SELECTIVE HARVEST MANAGEMENT OF A NORWEGIAN MOOSE POPULATION

Jon Lykke

Værdalsbruket, 7660 Vuku, Norway

ABSTRACT: The moose population at Værdalsbruket in the county of Nord-Trøndelag, Norway has been studied since the 1930s. Complete harvest and weight statistics for sex and age classes and detailed hunter observations have been collected since 1969 producing a data set of 2,667 harvested moose and 17,068 moose observations. These data were used to both manage and assess a selective harvest management system based upon annual hunter guidelines, contracts with sex-age quotas, and progressive pricing of hunting cost related to carcass weight. Combined with a relatively high hunting pressure, the system has produced a controlled increase in the moose population, and an improved population structure with more prime bulls, higher mean age of cows, and an improved cow:bull ratio. Long-term body weights and production have been stable, indicating a healthy moose population in balance with its resources. Success of the harvest system depended largely on the level and progression of the hunting price-carcass weight relationship.

ALCES VOL. 41: 9-24 (2005)

Key words: *Alces alces*, body weight, harvest, management, moose, Norway, population dynamics, reproduction

---

The history and development of the Norwegian moose (*Alces alces*) population is well documented and has shed light on interesting aspects of moose ecology. Moose gradually occupied the country after the last Ice Age some 10,000 years ago, and were followed by the first human inhabitants, the hunters. As discussed by Lykke (1960) and Lykke and Cowan (1968), pronounced fluctuations in both local density and range of moose have occurred since. Moose hides were exported from Norway to Britain as early as the 1100s, and moose were mentioned in older district laws. Hunting regulations were enforced in the 15th century, and severe restrictions against killing moose in the 18th and first half of the 19th century suggest scarcity at that time. Moose were nearly extinct about 1800 and were rare outside south-central parts of Norway and Sweden. Moose harvest statistics for Norway (Fig. 1) exist since 1889 and it is reasonable to believe that they reflect population trends.

Moose population dynamics in Norway have been addressed by many authors (e.g., Skuncke 1949, Lykke and Cowan 1968, Lykke 1974b, Haagenrud 1986). By 1900 large predators were almost exterminated, moose hunting was better controlled, and forest pasturing of sheep and cattle declined, all factors beneficial to moose. Relatively small population fluctuations in 1900-1935 were probably due to variable hunting pressure. The rapid population increase from 1935-1960 was triggered by lower hunting pressure when forestry practices changed, and possibly by climatic factors. The dramatic population increase in the 1950s was due to increased browse production from forestry practices, specifically clear-cuts, and fairly low hunting pressure. Around 1960 there were concerns about overpopulation, and moose were reduced through increased hunting pressure, even upon the most productive segments. Forage produc-

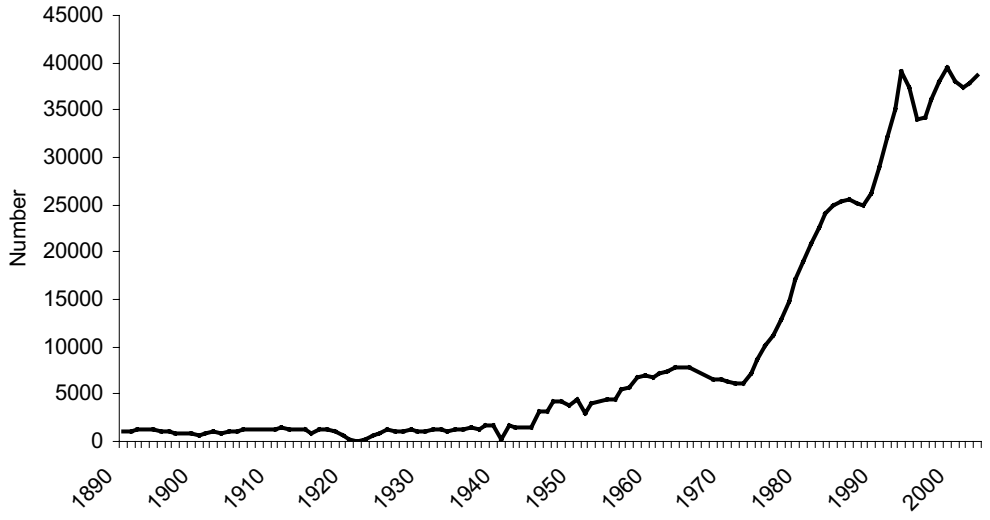

Fig. 1. Moose harvest in Norway, 1889-2003 (Bureau of Statistics).

tion continued to increase at a high rate in response to logging for the rest of the century, and selective hunting was steadily refined, especially from the 1970s on; both influential factors of moose population dynamics.

This paper addresses the moose population at Værdalsbruket, which is one of the largest private properties in Norway consisting of 900 km^2 of forests, mountains, marshland, rivers, and lakes. The area lies in Nord-Trøndelag County in central Norway and covers 60% of the municipality of Verdal. Most of the area is found in the upper, eastern part of Verdal near the Swedish border (Fig. 2). My father, Leif Lykke, was managing director at Værdalsbruket from 1931-1971 and I had the same position in 1971-2002. Together, we were responsible for all forestry and wildlife management for > 70 continuous years, and generated a historical database of moose statistics, especially since 1969. Analysis of these data is pertinent given the recent concerns about body size and reproduction, skewed population structure, overbrowsing and forest damage, and effects on biodiversity by moose in Norway and throughout Scandinavia (Lavsund 1987, Thompson 1990, Angelstam et al. 2000, Connor et al. 2000). The major objective of this study was to document the effect of a selective harvest system on the population structure, reproduction, body weight, and growth of the moose population at Værdalsbruket, Norway.

STUDY AREA

The area (latitude 64° N) is a varied landscape of high and low productive forests, with short distances from sea to farmland to forests to mountains. There is a mixture of mountains and forested valleys with numerous rivers, streams, and waterfalls. Altitude varies from 20-1100 m a.s.l., and treeline fluctuates from 350 m in the west to 550 m near Sweden. The area has a mix of coastal and inland climates. Average July temperature is 12-15 °C, with maximum diurnal temperature of 30°C. Average January temperature is –4 to –7°C, with a minimum of –35°C. Average yearly precipitation is 800-1100 mm. Snow depth is moderate in the lower western areas, while some eastern valleys may have > 2 m and are snow-covered 200 days a year.

The habitat was described previously by several authors (Lykke 1974b, Ahlen 1975, Krefting and Lykke 1976). The vegetation varies widely from highly productive farmland to alpine. There is a mixture of high and low productive forestland, bogs, marshland, and mountains. Land classification of Værdalsbruket shows 23% productive forestland with 3% highly productive, 12% other forestland, 10% marshland below treeline, 3% water, and 52% mountains. Three main tree species occur with Norway spruce (*Picea abies*) dominant and representing 79% of the cubic mass; Scots pine (*Pinus silvestris*) is 12%, and birch (*Betula* spp.) 9%. Preferred moose browse species are sallow and willows (*Salix* spp.), mountain ash (*Sorbus aucuparia*), juniper (*Juniperus communis*), aspen *(Populus tremula*), Scots pine, and birch. To some extent Norway spruce, grey alder (*Alnus incana*), and bird cherry (*Prunus padus*) are browsed. The summer diet consists of a wide variety of plant species, and of special interest is browsing of blueberry (*Vaccinium myrtillus*) in late fall.

Land Use and Management History

Forestry has been the main activity on the property since the 1600s, although portions were also used for grazing by Laplanders (reindeer) and farmers (sheep and cattle). Silvicultural practices have changed over time; before 1930 a selective cutting system was employed that was eventually replaced with moderate sized clearcuts. This change was of considerable importance to the moose population and was a primary factor in its dramatic increase since 1950. Benefits to moose included creation of a mixture of young and old forest stands, leaving forest vegetation as edge for marshland, water, and mountains, allowing broadleaved plants to grow with conifers in young stands, protection of marshland, and avoidance of herbicides. Currently 40% of the productive forestland of Værdalsbruket consists of young forests, most producing high volumes of moose browse.

Moose in Verdal occupy well-defined summer and winter areas, rutting locations, and calving grounds (Lorentsen et al. 1991). Home range size varies among animals, as does the distance between summer and winter ranges. The largest part of the population moves short distances from summer to winter range, relocating between higher and lower elevation (Baskin 1987). The rest of the population is migratory with a traditional shift of home range along well-defined routes to and from adjacent municipalities in Norway and Sweden. The moose population uses a larger area during summer than winter, notably in higher mountainous habitats.

Predators have minimal importance in the ecology of moose in Verdal (Lykke and Cowan 1968). A few Brown bears (*Ursus*

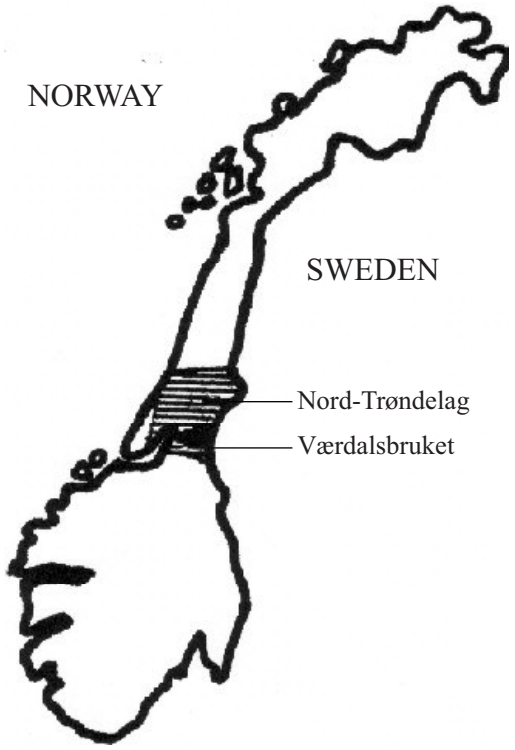

Fig. 2. Location of study area Værdalsbruket, Norway.

arctos) take the odd moose, but no wolf (*Canis lupus*) predation exists. However, the bear population is slowly increasing, and a few wolf packs have established ranges in southeastern Norway where they interact with the regional moose population (Sand et al. 2004); both predators are protected by law. Non-hunting losses are 10-15% of the legal harvest and vary annually due to snow depth, vehicular collisions, ice conditions on rivers and lakes, and time of flooding (Lykke 1952). Under these circumstances, the harvest data presumably indicate reasonable trends in the moose population.

The Norwegian moose hunting system was described by L. Lykke (1960), and J. Lykke (1974a); essentially hunting rights belong to the landowner and 80% of the forest area is privately owned. Since 1952, Norwegian authorities have controlled harvest by area and the minimum area required to harvest moose relative to population density. In Verdal it varies from 2-6 km^2 per moose from lower to higher elevation. We divided Værdalsbruket into approximately 20 hunting sections, each for exclusive use by a hunting team (usually 3-6 hunters) provided with a set quota of 2-6 moose. Open season is set by the authorities, and has varied somewhat, although the majority of hunting and harvest occurs in late September and October. The season is closed during the main rutting period (2-9 October) and has recently been extended into November.

A selective harvest system is important in moose management (Rausch et al. 1974, Mercer and Strapp 1978) and was introduced by landowners and central and local authorities in Norway. Harvest composition was essentially determined by local authorities since the 1970s until recently, when more responsibility was granted to landowners (e.g., Værdalsbruket) who develop 3-5 year management plans that are approved by local game boards. The objective of the selective harvest system is to protect the highest productive segment of the moose population. Calves were protected in Norway until 1963 when it became obvious they should be harvested to help manage the rapidly increasing population. Historical protection of calves inhibited many hunters from shooting them; a situation that lasted into the 1980s and still prevails in some districts.

An adaptable, selective harvest system has been used at Værdalsbruket since 1945, but has played an important role in moose management only since the 1970s. Important parts of the Værdalsbruket moose management plan are protection of mature cows (maximum 15% of total harvest) and prime bulls, high harvest of calves and yearlings (minimum 65% combined of total harvest), maintenance of a balanced sex ratio, and forestry practices beneficial to moose. Cows with calf at heel have always been protected and sex composition of the adult kill has been predetermined.

In 1960 we introduced a pricing system to protect older cows and bulls by making it more economically favourable to shoot young/small moose. The system was modified about 1970 to better achieve the desired population goals by charging per kilogram of meat according to a progressive pricing formula. The formula in 2004 was:

NOK/kg = carcass weight (kg)/9 + 33 (- 5 for calves).

For example, this formula produces a near doubling in price from 44 NOK/kg (6.5 USD) for a 65 kg calf to 83 NOK/kg (12.2 USD) for a 300 kg adult; both prices include 25% governmental tax. This approach was well received by hunters, and the formula is adapted to alter the progression to achieve specific harvest goals (Fig. 3).

METHODS

The moose population estimates were based upon harvest statistics since the late

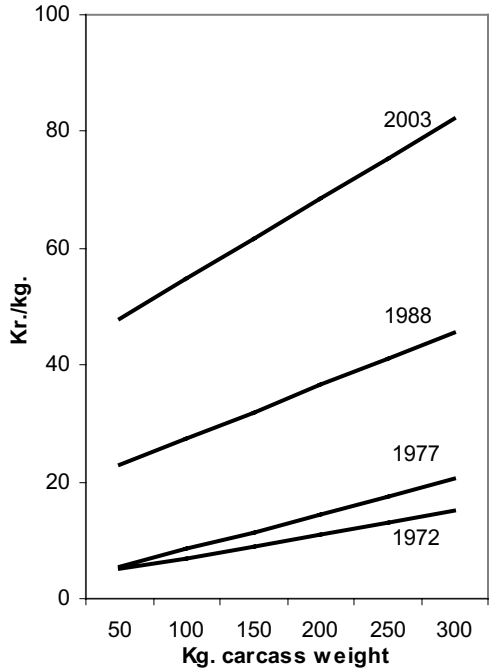

Fig. 3. The temporal change in the relationship of price and carcass weight of harvested moose at Værdalsbruket, Norway.

1880s, yearly notes of moose abundance, non-hunting losses, poaching records, and hunter observations the last 3-4 decades (L. Lykke 1962, 1968; J. Lykke 1964). Population characteristics were analyzed from annual harvest data and hunter observations from Værdalsbruket and a small adjacent area. Complete harvest data existed for the period 1945-2004 for 3,423 moose, with 92% of the kill after 1960. Since 1969 each harvested moose (n = 2,667) was sexed, aged, and weighed (Table 1). Age was primarily judged by wear of incisors up to 6-7 years (Heptner and Nasimowitsch 1967). Age was also determined from sectioned teeth in 1969-1972. The results were similar except for a few cases of misjudged 2-3 year olds. The carcasses were split into 8 pieces for weighing: 2 front legs, 2 hind legs, 2 sides, and the back and neck.

Since 1969 each hunting team provided daily observations of moose classified as bulls, cows without calves, cows with one calf, cows with two calves, and unknown. In total, 17,068 moose were observed on 26,010 man-days. It was assumed that the use of stable hunting teams in the same area each year provided reliable data (Solberg and Sæther 1999). Such observations allowed comparison of relative moose density, sex and age composition of the herd, number of barren cows (Schwartz 1998), reproduction, hunting pressure on various groups, and hunting success over time (Baskin and Lebedeva 1987, Gaidar et al. 1990). Hunting pressure was defined as the percentage of observed moose in each sex and age group that was harvested (harvest rate).

RESULTS

Harvest Statistics

Current harvest (2004) is about 10-fold higher than that in the late 1940s (Fig. 4). Since the minimum area requirement was introduced in 1952, one measure of hunter success is the percentage of predetermined moose harvested. The normal rate of success is 90% in Værdalsbruket (Fig. 4). The amount of harvested meat increased since 1970; likewise, the proportion of calf and yearling meat increased to > 50% of the total since 1990 (Fig. 5). The peak in 1963 was a result of very high hunting pressure

Table 1. Sex and age composition of the moose harvest, Værdalsbruket, Norway, 1969-2004.

	Calves		1.5-year-olds		2.5-year-olds		≥ 3.5 years old		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Males	511	19	461	17	399	15	280	11	1,651	62
Females	415	16	250	9	162	6	189	7	1,016	38
Total	926	35	711	27	561	21	469	18	2,667	100

(Figs. 4 and 5).

The overall sex composition of the harvest was dominated by males before 1955, declined in the early 1960s, and was relatively high in 1970-1985 (Fig. 6). Prior to 1980, only the odd (and large) calf was harvested, but the percentage of calves in the harvest increased to about 40% by 1990 (Fig. 7). Combined harvest of calves and yearlings rose to about 70%, and the percentage of harvested adult cows declined to about 12% (Fig. 7). The harvest of mature moose declined overall since 1969. Before 1980, about 40% of harvested adult moose were > 3 years old; current harvest is < 20%. Excluding calves, 63% of the harvest was male since 1945, and 66% since 1969; after 1982, 54.5% of harvested calves were male.

The average weight of all age and sex classes changed little over time; average weights of calf, yearling, and 2.5-year-olds were 61.3, 125.7, and 167.8 kg, respectively (Fig. 8). Average weights of male and female calves and yearlings were 63.2 and 58.6, and 128.5 and 120.7 kg, respectively.

Population Characteristics

Hunter observations in 1969-2004 were used to estimate the annual sex and age composition of the moose population in late September and October (Fig. 9). Cows represented 40-45% of the population prior to 1985, and about 50% afterward. The percentage of bulls was 25-30% prior to 1985, declining to 20% afterward. Calves were about 30% of the population during 1969-2004, ranging from 22.1-33.7%. Before 1985, the sex ratio (cows:bulls) of observed adult moose averaged 1.50 or 60% cows, varying from 1.05-1.84 annually. Since 1985, the ratio averaged 2.40 or 71% cows, but has dropped below 2.0 in recent years.

Reproduction was estimated from hunter observations since 1969; 35-40% of all cows had one calf at heel, and 10-15% had twins, with little variation since 1985. About 45-50% of all cows were barren annually; a downward trend existed since 1994. The number of calves per calf-producing cow was relatively stable, about 1.20, as was the number of calves per total number of cows (0.7; Fig.10). Late-born calves, defined as

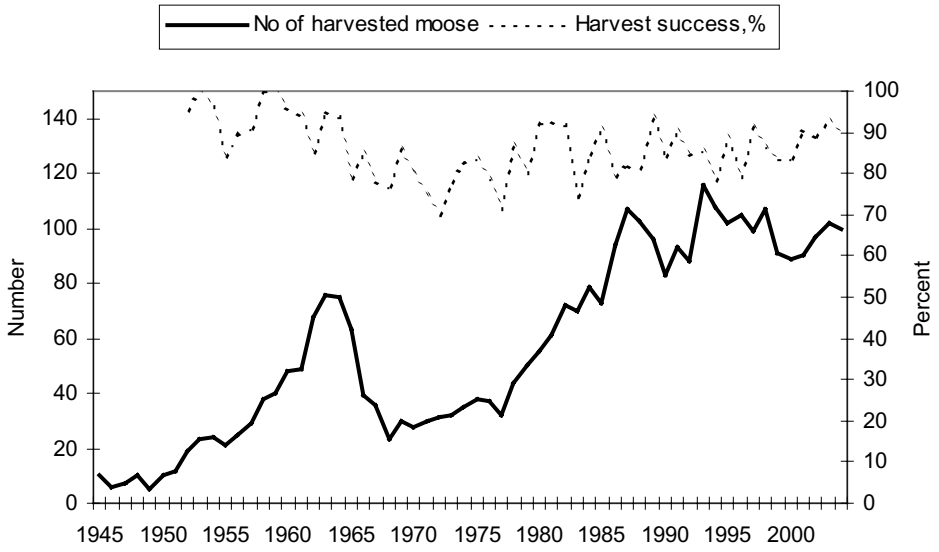

Fig. 4. Annual moose harvest at Værdalsbruket, Norway, 1945-2004.

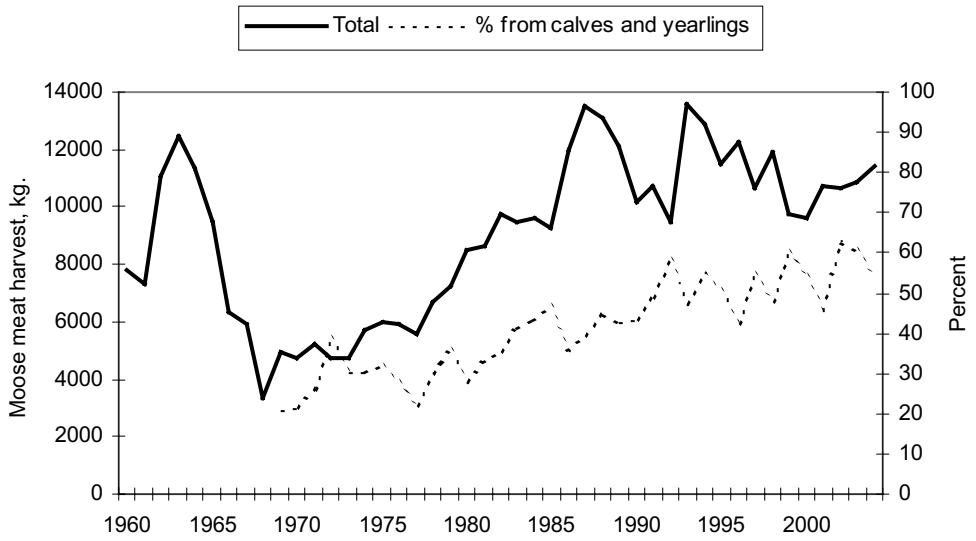

Fig. 5. Kilograms of moose meat harvested at Værdalsbruket, Norway, 1960-2004.

< 50 kg carcass weight, represented 10-15% of all calves with large annual fluctuation; in 1985-1994 it was 15.2%, dropping to 10.5% in 1995-2004.

The observed number of moose per man-day was a useful indicator of relative changes in moose density. An average of 0.6 moose (0.5-0.7) was observed per man-day before 1980 and about 0.7 moose (0.5-0.9) afterward (Fig. 11). It took approximately 12 man-days to kill a moose (Fig. 11) and this changed little despite the increasing moose population. A steadily refined selective harvest system produced change in harvest rate of various sex and age groups. Since 1969, the harvest rate for bulls declined from 30-35 to 20-25%, and from about 10 to 5% for adult cows (Fig.12). The harvest rate of calves increased from about 2 to 15%. The harvest rate for all moose fell from about 15 to 10%.

DISCUSSION

Population Development

Because there is almost no predation of moose in Verdal, and non-hunting loss is only 10-15% of the legal harvest (Lykke 1952, Haagenrud et al. 1975), the harvest statistics (Fig. 4) provide a reasonable estimate of the moose population. Population growth is best explained by food production as influenced by forest harvesting, hunting pressure, and harvest composition. Multiple factors led to increased food production, but most important was the use of clearcuts introduced in Verdal in the 1930s and increasingly used after World War II (Lykke 1974b).

A high percentage of bulls in the harvest is indicative of low hunting pressure (Cumming 1974, Haagenrud and Lørdahl 1979, Solberg et al. 2001). The combined effect of low hunting pressure (Fig. 6) and increased food production in the 1950s resulted in rapid population growth (Fig. 4). There was an eventual concern about overpopulation because even Norway spruce, a non-preferred forage, was heavily browsed (Lykke 1964). A decision was made to reduce the moose population and increase hunting pressure of cows (Fig. 6) and all large moose (Fig. 5), especially in 1960-1966 (Fig. 4).

In the period 1967-1985, the population increased again, although more slowly because of previous overbrowsing, harvest composition in the early 1960s, and relatively high hunting pressure on adult moose.

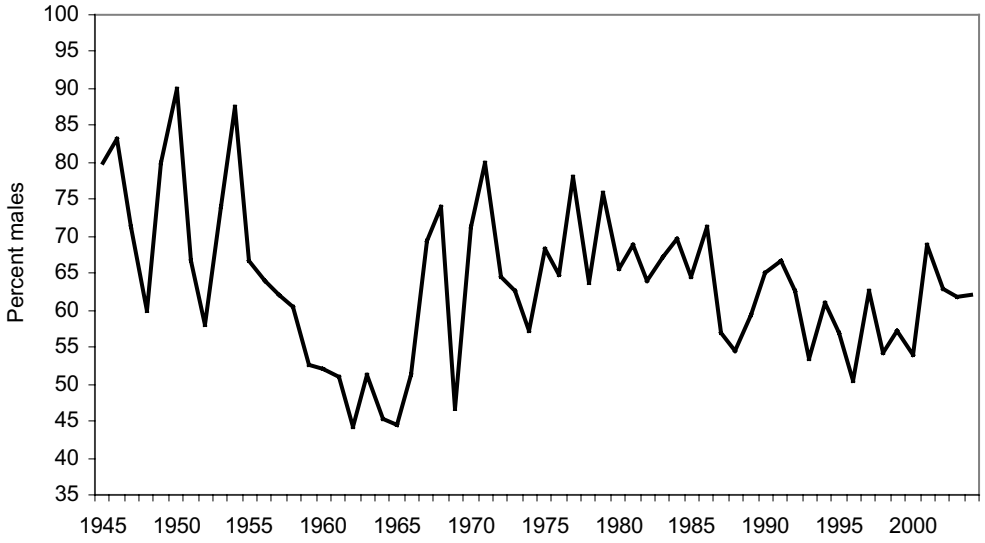

Fig. 6. Male fraction of moose harvested at Værdalsbruket, Norway, 1945-2004.

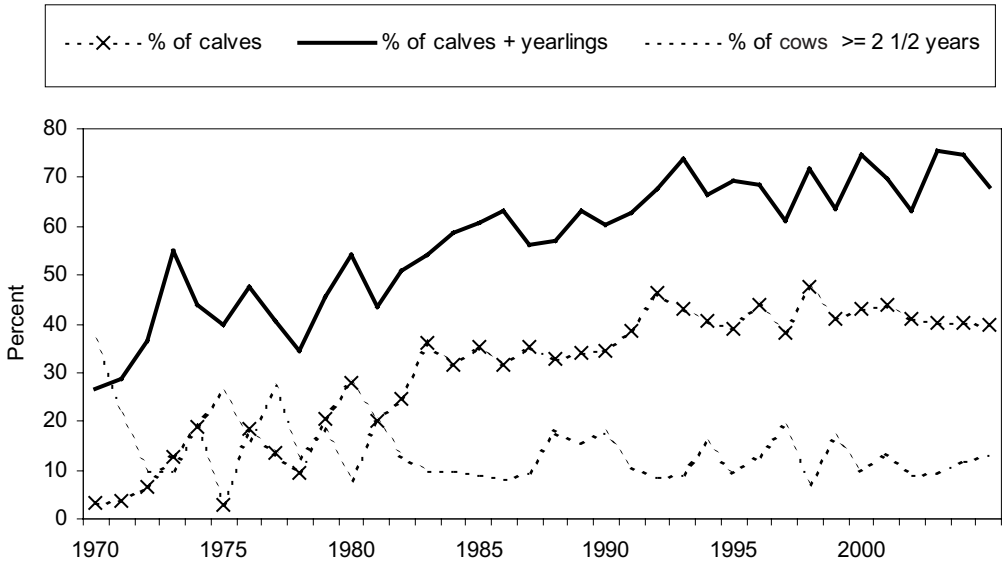

Fig. 7. Age composition of moose harvested at Værdalsbruket, Norway, 1969-2004.

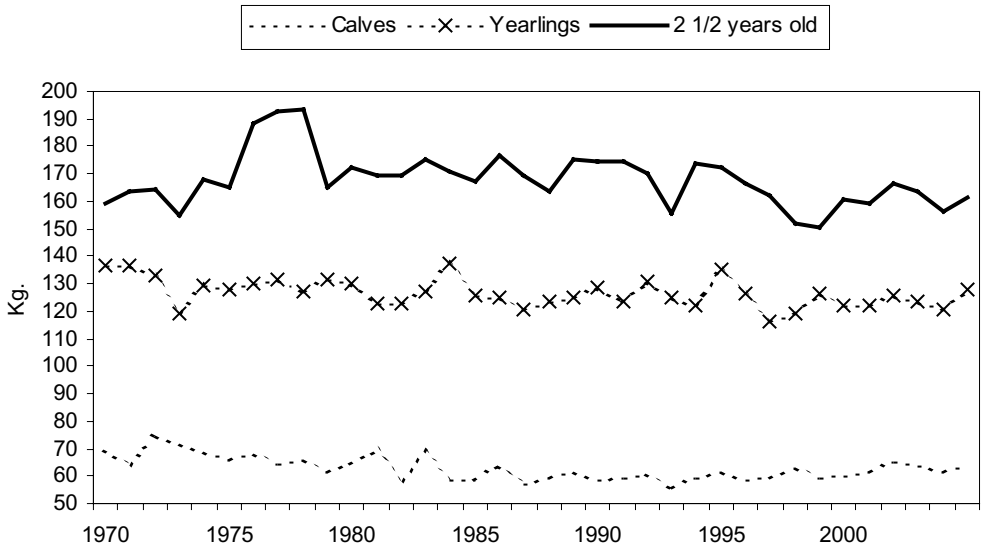

Fig. 8. Mean carcass weights of calves, yearlings, and two and a half year old moose harvested at Værdalsbruket, Norway, 1969-2004.

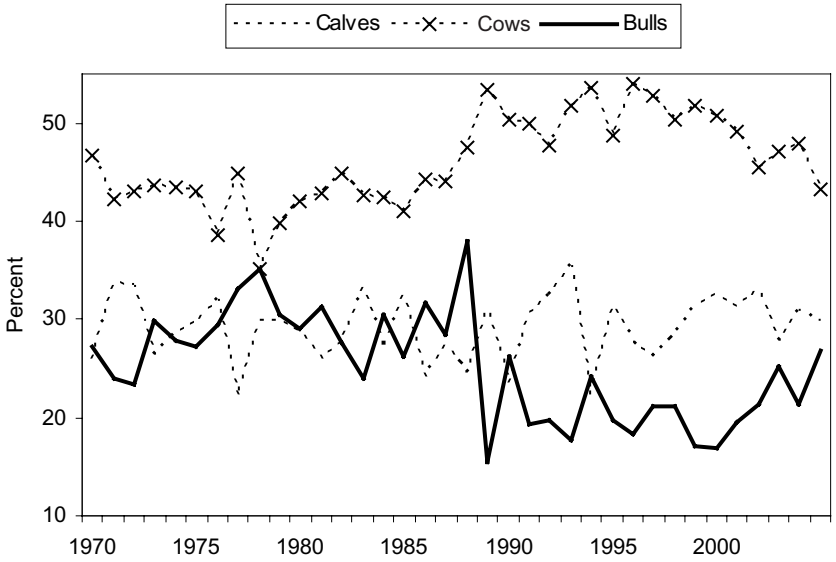

Fig. 9. Sex and age composition of moose observed by hunters during the hunting season at Værdalsbruket, Norway, 1969-2004.

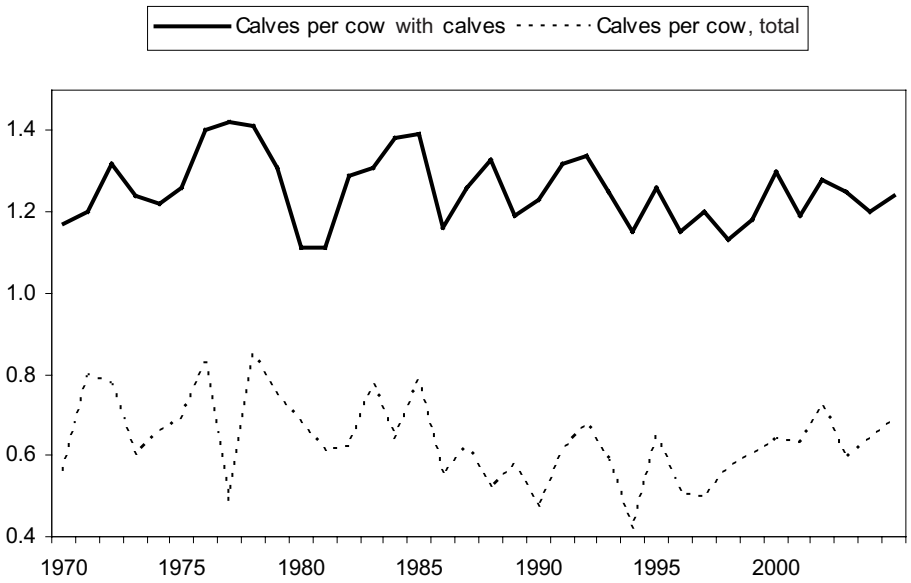

Fig. 10. Reproduction based on hunter observations during the hunting season at Værdalsbruket, Norway, 1969-2004.

Hunting pressure was gradually transferred to younger and smaller moose to reduce the harvest of mature moose (Fig. 12). This was accomplished by "education" of hunters, stipulations in their contracts, and a progressive pricing system. The hunter effort required to kill a moose, approximately 12 man-days per moose similar to that measured in Russia (Gaidar et al.1990), was stable despite the higher population since 1970 (Fig. 11), reflecting the increased demand on hunters to harvest the correct moose. Although hunter efficiency has not improved, effective population management has been realized through the selective harvest system. Since 1985 a stable, relatively high population has been maintained with high hunting pressure and harvest of young moose, thereby sparing most of the productive component of the population.

Hunter observations (number of moose observed per man-day, Fig. 11) to some extent describe the relative change in the moose population. However, it was obvious that after lengthening the season gradually after 1980, the mean number of moose observed declined in October and November because of the removal of 20-30% of the population; the majority early in the hunt. The long, late fall season also includes leaf fall and the first snow; periods which traditionally make moose more difficult to find. Thus, the rise in number of moose seen per man-day does not fully reflect the entire rise in the population. For the last 15 years Nord-Trøndelag county used CERSIM (Cervidae Simulation Model), a computer-based model that uses harvest statistics, hunter observations, and various biological parameters as input, to better integrate our hunter observations into population predictions. The calculations appear to be reliable, and are used to pre-determine the size and composition of moose harvest in subsequent fall seasons in each municipality.

Moose Density

Moose population density is primarily related to browse production and availability, snow conditions, and predation (Bubenik et al. 1975), and hunting pressure and strategy (Ritcey 1974, Timmermann 1987, Boer

1991). Værdalsbruket has about 400 km^2 of moose habitat including productive forests, other forestland, and marshland below tree line with a current harvest of 2.5 moose per 10 km^2. Population estimates based on harvests, observed population structure and reproduction, hunting pressure, and population growth indicated a prehunt (fall) density of 1.0-1.1 moose per km^2, and a winter density of 0.7-0.8 that underestimates localized winter concentrations. Current harvest in Norway is 3.0 moose per 10 km^2, with winter density of 0.8-0.9 moose per km^2. In the local county of Nord-Trøndelag harvest is 4.2 and some low lying, highly productive municipalities have harvests of 10-15 moose per 10 km^2. The population density at Værdalsbruket is similar to averages in Norway and Sweden (Pimlott 1959, Cederlund and Sand 1991), and higher than typical in North America (Karns 1998) or Russia (Baskin and Lebedeva 1987).

Population Structure

Because moose at Værdalsbruket are not harvested randomly, the harvest composition (Table 1, Figs. 6 and 7) does not reveal population structure of the herd. However, I believe that hunter observations provide a reasonable estimate of population structure in the hunting season (Fig. 9). Current population structure is a reflection of past harvest strategy and composition. The cow: bull ratio increased from approximately 1.50 to 2.50 after 1985, and recently declined to < 2.0. However, there are some biases due to moose behaviour, time and length of season, and differences in hunting pressure on various sex and age groups (Fig. 12). Thus, the estimates of 30% calves and 20-25% bulls are probably low. Although prime bulls have been protected to some extent, and a few are observed each year, their numbers are limited. It is difficult to increase the adult bull component of the population given continuous high hunting pressure of antlered moose.

Two reasons why the harvest of 60-65% males is sustainable, when only 52-54% are recruited, are that natural mortality and road/railway accidents are higher in cows. Cows are the most vulnerable segment because

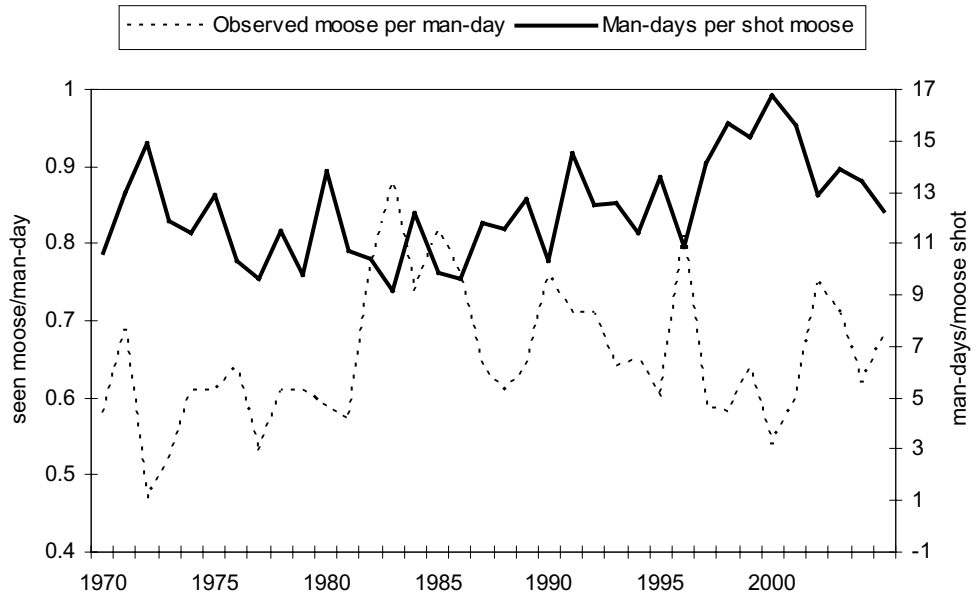

Fig. 11. Observed moose per man-day, and man-days per harvested moose during the hunting season at Værdalsbruket, Norway, 1969-2004.

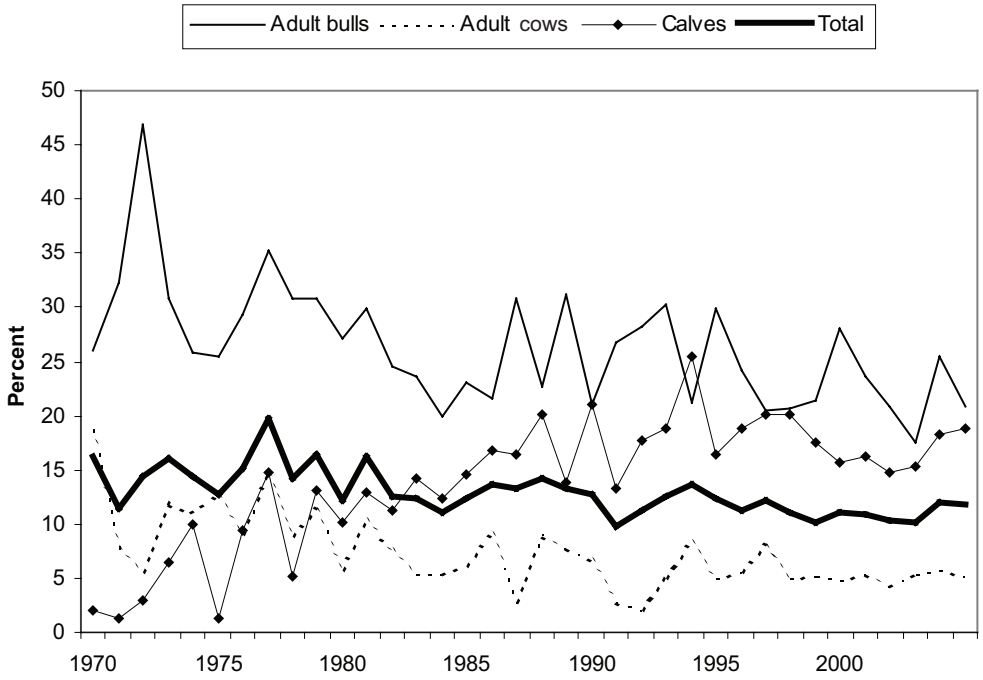

Fig. 12. Hunting pressure (harvest rate, %) on various sex and age groups of moose, Værdalsbruket, Norway, 1969-2004.

they are the largest and oldest segment of the population, they reside at lower elevations than bulls along roads and railways during winter, and they are in front during movements across roads, bad ice, and high water. Cows represent 80% of adult mortality from car collisions and 77% of all non-hunting losses in the area.

Body Weight

Body weight of moose in Norway is influenced by sex and age relative to quantity and quality of food, snow and other climatic conditions, population density relative to food sources, and genetic factors (Krafft 1956, Haagenrud and Lørdahl 1977, Hjeljord et al. 2000). It is believed that sex-age class weights have declined the last 20 years in conjunction with the increased moose population. Weight reductions might be expected in a high population density that reduces forage quantity and quality, dramatic change in environmental conditions (e.g., snow depth), and a skewed sex ratio causing delayed breeding and births.

Such relationships are important to investigate locally given the local management autonomy in Norway. Young moose are ideal for such evaluations because they undergo rapid growth between age classes, they are accurately aged, and their sample size is large. The average body weights of younger sex and age groups (calf-2.5 years) were reasonably stable at Værdalsbruket since 1980 (Fig. 8); obvious annual variation was probably due to winter severity. The stable weights of these young age classes indicate a moose population in balance with its food supply, and the ability of a strict harvest program to ensure such balance and a reasonable age and sex structure.

Reproduction

The possibility of lowered reproduction because of high population density and skewed population structure is central

to moose management concerns in Scandinavia. The productivity of 1.20 calves per reproductive cow, and 0.7 calves per cow (Fig.10) in Værdalsbruket, seems reasonable given the location. Cederlund and Sand (1991) found calf recruitment in south Sweden was twice that in northern Sweden. Markgren (1969) found that 51% of yearling cows ovulated in highly productive coastal areas and only 8% in inland habitat, and an adult ovulation frequency of 1.56 in coastal cows and 1.11 in inland cows.

Further, reproduction at Værdalsbruket has been relatively stable for the last 35 years (Fig. 9 and 10), despite variation in sex ratio of 1.5 to 3.0 cows per bull. A high cow:bull sex ratio typically results in a high percentage of late born calves. Taiga moose are serial maters (Bubenik 1998) and each cow occupies the bull for 3-5 days. Thus, a bull does not have the chance to mate with more than 2-3 cows in their first estrous, possibly fewer in low density populations.

The percentage of barren cows (young cows and "resting" cows) at Værdalsbruket has fluctuated minimally at 45-50% of all cows. The age and weight of cows are important factors in reproduction (Markgren 1969, Sæther 1987), and no cow is expected to reproduce every year; all have resting years and twins require more rest than single calves (Sand and Bergstrøm 2004); barren cows may be of any age (Schwartz 1998). In 1985-1995 the barren cow percentage at Værdalsbruket (55%) was somewhat higher than normal. Further, there was a concurrent 5% drop in the percentage of male calves in the harvest and the percentage of late born calves was high. If large bulls produce more male calves (Sæther et al. 2001), a lack of prime bulls may have influenced both the proportion of barren cows, the time of mating, and production of male calves at Værdalsbruket (Bubenik 1987, 1990, 1998; Sæther et al. 2001). Of interest is that the male fraction of harvested calves in Norway dropped from 56 to 51% from 1980 to 2003, and the low number of prime bulls in regional populations is a management issue in Scandinavia.

A slight increase in reproduction, a decline in barren cows, and an increase of male calves in the harvest have occurred at Værdalsbruket since 1995. The rise in reproduction is probably higher than indicated because of the extended hunting season and high hunting pressure on calves (Fig. 12). This higher production is probably associated with the higher mean age of cows, more bulls per cow, and more prime bulls in the population, all results of the selective harvest system.

FUTURE CHALLENGES

The data presented here indicate that a selective harvest system is an important and valuable tool in moose management. At Værdalsbruket it led to controlled population growth, improved age and sex structure, and stable production and body weights. Further, the implementation of the system was well received by hunters. The effectiveness of the system was largely dependent upon the level and progression of hunting price with body weight, and adherence to harvest guidelines that reflected population goals.

Future challenges include balancing the moose population density relative to growth and physical parameters, monitoring forest damage and effects on forest biodiversity, and implementing harvest strategies to manage population size relative to temporal changes in browse production. Of major importance is to focus moose management on reliable population data; specifically, accurate harvest statistics of sex and age composition, body weights, hunting pressure, and population characteristics including sex and age composition and reproduction. These data and continuous hunting pressure allow annual adjustments in harvest strategy that avoid abrupt, periodic changes in the

moose population.

Although the preferred browse species of rowan, aspen, and sallow/willows are heavily browsed in the primary wintering areas, forest damage and impact on biodiversity at Værdalsbruket is tolerable. Under these circumstances, population parameters are a better guide than forest damage to decide an appropriate population density, especially in spruce-dominated habitat. Regardless of overall winter density, there will always be over-browsing in localized areas of the winter range.

Given that hunting values are increasing and timber values have declined steadily since 1960, increased moose harvest and population density are possible. The population should be increased slowly, and controlled by a sensitive, selective harvest system. Should the habitat situation change, for instance by reduced clear-cutting and browse production, the moose population may require reduction. In that case, an increased harvest strategy should protect an adequate portion of adult cows and bulls. The important part of a selective harvest system is to protect and balance specific sex and age groups of the moose population, while maintaining high production and hunting opportunity. Future management programs should be designed to protect most mature moose, stabilize the cow:bull ratio at 1.5-2.0, and continue forestry practices beneficial to wildlife.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Anders Børstad – my successor at Værdalsbruket, and to Paul Harald Pedersen – wildlife manager at Nord-Trøndelag County, for their help in many ways. Furthermore, I am most grateful to all my North American moose biologist friends who have given me inspiration along the way since my stay at the University of British Columbia in 1968-1969 and the North American Moose Conference and Workshop in Alaska, 1968. Special thanks to Dr. Vince Crichton and Tim Timmermann, North American moose biologists, for valuable advice and critical review of the initial manuscript.

REFERENCES

AHLEN, I. 1975. Winter habitats of moose and deer in relation to land use in Scandinavia. Viltrevy 9:45-192.

ANGELSTAM, P., P.-E. WIKBERG, P. DANILOV, and K. NYGREN. 2000. Effects of moose density on timber quality and biodiversity restoration in Sweden, Finland and Russian Karelia. Alces 36:133-144.

BASKIN, L. M. 1987. Behaviour of moose in the USSR. Swedish Wildlife Research Supplement 1:377-387.

_____, and N. L. LEBEDEVA. 1987. Moose management in USSR. Swedish Wildlife Research Supplement 1:619-634.

BOER, A. H. 1991. Hunting: A product or a tool for wildlife managers? Alces 27:74-78.

BUBENIK, A. B. 1987. Behaviour of moose (*Alces alces*) of North America. Swedish Wildlife Research Supplement 1:333-366.

_____. 1990. Principles of sociobiological management based on the impact of maturation processes on population behaviour in moose. Abstracts of the Third International Moose Symposium, Syktyvkar, USSR:181.

_____. 1998. Behaviour. Pages 173-222 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D.C., USA.

_____, H. R. TIMMERMANN, and B. SAUNDERS. 1975. Simulation of population structure and size in moose on behalf of age-structure of harvested animals. Proceedings of the North American Moose Conference and Workshop 11:391-463.

CEDERLUND, G. N., and H. K. G. SAND. 1991. Population dynamics and yield of a moose population without predators. Alces 27:31-40.

CONNOR, K. J., W. B. BALLARD, T. DILWORTH, S. MAHONEY, and D. ANISONS. 2000. Changes in structure of a boreal forest community following intense herbivory by moose. Alces 36:111-132.

CUMMING, H. G. 1974. Annual yield, sex and age of moose in Ontario as indices to the effects of hunting. Naturaliste Canadien 101:539-558.

GAIDAR, A. A., N. N. GRAKOV, and B. M. ZHITKOV. 1990. The efficiency of collective moose hunts in a forest-taiga zone of Russia. Abstracts of the Third International Moose Symposium, Syktyvkar, USSR: 107.

HAAGENRUD, H. 1986. Elgens livshistorie. Pages 9-35 *in* P. Hohle and J. Lykke, editors. Elg og Elgjakt i Norge. Gyldendal Norsk Forlag, Oslo, Norway.

_____, M. HÅKER, and L. LØRDAHL 1975. Elgundersøkelsene i Grane,Vefsn og Hattfjelldal 1967-1975. Viltforskningen:1-41.

_____, and L. LØRDAHL. 1977. Vektutvikling om høsten hos elg i Trøndelag. (Carcass weight in moose from Trøndelag, Norway). Meddelelser fra Norsk Viltforskning 3(3):1-27.

_____, and _____. 1979. Sex differential in populations of Norwegian moose *Alces alces* (L.). Meddelelser fra Norsk Viltforskning 3(6):1-19.

HEPTNER, W. G., and A. A. NASIMOWITSCH. 1967. Der Elch. Die neue Brehm-Bucherei. Wittenberg Lutherstadt, Germany.

HJELJORD,O., E. RØNNING, and T. HISTØL. 2000. Yearling moose body mass: Importance of first year`s growth rate and selective feeding. Alces 36:53-59.

KARNS, P. D. 1998. Population distribution, density and trends. Pages 125-140 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D.C., USA.

KRAFFT, A. 1956. Størrelsen av norsk elg. Særtrykk av Jeger og Fisker 11 og 12:1-13.

KREFTING, L. W., and J. LYKKE. 1976. A comparison of moose habitat in North America and Norway. Proceedings XVI. IUFRO World Congress: 731-742.

LAVSUND, S. 1987. Moose relationships to forestry in Finland, Norway and Sweden. Swedish Wildlife Research Supplement 1:229-244.

LORENTSEN, Ø., B. WISETH, K. EINVIK, and P. H. PEDERSEN. 1991. Elg I Nord-Trøndelag. Fylkesmannen i Nord-Trøndelag, Rapport 1:1-208.

LYKKE, J. 1964. Elg og Skog. Studies of moose damage in a conifer forest area in Norway. Papers of the Norwegian State Game Research Institute 2(17):1-57.

_____. 1974a. Moose management in Norway and Sweden. Naturaliste Canadien 101:723-735.

_____. 1974b. Elgens økologi og skjøtsel. Moose ecology and management. Norwegian Journal of Forestry 82:235-337.

_____, and I. M. COWAN. 1968. Moose management and population dynamics on the Scandinavian Peninsula, with special reference to Norway. Proceedings of the North American Moose Conference and Workshop 5:1-22.

LYKKE, L. 1952. Avgang i elgstammen utenom jakttiden. Jeger og Fisker 10:369-373.

_____. 1960. Elgen og Elgjakten. Pages 197-219 *in* P.Hohle, editor. Jakt og Fiske i Norge, bind Jakt. Norsk Arkivforskning, Oslo, Norway.

_____. 1962. Elgtelling i Verdal. Jakt-Fiske-Friluftsliv 91:206-207.

_____. 1968. Forvaltningen av en elgstamme. Jakt-Fiske-Friluftsliv 7:310-313.

MARKGREN, G. 1969. Reproduction of moose in Sweden. Viltrevy 6(3):127-299.

MERCER, W. E., and M. STRAPP. 1978. Moose management in Newfoundland 1972-1977. Proceedings of the North American Moose Conference and Workshop 14:227-233.

PIMLOTT, D. H. 1959. Moose harvests in Newfoundland and Fennoscandian countries. Transactions of the North American Wildlife Conference 24:422-448.

RAUSCH, R. A., R. J. SOMMERVILLE, and R. BISHOP. 1974. Moose management in Alaska. Naturaliste Canadien 101:705-721.

RITCEY, R. W. 1974. Moose harvesting programs in Canada. Naturaliste Canadien 101:631-642.

SÆTHER, B.-E. 1987. Patterns and processes in the population dynamics of the Scandinavian moose (*Alces alces*): Some suggestions. Swedish Wildlife Research Supplement 1:525-537.

_____, M. HEIM, E. J. SOLBERG, K. JAKOBSEN, R. OLSTAD, J. STACY, and M. SVILLAND. 2001. Effekter av rettet avskyting på elgbestanden på Vega. Effects of sex- and age-specific harvesting on the moose population on the island of Vega. NINA Fagrapport 049:1-39.

SAND, H., and R. BERGSTRØM. 2004. Kalvar kostar kon krafter. Svensk Jakt 5:70-73.

_____, O. LIBERG, P. AHLQVIST, and P. WABAKKEN. 2004. Algjakten kan hotas i vargområden. Svensk Jakt 10:84-86.

SCHWARTZ, C. C. 1998. Reproduction, natality and growth. Pages 141-172 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington D.C., USA.

SKUNCKE, F. 1949. Algen. Studier, jakt och vård. P.A.Norstedt & Sons Forlag, Stockholm, Sweden.

SOLBERG, E. J., and B.-E. SÆTHER. 1999. "Sett elg". Elgen: 63-67.

_____, V.GRØTAN, M. HEIM, and B.-E. SÆTHER. 2001. Velger vi skogens konge eller skogens hellige kyr? Elgen 11:44-48.

THOMPSON, I. D. 1990. Effects of moose on structure and composition of forests in North America. Abstracts of the Third International Moose Symposium, Syktyvkar, USSR: 75.

TIMMERMANN, H. R. 1987. Moose harvest strategies in North America. Swedish Wildlife Research Supplement 1:565-579.