New Hampshire
MOOSE ASSESSMENT

2015

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INTRODUCTION

The New Hampshire Fish and Game Department has been actively managing moose since 1988. Species management requires input from three sources; the species in question, the department and the public. The department collects and analyzes data from the species, blends this together with knowledge of management and species requirements and presents the public with management recommendations that are designed to meet the species goals as set with public input during the planning process. This document should provide the reader with the knowledge necessary to develop goal input for moose in the six management regions of the state that are realistic and obtainable.

The knowledge contained herein is based on information gathered both from the New Hampshire moose herd and from other jurisdictions and represents the best information available on moose today. New Hampshire moose are managed based on six management regions which in turn are broken into 22 wildlife management units (WMUs). Each region represents an area that has broadly similar land use, habitat types and moose and human density patterns across it's WMUs. A map of the moose management regions and units is found in Appendix 1. The NH moose data are analyzed regionally. Regional assessment of the data provides sample sizes which, in most cases are large enough to accurately reflect the standing population. There are areas where data may be insufficient to provide this. In those cases interpretation of the data will be made based on knowledge of moose population dynamics. For some purposes data may be examined by WMU, however, WMU data often do not provide sample sizes that give an accurate representation of the population.

Goals for the moose management plan should be regionally based population goals.

NATURAL HISTORY

Description: Moose are the largest member of the deer family. They are often described as being an animal put together by a committee having a neck considerably shorter than their long legs, a large pendulous nose, very short inconspicuous tail and large hump over their shoulders. They stand approximately 6 feet tall at the shoulders have excellent senses of smell and hearing but tend to be near sighted. ((Franzmannand Schwartz 1997). While not the world's most beautiful creature they are very well adapted to live in a northern climate.

There are four sub-species of moose in North America; *Alces alces americana* found in the north east, A.a andersonii found in the northwest, *A.a. shirasii* found in the Rocky Mountains and *A.a. gigas* found in the Yukon and Alaska. Aside from size and antler conformation these sub-species are very similar (Chapman and Feldhammer 1982). New Hampshire's moose, *A.a.americana*, is medium sized, being smaller than *gigas* and larger then *shirasi*. New Hampshire bulls are larger than cows weighing 1000 lbs on average ranging up to 1400 lbs live weight while cows weigh approximately 700lbs ranging up to 1000 lbs. Moose continue to grow until the age of 5 years (Franzmann & Schwartz 1997)

Only bulls develop antlers. Antler growth occurs annually beginning in April. By August antlers have "hardened off" and the velvet is shed. Beginning in December bulls shed their antlers with the oldest bulls losing their racks first and the youngest losing theirs as late as March. In New Hampshire yearlings typically exhibit fork or cervicorn antlers with a mean spread of 23 inches, teenage bulls (2.5 – 4.5 years of age) usually exhibit medium to large palmate antlers with mean spreads of 40 inches and adult bulls (5.5 years plus) usually have large palmate antlers with a mean spread of 47 inches. The largest spread taken in the state measured 68.5 inches measured diagonally from legal tine to legal tine.

Both sexes have a flap of skin hanging under their throat but only bulls develop the large "bell". Adult bulls also have a black face while cows have a lighter brown face and a white patch of fur surrounding the vulva. Otherwise coat color, depending on the time of year, ranges from brown to black. Moose may have white or tan stockings. Occasionally albino moose may be seen. Excessive grooming in the late winter/early spring or sun exposure may cause a broken hair coat which will appear grey or white.

Moose are very well adapted to cold temperatures and deep snow due to their large size, thick skin, very dense hair coat and long legs. Moose calves can withstand temperatures as low at -22^{o} F before becoming cold stressed. (Renecker et al.1978). Long legs enable adult moose to move through powder snow up to depths of 38 inches, however depths of 28 inches impede movement sufficiently to cause moose to seek softwood shelter (Kelsall and Prescott 1971).

The same factors that enable moose to withstand cold pre-disposes them to heat stress. Summer thermal stress for moose begins at temperatures as low as 57^{o}F with panting beginning at 68^{o}F (Renecker and Hudson 1989, Renecker and Hudson 1990). Even in winter heat stress can occur at temperatures above 23^{o}F (Franzmann and Schwartz 1985). During periods of high temperature moose will cease to forage and instead seek shelter and rest in an effort to remain cool. This can cause reduced weight gain (Renecker and Hudson 1986). Renecker and Hudson (1992) have shown that lost feeding opportunities caused by heat stress in the summer can not be compensated for on other days. Heat stress may be felt more acutely by adults than by younger animals due to their larger body mass.

Distribution and Status: Moose are a boreal species with a circumpolar distribution. Boreal species are those which inhabit northern coniferous and mixed wood forests. Historically there are conflicting reports of the southern range of moose with some suggesting moose ranged as far south as Pennsylvania and others suggesting the northern border of Massachusetts was the southernmost boundary. We do know that at the time of European settlement moose were found statewide in New Hampshire with the highest densities occurring north of Concord (Silver 1957). Today's distribution pattern mimics the original. Moose are found statewide with the highest densities in the Ct. Lakes region and declining as you go from the North region south, with the lowest densities in the South East region (Figure 1). In the north eastern US strong moose populations also occur in Maine (Peek and Morris 1998) and Vermont (Alexander 1993) with small populations found in Massachusetts, Connecticut and New York (Wattles and De Stefano 2011). Southern distribution of moose is felt to be limited by heat (Kelsall and Telfer 1974.) Recent study results suggests warmer temperatures are responsible for increased parasite loads on moose which in turn may be the true limiting factor for southern distribution. (Musante 2006, Bergeron 2011)

Food Habits: Moose is an Algonguin term that means “eater of twigs”. With a neck considerably shorter than their legs moose tend to browse on twigs that are easily within their reach. This means the bulk of their food is found 2 feet off the ground to a height of 8 feet. Moose seldom graze as they must get on their knees to do so. Their most important food source is the leaves, buds and new year’s woody growth of hardwood and some species of softwood trees. Moose need to consume 40 – 60 pounds of hardwood browse daily to maintain good body weight (Allen et al. 1987). Browse species consumed by moose in New Hampshire include red, sugar, mountain, and striped maple, aspen, pin cherry, willow, mountain ash, paper and yellow birch, nannyberry, red-osier and alternate-leafed dogwood, hobblebush, alder, hazelnut, elderberry, honeysuckle, balsam fir, and American yew (Miller 1989, Pruss 1991). While hardwood browse is the most important source of food for moose they also feed on aquatic vegetation in the summer months and consume the bark of maples, aspen and other hardwood species in the fall and early winter.

Moose are ruminants which means they must bed down for approximately 10 hours per day to digest their food (Renecker and Hudson 1989a). As the quality of food declines in the late fall and winter the number of hours needed for digestion increases pre-empting the amount of time available for actual feeding. Moose do not feed as much in the winter months reducing their intake by up to 50%. This is due to both a longer rumen retention time of the lower quality browse and an apparent voluntary reduction of food intake. (Chapman and Feldhammer 1982)

Moose need sodium in order to maintain basic physiologic processes (Robbins 1983). They can obtain sodium from both aquatic plants (Fraser and Hristienko 1981) and from road side salt licks where road salt has washed into wet areas. Due to the very high salt concentrations found in licks moose can obtain sodium more efficiently using licks than feeding on aquatics (Belovsky 1978). In New Hampshire, moose utilize roadside salt licks most extensively during the months of May through October and will move up to 13 miles to access these sites. (Miller1989, Scarpitti 2006)

Habitat Requirements: Moose habitat is influenced by both the time of year and age and sex of the animal. In general good moose habitat provides hardwood browse, aquatic vegetation or mineral licks, plentiful water and cover that provides relief from the sun, excessive heat, insects, deep snow, crust and extreme cold.

During all times of the year moose need areas that provide an abundance of hardwood browse. Miller (1989) and Scarpitti (2006) found moose in northern N.H. spend a majority of their time in hardwood or mixed wood stands. While the production of hardwood browse is best met by cutting or fire, disease and insect outbreaks (such as spruce budworm), wind-throw, and beaver activity all provide patches of forest regeneration and increased browse availability. In addition shrubby browse is found on the edges of mature forest and in riparian areas. Mature stands of timber with a vigorous under-story component are also good sources of browse. Moose tend to avoid heavily stocked pole size stands of timber and in clear cuts tend to stay within 100 yards of the forest edge (Bangs et al. 1985, Neu et al. 1974).

In the winter moose use softwood cover if snow depths exceed 27 inches, or if snow becomes dense or develops a crust thus impeding travel (Kelsall and Prescott 1971). They will also utilize softwood cover to escape the sun on warm winter days. Moose tend to limit their movements in the winter due to snow conditions (Goddard 1970) and possibly due to a reduction in metabolic rate (Regelin et al. 1985) and need for greater rumination periods (Risenhoover 1986). As a result winter home range is smaller than that found in other seasons and averaged 2.6 to 3.7 mi^2 in northern New Hampshire (Scarpitti, 2006). Thompson (1987) found Maine moose winter home ranges from 0.6 to 3 mi^2 in deep snow winters.

In spring both bulls and cows begin to visit road side salt licks and increase their home range as they increase their foraging range. A Maine study found that cows prefer to give birth in undisturbed areas near water with plenty of available browse nearby (Leptich 1986). A recent NH study found no statistically significant cover requirements for birthing sites however, cows did utilize even aged pole and sawtimber spruce/fir and mixed wood stands more than others (Scarpitti 2006).

In summer bulls and cows use slightly different habitats. Cows with calves seem to prefer areas of denser cover that are near water (Frannzmann and Schwartz 1985). These areas provide lactating cows with increased nutrients, reducing foraging times and therefore the amount of time calves are active and at risk of predation (White et al. 2001). Scarpitti (2006) found NH cows preferred mature spruce/fir or mixed wood stands.   Bulls seek out more mature upland hardwood habitats that provide forage as well as cover from the sun (Leptich 1986, Miller 1989). Home range size for cows in the Ct. Lakes region of New Hampshire averaged 20.98 mi^2 (Miller 1989). Scarpitti had similar findings with the largest seasonal home range of cows in the North region found in the fall of the year at 24.7 mi^2 , and the smallest home range found in the winter at 10.7 mi^2.

Fall home range size is the largest due to the movements both sexes make in search of a mate. In New Hampshire Miller (1989) found average home range size of 29.55 mi^2 for both sexes combined. After the breeding season it is common to find many moose in areas that provide good forage.

Reproduction: The breeding season or “rut” occurs from mid-September through mid-October. It is amazingly synchronous across North America (Lent 1974). While the bulls court the cows it is the cow that decides who her partner will be. Due to differences in sexual pheremones adult bulls (animals 2.5 years and older) are more attractive to cows and may bring them into estrus more effectively than sub-mature bulls (Schwartz et al. 1990). Bulls court the cows until they become receptive, breed them and move on to another cow. The receptive period of the cow lasts from one hour to three days. Cows that are not bred may recycle every 28 days for as many as six consecutive estrous cycles. Breeding that takes place after the first rut results in calves that often are not large enough the following fall to make it through the winter. For this reason it is important to maintain an adult sex ratio of 40% prime bulls (Crete et al. 1981).

Cows breed for the first time at 1.5 year of age having their first calf at age 2. Cows remain fertile well into their teens with maximum reproductive output taking place in pluriparous females (cows that have had at least one calf previously) (Schwartz and Hundertmark 1993). Calves are born each spring from mid-May through early June and are usually weaned by mid-September. Calves stay with the cow for a year, cows usually driving them away just prior to giving birth. Twinning rate (the proportion of births that are twins or triplets) is influenced by the age cow and weight (Schwartz and Hundertmark 1993, Adams 1995). Based on animals taken during the fall hunts in Maine, Vermont and NH Adams (1995) found that cows with a dressed weight of 440 lbs or less are unlikely to ovulate, those weighing between 440 and 550 tend to ovulate one egg and those over 550 are most likely to produce two. Schwartz (1992) found that females between the ages of 2-15 lose 9.3% of their ova, yearlings loose none and animals older than 15 may loose up to 100%. Pregnancy and twinning rates for animals older than 2 years of 79-100% and 23-90% respectively are indicative of moose on good habitat or well below carrying capacity. Rates of 76-84% and 1-25% are indicative of animals nearing or at carrying capacity while rates of 60-74% and 0-3% are indicative of animals on poor ranges and well above carrying capacity respectively (Gasaway et al. 1992). Maximum productivity for cows occurs between the ages of 3 to 15 years (Schwartz and Hundertmark 1993, Crichton 1988).

Mortality: Moose mortality or survival rates are influenced by age and sex as well as density, weather and cause. As part of his NH moose mortality project, Musante (2006) compared survival estimates of North American and Scandinavian moose populations. His review of the literature revealed annual survival rates of calves between 20 – 71% and that of adult cows ranging from 75 – 95%. He found average annual survival rates of NH cows to be 87% and that of calves to be 45%. Given New Hampshire’s conservative harvest of moose, lack of predators and relatively mild winters, these rates are somewhat low.

Major causes of moose mortality in North America include predation, hunting, vehicle kill, parasites, starvation and age related skeletal problems. In the state of NH only black bear are a significant source of predation on moose and only for calves younger than 7 weeks of age. At the time of European settlement, wolves and mountain lions existed here and while they may yet return their presence has not currently been confirmed. Black bears hunt and kill young calves and may rarely take adult animals who are weakened by disease or parasites. Black bears are the primary predator of moose calves in eastern North America, killing from 2-50% of the calf crop each year (Franzmann and Schwartz 1997). Bear predation on calves generally declines as the calves mature, the bulk of predation occurring before the calves are 7-8 weeks of age. Musante (2006) documented annual NH neonate mortality of 29% although was unable to document cause. Coyotes have never been documented as being a significant predator on moose calves or adults.

Moose are subject to hunting in this state and the annual take is documented under Management Activities. A general rule of thumb in North America is to harvest less than 10-12 % of the population if population growth is desired. During the last decade harvest rates for NH moose have ranged from 1 – 9 %. In 2014 regional harvest rates were as follows: Ct. Lakes - 1.7%, North -2.8%, White Mtn. - 2.9%, Central - 2.2%, Southwest -1.4% and Southeast - 2.0%. Harvest accounted for 18% of the mortality for NH collared moose in a study conducted by Musante (2006) in the North region. Illegal kills are rarely documented and have averaged 2 per year during the last decade.

In the past 7 years, an average of 170 animals were struck and killed outright on our road system each year, down from an average of 240 the previous decade. This reduction is primarily due to the reduction in the moose population. However, there has been a concerted effort by a joint task force to address moose vehicle collisions in the state. This task force was composed of members of the Departments of Public Safety, Transportation and Fish and Game, as well as a member of the Governor's Council and an emergency room physician. Under this task force, flashing warning signs were introduced for use at moose/vehicle collision "hot spots', and a driver education segment covering driving practices designed to reduce wildlife collisions was written, produced and disseminated to all driver education instructors. While it is impossible to measure any possible reduction in vehicle collisions these practices may have engendered, it is known that installation of a flashing sign at the top of Franconia Notch on I-93 reduced human injury due to moose vehicle collisions from an average of five per year to zero (Littleton Hospital statistics). Child et al. (1991) suggests that actual number of road killed moose may be 3-6 times greater than those found dead on the road. However in a NH collaring study conducted from 2001 – 2005, Musante (2006) found all vehicle killed moose (n=10) on or next to the road. This same study found vehicle collisions accounted for 26% of all moose mortality.

Parasites are another major cause of mortality, primarily winter tick (*Dermacenter albapictus*), brainworm (*Parelaphostrongylus tenuis*) and possibly lungworm (*Dictyacaulus viviparous*). The primary host of brainworm is white-tailed deer which is able to carry the parasite with few ill effects. While moose may be able to survive limited infection rates but can die if infected with more than one or two worms (M. Lankester, Lakehead Univ., pers. comm.). An examination of the literature by Whitlaw and Lankester (1994) and a second by Lankester (2010) suggested that deer densities in excess of 10 -13/mi^{2}resulted in declining or extirpated moose populations due to increasing incidence of brainworm infection. Recent work done in Minnesota (Arno et al. 2014) on a declining moose population indicated that *P. tenuis* was responsible for as much as 54% of the mortality of collared animals. Musante (2006) did not find brainworm in any necropsied moose during the 2001-2005 NH mortality study. As deer densities were below 10-13% in the study area this finding was not surprising. Regional New Hampshire deer densities can be found in Table 3.

Winter tick has caused significant moose die offs over large areas of its North American range with the most recent being reported in the spring of 2011. That year several Canadian jurisdictions and eastern states including NH reported losing significant numbers of moose to winter tick. Winter tick is species specific using only cervids as host. They get on the moose in the fall and spend the winter feeding on their host, dropping off in the spring to lay eggs. An average tick load is about 35,000 ticks per moose with some animals carrying up to 150,000 ticks (Samuel and Welch 1991). It is believed that tick related death is due to a combination of anemia, increased energy expenditure resulting in depletion of fat reserves, secondary infections and hypothermia. While all sex and age classes of moose are impacted, animals which enter the winter in poor condition are more likely to die. Garner and Wilton (1993) also documented a rash of stillborn deaths and a 50% reduction in calf production in the spring following a tick outbreak. A mortality study conducted in NH in 2001-2005 documented a yearly loss of calves each spring as well as an irruptive loss of both calves and adults in the spring of 2001. During this study, winter tick accounted for 41% of mortality and compelling evidence was documented implicating winter tick induced anemia as the primary cause. In addition chronic heavy tick loads were implicated in declining moose weights resulting in reduced productivity (Scarpitti 2006; Musante 2006).

Tick incidence and resultant moose die offs are related to both moose numbers and weather. Moose densities and tick incidence are generally seen to be positively correlated. In an attempt to reduce tick induced mortality events, Ontario maintains moose densities below $1/mi^2$ (G. Eason, Ont. Ministry of Nat. Resources, pers. comm). Weather plays a major role in determining tick irruptions which cause moose die offs. Early spring and late winter arrivals tend to increase tick infection rates (Samuel 2004). Historically, this weather pattern has occurred intermittently across the North American moose range causing irruptive winter tick mortality events. Since 1970 changes in climate have shortened the number of snow covered days in northern NH from 6-18 days depending on location (Wake et al. 2014). This gives ticks a longer questing period in the fall resulting in heavier tick loads on moose and allows greater tick productivity as they are falling on bare ground in the spring.

Lungworm related mortality has not been reported in any jusrisdiction other than Maine (K. Morris, Maine Dept. of Inland Fisheries and Wildlife, pers comm.). Lungworm is widely distributed in moose but usually does not cause recognizable disease. Several collared moose that died in the 2001-2005 NH mortality study were lightly infected with lungworm but these animals were not exhibiting any evidence of respiratory disease related to the infection.

In general, moose which live into old age (older than 7 years) begin to suffer from joint disease especially in the hip and lower back (Wobeser and Runge 1975). Peterson (1988) found that 752 moose killed by wolves on Isle Royale were all over 7 years of age and all had degenerative joint disease. Osteoporotic changes coupled with periodontal problems contribute to the predation or age related mortality of moose (Hindelang and Peterson 1993).

Relationship to Carrying Capacity: There are two forms of carrying capacity. They are biological carrying capacity (K) and cultural carrying capacity (CCC). Biological carrying capacity (K) is the maximum number of individuals an area can support over a given period of time. A population has reached K when it's production is balanced against it's consumption of available resources. Going beyond K causes the population to deplete the available resources and the population declines. There are multiple influences on K and both renewable and non-renewable resources provide impacts. Availability of food and water are examples of renewable resources and space is a form of a non-renewable resource. Because these resources are ever changing, populations seldom remain at K for any period of time.

As populations grow towards K competition for resources grows as well. Klein (1981) summarized the effects of a deer population growing towards K. As populations grow and competition increases, some proportion of the population will not have access to good resources. As a result, incidence of reduced growth rates and poor body condition increases as does incidence of disease, parasitism and predation. Young of the year mortality increases and fertility decreases. The population may become skewed towards older animals as recruitment of young declines. Bucks will enter winter in poorer condition and will suffer higher mortality rates than does causing the adult sex ratio to skew towards females. K is reached when mortality offsets productivity. It's important to note that K is not the best place to be.

As the population grows towards K it's productivity changes. The best productivity is actually achieved when the population is at 0.56K. This point is known as maximum sustained yield (I). Below this point there is little to no competition for resources, above this point competition begins to have effects on the population, worsening as one gets closer to K. Below I all animals are well fed and productivity per cow is maximized. Growth rates of populations below I are usually high. Removing animals from this population has a direct negative impact on the number of calves produced. Fewer adults mean fewer calves produced. Above I animals are beginning to be nutritionally stressed and productivity is reduced. Reducing the number of animals in the population relieves nutritional stress and results in increased productivity.

A population's relationship to I also influences the effects mortality have on the population. Below I a population is experiencing little competition and is very healthy. Mortality due to stress or density dependent factors is very low. Any additional mortality, e.g. hunting or predation, is taking animals that may otherwise have lived. This is known as additive mortality. Above I animals are beginning to die due to density dependent factors. Additional mortality (e.g. hunting) has a higher likelihood of taking animals that would have died anyway. This is known as compensatory mortality.

Managing animals below I requires high harvest rates due to the potentially high population growth rate. But if the population is over-harvested the growth rate will be negatively impacted resulting in a decline which only the passage of time and reduction in harvest limits will bring back. Managing animals above I requires lower harvest rates due to lower reproductive rates and if over-harvest occurs, the ensuing increased productivity and decreasing density dependent mortality will enable the population to bounce back without stringent harvest restrictions.

While the concept of K and I is important in understanding how species population dynamics work, determining the density of moose at which K or I occurs has seldom been determined. Long term studies suggest moose populations will erupt in the presence of excellent browse supplies and in the absence of any regulatory effect will quickly outstrip the capability of the habitat to support them, whereupon the population will decline due to over-browsing and subsequent starvation, increased disease and parasitism and reduced fecundity. Because habitat components differ with every study, K and I differ as well. Crete (1989) reported a Quebec moose population had still not reached K at 5.2 moose/mi^2. Schwartz and Franzmann (1989) documented a moose population that increased to 9.3 moose/mi^2 before crashing to 0.8 moose/mi^2.

McCullough (1979) emphasized the importance of monitoring the recruitment of a population as an index to its' relationship to K. Peterson (1977) showed moose twinning rates are strongly correlated to population density. Productivity levels as an index to carrying capacity are documented in the "Reproduction" section. Because these indices to K are far easier to monitor than the habitat itself and possibly are more reliable indicators given the ease with which habitat conditions change and the difficulty and complexity of measuring habitat components, the department has used reproductive indices and changes in weight and antler characteristics of the moose to determine the population's relationship to K and I.

Working with UNH from 2001-2005, the department completed a habitat study in the North region. The study was designed to measure the habitat productivity based on its use by moose, not by direct measure of browse availability. The relatively small home range size and lack of difference in home range size between maternal and barren cows suggested that all habitat needs were being met within a small area and forage productivity was high across the landscape (Scarpitti 2006). Bergeron (2011) also conducted a browse impact study based within the White Mountains, North and Ct. Lakes regions. While this study found increasing levels of browse correlated to increasing moose density, browse levels in all regions were low with only 2 of 37 sites in the Ct. Lakes region and 1 of 40 in the White Mountain region showing severe browse impacts.

Cultural carrying capacity as defined by Ellingwood and Spignesi (1986) is the maximum number of animals that can exist compatibly with the local human population based on human perceptions, values, beliefs, attitudes and preferences. In New Hampshire, people in all management regions had reached their ability to tolerate existing moose densities during the last planning process. Like K, CCC is different for each moose management region. In New Hampshire CCC seems to be reached or influenced by numbers of moose/vehicle collisions, moose living in close proximity to people, agricultural impacts such as moose feeding in apple orchards, breaking maple syrup lines or hanging out with dairy cattle, and by browse impacts occurring in regenerating timber stands. In areas with few moose, CCC can also be influenced by the perception of problems rather than actual numbers of problems. CCC played a major role in the goals set during the 2006 planning process as seen in Table 1.

Interaction with Other Species: At high densities moose are capable of altering the environment by browsing and as a result can have a significant impact on many species of birds and animals. Studies on Isle Royale (Mclaren and Peterson 1994), in Alaska (Oldenmeyer 1981), in Vermont (C. Alexander, Vermont Fish and Wildlife Dept., pers. comm.) and in Maine (Morris 2002) have shown that moose can reduce the incidence of balsam fir, aspen, willow, mountain ash and aquatics through feeding. However, unless food supply is limited competition between moose and other cervids, in our case white-tailed deer, is unusual (Boer, 1992). In 1991 a study conducted by Pruss (1991) in NH found that moose were feeding in clear cuts adjacent to deer yards but this was not limiting the forage available for deer. Theoretically if moose numbers were to grow unchecked they could reduce the forage available around deer yards which would in turn impact the amount of food available to deer.

The most apparent effect of moose/deer competition in New Hampshire is the negative impact brainworm (*Paralaphostronylus tenuis*), has on moose. Deer are the primary host of brainworm and carry it with few or no ill effects and as deer numbers increase so to does the possibility of transmission of brainworm to moose. A study conducted in 1987 (NHF&G Pittman Robertson Report W-12-R-41) documented 60% of NH deer were infected with *P. tenuis*. Numerous North American studies have reported the decline of moose populations in the face of increasing deer populations and suggested brainworm may be the cause of the moose decline. (Telfer 1967, Karns 1967, Prescott 1974.) A recent review of the literature on North American moose population declines coupled with increasing deer densities by Lankester (2010) provides additional compelling evidence that brainworm transmission from deer to moose increases with increasing deer densities to the detriment of the moose population. Deer densities have increased in the state and in many parts of the state are now above the 10-13/mi^2 threshold that is felt to cause moose population declines (Table 3).

Because snowshoe hare share both the same habitats and foods as moose there is the possibility that these two species may compete for food. However, despite having an almost totally congruent North American distribution this has rarely been reported. Wolff (1980) reported that high hare densities in Alaska caused a decline in moose numbers while Dodds (1960) suggested that high moose densities caused snowshoe hare to be unable to utilize new cuts.

Beaver activities benefit moose by creating ponds in which aquatic vegetation flourishes and by cutting deciduous trees causing regrowth. In addition, when dams are breached and beaver leave the area the resultant "beaver meadow" will quickly get re-seeded providing deciduous browse. Bergerund and Manual (1968) found that moose can have a negative effect on beaver by inhibiting the growth of deciduous trees. In areas of Newfoundland where moose densities were less than 6/mi^2 beaver flourished but above this, beaver densities diminished.

Moose are a source of food for many species either as prey or carrion. The primary predator of moose in NH is the black bear. Calves supply black bear with an important protein source in the spring. Bear predation on calves ceases once calves reach 8 weeks of age and can outrun the bear. Ballard (1992) documented black bear densities and related causes of moose calf mortality for many jurisdictions in North America. At bear densities ranging from 0.02 to 1.47 bear/mi^2 bear predation was responsible for 3 – 50% of neonate mortality. Estimated regional NH bear densities range from .06 to 0.89/mi^2 and can be found in Table 3.

Shed moose antlers provide many wildlife species including moose, with an important source of calcium if the human shed hunters don't get them first!

Moose provide the New Hampshire people with a source of food, recreation and income. Each adult moose taken during the season provides the hunter's family and friends with approximately 350 pounds of boned out, lean meat.. The moose hunt provides a source of recreational hunting but moose viewing undoubtedly provides many more hours of entertainment as it takes place from early spring when moose first come out to the roadsides, till late fall. Moose watching sites draw both large numbers of tourists and local people. Moose are considered one of the most watchable species of wildlife in the state. Their reduced flight response and use of roadside salt licks makes it very easy to watch them at close quarters. The desire by the public to see moose has led to the establishment of several moose tour companies and the sale of thousands of dollars of moose related items each year. In addition many people have increased their incomes by selling dropped moose antlers or sheds.

Moose also interact with people through traffic accidents. Any animals hit on the roads are made available to the person who hit the animal, to local people in need or food banks. Aside from this benefit, moose/vehicle collisions tend to be a lose-lose situation, negatively impacting both moose and man. During the past decade an average of 170 vehicle accidents take place each year which result in the immediate death of the moose. Human fatalities continue to occur, although rarely. Five people have been killed in NH moose/vehicle collisions (MVC) since 2004. Because of the size of the moose, human injuries and damage to the automobile tend to be more significant in MVC than in those involving deer. Del Frate and Spraker (1991) suggested the average cost of property damage in an MVC was $4,000.00. Because moose tend to be taller than most oncoming vehicles, when hit the animal falls onto the top of the vehicle causing head and neck injuries to the occupants. Speed is a very important component of the occupant injury rate with vehicles traveling 55mph resulting in an occupant injury rate of 12.5% and vehicles traveling at 65 resulting in an occupant injury rate of 20.3%. (Lavsund and Sandegren 1991). The percentage of occupants killed tripled (0.5% -1.3%) as cars increased speed from 55 to 65 mph.

Multiple factors influence the moose/vehicle severity and collision rate; visibility, time of day, season, weather and road condition, moose and human densities, road type, speed, make and model of automobile, presence of road side salt, and surrounding habitat type and topography.

Moose and people compete for space. The state of New Hampshire is losing an estimated 14,000 acres of open space to development each year (Levesque 2010). As our human population grows and builds homes, businesses and roads, wildlife is displaced. According to the Center for Environment and Population each New Hampshire resident effectively occupies one-third more land area for housing, schools, shopping, roads and other uses than s/he did 30 years ago resulting in major losses of natural areas and widespread sprawl development. Approximately 241,573 acres were converted from forest to developed uses between 1982 and 2003, a 64% increase in total developed land area in just 21 years. NH's human population continues to increase with most growth occurring in Carroll County. Rockingham and Hillsborough County are currently home to half the state's human population. The state's human population has increased by 6.5% from 2000 to 2010. The corresponding reduction in open space, or space not occupied by people, has a direct negative impact on the state's carrying capacity for moose as well as increases the chance for negative moose interactions related to agricultural or property damage.

MANAGEMENT

Regulatory Authority: Prior to 1875 moose hunting was unrestricted in New Hampshire. Moose were utilized as primary source of both food and clothing by both native peoples and European settlers. This unrestricted use caused moose numbers to precipitously decline until only a small population was left in northern Coos County. From the years 1875 to 1901 the legislature adopted laws that regulated the timing, geographic area, hunting method and bag limit of moose. It wasn't until 1901 however, when moose numbers had reached all time lows (approximately 13 animals in Coos county), that the legislature banned moose hunting (Silver 1957).

From 1975 to 1984 several laws were introduced which would have allowed a statewide open season for part of the year. The Fish and Game Department testified against these bills due to their permissive nature. In 1985 with the help of the National and New Hampshire Wildlife Federation, the NHF&G Department introduced legislation that would allow for the taking of 75 moose during a three day October season in 11 of the 22 moose management units. The regulatory authority for the moose management program is found in RSA 208:1. In part it stipulates that the department has the authority to implement a comprehensive moose management plan that may include research, public education, and population and habitat management; and hold a lottery for moose permits. The current law has been amended once since 2006 in order to set the minimum price for non-resident permits. Rules governing the hunt and lottery can be found in the New Hampshire Code of Administrative Rules, Fis 301.02, 301.07-.071, 301.08 and 301.09.

Goals and Objectives: The first goal and objectives were outlined in 1984. The goal was to provide proper management of the herd under a multi-use concept which recognized moose for their aesthetic value as well as that of a big game animal. There were three objectives: 1) to increase our knowledge of the herd and its' habitat status and needs, 2) to determine what the public wanted in terms of herd densities, distribution and use, and 3) to combine the needs of moose and the desires of the general public into an active management program.

In 1990 a second set of goals and objectives was formulated . The goal was to maintain moose at the current level unless habitat or species impacts necessitated a reduction and to maintain viewing opportunities. Objectives were to 1) maintain moose numbers at current levels, 2) maintain harvest levels that provide for both consumptive and non-consumptive use within the constraints of the abundance objective and 3) determine habitat carrying capacity (K).

These first two planning documents were developed with little public input. Prior to the second document being drafted there was a public attitudes survey conducted by Donnelly et al. (1988) that helped shape the objectives. A third planning document was published in 1997 and had significant public input. Given an upper and lower limit within which to operate, the public set population goals based on observation rates of moose for each management region of the state. Each goal was to be reached over a four year period. In addition to staying within the range of observation rates as set by the department, the goals had to work within a set of established guidelines, the most important of which were that moose would be managed as a multiple-use resource, that all management would be based on scientifically accepted management principles and practices, and the adult sex ratio would not be allowed to fall below 40% bulls.

The most recent plan covers the years2006-2016 and can be viewed on our website, www.wildnh.com. This plan also had significant public input and utilized the same guidelines as outlined above. There were four overarching goals regarding inputs for moose management, education of the public and conservation of moose habitat. The population objectives were set under the first goal and included the reduction of the moose population objective in four regions and maintenance in two regions. Population objectives for the previous two plans and current population status for each region can be seen in Table 1.

Management Activities: In order to gather data on the herd the department has instituted several monitoring programs over the years. The primary method of monitoring change and determining moose population parameters is the deer hunter mail survey. This information has been collected since 1993.Each deer season, 18,000 previously successful muzzleloader and rifle deer hunters are sent a hunting diary card. During the entire muzzleloader season and the first twelve days of the rifle season these hunters are asked to record the number, sex and age (adult or calf) of moose seen, the wildlife management unit (WMU) and town of each observation, date observed and number of hours hunted per day. This information gives the department excellent state wide coverage of relative density patterns, adult sex ratios, fall recruitment rates, and rate of change of the regional moose populations. The department's moose population objectives are set using this observation rate since it provides and index to population density as well as sex and age ratios. Permit issuance by region and WMU is also tied to this observation rate, obviating the need for determination of a population figure.

Accidental kill data is also recorded annually. This includes cause, date, WMU, town and location of death, as well as sex and age (calf or adult) of the animal involved. The bulk of these reports are vehicle kills and the information is helpful in determining the desirability of changing moose densities both regionally and by WMU. This data helps pinpoint "hotspots" where moose/vehicle collisions are most problematic. The data set also contains limited information on the incidence of winter tick, brainworm, illegal, nuisance, accidental and other mortalities. While helpful in outlining parasite distribution, the very small sample sizes in these categories make it a questionable monitoring technique.

The physical evaluation of the moose taken during the hunting season is a very important part of the monitoring system. All animals taken are required to be brought to one of seven registration stations. These animals are weighed and aged. Cows are checked for evidence of pregnancy and antler measurements are recorded for bulls. This data gives us the best information on the moose population in relation to K in years of low tick infection and good information overall on tick impacts to moose productivity and health. Tick counts are conducted on all animals that have been dead for less than five hours (after which large numbers of ticks begin leaving the carcass as it cools) which gives us important information on tick productivity from the previous spring and minimum tick loads on moose for the coming winter. These counts are conducted on 4 sample areas on the carcass totaling an area of about 62 sq. inches. Approximately every ten years liver and kidney samples are taken for determination of cadmium levels. Cadmium, a toxic heavy metal which can have adverse health effects occurs at relatively high levels in moose. In addition, all moose hunters are asked to provide information similar to that required of the deer hunters.

The most recent addition to the monitoring system is the spring hair loss survey conducted in early May. This survey is in its infancy but should, over time, allow us to determine the winter tick mortality impacts for the past year.

All data sets are evaluated regionally to provide representative sample sizes. Certain parameters of all of these data sets are evaluated for trends over time. Changes are considered to be "real" if the probability of a statistically significant trend is 95% or greater. Sample sizes in some data sets may not always be large enough to provide statistically meaningful results.

There is an outreach program that is instrumental in educating the public about many aspects of moose biology, management and research. When first implemented the purpose of this program was to educate the public about moose life history and the purposes and possibilities of moose management. Since then the project has also initiated a public education campaign ("Brake for Moose") to help minimize the number of moose/vehicle accidents and one to encourage safe viewing practices. The Brake for Moose campaign is conducted in conjunction with the Dept. of Transportation and includes roadside signage, public service announcements, and distribution of literature and bumper stickers to enhance public awareness. Working with the Dept. of

Transportation, Dept. of Safety, a member of the Governor's Council and an emergency room physician, the department helped write, produce and distribute to all driver education teachers in the state a video outlining driving practices designed to reduce wildlife vehicle collisions. In addition, this group was able to implement flashing warning signs for moose/vehicle collision hotspots.

Three F&G Department sponsored research projects have taken place over the past ten years with a fourth currently underway. The primary purposes of the first of these three projects were to determine; seasonal home range characteristics and habitat relationships and neonatal habitat characteristics. The results of this study suggested that the decline in body weight of adult moose and stagnant population growth were not attributable to habitat constraints. In fact, the relatively small home ranges of adult cows and the lack of difference in home range size between barren and maternal cows, suggested that all habitat needs were being met within small areas and browse was abundant and ubiquitous across the study site. In addition, calving areas were most often found within mature spruce/fir or mixed wood stands and this type of site was also not limiting (Scarpitti 2006).

The second study which took place concurrently with the first was designed to determine productivity of cows and cause and rates of mortality of adult cows and calves. In addition metabolic impacts to calves was assessed using the information gained on tick infestation rates. This study indicated that ticks were the dominant cause of mortality for calves in all years and in some years could also be a major source of mortality for adults. In addition, it was shown that ticks were the probable cause of reduced weights in all age classes and the cause of subsequent reduced productivity (Musanti 2006).

The final study conducted during the past ten years was designed to determine the best method for monitoring annual tick loads on moose, assess temporal changes in productivity and physical characteristics of moose, determine relationships between weather and tick abundance and determine the relationship between moose population density and forest regeneration. Based on the results of this study the department implemented winter tick counts on hunter killed moose and has been conducting annual spring hair loss surveys as well. Reduction in adult body weights and subsequent reduction in productivity was documented. The relationship between weather and tick abundance will take additional time to fine tune but we know that reduced snow loads in spring and late snow arrival in fall is increasing tick abundance. Finally, the existing moose densities were not found to be negatively impacting stocking rates of commercial timber species although in some cases browsing was prolonging the period of growth to harvest. In addition, while severe browse damage was low in all regions (Ct. Lakes, North and White Mountains) it was correlated with moose density (Bergeron 2011).

The current study was implemented due to concerns that mortality may now be higher than that documented in the study that ended in 2006. This study is designed to again determine mortality rates and causes as well as productivity of moose in the North region. In addition, the study hopes to better identify weather conditions that result in increased tick induced mortality and reduced productivity. Field work is scheduled to continue through the winter of 2015.

Attainment of Objectives: Our annual monitoring programs and research projects have dramatically increased our knowledge of the moose population. We currently have very good information on regional adult sex ratios, population distribution, relative density patterns and population growth rates. We have a good index to fall recruitment but as the harvest is reduced so too is our ability to measure reproductive output. Our ability to monitor annual cause and rate of mortality continues to be limited but we do have excellent information on animals taken during the hunt and killed by motor vehicle. Recent research has given us tools that will become more useful over time in monitoring annual winter tick impacts and our knowledge of how severe these impacts can be for both mortality and productivity has been dramatically improved. Our research projects have increased our knowledge of habitat quality and quantity and answered questions regarding moose impacts to the forest products industry. Current research will provide more information on the most current rates and causes of mortality as well as document any changes to productivity for northern moose.

Historically, achieving the goals and objectives set in 1990 was hampered by a lack of data which would not allow an accurate prediction of harvest impact on the population. Corresponding conservative permit issuance caused moose numbers to increase beyond the 1990 level. Harvest levels did provide for both consumptive and non-consumptive use. While non-consumptive use has not been measured, the subsequent development of several moose tour companies, increased level of visits to known roadside moose licks, establishment of businesses devoted to moose memorabilia and an annual moose celebration in Pittsburg suggested viewing opportunities were at least adequate. Based on research conducted in several other jurisdictions (Gasaway et al 1992, Schwartz 1992, Boer 1992, Franzmann and Schwartz 1985) it was decided to utilize physical parameters of the moose for determination of the population's relationship to available browse. This worked until winter tick became an important influence on weights and productivity.

The population goals set in 2006 were based on the mail survey moose observation rate and in four regions, and people desired the goals to be lower than they had been. The overriding concern in most cases was moose/vehicle collisions but impacts to forestry were also of concern. These goals can be seen in Table 1. Graphs outlining the changes in both regional observation rate and the goal can be seen within the section on Population. Changes to the observation rate and population are achieved, or attempts are made to stabilize the observation rate and population by adjusting the regional permit issuance.

The observation rate in the Ct. Lakes region was reduced to goal in 2006 and has remained there for the past seven years. In the North region we have achieved or been below the goal during the last seven years primarily due to winter tick impacts. The goal in the White Mtn. region has only been briefly achieved and while the population seems to have recently stabilized, it is well below the 2006 goal. Given that the observation rate has been significantly lower than the desired goals since 1996, the goals may be unrealistic. The observation rate in the Central region was at or near goal for 15 years until 2009 at which point the population began a steady decline which only recently showed signs of slowing. The South West region was briefly at goal from 1996 – 1999. Since then, the population, while having occasional periods of growth, has also steadily declined. The South East region was reduced to goal in 2001. It remained at goal until 2011 and has been declining since then.

HABITAT

Past Habitat: In the northeastern United States moose habitat must be forested. When this state was first settled moose were found statewide with the primary range being described as everything north of the southern Carroll County line (Silver 1957). At that time it is estimated that the vast majority of the state was forested. Insect outbreaks, fire, beaver activity and wind-throw were the main causes of forest openings and subsequent regeneration.

By the early 1800's approximately 75% of the forested cover had been converted to row crops or open fields. With the advent of rail services, agriculture moved to the mid west and was largely abandoned in New England. By the end of the 19th century the reversion of fields back into forest was well underway (Silver 1957).

Due to the rapidity with which farming was abandoned, much of the regenerating forest was maturing at the same time. This even aged forest was not great moose habitat but was certainly better than previous agricultural based habitat. As the forest grew back the forest products industry grew as well. The large tracts of even aged timber made the forest susceptible to insect outbreaks. A severe spruce-budworm outbreak in the early 60's resulted in significant salvage cutting. Cutting at this time, whether done for salvage in the north or for merchantable timber across the remainder of the state, very quickly created the type of forest that was perfect for moose, a patchwork of old and regenerating stands of hardwood and softwood cover. This patchiness placed food and cover in close proximity to each other over much of the state. In the Ct. Lakes and North region, the large acreages of salvage cutting created an enormous browse supply that was a significant boost to the moose population.

According to Frieswyk et al. (2000) from 1983 to 1997 state wide forest cover decreased 2.7% or 134,500 acres. Levesque et al. (2010) noted that another 148,000 acres has been lost since 1997. These declines were caused by development or placing the land into uses other than forestry. Because timber production provides the majority of clearings in the forest, a decline in timber producing lands has a negative impact on availability of moose browse.

From 1980 to 2000, New Hampshire's human population increased by 34%. Average human density increased from 102.6 people/mi^2 to 137.7 people/mi^2. This dramatic rise in human population densities was seen in all counties with the exception of Coos where human densities actually declined slightly. From 2000 to 2010 human population increased again by 80,706 (6%). This increase was seen in all counties and resulted in a human density of 146/mi^2. This increase in human population with it's attendant housing needs and infrastructure amendments meant a reduction in open land or land that could be occupied by wildlife.

Current Habitat: Important components of moose habitat include areas of abundant deciduous browse, aquatic feeding sites, mineral licks, mature softwood shelter to provide protection from snow or heat and isolated sites for calving. Thomason (1973) recommended 25-40% of the available habitat within 10mi^2 blocks in Ontario be in browse producing age classes. Peek et al. (1976) working in Minnesota recommended it be 40-50% while 5-15% of the habitat be comprised of mature softwood shelter. Thomason (1973) felt mature hardwood/deciduous forest should comprise 45-60% and aquatic environments 15% while Peek et al. (1976) combined these two habitat components and suggested they comprise 35-55% of the available habitat.

Current New Hampshire habitat was assessed using information from the USGS National Land Cover Database (NLCD). According to this GIS data, all regions have a large percentage of the land base that could be defined as moose habitat (Table 2). All regions have more than or are at 15% of the land base in softwood cover with the exception of the Southeast which at 11% is still above the recommended minimum. All regions also have a large percentage of mature hardwood, birch/aspen and mixed wood stands ranging from a high of 62% in the Ct Lakes to 43% in the Southwest and Southeast. While the three northern regions fall within Peek's recommendation (Peek et al. 1976) for hardwood/deciduous and aquatic environments combined (35% - 55%), the remaining southern regions fall well below (22 % in Central, 16% in Southwest and 27% in the Southeast).

While a fairly small component of each region is listed as cleared/regenerating this data set does not capture all the browse producing acreage. Because the data are not broken out by age class much of the browse producing acreage is hidden in the other deciduous habitat types particularly birch/aspen, hardwood and to a lesser extent, mixed wood. Beech/oak stands produce little edible deciduous browse and would be considered marginal browse producers especially at higher beech/oak stocking levels. Therefore the regions with larger proportions of beech/oak will have less preferred hardwood browse species. If we examine only birch/aspen , hardwood and cleared stands as an indicator to the amount of available browse and eliminate beech/oak and mixed wood, we find that preferred browse species decline as you go from a high in the North and Ct Lakes (49 and 46% respectively) to the Southwest (13%) and then climbs in the Southeast to 24%. The Southeast figure is being heavily influenced by the large percentage of cleared land (15%). Given the level of development in this region it is doubtful that all this land is being used for or allowed to grow back into forest cover. If you adjust the figure to reflect cleared land values found in the Central and Southwest regions (average of 7%) the preferred browse category for the Southeast falls to 17 %.

While the incidence of natural mineral licks is unknown moose in NH do utilize road side salt licks as well as aquatic vegetation to satisfy their sodium requirements. This habitat does not appear to be in short supply anywhere in the state.

While all regions provide high quantities of the components of moose habitat not all of this habitat is equally available. Human development patterns often preclude use of available habitats. In the NLCD data base the definition of "developed" only includes areas that are significantly built up such as strip malls or industrial parks. One way to examine the influence of "light" development (homes and light industry) is to define habitat that is within 300 feet of a road. Habitat found within this boundary is most likely to contain residences and light development. It is here that we plainly see the impact the human population is having on wildlife. The Ct. Lakes region loses 4.4% of it's moose habitat, the North Region loses 6.1% of its moose habitat, the White Mountains 7.0%, the Central 15%, the Southwest 17.2% and the Southeast 24.1%.

Future Habitat: Future habitat will be influenced primarily by human population growth, development and land ownership patterns. The Society for the Protection of New Hampshire's Forests predicts that by 2030 forest cover will decline to 78.5% (225,000 acres removed) while the human population is predicted to increase by 180,000 people. While most population growth is taking place in the seven southern counties and particularly Carroll County (projected growth rate of 24%), housing increases are taking place statewide. By the year 2030 less than 1/3 of the state is expected to be rural and the bulk of that will be from the White Mountains north.

In the Ct. Lakes, North and White Mountain regions where human population growth is not quite as severe, habitat will be most affected by cutting practices. In the White Mountain region, the White Mountain National Forest makes up the bulk of the land area. Cutting practices on the Forest are not expected to change dramatically over the next ten years.

Land ownership in the Ct Lakes and North regions has been primarily by paper companies. In the past, cutting practices encouraged softwood regeneration. The loss of softwood stands during the spruce budworm outbreak coupled with strong softwood markets has gradually increased the amount of hardwood in the northern forest. Forest harvest practices for the foreseeable future are expected to focus now on hardwood regeneration with faster rotation times. This will increase browse production and may cause winter cover to decline if softwood continues to be cut and is not replaced. A decline in winter cover could increase calf mortality during winters of deep snow or crust. Perhaps of more concern is the change of ownership of former industry lands. As markets have changed and more economical outlets for timber became available, timber companies have sold lands that cannot produce timber at competitive rates or in a timely fashion. Today there are no longer any lands in NH owned by industrial forest companies. They have all been sold to timberland investment management organizations or TIMOs. These companies generally do not manage land for long term forest products. Instead the land is managed to get the most return on the investment. This return is made through timber management, sale of high value parcels, and appreciation of land values coupled with re-sale of the property. Length of ownership by a TIMO is usually 10 years or less. This high rate of turn over often results in a large contiguous forest being sold off as smaller parcels with increased development. This reduces acreage for all wildlife.

POPULATION

Past Population: According to Silver (1957) when European settlers first arrived in the state they reported moose throughout the state in large enough numbers to be a primary source of both food and clothing. While moose were found state wide, the primary range was described as being everything north of the southern Carroll County line. Conway was described as a place where moose could be hunted successfully at any time. Pinkham Notch was discovered by one Timothy Nash during a moose hunt. Moose were so plentiful in Warren and surrounding towns that people reported having many barrels of moose meat on hand at any time during the year. Moose were especially abundant in Coos County and were described as being far more plentiful than deer. A resident of Lancaster killed 99 moose in one winter and according to Merrill (1988) many others took similar numbers.

At the same time that moose were being taken in these record numbers forest cover was being cut down or burned to provide more arable land. By the mid 1800s 75% of the state had been converted to open fields. This dramatic reduction in habitat coupled with unregulated subsistence and market hunting caused moose numbers to decline precipitously so that by the early1800's moose were extirpated in southern and many parts of central New Hampshire. According to Dodds (1974) unrestricted harvest was the main cause of moose declines all across the north east. By the mid-1800's moose had been extirpated in all seven southern counties and were found only very rarely in northern Coos County. In 1898 only 13 moose were reported to have been found in Coos County.

A moose hunting ban in 1901 protected moose from further hunting but populations remained at very low levels until the early 80s. The slow recovery is attributed to loss of habitat to agriculture. Farmland began to revert to forest in the early 1900's and forestry became the dominant industry. Large acreage clear cutting in the 1960's made conditions very favorable for moose and in 1977 the herd was estimated at 500 based on conservation officer sightings. By 1982 moose were found in all WMU's with the exception of WMU M and based on deer hunter and conservation officer sightings the population figure had risen to approximately 1600. The northern three counties (Coos, Carroll and Grafton) accounted for 83% of total sightings. Based on steadily increasing vehicle kills moose numbers continued to grow through the 80's and 90's.

In the early nineties the department was successful in developing, testing and implementing the deer hunter mail survey for monitoring of the moose population. Biologists were concerned to see an apparent stabilization of moose in the North region and plans for a mortality survey were developed and approval for implementation sought. While this approval was denied, the department did now have the ability to effectively track the population. In 1996, population goals were reduced in the Ct. Lakes but increased in the North region. The North region moose population failed to grow and remained stable despite high reproductive rates. It was clear, there was additional non-harvest mortality in this population. The moose population just to the south in the White Mtns and Central regions was growing while that in the Ct Lakes was being reduced down towards the goal. Populations in the south were stable as well.

In 2001 the first mortality study was approved and implemented and the knowledge of winter tick impacts to mortality and productivity were added to the management of the species. In 2001 there was a severe irruptive winter tick mortality event that was seen most dramatically in the White Mountain population. This was followed by a period of relative stability or growth until 2005/06 when populations south of the Ct. Lakes began to decline again. Since then, the White Mtn and North regions appear to have recently stabilized, while the three southern regions have continued to decline.

Present Population:

Population size: Directly determining the number of animals in a population is a very expensive and time consuming operation. Knowledge of population size is critical however to proper management. Without this knowledge permit levels may be issued which are either too high or low to accomplish management objectives. In NH, seasons are set biennially so every two years we must know the status of the moose population is in all six management regions. In order to determine an actual number, aerial surveys using infrared thermal imagery would have to be flown. The cost of a aerial survey that provided information on the North Region in 2000 was $75,000.00. Obviously, this is not a method that can be conducted for the entire state or even one region on a regular basis. Using moose density estimates from infrared thermal imagery and regressing this against the observation rate of moose as seen by deer hunters, Bontaites et al. (2000) determined that the deer hunter sighting rate of moose documented population size and rate of change and provides a population index with sufficient accuracy for management purposes. This observation rate provides not only an index to population size, but also provides good information on adult sex ratios and fall recruitment rates. It takes place statewide each fall and is very cost effective. Based on this sighting rate we know that highest moose densities occur in the Ct. Lakes region and decline as one goes south and east, the lowest densities occurring in the Southeast Region (Tables 1 and 3).

In addition to knowing the size of the population it is also necessary to know the rate at which the population is changing. This is determined by estimating the rate of change of the observation rate. This observation rate is subject to outside influences. Changes in timing of the deer season and leaf drop, hunter access to landscapes, cutting practices and weather can all influence the ability of hunters to see moose. Because of this annual variation, changes in observation rate are monitored using a 2-year running average and are interpreted with caution. Changes are considered to be real if they occur with statistical significance over at least a three year period. Aerial infrared surveys may be flown in the future if populations fail to respond as expected to management activities or if there is a concern relative to population size that cannot be answered using established data sets.

Currently the only population at goal is that in the Ct. Lakes region. The North region has been below goal for three years but recently showed some growth back towards goal. The same is true for the White Mountain population. The three southern populations have been declining somewhat steadily since 2008 and are all below goal. Current statewide population estimate is 4000 animals. Graphs of regional population and goal changes over time can be found in Figure 1.

Population Structure: Fall recruitment and adult sex ratio are two components of population structure that are monitored annually through the deer hunter observation rate. Fall recruitment is an index to annual recruitment (numbers of calves added into the population each year). Knowledge of this parameter is important for interpreting and understanding changes in population growth rates. Given New Hampshire's lack of predators, relatively low snow depths and good habitat it was assumed that fall recruitment was probably quite close to actual recruitment of calves into the yearling age class. Results from the 2001 mortality study have proved this is not the case and that in some years it is significantly different.

Recruitment can be influenced directly by black bear predation of neonates or wolf predation, deep snow, severe cold and parasite loads. The fall recruitment index accounts for levels of black bear predation and the department can monitor for areas of deep snow (27 inches or more impedes calf movements) and severe cold (-22^{o}F). Unless wolves become part of the landscape this leaves parasites as the greatest impact on calf recruitment into the adult age class. We can make an educated guess about when these impacts may be occurring based on weather patterns the previous spring and fall. Early springs followed by dry, snow free falls will be years when tick loads may worsen and result in significant calf mortality. In addition, we can monitor tick loads on moose using fall counts on harvested animals followed by spring hair loss surveys. Based on results of the mortality surveys we know that recruitment of calves from the fall into the spring adult age category can be less than 50% but on average is 67%. This is low when compared to jurisdictions in both North America and Scandinavia (Musante 2006).

Adult sex ratios should not be allowed to fall below 40% bulls in order to maximize reproductive success. Maintaining maximum reproductive success is critical to growth of the population and also aids in the ability to interpret reproductive outputs as an index to health of the population. In an un-hunted moose population the adult sex ratio is close to 1:1. Because hunters tend to shoot bulls, hunting tends to skew the sex ratio towards cows. If too many bulls are taken an increasing number of cows will not be bred or will be bred late resulting in late born calves which may not survive the winter. The deer hunter moose observation rate provides good data on adult sex ratios. This information can also be found in Figure 1**.** Adult sex ratio is currently above or very close to 40% in all regions.

Relationship to Carrying Capacity: In New Hampshire the moose herd's relationship to K has been measured by the level and change of the pregnancy rate of adult and yearling cows, the changes in weight of yearling animals and the change in average rack spread for yearling bulls. Adams (1995) suggested that yearlings may be the most sensitive indicator of nutritional status. Sample sizes in these physical parameters are often small necessitating examination of the data as an average of multiple years.

Twinning rates of 25-90% in animals older than 2.5 years of age are indicative of moose on good habitat or well below carrying capacity, 5-25% is indicative of animals nearing carrying capacity while rates less than 5% are indicative of animals on poor ranges and well above carrying capacity (Gasaway et al 1992). This can be used as a template against which to measure adult productivity. Boer (1992) found similar rates for adults and suggested that yearling pregnancy rates of 18% were indicative of a population above K, 41% indicative of a population at or near K and 64% a population below K. Based on the work done by Adams (1995) body weight must reach 440 lbs for moose to become pregnant and must reach 550 lbs for twinning to occur. Musante (2006) has shown that winter tick is our greatest mortality influence and our monitoring programs have revealed that it is ubiquitous in time and area in the northern regions. Scarpitti (2006) and Bergeron (2011) have suggested that available browse does not seem to an issue in the northern regions although actual browse productivity studies were not conducted. Both Scarpitti (2006) and Bergeron (2011) also indicated that tick loads alone could influence body weight and productivity as did Garner (1993). This means that in areas where the moose population is large enough to support ticks, the Central region and northward, we have lost a relatively easy method of using reproductive output to measure where we are in relationship to K as defined by food availability. Winter tick is now felt to be the biggest influence on pregnancy rates and weights of yearlings and adults. As such, it is now a measure of the populations relationship to K as defined by levels of animals that can be supported without severe adverse impacts from parasitism. Regional adult twinning rates and yearling pregnancy rates can be found in Table 4.

Browse impacts were documented in the Ct. Lakes region in 1998 when a browse survey was conducted on Champion paper company lands in Pittsburg WMU's A1 and A2. At that time 10,530 plots were surveyed. Browse levels were categorized as light (<30% browsed), moderate (30-80% browsed) and heavy (>80% browsed). At that time less than 4% of the plots had been heavily browsed, 67% of the plots were moderately browsed and approximately 30% were lightly browsed. The moose density at that time was estimated to be approximately 4.3 moose/mi$^{2.}$.

In 2004 three different habitat models for the Ct. Lakes region suggested that supportable moose densities for that area ranged from 1.7 – 2.6/mi.^{2}. At that time the density was estimated to be 3.12/mi.^{2}.

In 2011, a study conducted jointly with UNH (Bergeron 2011) looked at the impacts of current moose densities on forest regeneration of commercially important trees in the three northern regions. Stocking rates were high in all age classes and all regions and the proportion of commercial trees with severe damage was low at < 10% in all regions. The exception to this was the 11 – 15 year age class in the Ct. Lakes region where severe browse damage was 16%. This accurately reflects the time (1995 – 1999) when moose densities were highest in this region. It was at this time that reproductive indices in this region began to decline.

Present population by Moose Management Region:

Ct. Lakes: The Ct. Lakes region has the highest observation rate of moose and the highest estimated density at 2.23moose/mi^2. There has been hardly any change in observation rate for the past five years and this has kept the population at goal. There is a healthy sex ratio at 41% adult bulls (Figure 1). Bulls in A1 continue to be seen at a lower rate than in A2 due to heavy hunting pressure on the Canadian border. However, the A1 adult sex ratio has climbed back to 39% bulls which is very good. Reproductive indices suggest this population is at or near K and habitat models suggested the population was above the carrying capacity of the habitat in 2004 (estimated density at that time 3.12/mi.^{2}) and had been since 1994.

Ninety-one percent of this region is in moose habitat types. The percentage of habitat that is browse producing and lies outside of the 300 ft road buffer is 71%. Since 2001, cleared acreage has almost doubled which coupled with a reduced moose density (currently 2.23) should put this population below K. However, low body weights (five year average for adult cows= 538, yearling cows=393) continue to result in low productivity.

The northern end of this region has the longest winter in the state, at an average of 115 snow covered days. This reduces the length of time ticks have to get on a moose. However, spring is arriving sooner here by approximately 10 days and this is allowing ticks to drop off moose, survive and reproduce. As moose densities are higher here than elsewhere in the state background levels of ticks remain high and contribute to tick related mortality and reduced productivity. The southern half of this region has seen its winters shorten by 18 days in the past 40 years. This increases tick infection rates and associated mortality events and reduced productivity for the region. Based on our tick counts of hunter killed moose, this region has the second highest fall infection rate of ticks and the second highest hair loss index in the spring. Overall deer herd density 9.97/mi^2 undoubtedly means there are areas here which exceed the threshold density of 10-13 above which brainworm transmission causes reductions in the moose herd. Vehicle kills averaged 10/annum in the past five years.

North Region: The North Region has the second highest observation rate of moose at 3.90moose seen/hundred hunter hours. Estimated density is 1.19moose/mi^2. When viewed over a five year period the observation rate was declining (-0.55/year) and is currently below goal but has recently rebounded. The adult sex ratio is good at 44% bulls (Figure 1). Five year average of weight for yearling and adult cows was 448 and 567 lbs respectively. This allowed for productivity that suggests the population is below K in spite of potential tick influences. While body weights were good enough to provide this level of productivity, they are hovering close to the thresholds of 440 and 550 lbs needed for pregnancy and twinning.

Habitat here is very similar to that found in the Ct. Lakes area with slightly more wetland and regeneration. These two northern areas are the state's best moose habitat. The percentage of this region that lies in browse producing habitat outside of the 300 foot road buffer is 63%. Nine percent of this area lies in wetlands.

The winter is 16 – 18 days shorter than that found in the northern Ct. Lakes region. This shorter winter coupled with high moose densities, yields the highest fall tick infestation rates and the highest spring hair loss index.

Based on results from the first mortality survey (Musante 2006), neo-nate survival is high (approximately 71%) but calf survival declines in the late winter and early spring, with mortality ranging from a possibility of approaching100% in high tick years down to 29%. This late winter early/spring mortality is due primarily to winter tick infestations (74%). This leaves us with an average calf (7-12 months of age) survival of 67% which is low in comparison to other North American and Scandinavian jurisdictions. By comparison, adult cows, which are less susceptible to winter tick mortality, had an average survival rate of 87%. This is similar to or slightly higher than Minnesota and Michigan, two North American jurisdictions on the southern edge of moose range that are also having trouble maintaining or increasing moose populations on good habitat. For all collared animals mortality causes accounted for the following percentages: hunting 18%, vehicle collision 26%, winter ticks 41% and unknown 13%.

The vehicle kill in this region has declined slightly over the past five years and averages 41 killed/annum since 2009. Only one brainworm mortality has been seen here in the recent past and it was found in WMU D1 where deer densities exceed 10/mi^2.

White Mountain Region: The White Mountain region has a lower density of moose than the North Region with a two-year average observation rate of 1.3 moose/hundred hunter hours. This would be an estimated density of 0.41moose/mi^2. The population and observation rate have shown slow decline over the past five years of -0.16 annually (Figure 1). It has been below goal since 2007. The adult sex ratio is sufficient at 46% bulls. Sample sizes for pregnancy and twinning rates are quite small and too small to develop reliable information on yearling productivity. Adult pregnancy rates in this unit were 90 % and twinning rates were 22% in 2013 with the five-year average being an 89% pregnancy rate and 15% twinning rate. These rates suggest the population is at or near K. Cow weights support this reproductive parameter. Adult cows weighed 537 lbs. dressed weight in 2013 and the five year average was only 533.

Habitat really starts to transition here from Boreal forest to Eastern Mixed forest. While 83.5% of the habitat is still within types that are listed as supporting for moose, the percentage that is within the beech/oak component has now doubled. Beech/oak forests supply very little moose forage. In addition, regeneration drops here to a low of 6%. This additional reduction in forage production is only slightly improved by the larger percentage of birch/aspen forest here. The regional percentage of browse producing habitats that lie outside of the 300 ft. road buffer drops down to 59.5%. This region has the lowest percentage of wetlands in the state at 3%.

Snow covered days are quite variable in this region ranging from 111 days at high elevations to only 82 on the western side of the region. Length of time of snow cover is also very different from east to west with the east having 10 days more on average. Spring is arriving 7-10 days earlier here than 40 years ago.

This region has the third highest level of fall tick infection rates. This is the last region for which we have good data on spring hair loss and it is the region with the lowest average rate of hair loss but this is not true for every year. Deer herd density is the lowest in the state at 5.6/mi^2 but one unit in the region has deer densities of 19.35/mi^2. Brainworm mortality seen in moose in this region usually 1/year. With one exception, all brainworm mortality has been found in WMU's with deer densities in excess of 10/mi^2.

Vehicle kill has been the highest in the state but five year trend information shows it is declining. Forty-five animals were killed in MVC in 2013. Kill rates may be exacerbated in this region due to the limited level terrain and the fact that the road corridors utilize a large part of this terrain. In addition these roads are designed for high speed traffic.

Central Region: The observation rate of the Central region is lower than that of the White Mountains. The two year average observation rate is 0.86 moose seen per hundred hunting hours which provides an estimated density of 0.27moose/mi^2. The five year rate of change in the observation rate is -0.10 annually. This population has been steadily declining away from goal since 2008. The adult sex ratio is approximately 39% bulls. This sex ratio produced a 100% adult pregnancy rate with twinning rates of 25% and yearling pregnancy rate of 50%. Five year averages yield adult pregnancy rates of 94% and twinning rates of 29% and yearling pregnancy rates of 28%. This suggests a population below K. Body weights are not as good as those seen in the North region with a five year average of 443 lbs for yearling cows and 547 lbs for adult cows. In 2013 yearling cows weighed an average of 433lbs and adults 552.

Habitat continues it's transition away from Boreal forest here with 20% of the available habitat in beech/oak. Seventy-three percent of this region is in habitat that can support moose but only 52% of the region is in habitats that provide forage and only 8% is in regenerating stands. When you remove the percentage of the browse producing habitat that is within 300 feet of a road you drop down to 44% of the area in browse producing habitat.

Snow covered days have declined the most in the western portion of this region at approximately 12 days in forty years and 8 in the east. This results in an average of 84 snow covered days in the west and 96 in the east. Tick counts in the fall on harvested moose have averaged 30 (forth highest region) in the past four years. There is no information on spring hair loss for this region as fewer and less visible moose make this technique impractical.

Deer densities average 13.37/mi^2 but run as high as 19.29 and 17.85 in the southern and western units in the region. Brainworm mortalities are seen annually in this region and have averaged 2.8 animals/annum in the past five years. With one exception, all brainworm mortalities occurred in WMU's with deer densities in excess of 10/mi^2.

Vehicle kill in this region has remained fairly stable over the past five years averaging 44/annum.

Southwest Region: The two year average observation rate of the Southwest region was 0.71 moose/hundred hunter hours in 2013. The observation rate has been declining since 2008 at -0.05 annually. The estimated moose density is 0.23 moose/mi^2. This population has been below goal since 2000. Adult sex ratio is high at 46% bulls. Very small sample sizes necessitate combining five years of data for estimation of adult pregnancy rate. Adult pregnancy rate has been 75% (N=15) with an adult twinning rate of 22%. Small samples sizes in the yearling age classes constrain the use of the five year trend data with only 2 yearling cows taken since 2009. This suggests this population is at or near K.

This region has the highest percentage of habitat in beech/oak at 23%. In addition only 6% of the habitat is in regeneration. While 41 percent of the region is in habitats that are browse producing and outside of the 300 ft road buffer, with such a high percentage in oak/beech a greater percentage of the habitat labeled mixed and hardwood will include beech and oak further limiting browse supplies here.

Deer densities average 15.9/mi^2. Well above the 10 – 13/mi^2 believed to be limiting for moose. While brainworm mortalities are seldom found, they are believed to be occurring.

This region has maintained the number of snow covered days in the northern half of the region at an average of 82 days. The one southern station records snow covered days declining by 6 days over the past 4 decades. This still leaves an 81 day season. The only information on winter tick for this region is fall counts on harvested moose. While sample sizes are quite small, (N=7) an average of 15 ticks are counted on moose in October.

Vehicle kill has been relatively stable in the last five years averaging 12/annum although 2013 saw only 4 vehicle kills recorded. Even at 12 the number of vehicle kills is still low compared to other regions.

Southeast Region: This region has the lowest moose population density with a two year average observation rate of 0.29 resulting in an estimated density of 0.10moose/mi^2. Over 5 years the observation rate change was -0.06 annually. The observation rate has fallen below goal the past three years. The adult sex ratio in 2013 was 39% bulls. Five year average adult pregnancy rate is 53% with a twinning rate of 40% but the harvest sample sizes are so small here that this is only evidence that reproduction is occurring, not rates of same.

Only 44% of this region lies in browse producing habitat types outside of the 300 foot road buffer. At 15%, this region has the highest percentage of regeneration. However, given the very high percentage of the region (24%) in the disturbed/developed/transportation type it is doubtful that all 15% of this regeneration will be allowed to actually regenerate. If we reduce this percentage down to that seen in the Southwest (6%) we now have only 39% of the region in browse producing acreage, the lowest in the state. Wetlands are very high at 18% but much of this can be attributed to salt marsh which is not good moose habitat.

Winters here are the mildest in the state with 59 snow covered days recorded for the past 4 decades. During this time snow covered days have declined by an average of 6.6/decade at one station and not at all at another. Deer densities are the highest in the state at 22.89/mi^2. This is well above the 10-13/mi^2 reported to reduce moose populations. Brainworm has not been recorded here in the past five years and this is probably due to the very low moose densities making it difficult to find moose.

Vehicle kills are the lowest in the state in this area averaging 6/annum since 2009. Three moose were killed on the highways in 2013. Other sources of mortality have not been documented since 2007.

Population Projections: The ability to maintain moose in these changing times is somewhat unknown and definitely hard to predict. The Ct. Lakes area has longer winters in its northern end than the southern. Regardless of this difference, winter ticks are a problem here and have undoubtedly contributed to reduced productivity and increased mortality in years which have shorter winters. Tick levels are high and will remain so given the high density of moose. This population exceeded measures of available browse for some time and while the population has been reduced since then and regeneration acreage has increased, it is unknown where the population lies in relationship to browse constraints at this time. Deer density here is high, and extensive feeding of deer is causing extremely high concentrations of deer in many spots across this region. This results in many areas that have very high brainworm transmission potential from deer to moose. Brainworm incidence is high here compared to the two regions to the south both of which have lower deer density. Given the high tick levels, this population will be subject to chronic reduced productivity and in years of short winters, high mortality. If deer density continues to climb and continues to be exacerbated by feeding of deer, brainworm may become a driving force here and this could result in a much lower moose population that will be unable respond to longer winters and reduced tick loads.

The North region by all recent measures is well below K but productivity and mortality are being impacted by chronic winter tick loads. Much shorter winters result in significantly increased mortality and reduced productivity. Based on recent trends it is probable that shorter winters will be occurring with greater frequency causing this population to exhibit a roller coaster growth pattern; declining sometimes dramatically, due to short winters with growth occurring whenever winter lasts long enough to reduce tick levels. Deer density is significantly lower in this region than in the Ct. Lakes and brainworm is seldom seen here.

The White Mountain region has the lowest deer density in the state in all but WMU D2 where deer density is estimated at 19/mi^2. The remainder of the region lies primarily within the White Mountain National Forest where deer densities are very low. As a result, with one exception, brainworm related moose mortalities have only been recorded in D2 in the past five years and while it may be influencing the moose population in this unit, it appears to be having no influence in the remainder of the region. Winter tick is a factor here and during shorter winters is a cause of increased mortality and reduced productivity. As is the case in the Ct Lakes region, both winter ticks and habitat may be contributing to reduced productivity here due to this region's very low percentage of regeneration. Without increased cutting, this region's moose population will probably not be able to grow substantially and due to tick impacts will be subject to years of heightened mortality and population declines. Brainworm impacts will probably not allow for growth in the D2 unit of this region.

The Central region is influenced by both winter tick impacts and brainworm. While winter tick impacts are low, moose densities remain high enough that we do see increased mortality in years of shorter winters. Brainworm however is probably having a large influence on this population and deer densities exceed 10/mi^2 in all but two of the WMUs. If deer densities remain high this moose population may continue to decline.

In the two southern regions, deer densities here are the highest in the state and brainworm is the probable primary influence. As moose have been able to hold on at very low levels in Massachusetts where deer densities are equally as high, moose may be able to remain here but at very low levels.

Limiting Factors: In the state of New Hampshire limiting factors can be both density dependent and density independent. Density dependent factors become more important as moose numbers increase. Eventually a point is reached where the resource in question can not support the population and the population crashes. Food and winter ticks are examples of a density dependent limiting factor. Density independent factors can limit population growth regardless of the number of animals on the landscape. No matter how much food or cover is available the population can not utilize it to grow because some other factor is causing increased mortality. Brainworm would be an example of a density independent factor.

In New Hampshire the most important limiting factors for moose include cultural carrying capacity, weather, winter tick, and brainworm. Food may also be a limiting factor but at this point, parasites are the primary driver for any region.

Winter tick is keeping the northern three populations at current densities or causing them to stagnate or decline by causing irruptive declines in certain years and/or reducing productivity. The irruptive patterns are related to weather with early springs and late winters increasing tick abundance. These weather patterns cannot be predicted but in the past 30 years, winter has shortened for much of the northern end of the state by up to 3 weeks (Wake et al. 2014). While winter tick has the ability to greatly reduce a moose population, once the population drops to lower levels, the tick density is reduced and the moose population grows again. In areas that sustain both deer and moose, Ontario attempts to keep moose densities at or below 1/mi^2 in an attempt to avoid tick impacts (G. Eason, Ont. Ministry of Nat. Resources, pers. Comm.). In our own state, once moose densities decline to 0.28/mi^2 tick counts on harvested animals are reduced to very low levels. Attempts to maintain moose densities at higher levels may be thwarted by increased tick mortality and reduced productivity

It is felt that brainworm will cause moose populations to inexorably decline at deer densities greater than 10 - 13/mi^2 (Whitlaw and Lankester 1994, Lankester 2010). In New Hampshire regional deer densities exceed this limit in the Southwest, Southeast and the Central regions and are approaching it in the Ct. Lakes. Within the remaining regions some WMU densities exceed this threshold. As deer densities increase it is probable that moose densities will decline.

No research has successfully been done to determine how or if increased temperatures limit moose distribution. While it is known that moose are easily heat stressed it has not been proven that this could cause increase mortality or decreased productivity. Historically, moose densities in southern NH have always been lower than those in the northern portion of the state.

Cultural carrying capacity has been limiting factor due primarily to concerns regarding vehicle moose collisions and browse impacts to regeneration. In the last planning process goals were reduced due to human concerns with safety and browse impacts to forestry. Currently, in all but the Ct. Lakes Region, the moose population resides below those goals due to presumed parasite impacts.

As our human population continues to grow and remove open space, the effects on wildlife will increase, reducing wildlife populations and eliminating some species from areas of the state.

Cadmium is a heavy metal that accumulates in moose liver and kidney tissue and has health implications for both the moose and moose consumers. Cadmium levels have been increasing and are currently high enough to cause acute toxicity after consumption of moose liver or kidney (Gustafson et al. 2000). Possible health effects for the moose include renal damage, acute toxicity, teratogenesis and bone tissue demineralization. Industrial atmospheric emissions are responsible for these increasing levels of cadmium. The results of recent liver and kidney sampling from harvested moose are pending and will tell us if this problem is continuing to grow.

USE AND DEMAND

Past Use and Demand: Moose have always been a useful item to have around. Native Americans used moose as a source of food, clothing and tools. Moose meat was valued by native Americans not only because one moose provided a lot of nutritious food but also because it gave them more energy than a similar amount of meat from any other species (Dudley 1721). Bernard Ross (1861) gave a partial list of the uses natives made of moose “the hide supplies parchment, leather, lines, and cords; the sinews yield thread and glue, the horns serve for handles to knives and awls as well as to make spoons of; the shank bones are employed as tools to dress leather with; and with a particular portion of the hair, when dyed, the Indian women embroider garments…The capotes, gowns, firebags, mittens, moccasins, and trousers made of it are often richly ornamented with quills and beads, and when new look very neat and becoming…"

Early European settlers utilized moose for both food and clothing. In addition the Hudson's Bay Company purchased large quantities of moose hides, the earliest records of such purchases being from 1671 and continuing at least through 1829 (Rich 1947). Grant (1894) wrote: "The early settlers in Vermont and New Hampshire found their (moose) meat a most welcome source of food; in fact, the number of moose alone enabled the colonists at first to keep from starvation during the long winters." Market hunting became popular in the mid-1800s and according to Silver (1957) market hunters often took only the skin, tallow and the nose (considered a delicacy) leaving the carcass to rot in the woods. Hunters hunted moose at all times of the year and market hunters routinely used dogs on crusted snow in the spring to bring down the greatest numbers of moose.

Subsistence and market hunting caused moose numbers to fall precipitously but even in the face of almost total extirpation interest in moose remained high. It wasn't until 1875 when the Fish and Game department reported moose to be so rare that they could be found only in museums that the legislature moved to shorten the season to two months instead of year round. In 1885 a sport hunter illegally shot and killed three moose in northern NH. Interestingly, when a Fish and Game Commissioner complained to the legislature he was reprimanded due to concerns that the hunter would not come back to the state to spend his money. Efforts by the department to ban moose hunting were routinely thwarted by legislation that continued to enable it. It wasn't until 1901 that the season was closed completely (Silver 1957).

As moose numbers began to make a comeback interest in the re-establishment of a moose hunt was renewed. In 1979 sportsmen petitioned the legislature to open the entire state to moose hunting for a period of three days. This bill was re-introduced at every legislative session for the next five years. The Fish and Game Department testified against this bill citing a lack of good data to effectively manage the resource. In 1985 the department partnered with the National and New Hampshire branches of The Wildlife Society to develop a bill the department could back. The result was RSA 208.1.

Knowledge of this bill engendered a wide range of concerns from the general public. Anti-hunting groups were heard from but so too were members of the general public who while not opposed to hunting, were concerned that hunting would eliminate the existing moose. A survey by Donnelly (1988) documented the importance of moose to the public and highlighted the public's desire to have moose managed as a multiple use resource. Uses included viewing, tourist attraction and hunting. Eighty percent of respondents felt moose were an important part of New Hampshire's image.

The first season took place in 1988. The season was three days long, 75 permits were issued and it took place in WMUs A1 – F and J1. As the season continued and moose numbers continued to increase in density and distribution concerns regarding the disappearance of moose disappeared themselves.

During the last planning process regional desires for size of the moose population differed as did the level of concern for various moose benefits. While noting that moose were important for viewing, the Ct. Lakes, North and White Mountain regions wanted a reduction in moose primarily due to concerns regarding moose/vehicle collisions and browse levels in regenerating cuts. The Southwest wanted fewer due to concerns regarding vehicle collisions while the Southeast and Central regions wanted moose densities to remain the same.

Today the season is statewide, runs nine days and permit issuance, which had been as high as 675 in 2006/07 has dropped to 124. Permit issuance has always been far less than the number of applications with 1-4 percent of applicants being drawn each year. As moose numbers have decreased there has not been a measureable corresponding decline in moose related recreational pursuits. Moose tour businesses which exist in the North and White Mountain regions no longer have a 100% sighting success rate but business is still good and moose are still seen nearly every night. A moose festival continues to take place annually in the Ct Lakes Region. There are several businesses in the North Region devoted to moose and moose related items are sold in stores throughout the state. Shed hunting (hunting for dropped antlers) remains very popular, so much so that in areas of high moose density sheds can be difficult to come by after shed hunting is done.

Current Use and Demand

Non-consumptive Use: The most current figures on non-consumptive use of wildlife in New Hampshire were compiled by the US Dept. of the Interior in 2011. That year approximately 311,000 people came to NH to see wildlife and 36% of New Hampshire’s residents participated in wildlife viewing. Combined these people spent an estimated $282,191,000 on associated wildlife costs (equipment, gas, food, lodging). While it is not known what proportion of this is related to moose viewing, there is no question that moose viewing is a valued experience for both residents and non-residents alike.

Moose viewing has been and continues to be a popular resident and tourist pass time in northern NH since at least 1986. The moose tour business located out of Gorham was begun in 1995 (Northern Forest Heritage Park pers. comm.) when mail survey moose observation rates were 7.55/100 hunter hours. At current observation rates of 3.9/100 hunter hours, the company continues to see moose although they now have the occasional night where no moose are seen. There are now moose viewing buses running out of Lincoln, North Conway, Berlin, and Gorham NH. In addition, hunting guides are beginning to offer moose viewing and photography trips.

In 1997 NHF&G published it's first wildlife viewing guide as a partner in the National Watchable Wildlife Program (Silverberg 1997). Many of the viewing locations list moose as one of the species that may be seen. Watching moose is a favorite pass time of residents and non-residents alike. Favored sites are often crowded with moose watchers and the resultant traffic flow problems are legendary in the north-country.

Moose are also used as a merchandizing commodity. There are several north-country businesses devoted to moose merchandizing and rare is the tourist trap that does not sell moose related memorabilia. In addition the moose is a popular logo being used by numerous businesses. The state’s conservation license plate features a moose.

A recent survey (Responsive Management 2014) of NH residents indicated that most residents (39%) want moose numbers to remain the same, 26% would like more moose and 2% would like to have fewer moose. Reasons for increasing the moose population included increasing viewing opportunities and increasing hunter success. Only 27% of respondents who wanted an increase would still support an increase if it meant reduced herd health while only 45% would support an increase if it meant less food for other species.

Hunting: Availability of hunting permits continues to be significantly less than the number of applications sold. Applications sold have declined from a high of 16,779 in 2007 to 13,137 in 2013. In 2003 a preference points system was added to the permit lottery. This did not have a negative impact on application numbers. Recent reductions in applications seem to be directly tied to recent reductions in permit numbers (from 675-124) and lower success rates (77% in 2005, 64% in 2013). Non-residents accounted for 37% of applications even though they were given less than 15% of the permits.

While permits may not be sufficient to satisfy all applicants, moose densities are currently high enough to maintain good success rates. Success rates are high in all regions but the Southeast and moose hunters generally see several moose while hunting. About half the moose seen are bulls. As only 19% of hunters in 2013 wanted to take an adult bull and only 15% were interested in taking a trophy bull, it seems that hunters should have been satisfied.

User Group Conflicts: Based on our history it seems that consumptive and non-consumptive uses can peacefully coexist. There have been concerns expressed by lodge owners in the Ct. Lakes region that numbers of big bulls and moose densities in general are now too low to provide ample viewing opportunities.

In the Ct. Lakes region, the famous Rte 3 corridor known as moose alley is no longer the moose draw for tourists that it used to be according to numerous reports by lodge owners and moose watchers. The regional moose observation rate is almost twice that of the North region at 7.36 moose seen/hundred hunter hours. However, lack of cutting near the road, re-growth of roadside clear cuts, and draining of roadside salt pools to reduce moose presence near the road have all worked together to reduce moose on the roadside. This is an area where forestry practices and safety concerns reduced moose viewing opportunities.

Negative Impacts: In the past decade on average there have been 190 moose vehicle collisions/annum on New Hampshire roads and highways. This is down from a high of 266 in 1997. Since 2004 here have been 1,884 such accidents that resulted in a dead moose on the road. Of these 5, or 0.3%, resulted in a human fatality. The number of collisions is influenced by numbers of vehicles and moose, speed, road side visibility, weather, time of day and year, surrounding topography and habitats and presence of salt licks. Speed and road side visibility have been identified as the primary influences on numbers and severity of collisions (Spencer and Chatelain 1953, Poll 1989, Lavsund and Sandegren 1991). In Alaska a public education campaign designed to increase public awareness of moose on the roadways was at least partially responsible for an 18% decrease in MVC's (Del Frate and Spraker 1991). A similar program was implemented here in 1991. Efforts to reduce road kills should focus on public education, speed reduction and increased road side visibility. With that focus in mind, an inter-department committee composed of members from Departments of Transporation and safety, the Governor's Council, and NHF&G instituted flashing warning signs for high accident areas and wrote, produced and distributed to all driving instructors a driver education DVD outlining driving practices designed to reduce wildlife collisions. During the past five years, vehicle/moose collisions have decreased in all regions.

Complaints regarding moose are low. Property damage caused by moose rarely causes serious economic loss. In New Hampshire the most serious problem is browsing in Christmas tree plantations. In the past 8 years, two plantations were browsed multiple times resulting in a monetary loss of $71,000.00. The only other economic impact was to two different apple orchardists with very modest claims of $100 and $25 each. Aside from browsing concerns, property damage resulting in downed electric fence lines or sap line repair are the most common problems. Having moose live in close proximity can result in requests for the animals' removal due to fraternization with livestock or fear of the animal. An average of 7 "nuisance" complaints per year were reported to USDA-APHIS/Wildlife Services in the preceeding eight years. Twenty-one percent of these calls were due to fear of moose rather than actual damage.

Complaints regarding moose browsing in regenerating forest cuts continue to be reported and occur across all moose densities.

Use and Demand Projections: New Hampshire is within a 2-4 hour drive of two of the most populous cities in North America, Boston and New York. As a result of this and the physical beauty and rural character of our state our economy is strongly affected by tourism. According to the 2011 National Survey of Fishing, Hunting and Wildlife-Associated Recreation 36% of New Hampshire residents participated in wildlife watching activities. Approximately 69,000 residents and 242, 000 non-residents made trips within or to New Hampshire to view wildlife. Approximately 387,000 residents watch wildlife at home. Residents and non-residents combined spent an estimated $281,191,000, on NH wildlife watching trips and associated costs. While levels of moose watching have never been formally documented, based on this general information, the number of businesses devoted to all things moose and the level of human activity at known moose licks, it would seem likely that moose watching will remain a popular past time for the foreseeable future.

The number of available moose permits is unlikely to ever satisfy the number of applicants. The implementation of a preference point system provides the consistent applicant with a better chance to acquire a permit but the likelihood of acquiring more than one permit in a lifetime is slim. Hunter satisfaction is likely to remain high if the ability of permittees to harvest a moose remains high.

A desire by some members of the general public to have fewer moose vehicle accidents and by land owners to reduce moose nuisance complaints or browsing in regenerating clear cuts, may cause conflict with both viewers and hunters. In the face of an increasing human population, moose/vehicle accidents and nuisance complaints may decline at a slower rate than the declining moose population.

SUMMARY AND CONCLUSIONS

New Hampshire's moose population has made a remarkable recovery since its almost total extirpation in the mid-1800s. It once again exists in all areas of the state and its primary range, the Ct. Lakes, North, White Mountain and Central regions, mimics that found by colonial settlers (everything north of the southern Carroll County line). Reintroduction of a moose season in 1988 was met with strong pro and anti sentiment. Continued moose population growth in the face of annual harvests caused the decline of anti moose hunting concerns. Early management efforts were hampered by limited population data and resulted in seasons that were designed to be recreational in nature and were very conservative in season length and/or perimit numbers. As data sets improved, seasons were designed to hold populations at certain levels or reduce them down to goals requested by the general public.

Recent population declines below goals are being driven by parasite loads caused by increasing deer densities, high moose densities and shorter periods of snow cover. In addition, some populations seem to have reached and even exceeded carrying capacity of the habitat for a time before dropping back down below K. At this point, populations in the Ct. Lakes and White Mtn. regions may be at or very close to K as defined by habitat.

Social carrying capacity for moose had been reached during the last planning process due to concerns regarding vehicle collisions and impacts of browse on forest regeneration. Currently, based on the results of a 2014 phone survey (Responsive Management 2014) of NH residents (see table below), most respondents desire that moose populations stay at current levels, but a fairly large percentage would like to see increases in the moose population in all regions. The driving force behind this desire is to increase the chance to see a moose.

Region	Increase	Maintain	Decrease
North	30%	44%	5%
White Mountains	23%	50%	9%
Central	28%	34%	2%
Southwest	32%	35%	4%
Southeast	20%	44%	1%

Due to increasing deer density and associated brainworm mortality, it is unlikely that moose densities will be able to sustain any increase where deer densities exceed 10-13/mi^2. Due to weather impacts on the secondary host that transfers the brainworm from deer to moose (land snails and slugs) we may occasionally see some increase in the moose population where deer densities exceed 10-13/mi^2, but it is unlikely that these increases will be sustainable. Slow declines may be inevitable and continue to occur in all regions with high deer densities. Feeding of deer can exacerbate this problem by increasing deer density around feeding stations and thereby increasing the possibility of transmission. This can be especially problematic if feeding is done routinely throughout an area and/or is done near moose feeding areas.

For much of the primary moose range, winter tick impacts will control the moose population, causing declines by either reducing productivity and/or increasing mortality. In some years, mortality events will be severe depending on length of snow cover in the winter. Reducing the moose population would reduce tick impacts but the level at which this would occur would be different for each region due to differences in timber cutting regimes and resultant moose distribution patterns. While some jurisdictions hold moose populations below $1/mi^2$ to alleviate tick impacts, sure knowledge of what the moose density needs to be for this to happen is not currently known. In the face of current tick levels and changeable winter weather patterns, the northern regions will continue to be subject to periods of decline and hopefully re-growth.

The Ct. Lakes, White Mountains and Central regions are all exhibiting productivity that suggests they are approaching or are at the carrying capacity of the habitat. While this may be exacerbated by heavy tick loads, the bottom line is that these populations have reached a level that is causing impacts to productivity and the answer for either tick or habitat concerns would be to reduce the populations or not allow for any further growth.

The reason the public in most regions would like to see increased moose population density is so that people may see moose more easily. This is a catch 22 situation as the place people are used to seeing moose, in salt licks near the side of the road, is the place where moose/vehicle accidents are most likely to occur. There is a solution that would allow populations to remain below K and possibly below a level that causes heavy tick loads. It is the establishment of moose watching areas that can be set up away from roads. Many North American jurisdictions are moving to implement such viewing areas. It would require that towns set aside land that could be easily accessed by the public. Viewing platforms are erected in the middle of the parcel and timber cuts are made in a spoke pattern radiating away from the platform. Additional cuts are made every 10 years to ensure the areas continue to provide good browse for moose.

In the face of increasing deer densities and shorter winters, moose mortality and productivity will continue to be eroded by increasing parasite loads. Unless deer densities are held to levels less than $10/mi^2$ moose populations may decline to very low levels or as has happened in some North American jurisdictions, completely disappear. As winters become shorter and winter tick becomes more problematic, it may be prudent to reduce the moose population below $1/mi^2$ to see if this will help stabilize the impacts of this parasite and thus stabilize the moose population.

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Table 1.
N.H. MOOSE POPULATION MANAGEMENT GOALS BY REGION
Moose seen per hundred hunter hours from mail survey

REGION	1997-2005 Objective	2006-2015 Objective	CURRENT LEVEL*	DESIRED % CHANGE
CT. LAKES	8.63	7.4	7.36	+1%
NORTH	8.63	6.0	3.90	+54%
WHITE MOUNTAINS	3.94	3.0	1.30	+131%
CENTRAL	1.50	1.5	0.86	+74%
SOUTH WEST	1.34	1.3	0.71	+83%
SOUTH EAST	0.50	0.5	0.29	+72%

* Moose seen per hundred hunter hours during the three years 2012-2013.
NOTE: Moose in New Hampshire are managed by regions rather than units (i.e. WMU's). This is because sample sizes on data collected are too small at the unit level to yield reliable information. Thus, several WMU's are consolidated into each region.
* In the last planning process, the Ct. Lakes region was separated out from the previous North region creating six moose management regions.

Table 2. Percentage of Regional Habitat Components

	CT. LAKES	NORTH	W. MTNS	CENTRAL	S. WEST	S. EAST
HABITAT TYPE						
Softwood	15	18	20	20	19	11
Birch/Aspen	4	8	12	2	1	2
Hardwood	31	26	24	12	6	7
Mixed Wood	27	18	22	30	36	34
Cleared/Regenerating	11	15	6	8	6	15
Beech/Oak	6	6	13	20	23	13
Wetlands	6	9	3	8	9	18
% of Region in Moose Habitat Types	95.3	92.3	89.8	85.6	87.2	68.9
% of Moose Habitat w/in 300 feet of a road.	4.4	6.1	7.0	15	17.2	24.1
% of Region in moose habitat minus 300 ft. road buffer.	91.1	86.7	83.5	72.8	72.2	52.2
% of Region in Disturbed/developed/transportation	1	3	3	6	8	24

Table 3. Estimated moose, deer and bear densities/mi^2 2013

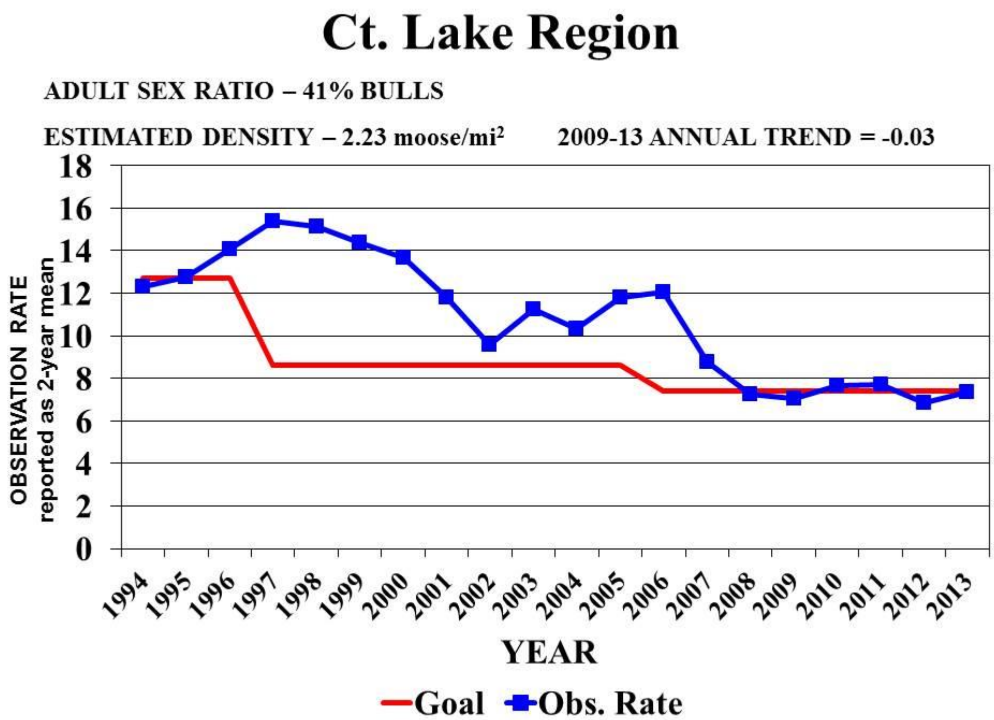
	Moose	Deer	Bear
Ct. Lakes	2.07	9.97	0.55
North	1.14	6.70	0.55
White Mtns	0.39	5.60	0.97
Central	0.29	13.37	0.76
Southwest	0.28	15.90	0.57
Southeast	0.11	22.89	0.07

Table 4. Regional Five Year Average Productivity Estimates

	Adult pregnancy rate	Adult twinning rate	Yearling preganancy rate
Ct. Lakes	80%	20%	30%
North	83%	21%	10%
White Mtns	89%	15%	20%
Central	94%	29%	28%
Southwest	*Ins data	Ins data	Ins data
Southeast	Ins data	Ins data	Ins data

*Insufficient sample size to determine productivity estimate.

Figure 1. Historical regional mail survey moose observation rates.



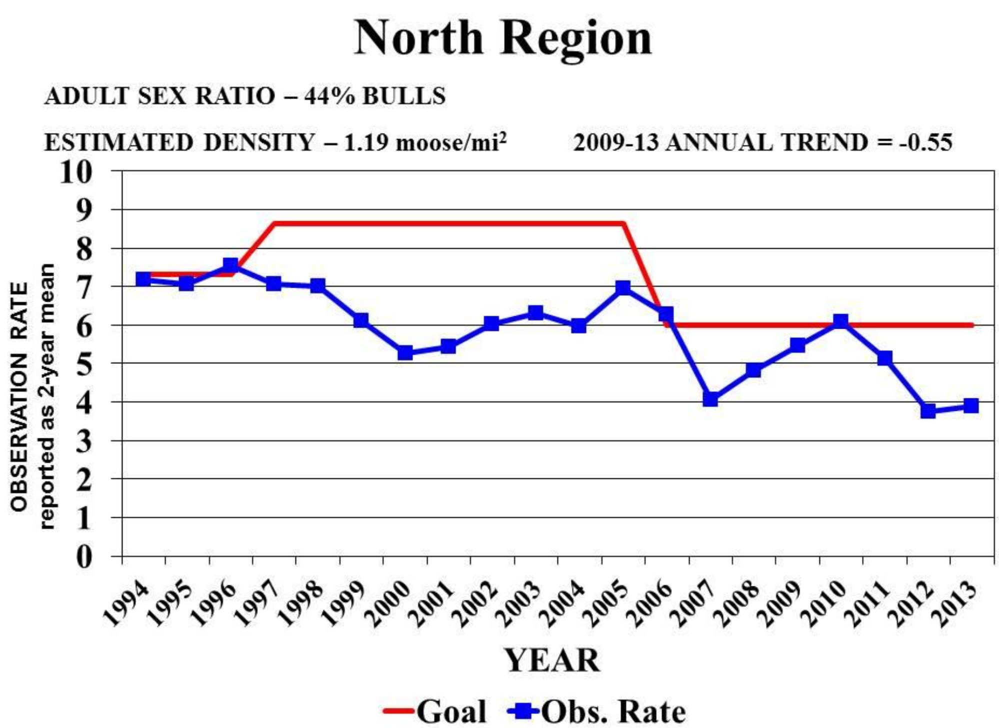
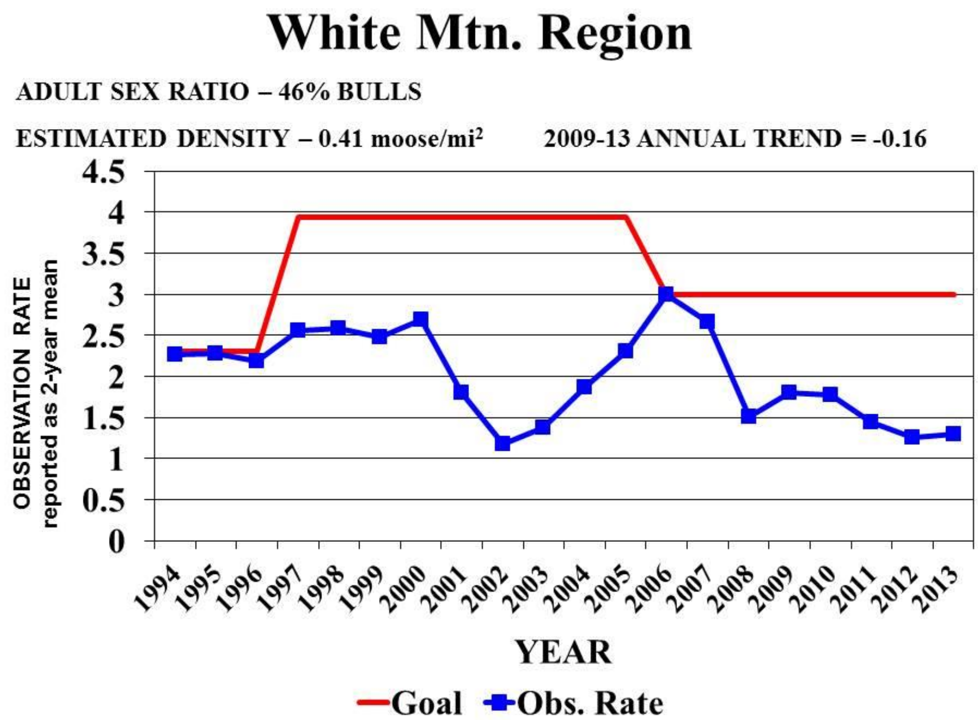


Figure 1. Historical regional mail survey moose observation rates (cont).



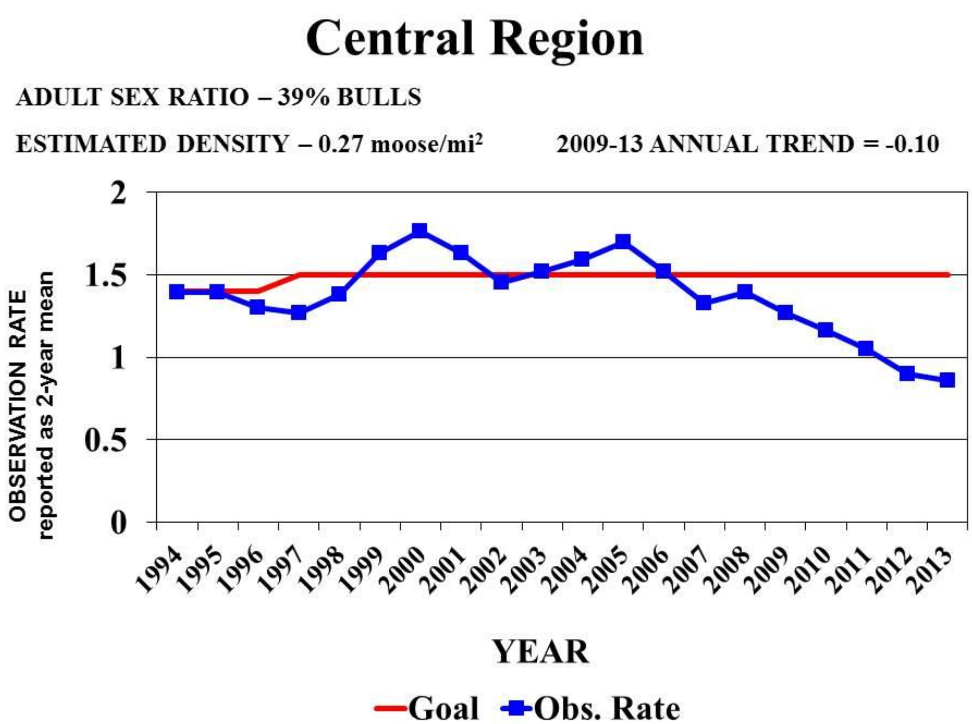
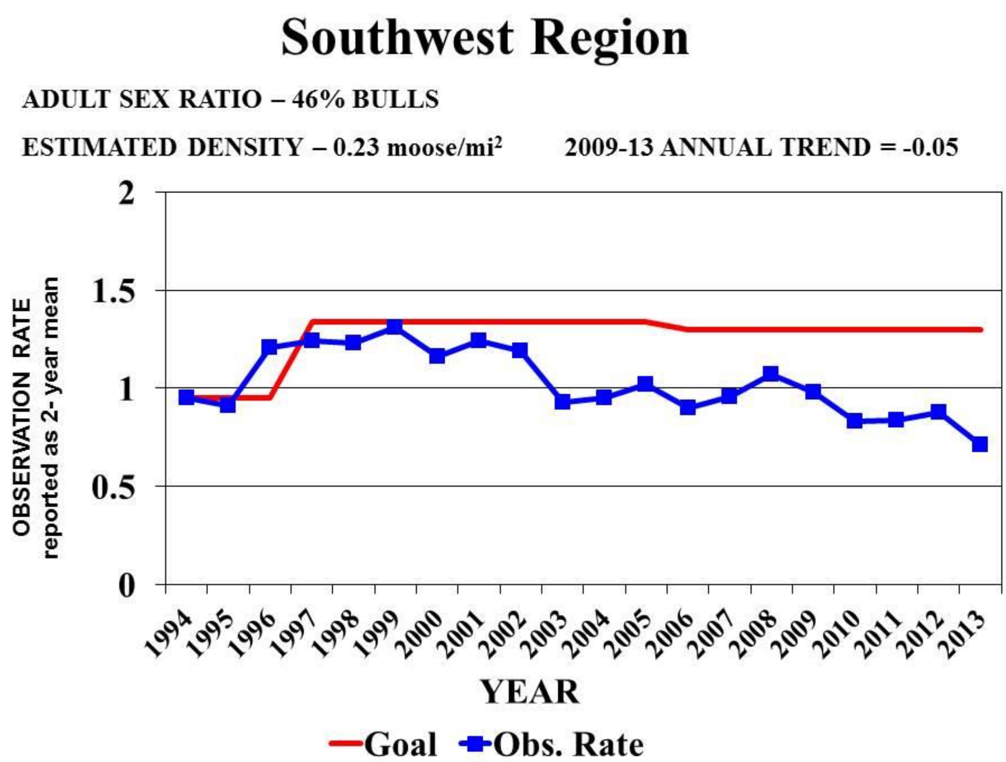
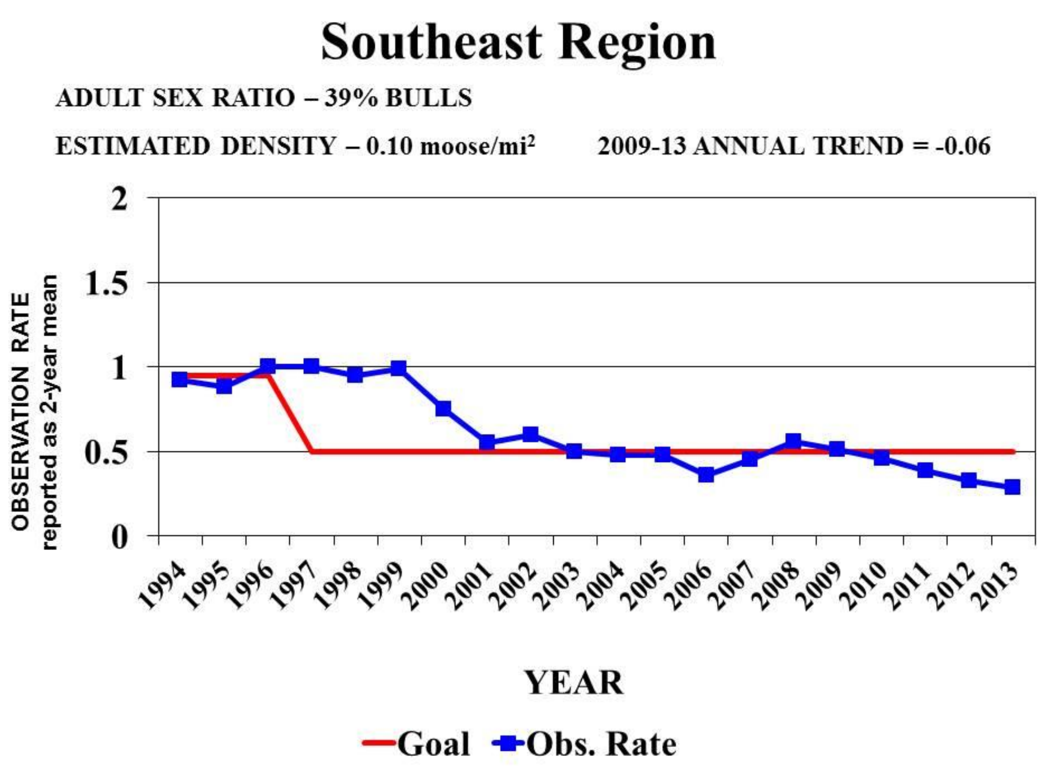


Figure 1. Historical regional mail survey moose observation rates (cont.).





Appendix 1. Moose Management Regions.