MOOSE ASSESSMENT

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INTRODUCTION

Since 1968, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has aggressively pursued development and refinement of wildlife species assessments and implementation of cost-effective comprehensive programs that support selected goals and objectives for the next 15 years. Assessments are based upon available information and the judgments of professional wildlife biologists responsible for individual species or groups of species. Precise data may not always be available or are too limited for meaningful statistical analysis; however, many trends and indications are sometimes clear and deserve management consideration.

The assessment has been organized to group information in a user-meaningful way. The Natural History section discusses biological characteristics of the species that are important to its management. The Management section contains history of regulations and regulatory authority, past management, past goals and objectives, and current management. The Habitat and Population sections address historic, current, and projected conditions for the species. The Use and Demand section addresses past, current, and projected use and demand of the species and its habitat. A Summary and Conclusions section summarizes the major points of the assessment.

Information used to compile this document was gathered from several sources that used different geographic units. In addition, moose hunting has been based on moose hunting zones established in 1986 but will be changing to zones based on the combination of recently established Wildlife Management Districts (WMDs) in 2000. Maps of various geographic units referred to in this document are presented as Appendix I.

NATURAL HISTORY

Description

Moose are the largest member of the deer family. Calves weigh about 30-35 pounds at birth and about 400 pounds at 5 months of age. In Maine, a typical adult male weighs 1,000 -1,100 pounds but very large specimens may weigh as much as 1,400 pounds (live weight). A typical adult female weighs 800-900 pounds. Moose are about 6 feet tall at the shoulder. Bulls grow a new set of antlers each spring and drop them in early winter. Antler size varies from spikes or forks on most yearlings to large palmate structures up to 6 feet wide on exceptionally large mature bulls. An antler spread of 4-5 feet is typical for adults.

Distribution and Status

Moose are found in northern latitudes of both the old and new worlds. They are well adapted to living in cold climates and are found as far north as there is available food. However, their inability to tolerate heat limits their distribution to the south (Karns, 1997). Moose were reduced in number or eliminated from much of their southern range in North America and Europe by over exploitation and/or habitat loss due to forest clearing for agriculture and development. During the last century, protection from excessive harvest and improving habitat conditions have allowed moose to increase in numbers and repopulate some of their former range. Moose have also been introduced

to previously unoccupied areas in Colorado (Duvall and Schoonveld, 1988) and Newfoundland (Peterson, 1955).

The northeastern United States was no exception to this general pattern of decline and recovery (Peek and Morris, in press). During the 17th Century, moose were reportedly abundant in New England and were found as far south as Pennsylvania. By the early 1900's, the moose population in the Eastern U.S. was reduced to a few thousand animals in Maine (Morris and Elowe, 1993), and extreme northern New Hampshire (Bontaites and Gustafson, 1993) and Vermont (Alexander, 1993). Moose are once again common in northern New England and moose hunting seasons have been reopened in the three northernmost New England states. Small populations have become established in New York and Massachusetts (Vecellio et al, 1993), and occasional animals wander farther to the south.

Food Habits

Moose subsist almost entirely on browse, the leaves and twigs of woody plants. Deciduous trees (hardwoods) and shrubs such as willow, aspen, birch, maple, pin cherry, and mountain ash are eaten year round. Although balsam fir is an important winter staple, it has lower nutritional value than the hardwoods and is not adequate by itself. Moose are large animals and require a correspondingly large amount of food. A lactating cow, the class of animal with the greatest nutritional needs, eats over 30 kg (66 lb wet weight or 9 lb dry weight) of browse a day (Allen et al. 1987), bulls and calves require less food. The large quantities of high quality browse needed by moose for efficient foraging are typically found in regenerating forest stands. Consequently, high or increasing moose populations are typically associated with early successional

habitat. Common causes of disturbance that provide feeding areas for moose include fire, wind throw, insects, and forest practices, such as clearcutting, that open the forest canopy.

Moose have access to food of higher quality and quantity during the growing season than during winter. During the growing season, hardwood leaves, herbaceous plants, and aquatic plants are available. Not only is the total amount of food lower in winter, a smaller proportion is available to moose when deep snow or crusts restrict their mobility. In addition, hardwood twigs and fir are less nutritious and more difficult to digest than hardwood leaves. Although winter foods are less available and nutritious, the nutritional requirements for moose in winter are also less. The metabolism of moose slows down in the winter, thus allowing them to decrease their appetite. In addition, moose rely on stored fat and normally loose weight during the winter.

In Maine, browse does not provide adequate sodium and moose must seek this from other sources. Natural salt licks are uncommon in this state and are not an important source of sodium for Maine moose. Artificial licks formed by runoff from salted roads are a commonly used source of sodium that is available throughout much of the state.

Aquatic plants, which have much higher sodium content than terrestrial plants, are eaten during the summer, and appear to be sought primarily as a source of sodium (Belovsky 1981). Moose have reduced the abundance of these plants in many shallow ponds in parts of northern Maine.

Habitat Requirements

During winter, moose select habitat based on food availability and snow depth. Until snow becomes restrictive, food availability is the more important factor. Moose commonly winter where hardwood browse is more available and often take advantage of regenerating areas. Mature softwood is used for winter cover and is especially important when snow depths of more than 3 feet impede travel (Telfer 1967). Dense snow or crusts can restrict movement when there is less snow. Moose use patches of softwood at a variety of elevations during most winters, but do not concentrate like deer do.

There do not appear to be highly specific cover requirements for calving in Maine. Leptich (1986) found that calving sites in Maine were typically undisturbed areas near water with available browse. Both forested areas and open bog sites were used. Suitable sites for calving appear to be readily available.

Bulls and cows use somewhat different habitats during the summer, probably reflecting a trade off between the need for thermal cover to reduce overheating and the needs of calf rearing. Bulls are more likely to use higher elevations while cows are typically found at lower elevations closer to aquatic feeding areas. This likely reflects the lactating cow's greater need for water and sodium (Belovsky and Jordan 1981) . Bulls use mixed and hardwood forest stands more than cows, while cows are more likely to use regenerating stands and adjacent softwoods. A more concentrated food source reduces foraging time, and therefore, the amount of time calves (which follow their mothers) are active and exposed to predation. Bulls prefer to feed in older mixed or hardwood areas where the food supply is lower but the thermal cover (shade) is better (Leptich 1986) . Both sexes may take periodic trips to feed on aquatic plants in a

lake or pond several miles from the core area of their home range (Crossley 1985, Leptich 1986). Miller (1989) noted the same pattern for use of roadside licks in New Hampshire.

Maine moose usually have a home range (the area they live in) of 20-30 km^2 (8-12 mi^2). Although moose are migratory in some areas, the summer and winter home ranges of Maine moose usually overlap or are in close proximity (Thompson 1987). Winter home ranges are normally smaller than summer home ranges. Thompson (1987) found that moose used areas averaging 7 km^2 (3 mi^2) during a winter with little snow but were restricted to home ranges averaging 1.5 km^2 (0.6 mi^2) during a winter with deep snow.

Reproduction

Breeding occurs in late September or early October. Calves remain with their mother for one year and are driven off shortly before the birth of the a calf in late May. Bulls do not reach their maximum size until they are 5 years old. Although bulls are physiologically able to breed as yearlings, most of the breeding is done by older bulls. Sex ratios that ensure that most cows are bred early in the season vary from 60 bulls per 100 cows in Quebec (Crete et al. 1981) to 16 bulls per 100 cows in Alaska (Schwartz et al. 1992). Alaskan (tundra) moose tend to form large rutting groups where one bull can service many cows, while moose in the forested areas of eastern North America tend to form pair bonds (Schwartz 1997). Therefore, although acceptable sex ratios have not been determined for moose in Maine, they are likely to be similar to those for Quebec.

Whether a cow produces none, one or two calves depends on her weight, age and fat reserves (Heard et al. 1997). Combined data from three New England states suggests that cows under 440 lb (dressed weight) are unlikely to ovulate, those from 440 to 550 lb will likely produce only 1 egg. Those over 600 lb are likely to produce two eggs and potentially have twins (Adams 1995). Cows may produce their first calf when they are two if they have had adequate nutrition, but two year olds rarely have twins. Most cows produce calves by age three and continue to produce calves into their late teens. However, older cows are less productive than prime aged (5 - 13 yr. old) cows (Schwartz and Hundertmark 1993, Heard et al. 1997).

Mortality

Causes of moose mortality include legal and illegal harvest, road kills, other accidents (e.g., drowning and falls), predation, disease, starvation, and old age. Animal condition, reflected by antler development and weight, peaks at around 5 years of age and begins to decline noticeably at 10 or 12 years of age. Moose occasionally live slightly more than 20 years.

Natural mortality has been assessed for some age classes in Maine by following radio-collared animals. Based on radio-collared adults in Maine, natural mortality is low, 6-9 % per year. Of 10 collared animals whose age at death could be determined, 70% were older than 10 and many were in their late teens. Old moose develop a variety of infirmities including cataracts, dental problems, arthritis and osteoporosis (Hindelang and Peterson 1993, Hindelang et al. 1992). The complications of old age appear to be a common mortality factor of adult moose in Maine.

Of 12 calves collared in Maine at 2 - 4 months of age, one was shot during the hunting season and the others all survived their first winter. In general, calf survival appears to be high after the first few months of age. However, it should be noted that calf survival may have been optimum during this study. None of the collared calves were orphaned, both winters of the study were relatively mild, and this study was done when moose populations were lower.

Predators capable of regularly killing adult moose are rare or absent in Maine, but some calves are lost to predators (exact numbers unknown). Predation by black bear on young calves is common where both species exist and up to half the calves are killed by bears in some areas (Boer 1988). The proportion of calves killed by bears has not been measured in Maine, but is likely similar to New Brunswick where 1 of 11 collared calves was killed by a bear (Boer 1988). The extent of coyote predation is unknown but is believed to be low and probably limited to small moose and exceptional circumstances.

Three parasites, present in Maine, have caused, or contributed, to mortality in moose. Brain worm *(Parelaphostrongylus tenuis)* is a parasite that infects deer without harming the host but almost always kills moose when this unsuitable host becomes infested. Winter tick *(Dermacenter albapictus)* and lungworm *(Dictyacaulus viviparus)* are common parasites of moose that often infest moose with little apparent harm to the host. However, they can contribute to mortality in some circumstances.

Brainworm has been implicated in moose declines and was considered a major reason why moose declined in areas with high densities of white-tailed-deer (Anderson and Lankester 1974). Recent increases in moose numbers in areas of New England and the upper Midwest with high deer populations have raised some question as to the

importance of this parasite in controlling moose numbers (Nudds 1990, Whitlaw and Lankester 1994).

The winter tick has been implicated in die offs in western and central North America and likely contributes to some late winter mortality in Maine, although dieoffs have not been recorded. Lungworm *(Dictyacaulus viviparus)* caused lung damage and was implicated in an unusual number of calf (about 11 months old), and to a lesser extent yearling, mortalities in Maine in the spring of 1995 and 1997. The majority of these animals also had heavy tick infestations. Lungworm related mortality has not been reported in any other year in Maine or from any other jurisdiction.

An animal whose health is compromised by one factor, becomes more susceptible to parasites and disease. Therefore, the effects of lungworm, ticks, and poor nutrition are probably linked. Transmission of both parasites increases at high moose densities, and weather conditions also influence transmission (Wilton and Garner 1993, and Anderson and Prestwood 1981). Moose populations may crash when hard winter conditions coincide with high tick numbers and poor nutrition (e.g., Peterson 1997).

Relationship to Carrying Capacity

Carrying capacity (or K) is the maximum number of animals that can be supported by the food available in their habitat over time. As a population increases and approaches its carrying capacity, the available food is divided among more and more individuals. As competition for food increases, undernutrition may occur and result in lower calf production per cow, and therefore total calf production. Poor nutrition also increases an animals susceptibility to disease. Deaths due to starvation and

disease increase once a population exceeds half of the carrying capacity of the habitat and reach their maximum near carrying capacity. At carrying capacity, births are balanced by death from natural mortality (deaths due to starvation, disease and old age) and the population ceases to grow. Although populations at carrying capacity become stable in theory, in reality, this stability does not last very long. Changes in the environment affect food availability over time. Therefore, carrying capacity frequently changes and the animal populations move in and out of balance with their food resources.

Populations near their carrying capacity respond differently to mortality than populations below half the carrying capacity of the habitat. As was stated previously, at carrying capacity, natural mortality is balanced with births. When traumatic losses (such as those from hunting or predation) occur in a population that is at or near carrying capacity, they remove many animals that would have died anyway from natural mortality. In this circumstance, traumatic mortality is referred to as "compensatory mortality". Compensatory mortality occurs when traumatic losses do not increase the total number of animals that die in a season but decrease the number of animals that would have died from natural causes. Compensatory mortality is most common when there is a significant amount of natural mortality, such as when a population is above half the carrying capacity of the habitat.

Animal populations below the carrying capacity of their habitat, particularly those below half the carrying capacity, have lower natural mortality rates than animals at carrying capacity. This is due, in part, to more abundant food sources and lower disease transmission than when a population is at carrying capacity. In this circumstance, the population will grow unless there is enough traumatic mortality to

offset the high reproductive rate. If traumatic mortality is high enough to prevent population growth, few animals will reach old age. Because most of the population is young and healthy, natural mortality tends to be insignificant and most mortality is due to traumatic factors. Since there is little natural mortality in this situation, compensatory mortality seldom occurs and most forms of mortality are additive (each form of mortality increase the total number of animals that die).

Reproductive rates also differ for populations at and below carrying capacity. When populations are above half of the carrying capacity, a decline in population will result in better nutrition and therefore higher productivity per cow. In this case, the total number of calves produced can remain stable or even increase even though the number of cows declines. This is not the case when the population is very low relative to carrying capacity. In this situation, all animals are well fed and productivity per cow is near maximum. Under these circumstances, if mortality increases the number of cows will decline but the number of calves produced by each cow will not increase. Therefore, with the fewer cows the number of calves born will decline.

Maintaining a stable population at or below half the carrying capacity of the habitat is difficult. To keep the high growth rate of the population in check, harvest rates have to be high, thus increasing the potential for overharvest mistakes. If too many animals are harvested, the mortality will be additive and it will likely reduce the number of females without increasing the productivity per cow. Therefore, it will be harder for a population to recover to its former level. For these reasons, wildlife populations are seldom maintained below half of their carrying capacity, except to reduce nuisance or damage complaints.

Harvested species are sometimes managed near half the carrying capacity of the habitat. At this level, population growth is at its maximum. All of this growth can be harvested and still leave enough animals to reproduce and bring back the population to the same pre-harvest level the next year. This level of harvest can be maintained indefinitely, if the harvest only removes the same number of animals that are added to the population each year. This management technique is referred to as managing a population to produce a maximum sustained yield (MSY). Because carrying capacity and hunter success vary from year to year, it is very difficult to harvest the exact number of animals to produce a MSY. Attempting to manage populations to produce a MSY puts us at risk of harvesting to many animals and causing a population decline. On the other hand, managing populations above half the habitat's carrying capacity allows for natural variations in carrying capacity, leaves room for error, and minimizes the risk that the harvest will decrease the reproductive potential of a population.

Interaction with other species

The diets of moose, deer, beaver, and snowshoe hare overlap considerably but several differences reduce competition. For instance, moose feed on taller plants than deer and hare, and beaver can use trees that have grown too tall for moose to reach. Moose eat more aquatic vegetation and less herbaceous vegetation than do deer or hare. Habitat preferences and the ability to access some feeding areas further reduce competition. For instance, deep snow will prevent deer from reaching food that moose can use for much of the winter and moose are not usually found in deer wintering areas where food supplies are usually not adequate for efficient foraging by such a large animal.

Competition between moose and other species may be most severe when one species depletes food supplies that another uses during winter when food is least abundant. For instance, winter food for deer can be reduced when moose eat browse adjacent to deer yards (Pruss and Pekins 1992). The fact that moose and deer do not usually spend the winter in the same place does not necessarily eliminate competition because moose may have eaten the browse before deer enter the yard for the winter.

Moose may influence the composition of vegetation by killing or suppressing particular species of plants. For instance, heavy browsing by moose has reduced the abundance of balsam fir and mountain ash on Isle Royale (McLaren and Peterson 1994) and aspen and willow in Alaska (Oldemeyer 1981). Moose have reduced aquatic plants in ponds in Ontario (Fraser and Hristienko 1983) and Maine. Moose may also be impacted by another species' food selection. Hare may suppress the regeneration of some browse species before they reach a height preferred by moose (Oldemeyer 1981).

On the other hand, the actions of one species may improve the habitat for other species. Browsing by moose tends to suppress succession and induce sprouting which may maintain feeding areas for many species of browsers (Oldemyer 1981, Danell et al. 1985). Moose benefit when beavers create aquatic feeding areas and set back succession.

Moose provide a source of food for many other species. In Maine, young moose calves are preyed on by black bears in early spring, in other parts of their range other predators take both young and adult moose. Carrion from moose is an important source of food for many species. Shed antlers are sought by rodents as a source of calcium.

As noted previously, the number of deer is one factor that influences the number of moose that become infested with brainworm. Based on anecdotal information there appear to be fewer cases of brainworm now than 30 or 40 years ago despite the higher number of moose and the recent increase in deer numbers. Because deer shed larvae mostly in the winter, deer yards are suspected as a focus of infection (Peterson et al. 1996, Whitlaw et al. 1997). Changes in forest practices that have increased the amount of regenerating forests away from waterways may have reduced the amount of time moose spend feeding near deer yards. This is one possible explanation for the lower incidence of moose with symptoms of brainworm.

MANAGEMENT

Regulatory Authority

Prior to 1830, there were no laws restricting the harvest of moose. The legislature gradually introduced more restrictive moose hunting regulations with respect to season length, bag limit, and the taking of cows and calves. From 1875-1935, the season fluctuated between closed seasons and open seasons. Moose hunting was outlawed after 1935 (Table 1).

Reestablishing a moose hunting season in Maine required legislative action. In 1943 and 1951, and during each session of the Legislature from 1957-1975, bills were introduced to reestablish a moose hunting season, but all were defeated. In 1977, a moose hunting bill passed both houses, but was vetoed by the Governor. A moose hunting bill passed both houses and was signed into law in 1979; it allowed the department to issue up to 700 permits to resident hunters and their subpermittees to hunt moose north of the Canadian Pacific Railroad (now know as the Eastern Maine Railway and the Canadian American Railroad) tracks during the last week of September in 1980. The law made no provision to distribute hunting pressure, and hunters concentrated east of Moosehead Lake, a popular area for moose watching. The kill was high in this area and caused public concern.

Moose hunting in Maine is regulated by MDIFW within a framework set by the legislature. In 1981, a bill was passed which allowed up to 1,000 moose hunting permits to be issued annually for the area north of the Canadian Pacific Railroad tracks.

The following aspects of the season framework have remained constant since 1981. Season length is limited to a maximum of six days. Each permittee may name one other person to hunt with her or him, either may shoot a moose but they may kill only one moose per permit. Up to 10% of the permits may be issued to nonresidents. Within this framework, the Department may establish more restrictive regulations, set the season dates, divide the hunting district into zones, and issue permits by zone.

Several bills have gradually liberalized the framework under which the Department and Advisory Council set hunting regulations. A bill that expanded the moose hunting district was passed in 1985 and went into effect in 1986 (Figure 1). By 1994, any area of the state could be opened to moose hunting. The legislature increased the maximum number of permits to 1,200 in 1994, 1,400 in 1995, and 1,500 in 1996, and 2,000 in 1998. Past season regulations are summarized in Figure 1 and Table 1.

The Penobscot Indian Nation and Passamaquoddy Tribe regulate hunting within their lands including issuing moose hunting permits for these areas. These seasons are separate from the MDIFW administered season described above and permits issued by these administrations are in addition to those authorized by the laws described above and issued by the state. Between 100 and 150 animals are harvested during these seasons each year.

Goals and Objectives

During the assessment process goals and objectives are set to guide management decisions. Objective harvests of 1,100 and 2,200 moose annually were

set in 1975 and 1980, respectively, and were the estimated allowable harvest at the time. No goals for population size or nonconsumptive use were set in either of these assessments.

In the 1985 revision of the moose strategic plan the public working group set 3 objectives: one for population size, a second for consumptive use, and a third for nonconsumptive use. These goals have been extended in subsequent updates of the assessment. These goals and objectives were:

GOAL

Maintain moose numbers at 1985 levels, increase harvest, and maintain viewing opportunity.

OBJECTIVES

Abundance: Maintain moose populations at 1985 levels in all WMUs through 1990.

Harvest: Increase harvest to 1,000-1,400 moose per year or whatever level is needed to maintain populations throughout the state by 1990.

Use: Maintain opportunity to view moose and decrease unsuccessful viewing trips by 50% by 1990.

Management activities

Several indices are used to determine if the number of moose is near the number present in 1985 (the population objective of the 1985 species assessment). To

determine the size of the moose population relative to 1985 levels in the hunted area, hunter success (Table 2) and sighting rates by hunters in recent years (Table 3) are compared to 1985 sighting and success rates. If there have been significant changes in season dates or management boundaries, only years with similar seasons (to account for differences in rutting behavior and leaf fall) and boundaries are compared. The number of road kills adjusted for traffic flow is used to monitor population trends in areas not open to hunting. However, changes in the requirements for reporting accidents changed in 1991 so comparisons can not be made between 1985 and recent years. Collectively, these indices indicate that the moose population is larger now than in 1985 for all moose hunting zones that were opened in 1985 and indicate that the moose population is above target levels. Since moose hunting was reestablished in 1980, the Department has issued the maximum number of permits allowed by law and opened the season for the maximum number of days allowed. Zones were established to prevent local overharvest and potential conflict between consumptive and nonconsumptive user groups.

Permits were issued for the entire area that could be opened to hunting through 1993. No additional areas were opened through 1996. Because the maximum numbers of permits have been issued each year, opening additional zones would not have allowed more hunters to participate, nor would it have improved our ability to limit the moose population to meet 1985 population goals. An additional zone was added in 1997, because residents of that zone wanted to have a chance to hunt there (Figure 1).

A survey of Maine heads-of-households indicated that those people who attempted to see a moose had high success (Boyle et al., 1991). Because the amount

and success of viewing activity have only been measured once, trends are not known. However, we assume that sighting rates by nonconsumptive users in the hunted area have increased, as that of hunters has increased (Table 3).

Three factors are believed to have increased the ease, and therefore the likelihood, of encountering a moose. First, the number of moose has increased both in commercial forest land and in areas of the state where most people live. Second, improvements to logging roads in much of northern Maine have made it easier for people to access areas with many moose. Third, guided trips to view moose have become more common. Because moose watching opportunity and success seem to be improving, we have not taken formal steps to increase either of these.

No habitat management for moose has been undertaken. The habitat has been adequate to support the moose population in good health. Because the current population is above the population goal, there has been no need to improve moose habitat to meet population goals.

Attempts to reduce the number of road accidents have primarily focused on public education. These have included public service announcements, cooperation with the media to increase awareness, and consultation with the Department of Transportation to improve signs, warnings, and road shoulder visibility. In addition, as the number of permits has increased, more permits have been issued in zones with a high number of road kills. However, the increase in permits in these zones is not sufficient to reduce local moose populations, and therefore, would not likely reduce the number of accidents in these areas.

Attainment of Objectives

The numeric harvest objective of 1,400 moose was probably conservative in 1985 (twice this many would likely have been sustainable) and is certainly conservative now due to the increase in the number of moose. Therefore, although the numeric harvest objective has been reached the functional objective of increasing the harvest to the level needed to stabilize the population (Table 4) has not been met. The objective of maintaining the population at 1985 levels was not achieved. In addition to the conservative number of permits set by the legislature, hunting has had little effect on the moose population because hunters select for bulls and the vast majority of cows are left to produce calves. Low hunting pressure and favorable habitat have allowed the moose population to expand beyond 1985 numbers. Based on sighting rates (Table 3) and road kills (Figure 2) the population is about 2 times the 1985 objective level in some zones and nearly 1.5 times the objective level statewide. Although we have not measured changes in nonconsumptive viewing success, this is assumed to have increased with increasing moose numbers.

HABITAT ASSESSMENT

Past Habitat

The amount of habitat available to moose depends on the amount of area that is forested. The amount of moose habitat was reduced when forests were converted to farms. Many of these farms were abandoned during the last half of the 19th century and throughout this century (Bureau of Census 1994). Moose habitat was regained as abandoned farms reverted to forest. At the same time, other forest land has been lost to development each year. In general, the amount of moose habitat declined during the 18th and early 19th centuries, and increased during the latter part of the 19th century and much of the 20th century.

Not only has the quantity of moose habitat increased during this century, the quality has also increased. The quality of the habitat for moose is determined by the amount and interspersion of early successional forests that provide abundant food, and older stands that provide cover. Fire, insects and clearcutting all create excellent feeding areas for moose. Forest harvesting creates new feeding areas throughout the state each year, while fire and insect infestations tend to be sporadic and often localized events that are likely to result in a "boom or bust" situation for moose. Forest harvesting has replaced fire, insects and disease as the dominant factor shaping our forests. When clearcutting became more common, the resulting patchwork of different aged forest stands provided moose with food and cover in close proximity in most of Northern Maine.

During the last decade, there has been little change in the overall amount of forested land in the state (Griffith and Alerich, 1996). Statewide, there is about 1% less forest now than in the early 1980's (Table 5).

Although the amount of moose habitat, as measured by the amount of forested land, has changed very little since 1982, the quality of moose habitat has changed (Table 5). Good moose habitat is a mixture of early successional stages that provide food and older stands that provide shade in summer and relief from deep snow in winter. Over the last 12 years, the total amount of early successional forests, and therefore the amount of food for moose, increased by 39%. This includes a 46% increase in the amount of hardwood dominated seedling and sapling stands. Despite the statewide increase in food producing stands, the amount of land in early successional stands declined in Washington, Hancock, Kennebec, Waldo, Knox, and Lincoln counties (Griffith and Alerich, 1996).

As the amount of early successional forest increased, habitat suitable for shelter during times of deep snow declined but is suspected to still be adequate. Based on the USDA Forest Inventory (Griffith and Alerich, 1996), the total amount of pole and saw log size hemlock and spruce-fir stands that provide winter shelter declined by 42% from 1982 to 1995.

Present Habitat

Current habitat conditions were assessed from data collected during the Fourth Forest Inventory of Maine (U. S. Forest Service 1997). See Chilelli 1998 (attached) for a description of this data set and its associated sampling error. The current availability

of preferred browse was estimated as described in Appendix 3. Estimated availability is summarized by WMD in Tables 6-8 and follows Allen et al. (1987) . The availability of different habitat types by WMD is compared in Table 9.

In almost all cases, the potential of an area to support moose will depend on its ability to produce browse. Estimates of the densities of moose that could be supported in good condition during the summer and winter (Table 10) were estimated as described in Appendix 4. In general, the most productive moose habitats are found in northwestern and western Maine with the next most productive areas being immediately to the south and east. Most coastal and southern areas appear to have relatively poor habitat for moose as reflected by the availability of preferred browse. The availability of browse for moose will be even lower in these areas due to the high number of deer in southern areas of the state. In general, the best moose habitat is associated with forests that are being commercially harvested and the poorest are associated with developed areas with little commercial forestry activity. Figure 3 depicts the amount of each township in stands that are likely to produce abundant browse for moose. In some cases, an area's ability to support moose may be lower than the number that could be supported by available browse because some other factor is in short supply.

To date, there has been little if any indication that moose in Maine suffer from a shortage of softwood cover. However, Allen et al. (1987) recommend that at least 5% of an area should be in pole or larger softwood stands suitable for winter cover. Only 2 of the WMDs have less than this amount of winter cover but several have only slightly more (Table 9). Most of these are in southern and coastal areas where snow conditions that force moose to use winter cover are rare. Only WMD 9 has a low amount of winter

cover and is likely to have deep snow for extended periods. Not only do most areas in northern and western Maine meet minimum winter cover requirements, most WMD's have an adequate amount of softwood stands that also provide preferred species of browse (Table 8). Note that Table 8 includes only preferred browse within softwood stands and does not consider less preferred staple foods such as balsam fir, or any food adjacent to softwood stands. The 4th Forest Inventory of Maine (U. S. Forest Service 1997) indicates that there is little if any heavy browsing on fir within suitable winter stands. Only WMDs 7 and 9 had appreciable use of fir within softwood stands (Table 11). Although winter cover does not seem to be a limiting factor for moose at this time, the amount of browsing on fir (by moose, hare, and deer) is much higher in WMD 9 than in the other WMDs (Table 11).

Sodium is required by all animals and moose must supplement their diet to consume adequate quantities. The primary sources of sodium for moose in Maine are aquatic plants and run off from salted highways. Although aquatic areas that can support aquatic plants are abundant in Maine, moose have greatly reduced the availability of these plants in some areas of northern Maine. Moose in many areas of the state have access to artificial roadside licks and will not need to use aquatic plants. However, many areas of Maine have few or no public roads and moose in these areas do not have access to this source. Moose in WMDs 1, 2, 4, and 5 have limited access to salted roads. They have also reduced the availability of aquatic plants in at least the eastern part of this area.

Future Habitat

Moose numbers are ultimately limited by habitat. Moose need a mix of forest types that provide abundant food, shade in summer, and relief from deep snow in winter. Future habitat conditions for moose in the state will depend on the amount and type of forest stands available and their distribution. Commercial forestry will be the major factor in determining what Maine's forests will look like in the future. Economic, social, political, and legal considerations will shape forest practices.

In general, forest harvesting is expected to continue with more emphasis on hardwood stands. New feeding areas will continue to be created following forest harvesting, and the available browse is expected to be able to support the current population in good condition for about the next 15 years. However, this situation should not be expected to continue forever. If selective cutting replaces clearcutting as the dominant harvest practice, forest stands are generally in older age classes, and/or the aspen/birch type declines the ability of the land to support moose will decline.

The amount of pole and saw timber size softwood cover suitable for winter shelter has been declining but is still adequate in all areas of the state. This trend is expected to reverse before a shortage of winter cover is a problem in most areas. Therefore, winter cover is expected to be adequate during the foreseeable future in most of the state. WMDs 9, 2, 3, and 6 are most likely to have an inadequate amount of winter cover in the next few decades.

Moose require access to aquatic feeding areas and/or licks to meet their dietary mineral requirements. Although the amount of shallow aquatic areas is unlikely to change very much, the quality of these areas may decline as moose deplete aquatic

plants. Roads will no doubt increase, and roadsides will provide a mineral source, as long as common salt is used for deicing.

POPULATION ASSESSMENT

Past Populations

According to the writings of early explorers, moose were plentiful in New England during the 1600's. Statewide populations had declined to an estimated 2,000 moose by the early 1900's (Banasiak et al. 1980). Several factors are believed to have contributed to the decline. These include clearing forests for farmland, brainworm, and unrestricted hunting. Clearing of forest for farmland reduced the amount of habitat available to moose. Mortality, due to brainworm infestations from increasing numbers of white-tailed deer, is commonly cited as contributing to declines in moose numbers in Maine (Gilbert 1974) and other areas of the Northeast (Anderson 1972). However, there is little hard evidence to support or refute this (Nudds 1990). The most important cause of the decline throughout eastern North America was probably unrestricted hunting, including market hunting (Dodds 1974).

During the1900's, protection from excessive hunting and improving habitat conditions allowed the moose population to increase. Reverting farmland increased the amount of forested habitat available to moose in southern and central Maine as well as providing food during early successional stages. Changes in forest practices, that included a greater amount of clearcutting, provided moose with an abundant food source as these areas regenerated. By 1985, moose numbers were estimated to be 21,150. Increases in hunter sighting rate, hunter success and the number of road kills

(Tables 2, 3 and Figure 2) all indicated that the number of moose increased through the 1980's.

Present Populations

Population Size

The current population estimate of 29,000 moose in winter (Table 12) is based on censuses done in the mid 1980's and trend information from hunting and road kill statistics. The 1985 population was recalculated by hunting zone rather than WMU, as they were in the previous assessment. This change makes it possible to use hunting statistics to update population estimates. Current winter population estimates for the Moose Hunting Zones (MHZ) and the unhunted area (Table 12) were calculated as described in Appendix 2.

Several factors contribute to the uncertainty of the population estimates. First, population estimates are based on censuses with wide confidence intervals (20-46%). To compound this problem, several of the zones have not been censused and the initial (mid 1980's) estimate was based on a census from nearby areas. These initial estimates were updated based on changes in the number of moose seen by hunters. Sighting rates are affected by several factors in addition to moose density. These include leaf fall, season timing, and weather. Therefore, the estimated winter population of 29,000 moose needs to be regarded with some caution. However, based on the high success and sighting rates in Maine, it is unlikely that this is a gross overestimate of the current moose population and is more likely to be an underestimate. This is further supported by a census in Northern New Hampshire last winter which estimated the population density to be about 3 moose /mi^2 (Bontaites, personal comm.)

Moose censuses have not been conducted recently. The amount of flying needed to obtain a good estimate over a large area is high. It was not considered reasonable to expend large amounts of money and staff time to census a population that was clearly above the population objective when only a conservative harvest was legally permitted. However, censuses should be done in future if regulations allow maximizing hunting opportunity, regulating hunting to reach population objectives, or if our trend indicators suggest a population decline.

Population Structure

In an unhunted moose population in southern parts of their range, such as Maine, the sex ratio is usually close to 1:1. Hunting tends to skew the sex ratio toward females because bulls are more likely to be shot than cows. The proportion of bulls to cows among hunter sightings is the only measure of population structure that is available on a regular basis. However, sightings are usually skewed toward bulls, and unless this is taken into account, they would indicate that there is a higher proportion of bulls than actually exists. This overestimate of bulls occurs for two reasons. First, bulls are more active, and therefore more often seen, during the rut. Second, a bull with a rack is easy to identify, with only a quick glimpse; a cow is likely to be classified as a moose of unknown sex under the same circumstances. To further complicate matters, the sex ratio of sightings can be expected to vary with season timing relative to rutting behavior and, perhaps, ease of identifying due to leaf fall. Therefore, they should not be used to track annual changes in the sex ratio or as a direct measure of the sex ratio. The population structure of the various zones (Table 12) was estimated following assumptions outlined in Appendix 2.

Relationship to Carrying Capacity

The size of moose taken during hunting seasons has varied among years but a comparison among years does not suggest any trend in moose condition (Table 13, Figure 4). The weights of adult cows and the antlers of yearling bulls show no trends. Because adult bulls lose weight during the rut, their weights vary with season timing and are not useful in assessing animal condition.

Measures of productivity from Maine cows have varied by year but do not suggest any trends. Although the number of calves per 100 cows reported by hunters has dropped (Figure 5), this is likely an artifact of a change in the questionnaire. The hunter reported calf:cow ratio dropped greatly in 1990, the same year the questionnaire was changed to include information on how to identify a calf. The number of yearling cows to adult cows in the harvest did not decline during this time and suggest no reduction in productivity. The number of eggs released is correlated with the weight of the cow (Sylvan et. al. 1980, Adams and Pekins 1995). As noted in the previous paragraph, there has been no decline in weights of harvested cows, so a decline in ovulation rate is unlikely.

As populations approach carrying capacity, animals consume a greater proportion of the available forage. The impact on the plants is likely to become apparent before changes in animal condition are noted. Browsing intensity, as assessed during the Fourth Forest Inventory of Maine (U.S. Forest Service 1997), is summarized in Tables 11, 14, and 15, as preferred hardwood browse appears to be only lightly or moderately used by all species of browsers (moose, deer, and hare) in most areas of the state. It should be remembered that the forest inventory was designed to assess general forest conditions and not browsing. Therefore, the survey

was not intensive enough to give precise information on browsing but only serves as a general indicator of differences between areas. According to the Forest Inventory, areas with high and very high browse production, where moose likely concentrate, rarely have heavy (>40% removal) browsing. Areas with medium (11-40% removal) browsing intensity are more common in the SW and SC hunting zones and the SE hunting zone than farther north (Tables 16 - 18). Balsam fir, a moderately preferred food which may be heavily used when moose are restricted by deep snow or have consumed more preferred foods, received heavy browsing in only a few areas (Tables 11 and 15).

Although none of the measures are precise enough to determine where the moose population is relative to K, three factors suggest that the moose population in Maine is still below carrying capacity. (1) productivity has remained high, (2) animal condition has not declined, and (3) browsing pressure is low.

Present Population by Moose Hunting Zone

The number and density of moose that could be supported by each zone was estimated by two methods. One estimates the number of moose that could support a maximum harvest, or the number at half the carrying capacity of the habitat. The other estimate was of the potential population that could be supported at the carrying capacity of the habitat. Both estimates were reduced to account for browse consumed by the existing deer population assuming that three or four deer would consume the same amount of browse as one moose (Tables 19 and 20).

The number of moose that could be maintained in healthy productive condition (Table 19) is based on estimates of browse production from the Fourth Forest Inventory

(U.S. Forest Service 1997) and Allen et al.'s (1987) habitat model. Because the information from the Forest Inventory was not as detailed as is required for the model the calculations were modified to fit the available data and to reduce the risk of overestimating production. These calculations are described in appendices 3 and 4. In addition, because of the limited number of plots, the estimated amount of browse has wide confidence intervals (Chilelli 1998).

Northwest (NW) Zone (WMD 1): This zone is 1,420 mi^2 with an estimated moose density of 1 moose/mi^2. This zone is almost entirely industrial forest land, with few residents concentrated in 1 town and little traffic resulting in few moose-vehicle accidents and other nuisance complaints.

The 1985 winter moose density for this area was estimated to be 0.5 moose per mi^2 based on a census done in the northeast corner of the Central (C) MHZ in 1985. The winter population is now estimated to be near 1.0 moose per mi^2 or about 1,420 animals. Hunters report seeing one of the highest bull:cow ratios in this zone so the sex ratio is probably about even. Small sample sizes from the harvest and lack of a census from within or adjacent to this zone make population estimates from this zone suspect.

Estimates of available browse suggest that this zone should be able to support 2.8 moose/mi^2 in good condition or 5.6/mi^2 at K. If competition with the existing deer herd is considered, these densities would be reduced to 1.2 and 4.0 moose/mi^2. Based on the Fourth Forest Inventory of Maine (U.S. Forest Service 1997), this zone has relatively low browsing pressure (by all species of browsing) compared to other zones (Tables 11, 14, and 15). Both the population estimate (Table 19) and the light browsing pressure indicate that moose are likely somewhat below half of the carrying capacity of

the zone. Additional moose could likely be supported without serious adverse effects on moose productivity or condition.

Northeast (NE) Zone (WMDs 2, 3 and 6): This zone is 3,573 mi^2 with an estimated moose density of 1.3 moose/mi^2. The population appears to be below half of the carrying capacity of the zone. The western part of this zone (WMD 2) is almost entirely industrial forest land, with few residents and little traffic resulting in few moose-vehicle accidents and other nuisance complaints. Eastern portions are a mixture of industrial and other private woodland, agricultural land, and towns. This creates a situation where moose vehicle accidents and other complaints are likely and widely dispersed.

The 1985 winter moose density for this area was estimated to be 0.5 moose per mi^2 based on a census done in the adjacent section of the central MHZ in 1985. Moose hunters reported seeing 2.5 times as many moose in recent seasons as in the mid 1980's. The estimated winter population is now near 1.3 moose per mi^2 or about 4,460 animals. The adult sex ratio is skewed toward cows with about 77 bulls:100 cows.

Estimates of available browse suggest that this zone should be able to support about 2.8 moose/mi^2 in good condition (3.5 in WMD 2 and 2.5 in WMD's 3 and 6) or about 5.6/mi^2 at K. If competition with the existing deer herd is considered, these densities would be reduced to about 2.1 and about 4.9 moose/mi^2. Compared to other zones, the NE has a moderate level of browsing (by all species of browsers) on fir within softwood stands but relatively light browsing on hardwood or fir outside of potential wintering areas (Tables 11, 14, and 15; U.S. Forest Service 1997). Both the population estimate (Table 19) and the light browsing pressure indicate that moose are likely

somewhat below half the carrying capacity of this zone. This zone could probably support more moose (Table 19).

Central (C) Zone (WMDs 4 and 5): This zone is 3,512 mi^2 with an estimated moose density of 1.1 moose/mi^2. The population appears to be at or somewhat above half of the carrying capacity of the habitat. This zone is almost entirely industrial forest land. The few residents and small amount of agricultural land is concentrated in the eastern edge of this zone.

The 1985 winter moose density for this area was estimated to be 1.1 moose per mi^2 based on a census done in the northeastern section of the C MHZ in 1985 and another done in the southern section in 1989. Because sighting rates have varied with no clear trends in this zone, the density is assumed to have remained near 1.1 moose per mi^2 or about 3,860 animals. The sex ratio is about 75 bulls:100 cows.

Estimates of available browse suggest that habitat conditions are quite variable within this zone. The C zone should be able to support 2.5 moose/mi^2 (3.2 moose/mi^2 in WMD 4 and 1.6 moose/mi^2 in WMD 5) in good condition or 5.0 moose/mi^2 at K. If competition with the existing deer herd is considered, WMD 4 could support 2.4 moose/mi^2 at half of the carrying capacity of the habitat and WMD 5 could support 0.7/mi^2 at half of the carrying capacity, or about 1 moose/mi^2. Overall, about 3.5 moose/mi^2 could be supported at K, with the current deer population. Based on the Fourth Forest Inventory of Maine (U.S. Forest Service 1997), this zone has a higher intensity of browsing (by all species of browsers) than either the NW or NE zones on preferred hardwood but there was little evidence of browsing on fir in softwood stands (Tables 11, 14, and 15). Population estimates suggest that this population is near or

slightly above half of the zone carrying capacity (Table 19) and browsing intensity on preferred hardwoods supports the view that the population density in this zone is somewhat higher relative to K than the 2 more northern zones. Eastern sections of this zone (WMD 5) may not be able to support many more moose without impacts on animal condition.

Southwest (SW) Zone (WMDs 8 and parts of 7 and 13): This zone is 3,250 mi^2. The moose density is estimated to be near 1.2 moose/mi^2 but evidence suggests that the estimate for this zone is too conservative. The population appears to be above half of the zone's carrying capacity but below K. This zone is almost entirely industrial forest land with a few towns. Accidents are common and concentrated along a few transportation corridors.

The 1985 winter moose density for this area was estimated to be 1.2 moose per mi^2 or about 3,900 moose, based on a census done in this zone in 1985 and adjusted for sightability by a correction factor for intensive searches of collared moose developed in 1989. Sighting rates have been extremely variable in this zone and do not suggest that the population is higher now than in the mid 1980's. Based on this information, the winter population is estimated to be near 1.2 moose per mi^2 or about 3,900 animals. The adult sex ratio is skewed toward cows (56 bulls:100 cows in hunter sightings). However, the population estimates for this zone are probably conservative. Because the sighting rate and success rate are so much higher in this zone than in the NW, NE, and C zones (Tables 2 and 3) it is likely that the population density is higher in the SW zone than in these 3 zones. Recent censuses in adjacent areas of New Hampshire

estimated the population density there to be over 3 moose/mi^2 and also, support the idea that 1.2 /mi^2 is a conservative estimate.

Browse production in WMD's 7 and 8 are very similar. The small portion of WMD 13 that is in this zone is poorer moose habitat than the remaining part of this zone. Estimates of available browse suggest that this zone should be able to support 2.8 moose/mi^2 in good condition or 5.6 /mi^2 at K. If competition with the existing deer herd is considered, these densities would be reduced to 1.5 and 4.2 moose/mi^2. Although heavy browsing on preferred hardwoods and fir is still uncommon, this is one of the most heavily browsed zones. This observation supports the view that the population estimate for this zone may be too low. It also suggests that the number of moose may be higher relative to K than the population and browse production estimates would suggest. However, because animal condition is similar to other zones the population is thought to be below K (Table 19).

Southcentral (SC) Zone (WMDs 9 and 14): This zone is 1,780 mi^2 with an estimated moose density of 3.4 moose/mi^2. The population in this area appears to be approaching K. This zone is industrial forest land in the northern part (WMD 9) and a mixture of private and industrial forest land, agricultural land, and towns in the southern part (WMD14). Although moose densities are greatest in the northern half, accidents are more common in the south where there is more traffic.

The 1985 winter moose density for this area was estimated to be 2.0 moose per mi^2 based on two censuses done in the adjacent sections of the C and SW MHZs in 1985 and 1989, and a third census done in the SC zone in 1983. Moose hunters reported seeing 1.7 times as many moose in recent seasons as in the mid 1980’s.

Based on these data, the winter population is now estimated to be near 3.4 moose per mi^2 or about 6,050 animals. The adult sex ratio is skewed toward cows (67 bulls:100 cows). Although 3.4 moose/mi^2 have been reported elsewhere (including a census in northern New Hampshire in the winter of 1998-1999), this is a much higher density than is reported in other zones. This zone has a much higher sighting rate than all other zones but the SW zone. New Hampshire's experience suggests that this is a reasonable estimate of moose density.

Estimates of available browse suggest that this zone should be able to support 3 moose/mi^2 in good condition (3.3 in WMD 9 and 2.5 in WMD 14) or near 6 moose/mi^2 at K. If competition with the existing deer herd is considered, the SW zone could support 2.5 moose/mi^2 in good condition and 5.5 /mi^2 at K. WMD 9 could support 2.9 moose/mi^2 in good condition and 5.5/mi^2 at K. WMD 9 (the northern half of this zone) has the greatest amount of browsing on fir of any WMD and about half of the potential feeding areas in this zone have some use of preferred hardwoods (Tables 11, 14, and 15; U.S. Forest Service 1997). During the past 3 years this zone has produced the lightest yearling bulls with the smallest antlers. However, these differences were not significant and small size has not been noted for any other sex or age class. Both the population estimates and the high browsing pressure suggest that this zone has the highest population density relative to carrying capacity and may be approaching K (Table 19).

Southeast (SE) Zone (WMD 10, 11, 19 and part of 18): This is the largest zone (5,148 mi^2) and has the lowest moose density (0.8 moose/mi^2). The population appears to be near half of the zone's carrying capacity. WMD 19 is primarily industrial forest land. The remainder of this zone is a mixture of private and industrial forest, agricultural

land, and residential areas. This zone is crossed or bounded by several major road corridors.

The 1985 winter moose density for this area was estimated to be 0.4 moose per mi^2 based on a census done in this MHZ in 1985 and corrected for sightability by tests done in 1989. Since then, the sighting rate by moose hunters has doubled. The winter population is now estimated to be near 0.8 moose per mi^2 or about 4,110 animals. The adult sex ratio is probably about even.

Estimates of available browse suggest that this zone should be able to support from 1.2 moose/mi^2 in WMD 18 to 2.3 /mi^2 in WMD 11 or about 2 moose/mi^2 overall at 1/2 K or 4 /mi^2 at K. If competition with the existing deer herd is considered, these overall densities would be reduced to 0.8 and 2.8 moose/mi^2. This zone has about the same amount of browsing on hardwoods as the C and S zones, and about the same rate of browsing on fir in softwood stands as the NW and S zones (Tables 11, 14, and 15; U.S. Forest Service 1997). The moose population in this zone is probably near MSY.

Southern (S) zone (WMDs 12, and parts of 7 and 13): This zone is 2,090 mi^2 with an estimated moose density of 1.1 moose/mi^2. The population appears to be below MSY. Northern parts are primarily industrial forest land. The remainder of this zone is a mixture of private, National, and industrial forest, agricultural land, and residential area. This zone is crossed or bounded by several major road corridors.

This zone was opened for the first time in 1997. The road kill rates in the counties comprising this zone are similar to those in Aroostook, Somerset and Piscataquis counties. Sighting rates are higher than the NE and C and lower than the

SW zone. Therefore, moose densities in the S zone are assumed to be similar to the NE, SW and C zones, or somewhat over 1 moose per mi^2. The population is estimated to be 2,300 in winter.

Estimates of available browse suggest that this zone should be able to support 2.5 moose/mi^2 at 1/2 K or near 5 /mi^2 at K. If competing with the existing deer herd is considered, these densities would be reduced to 1.8 and 4.3 moose/mi^2. Browsing appears to be light in most of this zone (WMDs 12 and 13) but some moderate to heavy use is noted in WMD 7.

Southern Maine (WMDs 15, 16, 17, part of 18, and 20-30): Based on accident rates, southern sections of the state probably have about a tenth the moose densities as hunted areas or 0.1-0.3 moose per mi^2 or 2-3,000 animals. Of course, more densities are extremely variable in this area. Based on browse production alone this area could support as many as 12,000 moose in good condition (Table 19). However, the high deer numbers in much of this area result in a great deal of competition for browse. In addition, the southern part of the state has the highest human population and the greatest amount of traffic. This makes the potential for vehicle accidents and other nuisance problems high.

Population Projections

Although accident rate, hunter success rate and sighting rate have stabilized, it is not clear that the population has stabilized. Vehicle strikes (Figure 2) show no real trends in recent years. Whether this is due to increased driver awareness, stabilization of the moose herd or changes in reporting procedures is not known. Because there is an upper limit to hunter success, there is a wide range of population density when

success will be at the maximum. In Maine, hunter success is above 90% overall and near 100% for several zones and this index to population is not sensitive to population changes when success is this high. Although there is no obvious maximum for the number of moose that can be seen in an hour as there is for hunter success, this index may also have become insensitive. In Maine, most people hunt for moose by driving along roads so the number of moose seen depends not only on how long they hunt but on how far they drive. As they encounter more moose they spend more time stopping (to decide if they want to kill that moose, to attempt to kill that moose, or merely to watch a moose that they have decided not to kill) and less time driving. Therefore, the amount of effort (miles driven) may decrease while our measure of effort (hours hunted) does not. Under this circumstance, the number of moose seen per hour should also be expected to become insensitive to population changes at high moose densities. In addition, the small number of permits and resulting conservative harvest rate encourage hunters to be selective and contribute to the insensitivity of these indices. This will be especially true when hunters are able to spend almost all of their search (hunting) time in high density areas and spend much less time driving through low density area.

Because our indices to population change are believed to be insensitive at current moose population levels and harvest patterns, we looked at other sources of information to see if there was any indication of increased mortality or decreased recruitment that could explain the apparent stabilization of the moose herd. The age structure of harvested animals gives no indication of increased mortality rates among adults. The lack of evidence for declines in physical condition of the moose makes it unlikely that the population has stabilized due to declines in reproductive rate. An increase in calf mortality due to the increase in bear numbers must be considered.

Although the number of calves seen per cow dropped (Figure 5) at about the same time the bear population increased the recorded drop was sudden and coincided with a change in wording of the questionnaire. If the change in the numbers of calves to cows was due to an increase in bear populations, which occurred over several years, one would expect the change in the calf:cow ratio to also have occurred gradually over several years. In addition, the ratio of yearling cows to cows over 2 years old in the harvest has not declined (Figure 5) which also indicates that recruitment has remained high. Under these circumstances the population should be expected to grow until it reaches or exceeds carrying capacity unless we take measures to limit it.

How fast the moose population will grow in the near future is conjectural. Based on population estimates from 1900, 1985, and 1998, the population has grown, on average, at about 3% per year during this century. However, based on increases in sighting rate it would appear that the population has grown by as much as 15% per year during the late 1980's. Increases in road kills also suggest that the 1980's were a period of rapid increase in moose numbers. Based on estimates of survival and recruitment from the age distribution of harvested animals it is unlikely that the population will grow at much more than 9 or 10% per year. At this rate, the population could double in 8 years.

Moose numbers are ultimately limited by the food supply. The availability of abundant food for moose is dependent on the availability of young forest stands that produce an abundance of browse. Food abundance is expected to be maintained or perhaps increase for the next 10 to 20 years. However, this situation cannot be expected to continue indefinitely. Maine’s forests are expected to mature. When this

occurs, the amount of browse available for moose and therefore the number of moose the state can support is expected to decline.

Limiting factors

Unless some other factor holds the population down, moose tend to increase until they reach or exceed the ability of the land to support them. Such increases are typically followed by a population crash.

Several mortality factors can hold moose populations below carrying capacity. These include legal and illegal harvest, accidents, parasites, and predation. Predation is most likely to limit the population where moose populations are already low or where there are several species of predators. At this time, the moose population in Maine is high and predation is largely limited to predation on young calves by black bear.

Mortality due to parasites and disease is most likely at high densities due to increased transmission of parasites and because nutritional stress makes animals less resistant. During two springs, calf mortality attributed to the combined effects of lungworm and ticks has been reported in Maine. Moose dieoffs have been attributed to winter tick in several jurisdictions and similar dieoffs could be anticipated in Maine.

Although moose can survive in lightly or moderately developed areas, human activities may limit the population. Illegal harvest and road kills may combine to limit populations or slow population growth in the more developed areas of the state. These two forms of mortality are more likely to impact adult cows, and therefore the productivity of the moose herd, than legal hunting as it is currently practiced in Maine.

Humans may also decide to purposely limit moose numbers. These decisions may be based on human intolerance of moose (for instance as related to traffic

accidents) or on a desire to prevent moose from exceeding carrying capacity. Legal hunting with regulations that encourage the harvest of cows is the most feasible means of limiting moose population growth.

USE AND DEMAND ASSESSMENT

In a recent public attitude survey on wildlife in Maine, respondents were asked which species they felt should be reduced in number and which should be increased. Moose were one of the most commonly mentioned animals in both responses (Boyle et al. 1991), clearly indicating that moose have negative as well as positive impacts on humans. Moose are valued for sport hunting, viewing, and the economic benefits associated with these activities. Nuisance complaints such as destruction of fences, maple sap tubing, gardens and other crops have not been thoroughly documented. Fortunately, moose prefer to browse on woody species with low commercial value so conflicts with forestry are relatively minor. Moose wandering into developed areas where people are not accustomed to them can cause problems with crowd control. Moose-vehicle accidents are the most serious problem involving moose. While many of these accidents are relatively minor, some cause serious human injury or death. Vehicle repair or replacement costs can be substantial.

Past Use and Demand

In past centuries, moose were valued as a source of meat, hides, and sport. They were important to both native people and settlers for subsistence and trade. In the 1700's and early 1800's moose hunting was unrestricted and commercial hunting and hunting to feed crews at logging camps was commonplace. As the number of moose declined throughout the Northeast, bag limits and season lengths were reduced and

moose hunting was eventually outlawed (Table 1). As moose numbers increased, interest in hunting moose grew. In 1943, legislators introduced the first of many bills to reestablish a moose hunting season.

Moose hunting was reestablished in 1980 but was restricted to a limited number of permittees who were selected by a lottery. The maximum number of permits has gradually been increased by the legislature (Table 1). The number of applicants exceeded the number of available permits each year and peaked in 1994 when 94,532 people applied for a permit. The applicants included people who did not care to hunt moose themselves, but applied for a permit so that a friend or relative could hunt as their subpermittee. Nonetheless, it is clear that the number of people who wanted to hunt moose exceeded the number of permits available (Figure 6). Only 1 to 2 percent of the applicants received a permit each year.

Not only has the number of permits been lower than the number of people who would like to hunt moose, it has also been lower than the number that would stabilize the population. In the early 1980's the estimated moose population could have easily supported a harvest of about 1,500 animals in the area that was then open to hunting. This was a conservative harvest estimate, and a harvest level of 2,000 in the open hunting area or 3,600 statewide would probably have been possible while maintaining the moose population. Even at these higher harvest levels, only about 4% of the people who wanted to hunt moose would have received a permit, assuming the success rate remained near 90%.

There is little information on demand for nonconsumptive use of moose, or indeed any wildlife, until recent decades. It is clear that our interest in wildlife, including

moose, has gradually changed. Until recently, most people's interest in wildlife focused on utilitarian and nuisance concerns. Nonconsumptive wildlife recreation and an intrinsic appreciation of all wildlife have become increasingly common. In 1989, 6% of Maine residents reported that they took at least one trip where 1 of the primary reasons was to see moose (Boyle et al. 1991). Moose were seen on 48% of trips made to view moose and almost all (94%) of the people who attempted to see moose saw a moose on at least one trip. Similar information is not available for nonresidents but moose are thought to have been a popular tourist attraction for some time.

Opportunity to see moose has increased due to increasing moose numbers and ease of access. Moose numbers have increased in central and southern Maine where most of the people live. Improved road systems in northern Maine have made it easier for people to access areas with many moose. Initially there was resistance to reinstating the moose hunt, in part due to the concern that hunting moose would make them less visible. Many believed that hunting would either decrease the number of moose or make them more fearful of people. There is little indication that moose became harder to see after they were hunted in Maine. In fact, hunters reported seeing increasing numbers of moose (Table 3) in the hunted area of the state. Because the chance of finding a moose is believed to be independent of whether the person plans to shoot it or look at it, nonconsumptive users are probably having improved success in seeing moose.

Collisions between moose and motor vehicles increased until the 1990's (Figure 2). Factors that contributed to the increase included more moose, more traffic, higher speed limits, and improved quality of rural roads. Trends in most other negative

aspects of moose human interactions are unmeasured but most have presumably increased with moose numbers. The exception may be in human crowd control; this seems to be more of a problem where moose are a novelty.

Current Use and Demand

Nonconsumptive Use

Quantified information on nonconsumptive use of moose is not available for nonresidents and has not been remeasured for residents since 1989. Nonetheless, it is clear that moose watching, and seeing moose while pursuing other outdoor activities are valued activities for many people. Because moose are rare or absent in areas south of northern New England, seeing a moose is a unique experience for most visitors. While unmeasured, it is clear from advertisements and souvenir shops that moose are a major tourist attraction. Several businesses cater to people who want to see moose.

Hunting

More people want to hunt moose than there are available permits. In 1997, 71,858 residents and 12,555 nonresidents applied for the 1,500 available permits. The chances of being drawn in the permit lottery were 1.9% for residents and 1.2% for nonresidents. Hunter density (number of permits) ranged from 4/100mi^2 in the S zone to 11/100mi^2 in the SW zone (Table 21).

The estimated harvest rates presented in Table 21 is based on estimates of population size and composition described in the previous section. The overall harvest

rate is low for all moose, especially cows. More moose could be harvested while maintaining the population at current levels (Table 4). Based on population estimates, the harvest rate appears high for bulls in the C zone, but, neither the age structure of harvested bulls nor the sex ratio of animals seen by hunters suggests that bull mortality is unusually high. There are two likely explanations. First, immigration into the heavily hunted areas west of Baxter Park from the park is offsetting high mortality, or second, the population estimate is conservative.

User Group Conflicts

The controversy over moose hunting in the 1980's was based in part on perceived conflicts between consumptive and nonconsumptive users. This appears to have abated in the area previously opened to hunting but was an issue when the South zone was opened. Although people still readily see moose, some feel that moose have become more skittish. There is no objective measure of whether hunting has affected the ability of people to view moose for long periods of time or take close up photographs. It is clear that both types of moose oriented recreation contribute to the economy of northern Maine.

Negative Impacts

About 600 moose-vehicle accidents have been reported annually in recent years. The largest number of accidents to date (742) was reported in 1996. Road safety is only partly related to moose numbers. There are many areas of the state, such as WMD's 1, 2 and 4, with few accidents despite high moose densities because there is

little high speed traffic. In 1996, there were 3 areas of the state with 4 or more accidents per 100 mi^2 of land area (Table 22). Two areas, eastern Aroostook County (WMDs 3 and 6), and western Maine on the New Hampshire border (WMDs 7 and 12) have high moose populations and moderate traffic volume. An individual driver's chance of striking a moose is 0.2-0.4 accidents/million miles driven in these areas. The third area, WMD 24 in southern Maine, has a high accident rate on the basis of area but a low rate based on traffic volume (Table 23). In this case, the driver's risk is relatively low (0.01-0.02 accidents/million miles driven), but the moose's risk of being struck is high.

During the last 3 years, 12 cases of moose causing property loss or damage were reported to APHIS (U.S. Department of Agriculture). This is undoubtedly not a complete count. Most cases of damage (e.g., fences knocked down) are occasional rather than chronic problems and are repaired by the landowner.

Use and Demand Projections

The number of people who would like to hunt moose is expected to exceed the number of available permits in the foreseeable future. Even with preference points for previous unsuccessful applicants, an individual's chance of being drawn will remain low. Although the maximum number of permits available increased by 33% in 1998, an individual's chance of being drawn was still very low. Even if the number of permits was increased sufficiently to stabilize or reduce the moose population (a harvest of 4-5 thousand is probably sustainable), it is doubtful that everyone who wants to hunt moose would be able to do so even once every 10 years. Regulation changes that reduce

hunter success, such as shorter seasons, restriction of hunting methods, or weapon restrictions, would make it biologically feasible to issue more permits than could be issued under current regulations. Sex and age specific permits (which would probably be needed to meet future demands for the presence of large bulls) would also be expected to reduce success and allow more permits. Furthermore, if areas in southern Maine are opened, success rates are expected to be lower than in areas with denser moose populations, so more permits could be issued.

An increase in permit numbers could reduce the quality of the hunt and increase conflicts among groups. Some moose hunters report feeling crowded under the current hunting regulations and permit allocations. Other groups such as bird hunters, tourists and timber harvesters could also be impacted by an increased number of moose hunters using logging roads. The potential for real or perceived conflicts increases when the opening of moose season, the opening of bird season, and/or peak foliage season coincide.

Because interest in nonconsumptive wildlife recreation has been increasing (U. S. Dept. Int. 1994), demand for and amount of nonconsumptive use of moose are expected to increase. In addition, a campaign to promote tourism in interior sections of the state is expected to direct more visitors to areas with moose watching opportunities.

Although consumptive and nonconsumptive uses of moose are largely compatible, some potential conflicts should be kept in mind if moose hunting opportunities are expanded. The preferences of moose watchers and hunters can impact each other because both appear to prefer large bulls (Boyle et al. 1991, and Boyle and Clark 1993). Moose hunters are very selective and the kill is typically about

80% bulls. Palmate antlered bulls still make up over 70 % of the bulls seen by hunters in all zones. Sex ratios have apparently begun to favor cows, especially in the SW and SC zones (Table 24). If the harvest increased substantially, with no means of controlling the bull harvest, it could reduce the number of large bulls available for both viewing and hunting. Situations that impact either group's enjoyment such as crowding, fear of hunters, not wanting to see a dead moose, or not wanting to hunt with an audience are important, even though they may not actually reduce anyone's opportunity to hunt or observe moose. While concern about hunting's impact on moose viewing appears to have abated in areas that have been opened to hunting for several years, they should be anticipated whenever a new zone is opened or the number of permits is increased substantially.

Greater conflicts will occur between groups who want high moose populations for hunting and viewing and groups who want lower populations to reduce nuisance problems. This issue should be expected to become more of a concern if traffic volume, and the number of people residing in rural and semi-rural areas increase, whether or not the moose population increases.

SUMMARY AND CONCLUSIONS

Humans have had a great impact on moose populations in Maine. The decline in moose during the 19th century is largely attributed to excessive harvest and the conversion of forest habitat to farmland. The increase in moose numbers during the 20th century is attributed to protection from excessive harvest and the creation of excellent habitat due to forest practices and abandonment of farmland.

The moose population (29,000) creates both benefits and costs for people. Benefits include sport hunting, viewing, meat, and income from moose related tourism. Costs include damage to crops, trees and property, road hazard and crowd control. In addition, many people value moose because moose are rare in areas where most people live so encountering one is an unusual occurrence. These costs and benefits result in real and perceived conflicts between groups of people regarding how we should manage moose.

The moose population is currently high and within carrying capacity. In some parts of the state, the number of moose is also below the level that would provide a maximum harvest. However, this situation cannot be expected to continue indefinitely. Maine is now able to support many moose because forest practices have resulted in an abundance of young stands that provide a large quantity of browse. However, the condition of the forest is expected to change. As the forest matures and the amount of areas in young stands declines, the ability of the land to support moose will decline. At the same time, the moose population is expected to continue to increase in the near future (given the current, conservative, bull dominated harvest).

If population trends proceed as expected, several consequences are possible. First, the amount of damage to forest and agricultural crops, as well as other nuisance problems would probably increase. Second, the moose will be in poorer physical condition. If no action is taken to maintain moose numbers within the ability of the land to support them, the moose population may exceed carrying capacity and then decline to a lower level.

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Table 1. Moose management history.

Year(s)	Estimated Harvest	Estimated Effort	Hunting Regulations			Number Of Permits	Open Areas	Number Of Zones
			Bag Limit	Sex/Age Restricted	Season Length			
Prior to 1830	---	---	Unrestricted	Unrestricted	12 months	N/A	Statewide	1
1830 - 1839	---	---	Unrestricted	Unrestricted	4 months	N/A	Statewide	1
1840 - 1852	---	---	Unrestricted	Unrestricted	8 months	N/A	Statewide	1
1853 - 1854	---	---	Unrestricted	Unrestricted	6½ months	N/A	Statewide	1
1855 - 1869	---	---	Unrestricted	Unrestricted	5½ months	N/A	Statewide	1
1870 - 1872	---	---	Unrestricted	Unrestricted	4 months	N/A	Statewide	1
1873 - 1874	---	---	Unrestricted	Unrestricted	3 months	N/A	Statewide	1
1875 - 1879	NO OPEN SEASON							
1880 - 1888	---	---	Unrestricted	Unrestricted	3 months	N/A	Statewide	1
1889 - 1896	100-220	---	1	Bulls only	3 months	N/A	Statewide	1
1897 - 1912	160-410	---	1	Bulls only	1½ months	N/A	Statewide	1
1913 - 1914	90-100	----	1	Bulls only	1 month	N/A	Statewide	1
1915 - 1918	NO OPEN SEASON							
1919 - 1920	250	---	1	Bulls only	11 days	N/A	Statewide	1
1921 - 1926	NO OPEN SEASON							
1927	125	---	1	Bulls only	6 days	N/A	8 Counties	1
1928	NO OPEN SEASON							
1929	100	---	1	Bulls only	6 days	N/A	7 Counties	1
1930 - 1934	NO OPEN SEASON							
1935	45	---	1	Bulls only	3 days	N/A	3 Counties	1
1936 - 1979	NO OPEN SEASON							
1980	635	700[1]	1	Unrestricted	6 days	700	N of CP tracks	1
1981	NO OPEN SEASON							
1982 - 1985	754-883	1,000[1]	1	Unrestricted	6 days	1,000	N of CP tracks	6
1986 - 1993	856-960	1,000[1]	1	Unrestricted	6 days	1,000	N of Rts 16, 6, 2, 178, and 9	6
1994	1,130	1,200[1]	1	Unrestricted	6 days	1,200	N of Rts 16, 6, 2, 178, and 9	6
1995	1,304	1,400[1]	1	Unrestricted	6 days	1,400	N of Rts 16, 6, 2, 178, and 9	6
1996	1,384	1,500[1]	1	Unrestricted	6 days	1,500	N of Rts 16, 6, 2, 178, and 9	6
1997	1,374	1,500[1]	1	Unrestricted	6 days	1,500	N of Rts 16, 6, 2, 178, and 9	7

[1]Number of permits - almost all permittees have a subpermittee.

Table 2. Percent success rate of Maine moose hunters by zone and year.

	Moose Hunt Zone							
Season	NW	NE	C	SE	SC	SW	SO[2]	ALL
1980 (9/22-27)				No Zones				91
1982 (9/20-25)				Not registered by zones				88
1983 (9/19-24)	57	66	78	65	95	92	n/a	74
1984 (10/8-13)	67	78	82	83	94	91	n/a	82
1985 (10/21-26)	73	86	89	86	98	98	n/a	88
1986[1] (10/20-25)	65	85	90	72	100	91	n/a	86
1987 (10/18-23)	64	90	96	78	98	98	n/a	89
1988 (10/17-22)	84	93	92	82	98	100	n/a	93
1989 (10/16-21)	82	95	93	85	99	97	n/a	92
1990 (9/24-29)	74	88	93	75	97	98	n/a	88
1991 (10/7-12)	90	99	97	89	99	98	n/a	96
1992 (10/5-10)	78	93	94	79	98	96	n/a	91
1993 (10/4-9)	80	95	96	85	98	99	n/a	93
1994 (10/3-8)	85	96	95	88	98	98	n/a	94
1995 (11/2-7)	78	94	93	88	98	99	n/a	93
1996 (10/7-12)	76	96	93	87	100	96	n/a	92
1997 (10/6-11)	81	93	92	72	98	94	88	92

[1]Area open to hunting expanded in three southern zones.
[2]The South Zone was opened in 1997.

Table 3. Average number of moose seen/10 hours hunted in Maine by hunting zone by year.

Opening Year	Day	Zones							All
		Northwest	Northeast	Central	Southeast	South Central	Southwest	South[2]	
1980	9/22				No Zones				1.7
1982	9/20	0.8	1.4	2.2	1.0	3.8	2.2	-	1.7
1983	9/19	0.7	0.7	1.2	0.7	2.0	2.4	-	1.1
1984	10/8	0.7	1.0	1.6	1.0	3.3	3.1	-	1.4
1985	10/21	1.4	1.9	2.7	1.3	4.4	3.1	-	2.2
1986	1020	0.9	1.5	3.0	1.0	4.5	6.4	-	2.2
1987	10/18	0.8	2.0	3.9	1.1	7.5	4.8	-	2.7
1988	10/17	2.2	3.2	5.3	1.3	5.3	8.8	-	3.8
1989	10/16	2.4	3.4	5.5	2.1	11.0	10.7	-	4.5
1990	9/24	1.1	1.5	2.4	0.9	4.0	4.2	-	2.0
1991	10/7	1.2	4.1	4.8	1.7	9.6	10.3	-	4.5
1992	10/5	2.4	2.9	3.7	1.5	7.9	7.7	-	3.5
1993	10/4	1.9	3.5	4.2	1.8	7.7	8.2	-	4.0
1994	10/3	2.3	5.0	5.0	2.4	12.8	9.8	-	5.5
1995	10/2	2.1	4.3	3.0	2.2	10.4	6.8	-	4.3
1996	10/7	2.1	4.3	3.4	2.0	8.0	8.1	-	4.2
1997	10/6	2.8	4.0	3.8	2.1	7.3	5.9	4.8	4.2

[1]The SW, SC, and SE zones were expanded in 1986.
[2]The south zone was opened in 1997

Table 4. Estimated sustainable harvest (12-20% of population) at current populations and estimated maximum sustainable harvest that could be attained with the current deer population and without competition with deer for browse (see table 19).

Zone	WMD's	Sustainable Harvest At Current Pop.	Maximum Sustainable Harvest (w/deer)	Maximum Sustainable Harvest (w/o deer)
NW	1	170 - 284	198 - 330	486 - 810
NE	2, 3, 6	535 - 892	890 - 1,480	1,200 - 2,000
Ce	4, 5	463 - 772	421 - 702	1,050 - 1,750
SW	8, 7[b], 13[b]	468 - 780	582 - 970	1,070 - 1,790
SC	9, 14	726 - 1,210	538 - 896	629 - 1,050
SE	10, 11, 19, 18[a]	493 - 822	469 - 782	1,240 - 2,060
So	12, 7[c], 13[c]	276 - 460	446 - 744	624 - 1,040
Unhunted		300 - 500	720 - 1,200	1,450 - 2,420
ALL		3,480 - 5,800	4,260 - 7,100	7,750 - 12,900

[a]Eastern parts only.

[b]Northern parts only.

[c]Southern parts only.

Table 5. Estimated amount of moose habitat in 1982 and 1995 in thousands of acres and percent change over 13 years. Data from Griffith and Alerich. 1996. Forest Statistics for Maine, 1995. USDA. Northeastern Forest Experiment Station, Resource bull NE-135.

	TOTAL FORESTED AREA			WINTER COVER[1]			ALL SEEDLING AND SAPLING STANDS[2]			HARDWOOD SEEDLING AND SAPLING STANDS		
AREA	1982	1995	% Change	1982	1995	% Change	1982	1995	% Change	1982	1995	% Change
Aroostook Co.	3,759	3,751	<-1	1,260	537	-57	526	1,162	+86	305	529	+73
Capital[3]	1,173	1,174	0	219	250	+1	200	214	+7	126	167	+32
Casco Bay[4]	1,212	1,167	<-1	106	110	+4	247	158	-36	191	143	-25
Hancock Co.	836	855	2	342	317	-7	240	138	-42	130	80	-38
Penobscot Co.	1,856	1,848	<1	599	434	-28	255	448	+75	132	314	+138
Piscataquis Co.	2,244	2,213	-1	1,030	433	-58	337	637	+89	116	311	+168
Somerset Co.	2,335	2,353	1	861	415	-52	373	638	+71	186	351	+89
Wash. Co.	1,489	1,386	-7	625	403	-34	526	422	-20	264	207	-22
Western[5]	2,231	2,190	-1	492	347	-30	330	396	+20	172	254	+48
Statewide	17,134	16,938	-1	5,460	3,140	-42	3,035	4,216	+39	1,620	2,360	+46

[1]Spruce-fir or hemlock stands of pole or sawlog class

[2]Seedlings and saplings = trees with DBH $\leq$ 4.9 inches.

[3]York, Cumberland, Androscoggin and Sagadahoc Counties

[4]Kennebec, Waldo, Knox and Lincoln Counties

[5]Franklin and Oxford Counties

Table 6. Percent of total land area with different levels of growing season preferred browse production for moose[1]. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

	Browse Production Level				
WMD	Low (0.18-0.47 oz/yd^2)	Medium (0.48-0.77 oz/yd^2)	High (0.78-1.07 oz/yd^2)	V. High (≥1.08 oz/yd^2)	Low-V. High Production
1	11%	9%	9%	49%	79%
2	7%	16%	10%	56%	89%
3	7%	15%	11%	35%	68%
4	9%	13%	10%	52%	83%
5	16%	10%	6%	42%	74%
6	12%	10%	8%	40%	70%
7	11%	10%	6%	56%	83%
8	10%	13%	7%	55%	86%
9	4%	10%	12%	62%	88%
10	10%	8%	6%	47%	71%
11	8%	10%	12%	43%	73%
12	11%	5%	14%	39%	69%
13	15%	6%	15%	31%	66%
14	17%	8%	9%	45%	78%
15	17%	16%	3%	27%	63%
16	15%	5%	6%	30%	56%
17	13%	10%	4%	25%	52%
18	13%	12%	4%	22%	52%
19	16%	13%	6%	33%	68%
20	12%	10%	4%	21%	46%
21	12%	4%	9%	22%	47%
22	15%	7%	10%	25%	57%
23	16%	8%	3%	15%	42%
24	3%	14%	0%	12%	29%
25	14%	11%	2%	13%	41%
26	9%	10%	2%	19%	41%
27	19%	10%	4%	7%	40%
28	8%	10%	7%	26%	51%
29	12%	16%	2%	22%	52%
Statewide (excluding BSP & WMD30)	12%	10%	7%	36%	66%

[1]See Appendix 3.

Table 7. Percent of total land area with different levels of dormant season preferred browse production for moose[1]. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

	BROWSE PRODUCTION LEVEL				
WMD	Low (0.18-0.47oz/yd^2)	Medium (0.48-0.77oz/yd^2)	High (0.78-1.07oz/yd^2)	V. High (≥1.08 oz/yd^2)	Low-V. High Production
1	21%	13%	16%	17%	68%
2	25%	24%	14%	21%	84%
3	23%	17%	13%	10%	62%
4	21%	17%	11%	23%	73%
5	31%	18%	5%	3%	57%
6	22%	19%	7%	16%	63%
7	26%	14%	11%	21%	72%
8	26%	17%	10%	21%	75%
9	29%	16%	13%	22%	80%
10	30%	13%	10%	7%	59%
11	27%	14%	10%	12%	63%
12	25%	17%	6%	17%	65%
13	35%	17%	9%	5%	66%
14	17%	18%	16%	11%	62%
15	22%	14%	3%	7%	46%
16	25%	14%	3%	11%	52%
17	18%	7%	10%	6%	41%
18	25%	6%	4%	5%	40%
19	24%	15%	3%	9%	51%
20	26%	8%	2%	6%	41%
21	22%	4%	10%	5%	40%
22	27%	12%	4%	4%	46%
23	13%	8%	5%	6%	32%
24	10%	11%	0%	0%	21%
25	29%	2%	1%	3%	35%
26	14%	8%	4%	5%	31%
27	18%	5%	0%	3%	26%
28	17%	11%	6%	9%	43%
29	12%	10%	6%	4%	32%
Statewide (excluding BSP & WMD30)	23%	13%	8%	11%	56%

[1]See Appendix 3.

Table 8. Percent of total land area in winter cover with different levels of dormant season preferred browse production for moose[1]. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

	BROWSE PRODUCTION LEVEL					
WMD	Low (0.18-0.47oz/yd^2)	Medium (0.48-0.77oz/yd^2)	High (0.78-1.07oz/yd^2)	V. High (≥1.08 oz/yd^2)	Severe Winter Habitat with Preferred Browse	All Severe Winter Habitat
1	3%	2%	1%	1%	7%	14%
2	3%	2%	1%	0%	6%	8%
3	3%	1%	2%	0%	6%	7%
4	4%	2%	1%	2%	9%	11%
5	4%	0%	1%	1%	6%	11%
6	2%	<1%	0%	1%	4%	6%
7	5%	1%	2%	1%	9%	17%
8	3%	3%	1%	1%	8%	14%
9	3%	1%	0%	0%	4%	4%
10	5%	0%	1%	0%	6%	15%
11	4%	2%	2%	1%	9%	10%
12	5%	3%	1%	0%	9%	12%
13	3%	2%	0%	0%	5%	8%
14	3%	4%	0%	0%	7%	16%
15	3%	2%	0%	0%	5%	9%
16	1%	1%	0%	0%	2%	6%
17	2%	<1%	1%	<1%	4%	15%
18	7%	0%	0%	0%	7%	19%
19	5%	2%	1%	3%	11%	17%
20	3%	0%	0%	0%	3%	5%
21	0%	0%	0%	2%	2%	6%
22	0%	0%	0%	0%	0%	3%
23	3%	0%	0%	1%	4%	19%
24	0%	0%	0%	0%	0%	9%
25	3%	0%	0%	2%	5%	15%
26	4%	1%	0%	0%	5%	19%
27	4%	0%	0%	0%	6%	26%
28	0%	2%	0%	0%	2%	16%
29	3%	0%	0%	0%	3%	16%
Statewide (excluding BSP & WMD30)	3%	1%	1%	1%	6%	12%

[1]See Appendix 3.

Table 9. Percent of area in moose habitat types by WMD. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

		% Land Area in listed habitat types:				
WMD	LAND (sq. mile)	Potential Habitat	Severe Winter Habitat	Clearcut & Stripcut	Partial Cut	Aquatic Feeding Areas: Fresh Marsh, Wooded Swamp, Bog
1	1,420	97%	14%	11%	29%	4%
2	1,190	97%	8%	9%	33%	2%
3	966	84%	7%	8%	25%	1%
4	1,963	99%	11%	20%	22%	5%
5	1,549	99%	11%	14%	29%	3%
6	1,417	83%	6%	8%	33%	2%
7	1,393	96%	17%	6%	25%	1%
8	2,054	99%	14%	18%	21%	2%
9	979	96%	4%	12%	27%	3%
10	898	92%	15%	7%	29%	3%
11	1,700	92%	10%	12%	41%	6%
12	996	88%	12%	1%	38%	1%
13	575	95%	8%	3%	48%	1%
14	798	96%	16%	19%	34%	1%
15	1,038	87%	9%	<1%	37%	2%
16	826	75%	6%	8%	27%	3%
17	1,430	86%	15%	8%	29%	3%
18	1,367	91%	19%	10%	35%	6%
19	1,176	96%	17%	19%	35%	7%
20	646	83%	5%	0%	21%	<1%
21	629	71%	6%	0%	23%	<1%
22	576	80%	3%	0%	32%	2%
23	1,035	78%	19%	6%	31%	2%
24	374	56%	9%	0%	14%	1%
25	550	75%	15%	2%	31%	1%
26	654	86%	19%	4%	14%	1%
27	896	85%	26%	4%	16%	0%
28	831	90%	16%	11%	14%	2%
29	513	88%	16%	13%	28%	1%
Statewide (excluding BSP & WMD30)	30,441	90%	12%	9%	29%	3%

Table 10. Estimated number of moose that could be supported in good condition on 100 mi^2 by available browse during the growing season and dormant season. See appendix 4 for description of calculations.

WMD	Growing Season (moose/100 mi^2)	Dormant Season (moose/100 mi^2)
1	350	285
2	407	348
3	292	238
4	379	315
5	308	165
6	300	254
7	379	299
8	385	305
9	428	329
10	322	200
11	328	233
12	304	254
13	272	203
14	333	254
15	231	152
16	226	186
17	201	151
18	190	121
19	267	173
20	172	126
21	188	140
22	221	138
23	140	119
24	110	56
25	131	84
26	154	109
27	110	70
28	213	163
29	192	116

Table 11. Percent of available severe winter habitat (pole and sawlog sprucefir or hemlock) with various amounts of browsing on fir. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

WMD	Browse Intensity for Balsam Fir on Severe Winter Habitat for Moose (% of severe winter habitat)			
	negligible intensity	light intensity	medium intensity	heavy intensity
1	94.3	0.0	5.7	0.0
2	100.0	0.0	0.0	0.0
3	85.6	14.4	0.0	0.0
4	100.0	0.0	0.0	0.0
5	100.0	0.0	0.0	0.0
6	75.5	24.5	0.0	0.0
7	70.7	17.0	12.3	0.0
8	87.1	12.9	0.0	0.0
9	48.6	23.3	28.1	0.0
10	91.2	8.8	0.0	0.0
11	94.3	0.0	5.7	0.0
12	100.0	0.0	0.0	0.0
13	100.0	0.0	0.0	0.0
14	91.7	8.3	0.0	0.0
15	100.0	0.0	0.0	0.0
16	100.0	0.0	0.0	0.0
17	97.2	2.8	0.0	0.0
18	95.8	4.2	0.0	0.0
19	87.3	12.7	0.0	0.0
20	100.0	0.0	0.0	0.0
21	100.0	0.0	0.0	0.0
22	100.0	0.0	0.0	0.0
23	100.0	0.0	0.0	0.0
24	100.0	0.0	0.0	0.0
25	100.0	0.0	0.0	0.0
26	100.0	0.0	0.0	0.0
27	92.0	8.0	0.0	0.0
28	94.3	5.7	0.0	0.0
29	85.6	14.4	0.0	0.0
Statewide (excluding BSP & WMD30)	92.6	5.8	1.6	0.0

Table 12. Estimated winter moose population by zone based on census work done in the mid-1980's and updated using trend information from hunting and road-kill statistics.

				Calves / 100 Cows	
Zone	Population	Moose / mi^2	Bulls / 100 Cows	Min[1]	Max[2]
NW	1,420	1.0	100	42	70
NE	4,460	1.3	77	40	63
Ce	3,860	1.1	75	38	63
SW	3,900	1.2	56	41	75
SC	6,050	3.4	67	34	65
SE	4,110	0.8	100	40	70
S	2,300	1.1	100	N/A	N/A
Unhunted	3,000	0.2	100	N/A	N/A
Total	29,000	0.9	83	39	67

[1]From hunter sighting reports
[2]Female yearlings/2+ cows
[3]Population estimate if believed to be too low
[4]Population estimate if believed to be too high

Table 13. Mean sizes of yearling moose killed during moose seasons.

	Mean Yearling Weight (lb)				Mean Yearling Antler Size					
Year	Cows	n	Bulls	n	spread (cm)	n	beam (mm)	n	points	n
80	453	13	446	32	51	36	31.2	48	3.1	50
82	409	40	494	49	56	73	34.5	78	4.0	84
83	397	38	428	68	52	67	33.1	77	3.7	79
84	442	29	461	48	54	75	33.4	80	3.6	73
85	n/a	0	n/a	0	n/a	0	n/a	0	n/a	0
86	465	31	492	85	59	100	35.0	114	4.4	120
87	418	23	465	46	55	95	34.0	102	3.7	105
88	445	16	467	59	53	101	33.2	116	3.7	118
89	436	12	443	37	52	72	31.9	81	3.7	82
90	431	20	466	59	56	82	35.1	101	3.9	99
91	436	15	456	42	56	74	34.8	89	4.0	91
92	433	18	473	43	56	69	33.8	77	4.5	75
93	437	15	476	39	57	60	34.1	71	4.8	76
94	441	18	473	65	58	97	33.8	106	4.0	103
95	429	22	496	58	58	90	34.1	94	4.5	114
96	412	15	463	40	52	63	31.6	67	3.7	71
97	430	19	452	54	53	69	32.2	77	3.9	77

Table 14. Percent of area that produces at least 0.18oz/yd^2 of browse with various degrees of browsing on preferred dormant season browse. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

	Browse Intensity Levels			
WMD	negligible	light	medium	heavy
1	84.9	15.1	0.0	0.0
2	89.5	10.5	0.0	0.0
3	87.3	12.6	0.0	0.1
4	61.6	36.8	1.6	0.0
5	78.8	15.9	4.0	1.4
6	83.9	13.9	1.1	1.1
7	56.4	27.6	14.4	1.7
8	46.5	36.3	14.8	2.4
9	59.3	34.5	6.2	0.0
10	75.2	20.2	4.5	0.0
11	67.6	21.6	10.7	0.0
12	93.9	4.7	1.4	0.0
13	68.4	19.9	11.7	0.0
14	42.3	40.9	16.8	0.0
15	93.3	6.7	0.0	0.0
16	80.4	11.9	5.8	2.0
17	71.5	23.6	4.9	0.0
18	81.0	13.5	3.7	1.9
19	65.9	19.8	10.1	4.1
20	95.3	0.0	0.0	4.7
21	95.9	4.1	0.0	0.0
22	88.7	11.3	0.0	0.0
23	81.5	18.5	0.0	0.0
24	81.8	0.0	18.2	0.0
25	82.9	17.1	0.0	0.0
26	96.1	3.9	0.0	0.0
27	59.6	36.6	0.0	3.9
28	68.0	18.5	10.8	2.7
29	51.7	32.0	16.3	0.0
Statewide (excluding BSP & WMD30)	72.4	21.1	5.7	0.9

Table 15. Percent of areas that produce at least 0.18 oz/yd^2 of dormant season preferred browse with various degrees of browsing in fir. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

	Browse Intensity Level			
WMD	negligible	light	medium	heavy
1	98.9	0.0	1.1	0.0
2	98.9	0.0	1.1	0.0
3	93.6	4.8	0.0	1.6
4	96.0	3.2	0.8	0.0
5	94.7	3.9	1.4	0.0
6	97.4	2.6	0.0	0.0
7	69.6	13.8	12.7	4.0
8	90.4	7.2	1.6	0.8
9	78.3	13.4	8.3	0.0
10	88.1	2.4	7.1	2.4
11	93.8	3.6	2.7	0.0
12	98.4	1.6	0.0	0.0
13	96.3	3.7	0.0	0.0
14	95.8	2.1	0.0	2.1
15	100.0	0.0	0.0	0.0
16	98.0	0.0	2.0	0.0
17	98.8	0.0	1.2	0.0
18	94.4	3.7	1.9	0.0
19	93.8	6.2	0.0	0.0
20	100.0	0.0	0.0	0.0
21	100.0	0.0	0.0	0.0
22	100.0	0.0	0.0	0.0
23	100.0	0.0	0.0	0.0
24	100.0	0.0	0.0	0.0
25	100.0	0.0	0.0	0.0
26	100.0	0.0	0.0	0.0
27	100.0	0.0	0.0	0.0
28	100.0	0.0	0.0	0.0
29	89.0	11.0	0.0	0.0
Statewide (excluding BSP & WMD30)	93.7	3.8	2.1	0.5

Table 16. Percent of area in each of 4 dormant season preferred browse productivity classes[1] with negligible, light medium or high browsing intensity in WMDs 1, 2, 3, 4, 5, and 6 (NW, NE and C MHZs). Adjacent zones were grouped to improve sample size. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

Browse Production Levels	BROWSE INTENSITY (% REMOVED)			
	negligible (<1%)	light (1-10%)	medium (11-40%)	heavy (>40%)
low	84.6%	13.8%	0.5%	1.1%
medium	80.4%	18.1%	1.4%	0.0%
high	75.6%	22.0%	2.4%	0.0%
very high	72.9%	26.3%	0.8%	0.0%

Table 17. Percent of area in each of 4 dormant season preferred browse productivity classes[1] with negligible, light, medium or high browsing intensity in WMDs 7, 8, 9, 12, 13, 14 (SW, S, and SC MHZs). Adjacent zones were grouped to improve sample size. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

Browse Production Levels	BROWSE INTENSITY (% REMOVED)			
	negligible (<1%)	light (1-10%)	medium (11-40%)	heavy (>40%)
low	64.3%	21.6%	11.8%	2.2%
medium	61.2%	29.7%	9.0%	0.0%
high	53.0%	31.7%	14.0%	1.2%
very high	53.4%	35.7%	10.9%	0.0%

Table 18. Percent of area in each of 4 dormant season preferred productivity classes[1] with negligible, light, medium or high browsing intensity in WMDs 10, 11, 18, 19 (SE MHZ). Adjacent zones were grouped to improve sample size. Data from U.S. Forest Service, 1997. Fourth Forest Inventory of Maine.

Browse Production Levels	BROWSE INTENSITY (% REMOVED)			
	negligible (<1%)	light (1-10%)	medium (11-40%)	heavy (>40%)
low	66.1%	25.1%	7.2%	1.6%
medium	78.2%	12.9%	8.9%	0.0%
high	71.8%	18.9%	9.3%	0.0%
very high	76.9%	11.7%	9.0%	2.4%

[1]See Appendix 2.

Table 19. Estimated winter moose population by hunting zone and potential populations with and without the current deer population. Maximum sustainable harvest (MSY) is achieved at 50% of K. Potential populations with the current deer population were not calculated for Southern Maine because deer use agricultural and suburban areas to a greater extent than moose.

Zone	WMD's Included	Estimated Winter Pop.	Winter at 50%K (w/o deer)	Winter at 50% K (w/ deer)	Winter at K (w/o deer)	Winter at K (w/ deer)
NW	1	1,420	4,050	1,650	8,100	5,700
NE	2, 3, 6	4,460	10,000	7,420	20,000	17,400
C	4, 5	3,860	8,740	3,510	17,480	12,300
SW	8, 7[b], 13[b]	3,900	8,930	4,850	17,860	13,800
SC	9, 14	6,050	5,240	4,480	10,480	9,820
SE	10, 11, 19, 18[a]	4,110	10,300	3,910	20,600	14,200
S	12, 7[c], 13[c]	2,300	5,200	3,720	10,400	8,920
Unhunt		2-3,000	12,100	N/A	24,200	N/A
All		29,000	64,600	29,540[+]	129,200	82,140[+]

Table 20. Estimated winter moose density (moose/mi^2) by hunting zone and potential density (moose/mi^2) with and without the current deer population. At 50% of k the maximum moose harvest can be sustained (i.e., MSY).

Zone	WMD's Included	Winter Density	Without deer		With current deer population	
			50% K	K	50% K	K
NW	1	1.0	2.8	5.6	1.2	4.0
NE	2, 3, 6	1.3	2.8	5.6	2.1	4.9
C	4, 5	1.1	2.5	5.0	1.0	3.5
SW	8, 7[b], 13[b]	1.2	2.8	5.6	1.5	4.2
SC	9, 14	3.4	3.0	6.0	2.5	5.5
SE	10, 11, 19, 18[a]	0.8	2.0	4.0	0.8	2.8
S	12, 7[c], 13[c]	1.1	2.5	5.0	1.8	4.3

[a]Eastern parts only.

[b]Northern parts only.

[c]Southern parts only.

Table 21. Current consumptive use of moose based on 1997 permit allocations.

Zone	WMD's Included	1997 % Success	# Permits	Permits mi^2	Expected Harvest mi^2	Estimated % of Winter Population Shot in 1997		
						All	Bulls	Cows
NW	1	76	140	0.09	0.08	8%	11%	2%
NE	2, 3, 6	96	260	0.07	0.07	6%	10%	3%
C	4, 5	93	320	0.10	0.10	8%	14%	3%
SW[e]	8, 7[b], 13[b]	98	340	0.11	0.11	7%	16%	4%
SC[d]	9, 14	100	140	0.08	0.08	2%	3%	1%
SE	10, 11, 19, 18[a]	87	220	0.06	0.05	4%	7%	3%
S	12, 7[c], 13[c]	na	80	0.04	0.04	na	na	na
All Hunted		92	1,500	-	-			

[a]Eastern parts only.

[b]Northern parts only.

[c]Southern parts only.

[d]Population estimates may be high for this zone. Therefore, the percent of the population shot may be higher.

[e]Population estimate is believed to be low for this zone

Table 22. Number of moose-vehicle accidents by Wildlife Management District in 1995 and 1996 and the rate of moose-vehicle accidents per 100 mi^2 of land area. The highest number of reports on record were received in 1996. 1995 had the lowest number of reports since 1991.

	1995		1996	
WMD	Number of Accidents	Accidents 100 mi^2	Number of Accidents	Accidents 100 mi^2
1	6	0.4	8	0.6
2	3	0.2	8	0.6
3	42	4.8	42	4.8
4	0	0.0	3	0.3
5	16	1.0	17	1.0
6	62	4.2	87	5.9
7	52	3.4	63	4.0
8	49	2.2	77	3.4
9	8	0.7	12	1.0
10	18	1.8	19	1.9
11	44	2.4	54	3.0
12	32	3.0	49	4.5
13	6	1.0	20	3.3
14	19	2.2	30	3.4
15	21	1.9	37	3.4
16	18	2.0	15	1.6
17	11	0.7	31	2.0
18	17	1.2	23	1.6
19	11	0.8	17	1.2
20	14	2.0	11	1.6
21	21	2.9	20	2.8
22	10	1.6	22	3.5
23	9	0.8	10	0.9
24	23	5.9	24	6.1
25	7	1.2	9	1.5
26	6	0.8	8	1.1
27	9	1.0	10	1.0
28	2	0.2	10	1.1
29	9	1.7	6	1.0
30	0	0.0	0	0.0

Table 23. Number of moose-vehicle accidents (reported by State Police and Wardens) per 10^6 vehicle miles traveled by county by year.

	Year						
County	1990	1991	1992	1993	1994	1995	1996
Androscoggin	0.013	0.023	0.031	0.039	0.019	0.015	0.025
Aroostook	0.178	0.224	0.180	0.199	0.213	0.209	0.307
Cumberland	0.016	0.019	0.010	0.011	0.012	0.010	0.014
Franklin	0.199	0.168	0.193	0.220	0.178	0.172	0.319
Hancock	0.013	0.009	0.014	0.005	0.022	0.012	0.023
Kennebec	0.022	0.024	0.019	0.014	0.021	0.010	0.019
Knox	0.017	0.024	0.013	0.013	0.016	0.006	0.006
Lincoln	0.019	0.010	0.009	0.031	0.052	0.018	0.047
Oxford	0.129	0.128	0.107	0.096	0.124	0.102	0.153
Penobscot	0.021	0.032	0.032	0.036	0.031	0.029	0.043
Piscataquis	0.327	0.336	0.285	0.254	0.283	0.160	0.372
Sagadahoc	0.015	0.014	0.008	0.011	0.003	0.011	0.023
Somerset	0.218	0.221	0.158	0.139	0.162	0.106	0.180
Waldo	0.012	0.013	0.024	0.020	0.011	0.023	0.022
Washington	0.038	0.045	0.054	0.050	0.082	0.090	0.168
York	0.013	0.017	0.011	0.023	0.023	0.014	0.017
Total	0.049	0.056	0.047	0.050	0.053	0.040	0.058

Table 24. Bulls per 100 cows among moose sightings reported by moose hunters by hunting zone and year.

		ZONES							
Year	Opening day	Northwest	Northeast	Central	Southeast	South Central	Southwest	South[2]	All
1980	9/22				No Zones				133
1982	9/20	244	119	109	132	89	125	-	120
1983	9/19	94	108	91	110	85	102	-	97
1984	10/8	117	116	115	151	76	107	-	110
1985	10/21	100	89	89	123	74	90	-	91
1986[1]	10/20	85	103	78	104	72	64	-	81
1987	10/18	98	90	73	104	61	77	-	82
1988	10/17	65	84	99	109	70	75	-	86
1989	10/16	82	89	83	93	70	80	-	82
1990	9/24	123	129	116	170	112	111	-	121
1991	10/7	81	85	105	140	91	73	-	92
1992	10/5	103	96	111	152	88	83	-	101
1993	10/4	163	132	132	164	111	94	-	124
1994	10/3	178	129	123	153	107	94	-	117
1995	10/2	158	99	130	151	82	106	-	111
1996	10/7	138	105	107	138	93	77	-	98
1997		118	98	91	137	63	81	113	94

[1]The southwest, south central, and southeast zones were expanded in 1986.
[2]The south zone was opened in 1997

APPENDIX 1. GEOGRAPHICAL AREAS USED IN THIS ASSESSMENT.

Figure 1. Maine's Wildlife Management Districts (WMDs)

Figure 2. Moose hunting zones and Wildlife Management Districts

Figure 3. Maine Counties

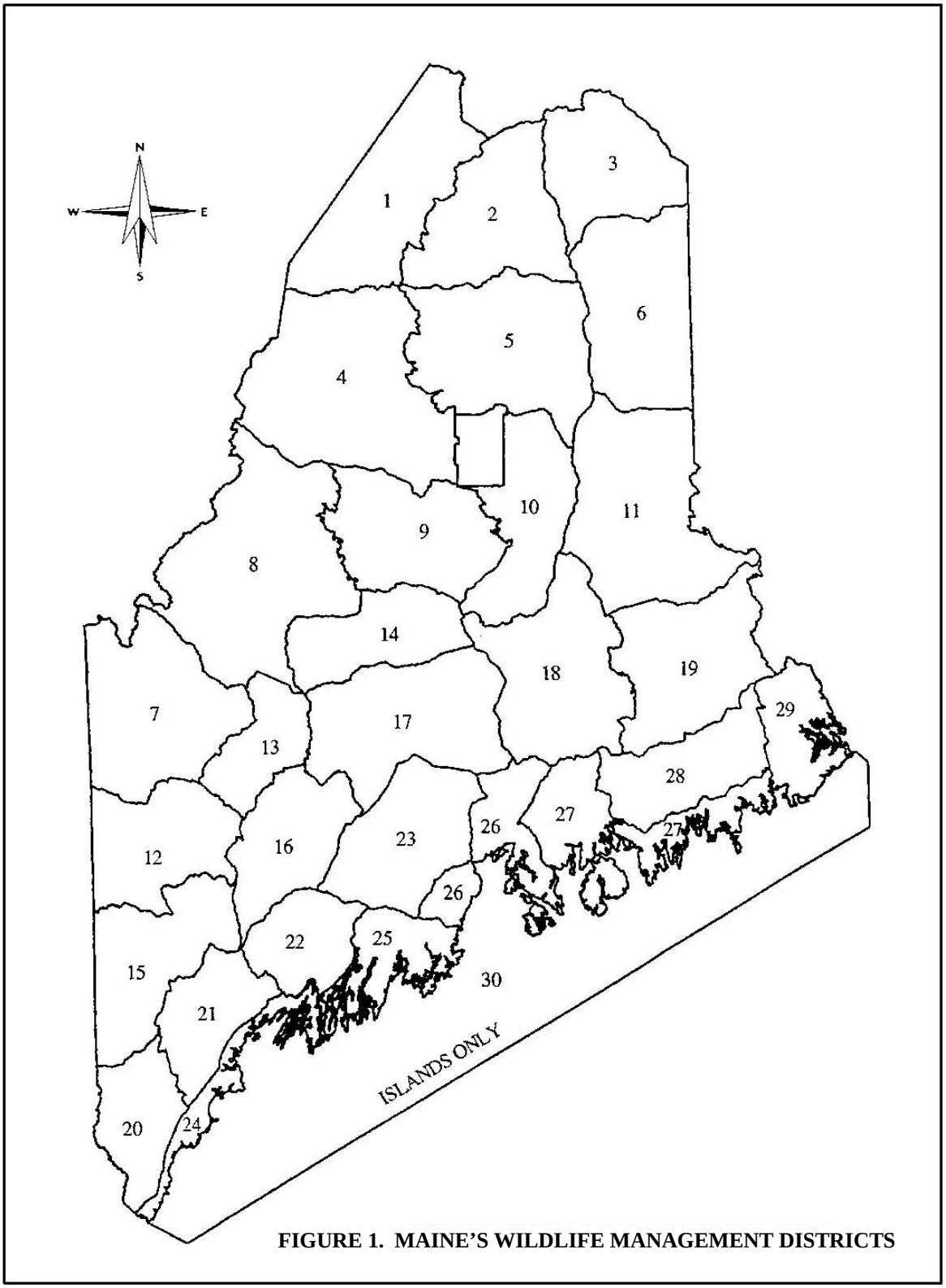


FIGURE 1. MAINE'S WILDLIFE MANAGEMENT DISTRICTS

MDIFW WMD'S

JULY 2000

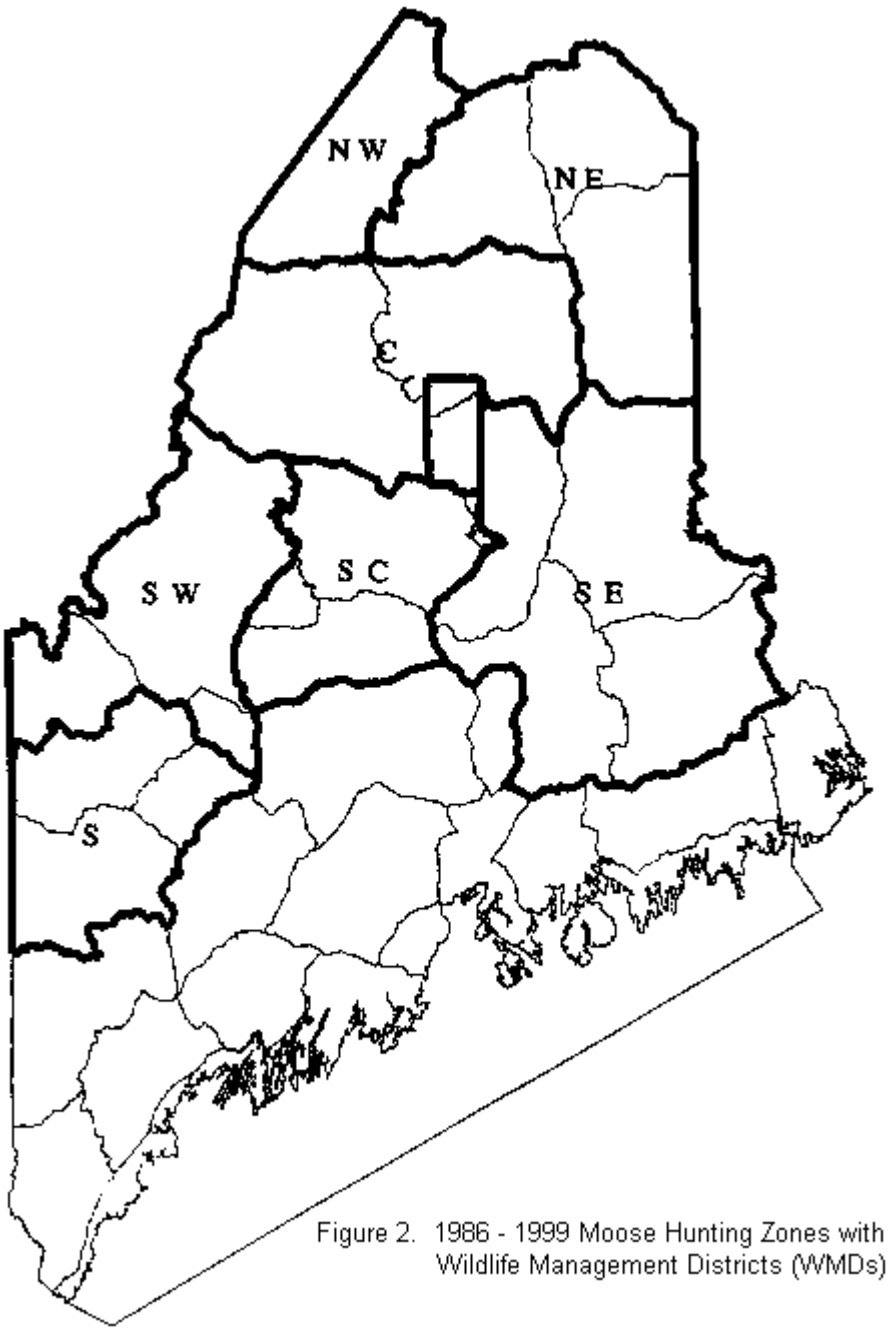


Figure 2. 1986 - 1999 Moose Hunting Zones with Wildlife Management Districts (WMDs)

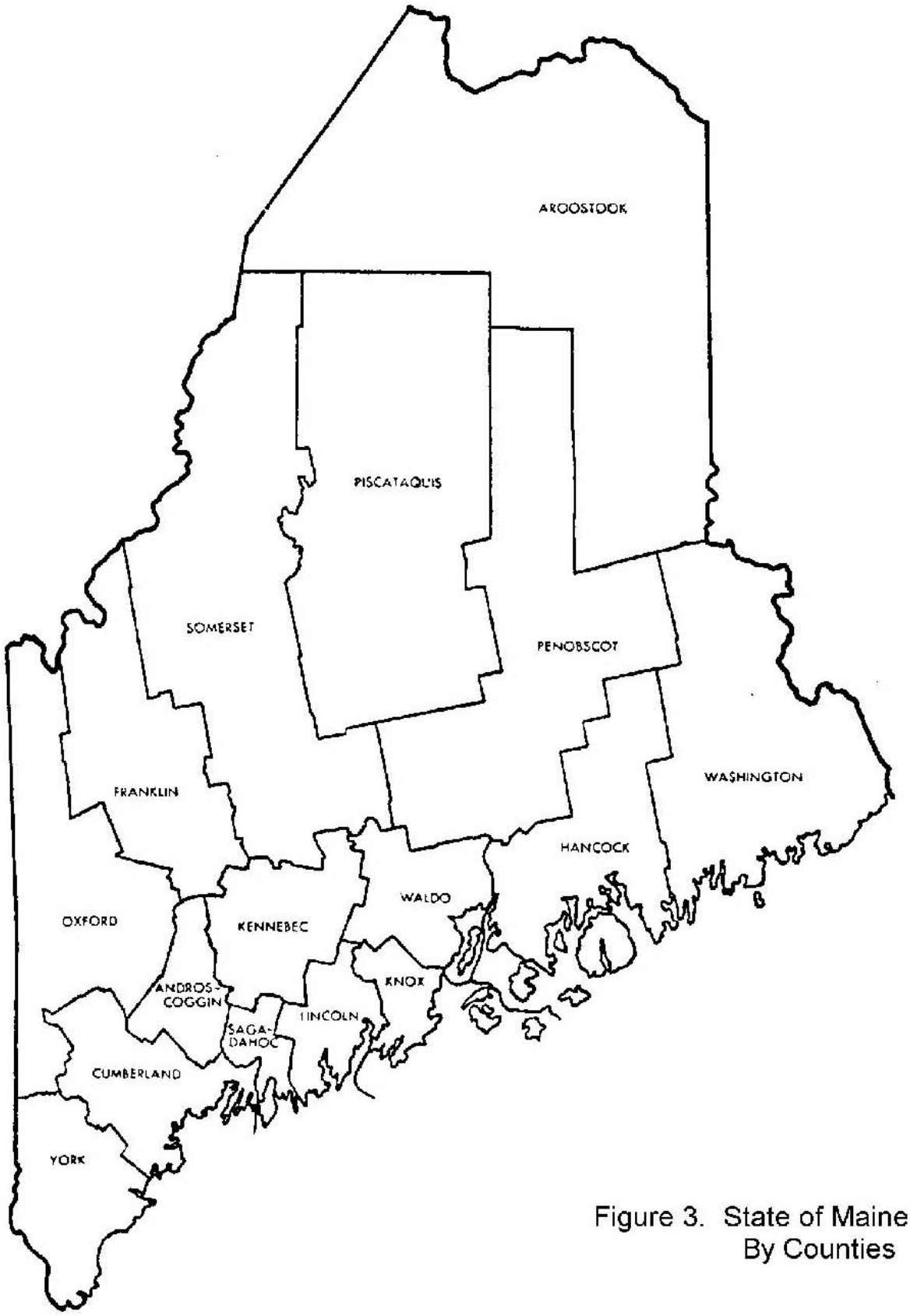


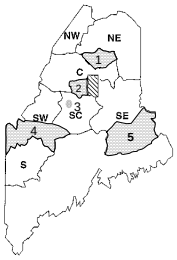
Figure 3. State of Maine
By Counties

APPENDIX 2. ESTIMATION OF MOOSE POPULATIONS

THE LOCATIONS AND RESULTS OF 5 AERIAL CENSUSES USED IN CALCULATING MOOSE POPULATIONS ARE PRESENTED BELOW.

Summary of moose census completed in the mid 1980's.

Census	Year	Moose $mi^2 \pm 80ci$	With Sightability Correction	Sightability Correction Applied from a Similar Census	Final Density
1	1985	0.55 ± 27	yes (1.7)	n/a	0.5
2	1989	1.70 ± 20	yes (1.2)	n/a	1.7
3	1984	$3.06 \pm$ n/a	no	none	3.1
4	1985	1.04 ± 23	no	1.2	1.2
5	1985	0.38 ± 48	no	1.2	0.5



THE FOLLOWING CENSUS DATA WAS USED IN CALCULATION OF 1985 POPULATION DENSITY BY MOOSE HUNTING ZONE:

NW population density from census 1 or 0.5 moose per mi^2
NE population density from census 1 or 0.5 moose per mi^2
C mean of population densities from censuses 1 and 2 or 1.1 moose per mi^2
SW population density from census 4 or 1.2 moose per mi^2
SC mean of population densities from censuses 2, 3 and 4 or 2.0 moose per mi^2
SE population density from census 5 or 0.5 moose per mi^2

THE FOLLOWING METHOD WAS USED TO CALCULATE CURRENT POPULATION DENSITY FROM 1985 POPULATION DENSITY ESTIMATES.

It was assumed that changes in hunter sighting rate (S) and moose density (D) were directly proportional. A correction factor (F) was calculated for each zone based on changes in hunter sighting rate:

$$F = S_1 / S_2 = D_1 / D_2$$

For the NW and NE zones, the mean of the 1985 and 1986 sighting rates were used to compare the mean of the 1996 and 1997 sighting rates. For the SE and SC zones only 1986 data was used because the zones were expanded in 1986. No correction factor was used for the central and SW zones because sighting rates during the last few years overlapped the sighting rates of the mid 1980's. This suggests that there has not been much change in the population.

TO ESTIMATE THE CURRENT POPULATION THE FOLLOWING FORMULA WAS USED:

1997 density estimate = F(1985 density estimate)

ESTIMATION OF MOOSE POPULATIONS OUTSIDE OF THE CURRENTLY HUNTED AREA.

Population information from this section of the state is limited and estimated densities are based on comparisons of road kill rates between different areas of the state and/or on population estimates from nearby areas.

Baxter Park. This area is adjacent to the most recently censured area in the C zone. Population densities are assumed to be similar or about 1.1 moose / $mi^{2.}$

The South Zone. The number of moose-vehicle accidents per vehicle mile traveled for the counties in this zone is similar to accident rates in Aroostook, Somerset and Piscataquis Counties. Therefor, the moose density is assumed to be similar, or a bit over $1/mi^2$. In 1997, the sighting rate for the South zone was between that of the NE and the SW zones. This suggests that the density is probably similar, or a bit over 1 moose/mi^2

Remaining unhunted. The number of moose-vehicle accidents per vehicle mile traveled for this area is about 10% of the accident rate in the hunted areas of the state. Therefor the population density is believed to be about one tenth of the hunted area or around 0.1-0.3 moose / mi^2 overall. Moose densities in this area are extremely variable and are highest just south of the hunted areas and lowest near the coast.

ESTIMATES OF POPULATION STRUCTURE

The sex and age structure of the moose populations of the various hunting zones was estimated from hunter sighting statistics using the following assumptions: 1. The ratio of calves to cows was accurate. 2. Bulls are more likely to be seen than cows due to greater activity during the breeding season. 3. Bulls are less likely to classified as unknown than cows. and 4. The number of bulls in the population never exceeds the number of cows because the sex ratio is nearly even at birth and the mortality rate for bulls tends to be higher than for cows, especially in hunted populations. The highest sex ratio among sightings during the 1996 season (138 bulls:100 cows) was assumed to represent a natural sex ratio of close to 1:1. The following formula was used to adjust the sex ratios reported by hunters for differences in sighting and identification:

Actual ratio = (observed bulls /observed cows) (100/138)

APPENDIX 3 : 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*.

The area of each WMD covered by the various browse abundance categories was calculated as described in Appendix 4.

APPENDIX 4. 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 ith 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 ith stand except enter 0 for all areas where density is <1 g/m^2 dry weight

A_i = area of ith stand

$SIV4_i$ = suitability index for proportion of woody browse composed of coniferous species in ith stand

$SIV5_i$ = suitability index for mean distance to dormant-season cover in ith 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 (see appendix 3).