vary in direct proportion to the number of moose a WMD could support at 55%-65% K. Estimates of available browse (habitat quality) for each WMD were determined using a model from the Great Lakes region (Allen et al. 1987) that predicts the number of moose that can be supported in good condition (approximately 50% K). This model was modified to fit conditions in Maine and to make use of data from the Fourth Forest Inventory of Maine (US Forest Survey 1997) (Appendix 1). The Forest Inventory was not designed to measure browse availability on areas as small as a WMD, and more likely reflects habitat quality, relative to other areas in Maine, rather than the actual number of moose that can be supported.

Deer and moose compete for available browse. Therefore, in forested habitats where deer and moose occur sympatrically, and where food is thought to be the limiting factor, the estimate of the habitat's carrying capacity for moose needs to be reduced to account for browse removal by deer. Equations 3 and 4 calculate the number of moose that should be subtracted from D_{M55} and D_{M65} by determining the number of "moose browsing units" represented by the deer in WMD_x.

Eq. 3 $D_{T55} = D_{M55} - (D_d / 3.5)$

Eq. 4 $D_{T65} = D_{M65} - (D_d / 3.5)$

In equations 3 and 4,

$\mathbf{D_{T55}}$ and $\mathbf{D_{T65}}$ are the densities of moose, for $WMD_{x,}$ at 55% or 65% K, respectively, corrected for the amount the local deer population reduced the WMD's carrying capacity (e.g., D_{t55} = target moose density at 55% K);

$\mathbf{D_d}$ is the density of deer in WMD_x from Table 1 PR report for job 306 ; and

3.5 represents the approximate number of deer required to eat the same amount of food as one moose based on metabolic body size.

Assumption

Many of the studies used to estimate $\mathbf{D_{M55}}$ and $\mathbf{D_{M65}}$ were done in areas with no white-tailed deer and in some cases no other large herbivores. To account for this, it was assumed that deer and moose in the forested areas of the Recreational Management Area overlap in food selection sufficiently to reduce the carrying capacity for either species. No attempt was made to quantify the degree of this overlap. Consequently, the assumption that deer and moose compete for food should be reexamined if the moose population exceeds D_{t55} to D_{t65}, but condition indices do not reflect that the moose population is approaching K.

CRITERION $A1_{COND}$

The target population density (D_{t55} to D_{t65}) is only an estimate; consequently, it will be necessary to evaluate the condition of moose in a given WMD to make sure that the population objective is not exceeded. At this time, physiological measurements should be used cautiously, since the exact relationship between the suggested measurements and the population's size, relative to K, is unknown. The relationship between physiological measurements and population status has not been worked out for any subspecies of moose. Given the information available, mean yearling antler spread (Y_S) seems to hold the most promise as a predictor of animal condition (Adams and Pekins 1995). However, some combination of spread, beam diameter, number of points and/or beam length may prove to be a better measure of antler mass as the population increases relative to K, and we will continue to investigate these. Therefore, criterion $A1_{COND}$ should be considered tentative. We will adjust this index as we gather additional data on how the suggested measurements change with population size and habitat conditions. In addition, other techniques will be investigated as they become available. For instance, if the season is held after mid-October, female reproductive tracks may be collected to evaluate productivity by the number of corpora lutea.

In the meantime, two measures of Y_S will be used to guide management decisions as well as to determine when criteria A_1 need to be reevaluated. The first is the measure of Y_s from a reference population that is below 60% K but as close to 60% K as we have experienced. The second is a point estimate of Y_s at 60% K. Moose populations with yearlings that produce antlers as wide or wider than yearling antlers from the reference population are at densities lower than 60% K. If Y_s becomes less than Y_s of the reference population, the population is getting nearer to 60% K but may still be below 60% K. The exact measure of Y_s at 60% K is not known but moose populations with yearlings that produce antlers smaller than the point estimate are likely at densities greater than 60% K. Therefore, for the time being, the second measure will serve as a warning that the population may be exceeding the target.

The first measurement was developed using a reference population of moose harvested from WMD 9 from 1984-1995. The moose population in WMD 9, during this period of time, was closer to the population objective of 55% to 65% K than any other moose population in Maine. Population comparisons between the reference population and current moose populations will be made using the Mann-Whitney test (Zar 1984), a non-parametric statistical test that can be used with small ($n \geq 10$) samples. The mean Y_s for moose from this reference population was 54 cm.

The mean Y_s at 60% K is not known; therefore, a value was estimated from yearling moose harvested in Maine after 1979. To estimate Y_s at 60% K, the smallest Y_s (20 cm) and largest Y_s (101 cm) were assumed to represent Y_s at K, and Y_s at 0% K, respectively. It was also assumed that the relationship between Y_s and the population's relationship to K was linear. These extreme values of Y_s were used as endpoints on a graph of Y_s vs. K, and the value for Y_s at 60% K was interpolated from that graph. From these data, it is estimated that Y_s is 48 cm at 60% K.

Criteria A will be evaluated as follows.

<u>Step 1:</u>

Compare the target moose density ($D_{t55} – D_{t65}$) of WMD_x to the current moose densities (D_c) in WMD_x . Current moose densities are determined either by using a regression of moose sightings by deer hunters on population size (Bontaites et al 2000) or by aerial census.

Step 2

Compare Y_S of WMD_x to that of the reference population and to the estimated value at 60% K.

Step 3

Use the results from Step 1 and Step 2 to determine population status relative to the target.

A. If $D_c < D_{65}$ and if Y_S from WMD_x are ≥ the reference population, the population is considered below target.

B. Whenever mean Y_S < 48 cm and $D_c > D_{65}$, the population is considered above target for management (permit allocation) purposes. When this occurs, we will determine if excessive browsing is occurring and both the estimate of Y_S at 60% K and the target population will be reevaluated.

C. If neither A or B is met, the population will be considered on target for permit allocation purposes. However, browsing levels and habitat conditions should be evaluated in the WMD of question. This information should be used to evaluate the validity of the target density (D_{55} – D_{65}), and the point estimate of Y_s for 60%

K. Whenever a WMD has a population closer to 60% K than the current reference population, but at or above 60% K, it will become the reference population used in step 2 (page 22).

Criterion A2

In six WMDs (3, 6,11,15,16, and 17), we are to reduce the moose population by 1/3 to improve road safety while still maintaining some recreational opportunity. This criterion ***(A2)*** compares the current moose population to the target population, or 67% of the size of the moose population in 2000.

Determine current moose density (D_C) each year by the regression of moose sightings by deer hunters developed by New Hampshire Fish and Game (Bontaites et al 2000) or by aerial census.

Estimate the moose density in 2000 by the regression of moose sightings by deer hunters in 2001 (no survey was done in 2000). The target density (D_T) is 67% of the population in 2000.

If $D_C < 0.8\ D_T$ the population is below target.

If $D_C > 0.8\ D_T$ and $< 1.2\ D_T$ the population is on target.

If $D_C > 1.2\ D_T$ the population is above target.

Criterion A3

The population objective for WMDs 20-27 is: "Reduce the population to the extent necessary to minimize the danger to motorists." As written, this objective suggests that the moose population should be very low; however, no population level was specified. Hunting will be opened under a permit season and liberalized as is socially acceptable. The timing of the season will be determined by social acceptability and will most likely be during the deer season, as recommended by the working group. The number of road accidents and accidents per million vehicle miles will be used to assess the impact of a hunting season on traffic safety.

CRITERIA B: *population change*

The second step needed for population management is to determine the impact of the current harvest regime. Two measures will be used. Criterion B_{TREND} will be used to determine if the current harvest regime is causing the population to increase, decrease, or remain constant. Criterion B_{RATE} will be used to estimate the rate of change. For both criteria, all data points must reflect the impact of moose hunting seasons with regulations very similar to the current season.

CRITERION B_{TREND}: *population trend*

The direction of the population change will be assessed using the following steps.

1. If there is a series of 6[5] or more years of moose sighting rates by deer hunters that reflect similar moose seasons, the Cox and Stuart test for trend (Conover 1980) is used to determine whether or not the population is stable.

2. If there is not a series of 6 or more years of sighting rate data the following rules will be used.

   A. If the population status (based on criteria A) changes from above target to below target

   or

   If the population status (based on criteria A) changes from above target to on target, or from on target to below target, and keeps the new status for 2 years then the population will be assumed to be declining.

   B. If the population status (based on criteria A) changes from below target to above target

   or

   If the population status (based on criteria A) changes from below target to on target, or from on target to above target, and keeps the new status for 2 years then the population will be assumed to be increasing.

[5] Minimum sample needed for the Cox and Stuart test for trend.

3. Until 2002 (when 2a and 2b can be used), moose sightings by moose hunters will be used as in #1. Unfortunately, this will have to be based on moose hunting zones rather than WMDs.

CRITERION B_{RATE}: *rate of change*

The rate at which the population is growing or declining will be needed to calculate permit allocations. The rate of change of a population is the slope of the natural log of the population estimate regressed on time (Caughley and Birch 1971). Moose sighting rates by deer hunters will be used as an index to the moose population. To determine the rate of change of the moose population under the current harvest regime, the natural log of the moose sighting rate by deer hunters will be regressed on time. At least 5 years of moose sighting rates by deer hunters will be used. Until there are 5 years of sightings by deer hunters (2005), the sighting rates reported by moose hunters will be used.

CRITERION C: *population composition*

The third step needed to meet population goals is to determine if the composition of the herd is at the desired level. Two levels have been specified. WMD 11 is to have at least 38% bulls (60 bulls : 100 cows). In WMDs 1-10, 12-14, and 18, 19, 28, and 29 the population is to have 17% mature (over 4 years old) bulls.

Determine the composition of the moose herd from moose sightings reported by deer hunters and the ages of harvested animals using the following equations.

Eq. 5 $S = (B/(B+C))100$

Eq. 6 $A = (F/T)100$

Eq. 7 $P = (B/(B+C))(F/T)\times 100$

For equations 5-7,

S= Percentage of bulls in the population. Initially, use proportion of bulls to cows in sightings by deer hunter (pers. com. Bontaites and Gustafson).

A = Percentage of mature bulls[6] among antlered bulls.

B= number of bulls seen by deer hunters

C= number of cows seen by deer hunters

T= number of bulls over 2 in the harvest

F= number of bulls over 5 in the harvest

P= Percentage of mature bulls[6] in population.

Determine the status of the population structure.

For WMD 11:

If $S < 38\%$ there are too few bulls in the population.

If $S \geq 38\%$ the sex composition of the population is acceptable.

[6] Ideally, this is the percent of bulls over 4 years of age among adult and yearling bulls. However, because hunters select against yearlings, the percent of 2+ bulls in the harvest that are over 5 years old will be used as an estimate.

For WMDs 1-10, 12-14, and 18, 19, 28 and 29:

If $P < 17\%$ there are too few mature bulls in the population.

If $P \geq 17\%$ the sex and age composition of the population is acceptable.

ESTIMATING CHANGE IN HARVEST NEEDED

Two processes are available to determine the magnitude of the harvest. When the population is to be increased (management option 4), it will often be possible to prescribe a harvest based on previous experience. If a lower harvest was allowing the population to increase by up to 5 % per year (based on sighting rates), we will reduce the harvest to that level. Otherwise, the harvest prescriptions will be determined following the four sections in worksheet 1 (Figure 3).

SECTION 1: Determine population status

SECTION 2: Determine management needs

The manager selects the needed changes in population size and structure based on population status described in step 1. The desired rate change in population size is selected using the following guidelines.

The rate of change should be lower (near 2% per year) when the population is approaching the target and higher (up to 5% per year) when it is far from target.

Changes of more than 5% per year in either direction should be avoided unless there is a high risk of habitat damage or extirpation of moose.

SECTION 3. Determine needed change in harvest

Figures 3a and 3b are used to determine the change in the harvest (expressed as a percent of the total population) needed to produce the desired change in population.

The needed change in harvest is determined separately for cows (3a) and bulls (3b). Figures 3a and 3b were developed following a model developed to predict the effects of different harvests (Schwartz 1993). The following procedure is used to determine needed changes in harvest:

First, to determine the necessary change in the cow harvest, use Figure 3a. The graph includes lines for nine variations in population composition and trend. Pick the line that best describes the current population, or two lines to interpolate between.

Second, pick the desired population trend (F from worksheet 1) on the X-axis and read the change in harvest from the Y-axis.

Figure 3. **WORKSHEET 1**

TO CALCULATE BULL AND COW HARVEST PRESCRIPTION WMD _____ YEAR _______

1. DETERMINE POPULATION STATUS USING CRITERIA A, B, C, AND HARVEST DATA.

A. POPULATION ESTIMATE…………………………………..**A=** _________

AND STATUS (above, on, or below) TARGET……………..__________

B. POPULATION TREND (% change from regression of ln sighting rate on year) ______

C. ADULT SEX RATIO (bulls : 100 cows from deer hunter survey)…….……….______

D. COW HARVEST UNDER CURRENT REGULATIONS………..**D=**_________

E. BULL HARVEST UNDER CURRENT REGULATIONS………..**E=**_________

2. DETERMINE MANAGEMENT NEEDS

F. DESIRED POPULATION TREND AND RATE (-5% TO +5%).…………. ______

G. INCREASE % OF (MATURE) BULLS? (YES OR NO) ………………….________

3. DETERMINE NEEDED CHANGE IN HARVEST FROM FIGURES 3A and B

H. CHANGE IN BULL HARVEST (as % of total population)………**H=**_________

I. CHANGE IN COW HARVEST (as % of total population)…………**I=**__________

4. CALCULATE HARVEST PRESCRIPTION

J = A(H/100%) + E = _________ BULLS TO BE HARVESTED

K = A(I/100%) + D = _________ COWS TO BE HARVESTED

Figure 3A. Changes in cow harvest (as % of the population) needed to change population trend for 9 initial populations. For each line the first 2 numbers is the number of bulls:cow, ok or inc indicates if the sex ratio is ok or needs to be increased and the last number is the annual rate of change in population size. The desired population change is chosen by the manager.

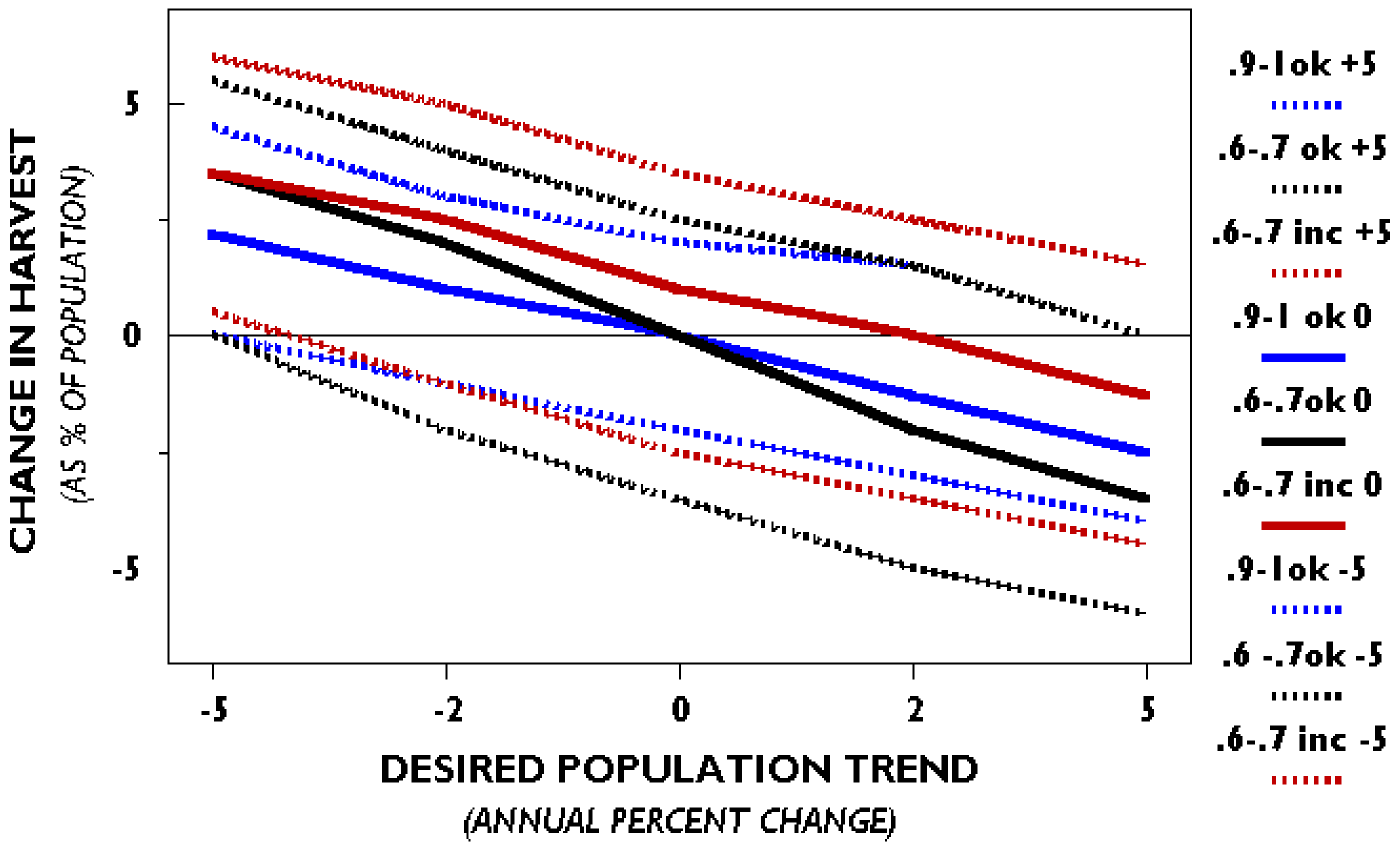
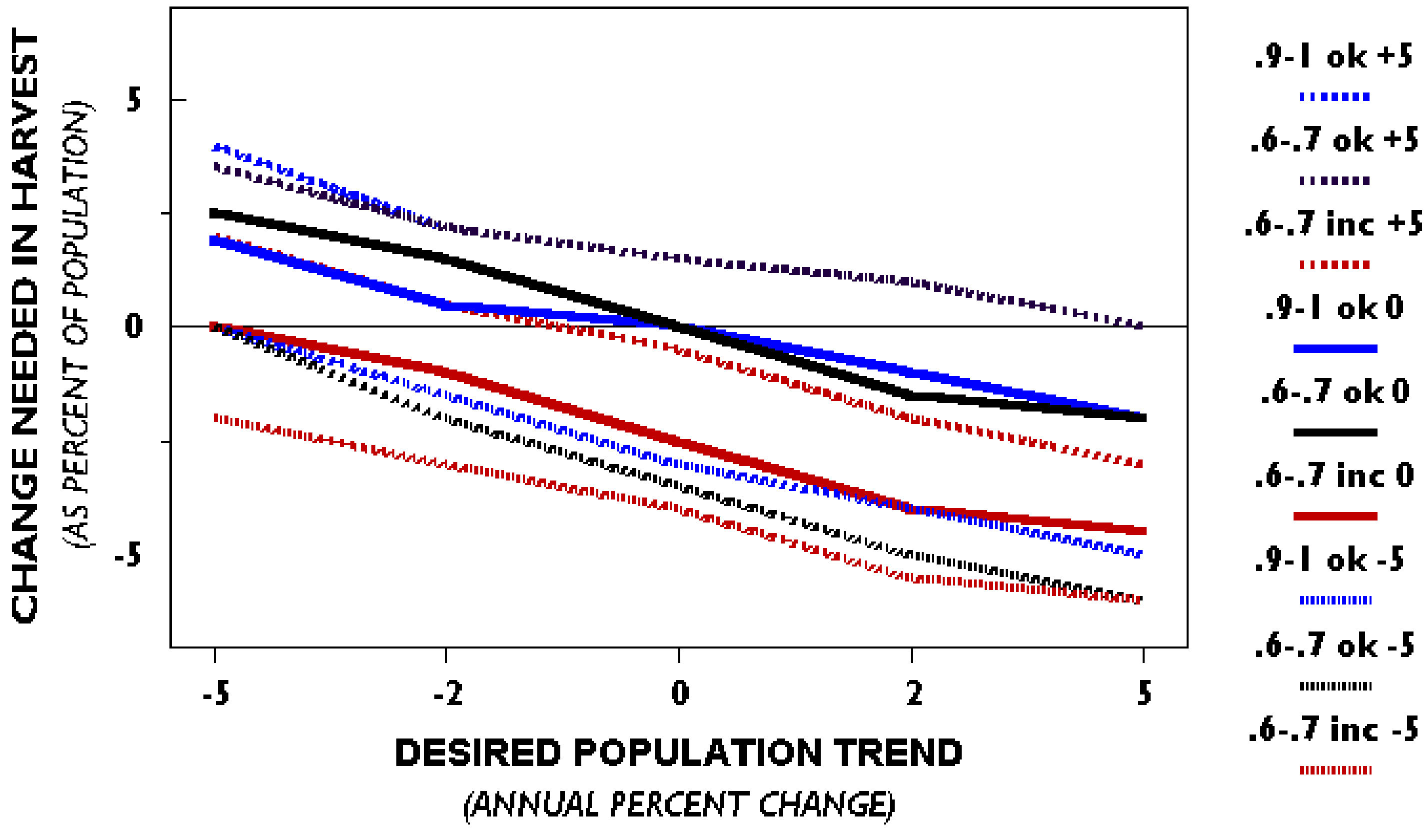


Figure 3b. Changes in bull harvest (as % of the population) needed to change population trend for 9 initial populations. For each line the first 2 numbers is the number of bulls:cow, ok or inc indicates if the sex ratio is ok or needs to be increased and the last number is the annual rate of change in population size. The desired population trend is chosen by the manager.



Third, record the needed change in harvest in section 3 of the worksheet.

Repeat for bulls using figure 3b.

SECTION 4. Calculate harvest prescription

Calculate the harvest prescriptions for bulls and cows using the formulas on worksheet 1.

CALCULATING PERMIT NUMBERS

Under current regulations, two types of moose permits are issued. An any moose permit (AMP) allows the hunter to shoot a moose of either sex or any age. An antlerless only permit (AOP) allows a hunter to shoot a cow, a calf, or a bull with antlers shorter than its ears. The number of AMPs and AOPs needed to reach the harvest prescription are determined using the data inputs and formulas from worksheet 2 (Figure 4). The derivation of formula 3b is explained in Appendix 2.

AOPs and AMPs make it possible to adjust the sex ratio of the harvest, but only within certain limits. The proportion of bulls in the harvest cannot be greater than the proportion of bulls among moose killed by AMP holders or less than the proportion of bulls among moose killed by AOP hunters. If the harvest prescription calculated on worksheet 1 falls outside these limits, the harvest prescription cannot be met using

Figure 4. WORKSHEET 2

TO CALCULATE PERMIT ALLOCATION
WMD _____ YEAR_____

1. DETERMINE HUNTING STATISTICS USING HARVEST DATA

PROPORTION OF AOP HARVEST THAT IS BULLS…………**B_{AOP}= ______**
PROPORTION OF AOP HOLDERS THAT KILL A MOOSE……...**S_{AOP}= _____**
PROPORTION OF AMP HARVEST THAT IS BULLS…………….**B_{AMP}= ______**
PROPORTION OF AMP HOLDERS THAT KILL A MOOSE……...**S_{AMP}= _____**
CURRENT OVERALL SUCCESS…………………………………………**S=_______**

2. ESTIMATE TOTAL NUMBER OF PERMITS (P_T) TO BE ISSUED

$$P_T = (J+K)/S$$

P_T = _________

J = BULL HARVEST PRESCRIPTION FROM WORKSHEET 1
K = COW HARVEST PRESCRIPTION FROM WORKSHEET 1

3. DETERMINE AMP ALLOCATION (P_{AMP}):

$$P_{AMP} = (J - P_T(B_{AOP} S_{AOP})) / (B_{AMP} S_{AMP} - B_{AOP} S_{AOP})$$

AMP=______

4. DETERMINE AOP ALLOCATION (P_{AOP}) :

$$P_{AOP} = P_T - P_{AMP}$$

AOP

AOPs and AMPs. As long as moose hunters maintain their strong selection for bulls, this will not be a problem. However, if hunters stop selecting for bulls, it may be necessary to change to permit types that protect cows and/or force hunters to shoot bulls.

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APPENDIX 1.

METHOD USED TO CALCULATE BROWSE AVAILABILITY

Availability of preferred browse was calculated using 3 sources of information. The number and dbh of stems less than or equal to 3.0 inches dbh was taken from the Fourth Forest Inventory of Maine (U. S. Forest Service 1997). Browse production was based on regressions of browse production of *Populus trichoptera* on basal diameter from MacCracken and Van Ballenberghe (1993). The regression formula was modified with data from measurements from *P. tremuloides* to adjust from basal diameter to dbh. The resulting formulas were:

growing season browse production = dbh*4.5*stems per m^2

dormant season browse production = dbh*1.2*stems per m^2

Browse production is in g/m^2 and dbh is the average for the stand in mm.

Survey plots from the forest resurvey were classified by browse abundance following Allen et al. (1987). Classifications were: none (<6 g/m^2), low (6 -15 g/m^2), medium (16 -25 g/m^2), high (26 - 35 g/m^2), and very high (> 35 g/m^2). These calculations are much simplified from Allen et al. (1987). We did not have adequate data to adjust for differences in browse quality by canopy closure, or availability by distance to winter cover as in Allen et al.(1987). Browse production would have been overestimated without these considerations. To compensate for this we only calculated the amount of preferred browse and did not include browse produced by less preferred, but still commonly used, species such as fir, sugar maple and yellow birch.

Species for which browse production was calculated for the dormant season included: *Populus* spp. , *Prunus* spp, *Sorbus* spp, *Salix* spp, *Quercus rubra*, *Cornus* spp, *Vibernum* spp, and *Corylus* spp. Growing season preferred browse included: *Populus tremulades* and *P. grandidentata*, *Prunus* spp, *Sorbus* spp, *Salix* spp, *Amelanchior* spp, *Acer spicatum*, *A. rubrum*, *A. pensylvanicum*, and *Betula papyrifera*.

CALCULATION OF POTENTIAL MOOSE POPULATION.

The number of moose that can be supported (in good condition) by the available browse on each WMD was calculated following the formulas of Allen et al. (1987):

$$M_1 = \sum_{i=1}^{n} (0.2)[D_i)(A_i)/1,000]/432$$

where M_1 = potential number of moose that could be supported by browse during the growing-season, assuming optimum browse quality in evaluation unit

0.2 = reduction factor accounting for 20% maximum cropping rate

D_i = estimated density of growing-season browse (g/m^2 dry weight) in stand "i"; enter 0 for all areas where density is <5 g/m^2 dry weight

A_i = area of i<u>th</u> stand

1,000 = conversion constant $\frac{\text{grams}}{\text{kilograms}}$

432 kg = dry weight (kilograms) of browse consumed by a lactating cow, which is assumed to be enough browse to support a moose of any age or sex

and

$$M_5 = \left(\frac{SIV6}{1,028}\right) \times \sum_{i=1}^{n} (0.6)[D_i \times A_i \times SIV4_i \times SIV5_i)/1,000]$$

where M_5 = potential number of adult moose that could be supported by browse during the dormant-season at measured level of coniferous species composition, distance to dormant-season cover, and species composition in the evaluation unit

0.6 = reduction factor accounting for 60% maximum cropping rate

D_i = estimated density of dormant-season browse (g/m^2 dry weight) for the i<u>th</u> stand except enter 0 for all areas where density is <1 g/m^2 dry weight

A_i = area of i<u>th</u> stand

$SIV4_i$ = suitability index for proportion of woody browse composed of coniferous species in i<u>th</u> stand

$SIV5_i$ = suitability index for mean distance to dormant-season cover in i<u>th</u> stand

$SIV6_i$ = suitability index for dormant-season browse species composition rating in entire evaluation unit

1,000 = conversion constant $\frac{\text{grams}}{\text{kilograms}}$

1,028 = number of kilograms of browse consumed by one adult moose during dormant-season

Major assumptions in Allen et al.'s model include: 1. A moose requires 432 kg of browse during the growing season; 2. The maximum cropping rate for growing season browse is 20%; 3. A moose requires 1,028 kg of browse during the dormant season; and 4. The maximum cropping rate for dormant season browse is 60%.

Several modifications were made to adapt this model to our data and use: 1. Each browse abundance class in our calculations was treated as a stand is in Allen et al.'s formulas; 2. For ease in comparison, we expressed the number of moose that could be supported as moose per square mile rather than the total number that could be supported by the WMD; 3. The distance from softwood cover was not available and therefore not used in calculating dormant season browse; 4. To reduce the risk of overestimating browse availability, only preferred species of browse were considered.

APPENDIX 2. Derivation of Formula to Calculate Number of AMPs to Issue.

Variables:

B_{AOP} = Proportion AOP harvest that is bulls*

S_{AOP} = Proportion of AOP hunters that kill a moose*

P_{AOP} = Number of AOP to be issued (unknown)

B_{AMP} = Proportion of AMP harvest that is bulls*

S_{AMP} = Proportion of AMP hunters that kill a moose*

P_{AMP} = Number of AMP to be issued (unknown)

J = Bull harvest prescription calculated on worksheet 1

J_{AOP} = Bulls killed by AOP holders (unknown)

J_{AMP} = Bulls killed by AMP holders (unknown)

P_T = Total number of permits calculated on Worksheet 2

Equations Used in Derivation:

Equation 1 $P_T = P_{AMP} + P_{AOP}$ or $P_{AOP} = P_T - P_{AMP}$

Equation 2 $J_{AMP} = P_{AMP}\ B_{AMP}\ S_{AMP}$

Equation 3 $J_{AOP} = P_{AOP}\ B_{AOP}\ S_{AOP}$

Derivation:

$J = J_{AMP} + J_{AOP}$

$J = P_{AMP}\ B_{AMP}\ S_{AMP} + P_{AOP}\ B_{AOP}\ S_{AOP}$ *[replace J_{AMP} and J_{AOP} using equations 2 and 3]*

$J = P_{AMP}\ B_{AMP}\ S_{AMP} + (P_T – P_{AMP})\ B_{AOP}\ S_{AOP}$ *[replace P_{AOP} using equation 1]*

$J = P_{AMP}\ B_{AMP}\ S_{AMP} + P_T\ B_{AOP}\ S_{AOP} - P_{AMP}\ B_{AOP}\ S_{AOP}$

$J = P_{AMP}\ (B_{AMP}\ S_{AMP} - B_{AOP}\ S_{AOP}) + P_T\ (B_{AOP}\ S_{AOP})$

$J – P_T\ (B_{AOP}\ S_{AOP}) = P_{AMP}\ (B_{AMP}\ S_{AMP} – B_{AOP}\ S_{AOP})$

$(J – P_T\ (B_{AOP}\ S_{AOP}))\ /\ (B_{AMP}\ S_{AMP} – B_{AOP}\ S_{AOP}) = P_{AMP}$

*from a recent harvest under similar regulations