SCIENCE-BASED GUIDELINES FOR MANAGEMENT OF MOOSE IN YUKON

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SCIENCE-BASED GUIDELINES FOR MANAGEMENT OF MOOSE IN YUKON

Yukon Department of Environment
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Copies available from:

Yukon Department of Environment
Fish and Wildlife Branch, V-5A
Box 2703, Whitehorse, Yukon Y1A 2C6
Phone (867) 667-5721, Fax (867) 393-6263
Email: environmentyukon@gov.yk.ca

Also available online at www.env.gov.yk.ca

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Summary

The following guidelines provide an overview of the scientific information used by Environment Yukon and other parties, as appropriate, to make monitoring and harvest management decisions specific to moose (*Alces americanus*) populations in Yukon. They are not meant to replace management planning but are a resource that will help promote consistent science-based input and responses to management plans, programs, and regulation proposals. They are a working document that will be reviewed periodically and updated based on new information. Future iterations of the guidelines are intended to include a section on mitigating impacts of land use on moose.

For clarity, the information in these guidelines is only part of what is needed to make wildlife management decisions. It complements other sources of information used to manage wildlife in Yukon, including traditional and local knowledge, as well as wildlife management processes undertaken by the Yukon Fish and Wildlife Management Board (YFWMB), Wildlife Management Advisory Council-North Slope [WMAC-(NS)], renewable resources councils (RRCs), and others.

Decisions based on these guidelines will help ensure the long term sustainability of Yukon's moose populations, resulting in long term benefits for Yukoners.

Overview of moose management guidelines

Two of the primary tools used to manage moose populations in Yukon are population monitoring (Section 3.1) and harvest management (Section 3.3).

Population monitoring (Section 3.1)

1. *Moose in Yukon are managed in 61 Moose Management Units (MMUs) (Section 2.1).*
    - These units are generally groupings of Game Management Subzones (GMSs) that encompass, to the best extent possible, biologically distinct moose populations.
    - MMU boundaries are modified when new information is available.
    - Harvest is evaluated at the MMU scale although management actions may apply to individual GMSs.
2. *Natural moose densities (number of moose per 1,000 km^2) in Yukon are relatively low when compared to those observed in other regions of North America and the world (Section 2.6.1).*
    - Moose densities throughout Yukon generally range between 100 and 250 moose for every 1,000 km^2 of suitable moose habitat.
3. *Aerial surveys are currently the most effective and efficient tool to assess the status of moose populations. (Section 3.1)*
    - Early-winter aerial surveys provide estimates and confidence intervals for the total number of moose in an area and the breakdown of adult cows, adult bulls, yearlings and calves.

- The criteria used to select which MMUs to survey include:
    - Amount of access;
    - Harvest rates and availability of harvest information from all users;
    - Current and anticipated land use activities; and
    - Social, financial, and political considerations.
- Generally, moose populations do not exhibit large changes in population size from year to year. MMUs are not surveyed more frequently than every 5 years as this is the amount of time it takes to detect if a population has changed in size and trend.
- Survey results provide the information required to estimate the sustainable harvest for an MMU.

4. *Survival of young moose generally ranges from 10 to 50 calves and 5 to 40 yearlings per 100 adult cows in early winter (Section 2.6.3).*
    - Calf survival is represented by recruitment ratios (the number of calves per 100 adult cows) and is an indicator used to estimate the number of calves entering the population as yearlings.
    - Yearling survival is represented by yearling ratios (the number of yearlings per 100 adult cows) and is an indicator used to estimate the number of yearlings entering the population as adults.
    - Individual estimates of recruitment are “snapshots” in time and will vary from year to year. A single “good” or “bad” year of recruitment is not sufficient to make management recommendations.
5. *Between 5 and 15 of every 100 adult moose die of natural causes each year (Section 2.6.4).*
    - Most natural adult moose mortality is caused by predation, but other factors such as weather, forage availability and quality, and disease or parasites also play a role.

Harvest management (Section 3.3)

Harvest rate recommendations are guidelines and may be adjusted where detailed population-specific information is available. Guidelines must also be considered in light of meeting obligations under the *Umbrella Final Agreement* (1993) and *Inuvialuit Final Agreement as Amended* (2005) related to conservation and long term optimum productivity.

The following are guidelines for harvest management within specific MMUs:

6. *Management actions may be required when the adult sex-ratio falls below 30 bulls per 100 cows.*
    - The hunting of bulls can decrease the ratio of adult bulls to adult cows in a population.
    - Adult sex ratios (number of bulls per 100 cows) strongly skewed towards females may impact reproductive success.
7. *Management actions may be required when successive early-winter aerial surveys detect a decline in the total population.*

8. *Management actions may be required when the total harvest in an MMU approaches or exceeds sustainable limits.*
9. *In surveyed MMUs where the number of adult bulls is known, the recommended harvest rate is 10% of the adult bull population.*
10. *In MMUs where no survey information is available, recommended harvest rates are based on estimated population density (number of moose per 1,000km^2 of moose habitat):*
    - Less than 110 moose per 1,000 km^2: No sustainable harvest.
    - 110 to 145 moose per 1,000 km^2: a bull only harvest rate of up to 2% of total estimated population size.
    - 145 to 180 moose per 1,000 km^2: a bull only harvest rate of 2-3% of total estimated population size.
    - More than 180 moose per 1,000 km^2: a bull only harvest rate of 3% of total estimated population size.
    - More than 350 moose per 1,000 km^2: higher harvest rates may be sustainable but will require a case-by-case assessment of the MMU, given current harvest pressure, potential harvest pressure given access, population trend, etc.
    - Population density in unsurveyed MMUs is estimated based on densities in similar adjacent areas, habitat availability, harvest pressure, access levels, and local information
11. *All cow harvest should be avoided.*
    - Cow harvest is associated with a high risk of population decline.
        - Cow harvest has a greater impact on populations than bull harvest because it also represents a potential loss in calves/reproductive capacity of the population.
    - The harvest of 1 cow is equal to the harvest of 3 bulls.
    - More than 80% of adult cows produce calves each year. Cows without calves ("dry cows") are generally those that have lost their calf and will reproduce again in subsequent years.
12. *Bull only harvest rates should be adjusted based on the number of cows removed from the MMU, in which the removal of 1 cow is equal to the removal of 3 bulls.*

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1 Introduction

1.1 Purpose

The following guidelines provide an overview of the scientific information used by Environment Yukon and other parties, as appropriate, to make monitoring and harvest management decisions specific to moose (*Alces americanus*) populations in Yukon. The intent of the guidelines is to help users provide consistent science-based input and responses to management plans, programs, and regulation proposals based on the most up to date scientific information.

Guidelines are not the same as a management plan but they will be used to provide science-based direction for managing wildlife populations and assessing population status and trend. Monitoring and management recommendations depend, in part, on this assessment; for example, survey work may be prioritized for a population deemed to be at increased risk of decline because of high harvest pressure. Environment Yukon uses as many lines of evidence as possible to make inferences about a population to ensure management actions are sound.

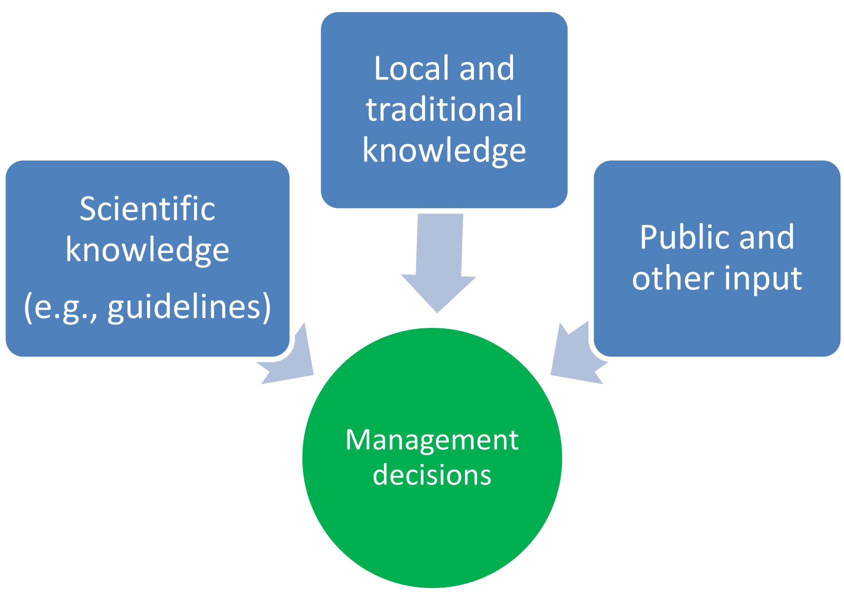

Figure 1. Role of guidelines in wildlife management in Yukon.

These guidelines are a starting point for discussion and may be adjusted pending more specific, objective knowledge of a population. They are one part of what is needed to make wildlife management decisions (Figure 1). Processes exist in Yukon to integrate scientific, local, and traditional knowledge and ensure that this knowledge is used to inform wildlife management. Public participation in wildlife management processes is facilitated by public bodies such as the Yukon Fish and Wildlife Management Board (YFWMB), Wildlife Management Advisory Council-North Slope [WMAC-(NS)], renewable resources councils (RRCs), and others. For more information on the role of the YFWMB and RRCs in wildlife management, please see Chapter 16 of the *Umbrella Final Agreement* (1993). For more information on the role of WMAC-(NS) in fish and wildlife management, please see the *Inuvialuit Final Agreement as Amended* (2005).

1.2 Management and regulatory context

Stewardship of natural resources in Yukon is mandated through the Wildlife Act, Environment Act and constitutionally entrenched land claim agreements. Within Yukon land claim agreements, the principles of conservation[1,2], long term optimum productivity, and sustainability guide management programs while actions are guided through related legislation, policy, guidelines, or formal agreements.

1.3 Management principles for Yukon's wildlife

Management of Yukon's wildlife is guided by the following principles. These principles are derived from fundamental practices within the fields of wildlife management and conservation biology.

1. Naturally self-sustaining wildlife populations are the principal management objective.
2. Wildlife populations will be, to the best extent possible, managed within their natural range of variation[3].
3. Management of human activity, including harvest, disturbance, and land use are the primary tools available for recovering or maintaining wildlife and wildlife habitat.
4. Management will be adaptive.
5. The interests of all consumptive and non-consumptive users will be recognized and considered in the management of wildlife populations.
6. Management will be guided by the precautionary principle.
7. Management will, to the best extent possible, be ecosystem based.

1.4 Review process and future iterations of the guidelines

These guidelines are part of a living document which may be revised as new information becomes available. For example, future iterations of this document

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[1] Conservation as defined in the *Umbrella Final Agreement* (UFA; 1993): the management of Fish and Wildlife populations and habitats and the regulation of users to ensure the quality, diversity and Long Term Optimum Productivity of Fish and Wildlife populations, with the primary goal of ensuring a sustainable harvest and its proper utilization. In the UFA, Long Term Optimum Productivity is defined as productivity required to ensure the long term continuation of a species or population while providing for the needs of Yukon Indian People and other harvesters and non-consumptive users of Fish and Wildlife in the short term.

[2] Conservation as defined in the *Inuvialuit Final Agreement as Amended* (IFA; 2005): the management of the wildlife populations and habitat to ensure the maintenance of the quality, including the long term optimum productivity, of these resources and to ensure the efficient utilization of the available harvest.

[3] Meeting the principle of optimum productivity may mean managing for moose densities at the higher end of this range in areas where demand for hunting opportunities is high.

are intended to include a section on mitigating impacts of land use, as our knowledge of the specific responses of Yukon's moose to human activity increases. Currently, Environment Yukon reviews and provides advice on a variety of land use and development applications, most commonly under the Yukon Environmental and Socio-Economic Assessment Act (YESAA). Other legislation, in addition to the Wildlife Act, Environment Act, and land claim agreements, is in place to ensure responsible resource development in moose habitat. These include the Forest Resources Act, Quartz Mining Act, and Placer Mining Act.

In addition to the as-needed revisions, these guidelines will be reviewed and updated, in full, every 10 years. This periodic review process will ensure the document remains current with scientific understanding, and relevant to Yukon.

2 Species background

2.1 Description, distribution and status

Moose (*Alces americanus*), along with their close relative the Eurasian elk (*Alces alces*), are the largest members of the deer family (Cervidae) (Hundertmark et al. 2002, Bowyer et al. 2003, Hundertmark and Bowyer 2004, Bradley et al. 2014). Four subspecies are recognized in North America and two currently inhabit Yukon: the tundra moose (*A. americanus gigas*) and the northwestern moose (*A. americanus andersoni*).

The earliest known *A. americanus* fossils suggest it is a relatively young species, originating in Europe from the now extinct *A. latifrons* approximately 100,000 years ago. *A. americanus* first appeared in the fossil record of North America approximately 9,700 years ago (Bowyer et al. 2003, Bradley et al. 2014), and likely colonized North America across the Bering land bridge as part of a population expansion that occurred 14,000 years ago at the end of the last ice age (Hundertmark et al. 2002, Hundertmark and Bowyer 2004).

Moose occupy all boreal and subalpine habitats throughout the territory. Over the last 3 decades, moose have continued to expand their range onto the Yukon North Slope and are now common as far north as the Beaufort Sea (Environment Yukon, *unpublished data*). The larger tundra moose generally occupies the northern half of the territory while the northwestern moose occupies the southern half. A broad east-west transition runs through central Yukon and there is likely considerable intermixing between the subspecies.

There are an estimated 70,000 moose in Yukon, which is a coarse estimate derived from summing all the population estimates in each GMS within the territory. The conservation status of moose in Yukon has been described as "secure" (Yukon Conservation Data Centre 2014). Moose are listed as "big game" under Yukon's Wildlife Act.

In Yukon, moose are currently described and managed in 61 Moose Management Units (MMUs) (Figure 2; Table 1). MMUs are meant to encompass, to the best extent possible, biologically distinct moose populations. Boundaries are based primarily on natural geographical features (e.g., lakes, watersheds, topography), roads, and in some cases on radio collared moose movement patterns. MMUs are generally based on groupings of Game Management Subzones (GMS) because this is the spatial scale at which harvest data is collected. Recognizing that most GMS boundaries are in valley bottoms and not ideal to delineate moose populations, case-specific adjustments are made to MMU boundaries when there is enough information to more accurately depict a population. Boundaries of MMUs are updated periodically when new information is available.

2.2 Habitat requirements

Moose are found in a mosaic of habitat types that provide abundant deciduous browse (willow, aspen and birch) interspersed with stands of mature conifer that provide cover from predators as well as thermal and snow interception cover. In locations with low snowfall, moose may use the subalpine shrub zone year-round, while in other areas moose may migrate seasonally to avoid deep snow. Moose movements and habitat use represent trade-offs between accessing high quality forage, minimizing energy expenditure, and avoiding predation risk. Because disturbances like fire are common in the boreal forest and early successional communities are quick to regenerate, food availability (primarily willows) is typically not limiting for moose.

Moose generally prefer dense shrub habitats where abundant browse can be found including:

- Riparian areas (Jacqmain et al. 2008).
- Floodplains and deltas (Collins and Helm 1997, MacCracken et al. 1997).
- Subalpine climax willow communities (Poole and Stuart-Smith 2005).
- Early successional communities associated with disturbed habitats such as recently burned or logged forest stands (Maier et al. 2005, Stephenson et al. 2006).

2.3 Mineral licks

All Yukon ungulates use mineral licks, which are areas where dissolved elements or clays have been naturally deposited. Mineral licks, which are scattered throughout Yukon, provide animals with essential minerals such as sodium, magnesium and trace elements necessary for dietary and health reasons (Ayotte et al. 2006). Mineral licks influence how moose are distributed across the landscape at different times of the year (Panichev et al. 2002) and can have an important influence on population health. While moose visit mineral licks throughout the year, use is greatest during spring and early summer as these are the periods when the deficiency between nutritional demands and the chemical composition of forage is greatest (Rea et al. 2004, Ayotte et al. 2006).

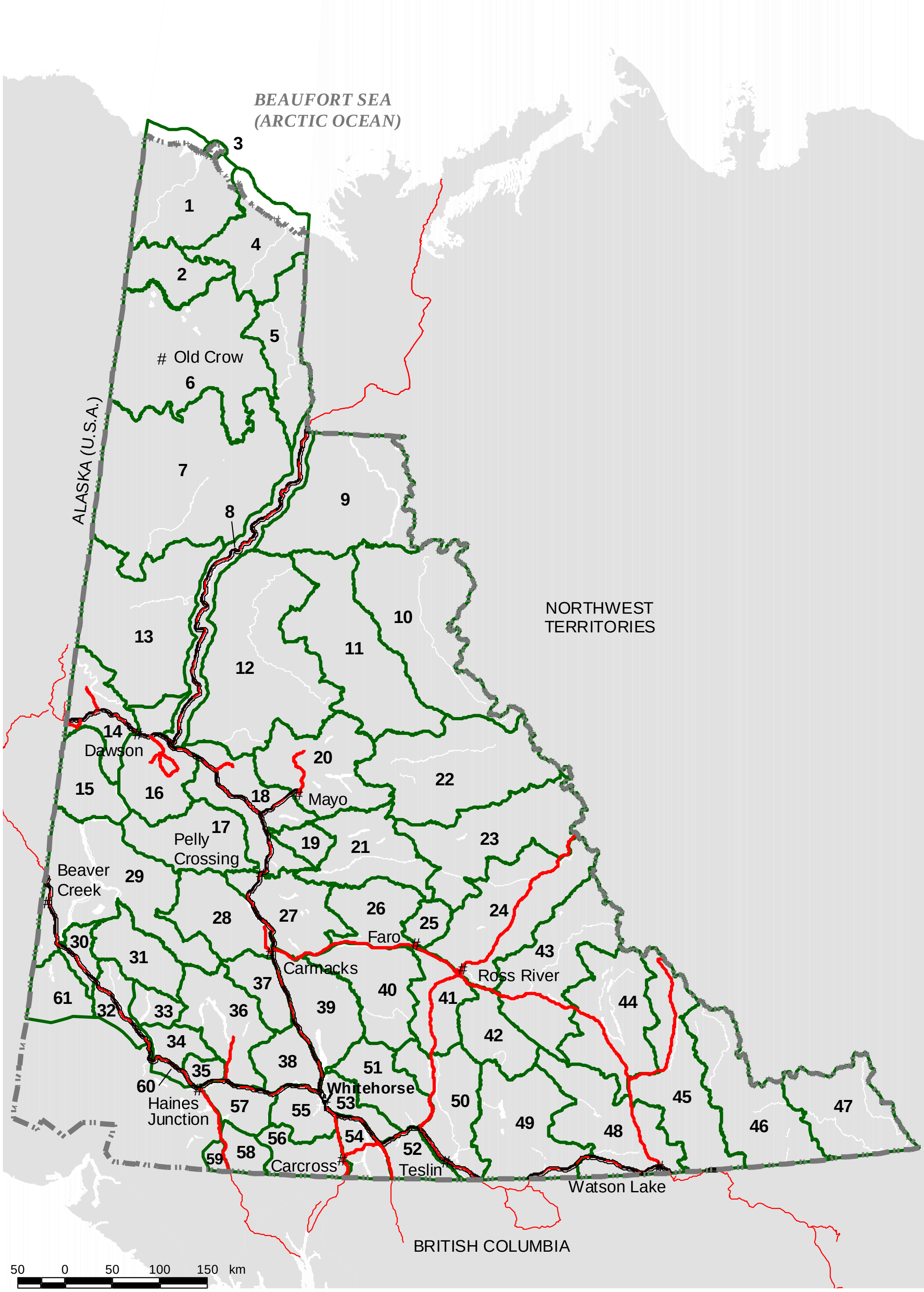


Figure 2. Moose Management Units (MMUs) in Yukon. See Table 1 for associated names.

Table 1. Names of Moose Management Units (MMU) in Yukon.

MMU ID	MMU NAME	MMU ID	MMU NAME
1	Ivvavik National Park	35	Paint Mountain
2	Vuntut National Park	36	Aishihik
3	Herschel Island	37	Nordenskiold R
4	North Slope	38	Sifton-Miners Range
5	North Richardsons	39	Lake Laberge
6	Old Crow Flats	40	Big Salmon
7	Fishing Branch/Eagle Plains	41	South Canol
8	Dempster Highway	42	Pelly Mountains
9	South Richardsons	43	Pelly River
10	Snake River	44	Frances Lake
11	Wind River	45	Hyland River
12	Hart River	46	Coal/Rock River
13	Ogilvie River	47	Beaver/La Biche Rivers
14	Top of the World	48	Liard Basin
15	Matson Creek	49	Wolf Lake/CassiarMtns
16	Dawson Gold Fields	50	Nisutlin River/Quiet Lake
17	Lower Stewart R	51	Teslin River
18	Upper Klondike Highway	52	Teslin Burn
19	Ddhaw Ghro	53	Whitehorse
20	Mayo	54	Mount Lorne
21	Lower MacMillan River	55	Fish Lake
22	Upper Stewart River	56	Wheaton River
23	Upper MacMillan River	57	Alsek North
24	Ross River	58	Alsek South
25	Faro	59	Tatshenshini River
26	Glenlyons/Lower Tay R	60	Jarvis River
27	Tatchun	61	Donjek River/White River
28	Carmacks West		
29	White River		
30	Koidern		
31	Kluane North		
32	Kluane River/Duke River		
33	Talbot Arm		
34	Cultus		

2.4 Habitat use and selection

Calving habitat – Selection for calving habitat represents a balance between meeting nutritional requirements for lactation and minimizing the risk of predation on newborn calves. Riparian habitats are especially important for calving in Yukon because of the combination of forage availability, cover, and proximity to water, which provides an escape from predators.

Summer habitat – During summer, most moose are typically associated with habitats with the greatest food availability (Dungan and Wright 2005), which are often in riparian areas (Fraser et al. 1980, MacCracken et al. 1993, Bump et al. 2009).

Summer habitats must also provide protection from predation as this is when calves are especially vulnerable (Gasaway et al. 1983, Larsen et al. 1989, Gasaway et al. 1992, Boertje el al. 2009). Consequently, females with calves primarily select habitats with maximum cover, such as dense conifer stands, over forage availability (Miquelle et al. 1992, Bowyer et al. 2001).

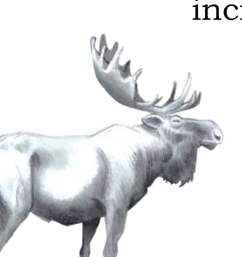
Winter habitat – Moose typically select winter habitats with high shrub density (primarily willow) and low crown cover when foraging (Suring and Sterne 1998; Poole and Stuart-Smith 2005, Poole et al. 2007). Mature forest stands become important for cover from predators, for providing thermal protection, and for relief from deep snow conditions when traveling (Poole and Stuart-Smith 2005, Sand et al. 2006, Gillingham and Parker 2008, Lundmark and Ball 2008).

Typically, moose in Yukon move to higher elevations in the early winter period and then descend to lower elevations in late winter (Johnston et al. 1984, Smits 1991). Differences in elevation movement patterns among populations can often be attributed to avoidance of deep snow and movement to areas with abundant browse. Because patterns of snow accumulation vary among locations and years, differences in movement patterns are expected.

2.5 Climate change

Scientists predict increased average global temperatures and changes in precipitation regimes as a result of anthropogenic contributions of greenhouse gases to the atmosphere (Post et al. 2009). The most rapid and severe changes associated with this trend are expected for northern regions like Yukon and Alaska (ACIA 2005; IPCC 2007). Because of associated shifts in climate envelopes, scientists predict distributional shifts for many species and changes in habitat composition (Walther et al. 2002).

Such ecological changes have already been observed in the north, including the upward migration of the treeline observed in southwestern Yukon (Danby and Hik 2007) and the increase in shrub density in Alaska (Sturm et al. 2001, Tape et al. 2006). Changing climatic regimes may also lead to increased winter precipitation (i.e., snow; Environment Yukon 2009), more icing events, changes in the timing of spring green-up, the emergence of new diseases and parasites (Altizer et al. 2013), and increased forest fire frequency due to increasing temperatures (Gustine et al. 2014).



In Yukon, studies predict an increase in productivity of browse species like willow and other shrubs as a result of the increased precipitation and temperature (Sturm et al. 2001, Tape et al. 2006). If so, then climate change may benefit moose in many areas of Yukon. Areas like the North Richardson Mountains have experienced dramatic population increases from at least 266 moose in 1989 to 678 in 2013, likely as a result of shrub invasion (Environment Yukon, *unpublished data*). However, moose are vulnerable to thermoregulatory (heat) stress and links between a warming climate and declining moose populations in southern areas have been suggested (Murray et al. 2006, Lenarz et al. 2009, 2010, Broders et al. 2012). Changes in Yukon's climatic conditions also have the potential to influence patterns of disease and parasitism in moose. For example, winter ticks are generally believed to be expanding their geographic range north as a result of climate change (Kutz et al. 2009).

Predicting the magnitude and direction of climate change impacts on moose distribution and abundance in Yukon is difficult, but is still an important consideration when developing long term management and monitoring actions for moose.

2.6 Population biology

2.6.1 Density

Moose densities throughout Yukon generally range between 100 and 250 moose for every 1,000 km^2 of suitable moose habitat, although densities in excess of 400 moose for every 1,000 km^2 have been recorded. Natural moose densities in Yukon are relatively low when compared to other regions of North America and the world. These low densities are primarily the result of moose coinciding with three relatively intact predator populations (grizzly bears, black bears and wolves), which results in high predation pressure (Larsen et al. 1989, Gasaway et al. 1992, Van Ballenberghe and Ballard 1994, Boertje et al. 1996, Crete and Courtois 1997, Hayes et al. 2000, Hayes and Harestad 2000, Hayes et al. 2003, Boertje et al. 2009, Boertje et al. 2010).

Most evidence suggests that, in unexploited and lightly harvested multi-predator systems, the combined predation of bears and wolves in areas where moose are the primary prey can hold moose abundance in a low-density dynamic equilibrium (LDDE; Messier and Crete 1985, Van Ballenberghe 1987, Larsen et al. 1989, Hayes and Harestad 2000). In their review of 36 study sites in Alaska and Yukon, Gasaway et al. (1992) found that areas with lightly harvested bear and wolf populations had moose densities of less than about 400 moose per 1,000 km^2. Only in areas with a single or no predator species, where predators were harvest limited or had undergone control, or where moose were a secondary prey species, did moose densities normally exceed 400 moose per 1,000 km^2. Studies have not found habitat to be a significant limiting factor for northern moose populations (Gasaway et al. 1992).

2.6.2 Reproduction

Most moose populations in higher density areas tend to exhibit a communal or harem breeding strategy where dominant bulls attract and defend small groups of females against competing bulls (Environment Yukon, *unpublished data)*. Alternatively, some forest-dwelling moose use a serial “pair mating” strategy (Environment Yukon, *unpublished data*). A male finds a female nearing her receptive period and if the cow accepts the bull, he stays with her until she is bred. After mating, the bull moves on to find another receptive cow. This mating strategy also is observed in areas where moose densities have been reduced by overharvest (Environment Yukon, *unpublished data*).

A cow moose generally mates for the first time when she is 2.5 years old. Age at first reproduction and twinning rates are typically related to climate and nutrition in a specific area (Pimlott 1959, Franzmann and Schwartz 1985). There is currently very little scientific information on twinning rates for Yukon moose because most aerial surveys are conducted in early-winter when most calf mortality has already occurred. Calf production varies with cow age, with yearling cows and those older than 15 years producing the fewest calves (Saether and Haagenrud 1983, Schwartz and Hundertmark 1993, Ericsson et al. 2001).

More than 80% of adult cows produce calves each year (Larsen et al. 1989, Gasaway et al. 1992). Cows without calves (“dry cows”) are usually those that have lost their young and will reproduce again in subsequent years. Timing of parturition (birth) in moose appears to be consistent among years and unrelated to short-term changes in their environment (Bowyer et al. 1998). Sigouin et al. (1997) compiled calving data from 18 studies around the world to find that most calving takes place between May 15 and June 8. In Yukon, the median calving date is May 25 and parturition is highly synchronized (Larsen et al. 1989). However, poor female body condition has been correlated to later births in other areas (Testa and Adams 1998).

2.6.3 Calf and yearling recruitment

Calves are the segment of the population with the lowest survival rates. Survival rates vary depending on predation rates, habitat quality, weather and other factors such as disease. Most natural mortality occurs within the first 6 weeks following birth (Larsen et al. 1989, Ballard et al. 1991). Predators limit moose populations by preying primarily on juveniles (i.e., calves and yearlings; Gasaway et al. 1983, Larsen et al. 1989, Gasaway et al. 1992, Hayes et al. 2000, Hayes et al. 2003, Boertje et al. 2009). Mean calf recruitment for Yukon areas surveyed since the early 1980’s is variable from year to year and generally ranges from 10 to 50 calves per 100 adult cows in early winter (average is 29 calves per 100 adult cows, Environment Yukon, *unpublished data*).

Bear predation is most common in the first 2 months of a calf’s life, while wolf predation is considered to have a greater influence in the remainder of the calf’s first year (Larsen et al. 1989, Ballard et al. 1981, Ballard et al. 1991, Hayes et al. 2003). Recruitment ratios (number of yearlings that survive to become members of the adult breeding population) are highly variable from year to year and area to area, but in Yukon, generally range from 5 to 40 yearlings per 100 adult cows in early winter (Gasaway et al. 1992, Environment Yukon, *unpublished data*). The mean number of yearlings observed in Yukon during early-winter aerial surveys conducted since the early 1980's is 18 yearlings per 100 adult cows in early winter (Environment Yukon, *unpublished data*). Winterkill is occasionally important to moose population dynamics, as it may result in poor recruitment rates.

2.6.4 Adult mortality

Most natural adult moose mortality is caused by predation, but other factors such as weather, forage availability and quality, and disease and parasites also play a role (Larsen et al. 1989, Gasaway et al. 1992, Bertam and Vivion 2002, Boertje et al. 2009). Depending on the system, either bears or wolves can be the primary cause of adult mortality (Larsen et al. 1989, Bertram and Vivion 2002, Boertje et al. 2009). Based on studies conducted in Yukon and Alaska, and summarized by Van Ballenberghe and Ballard (1998), it is likely that between 5 and 15 of every 100 adult moose in Yukon die of natural causes each year. Most studies in Alaska and Yukon have determined that winterkill on adult moose is negligible (Keech 2005; Boertje et al. 2009) unless there is severe cold combined with deep snow (Bishop and Rausch 1974). For a population to remain stable, average total mortality must equal average recruitment.

2.6.5 Adult sex ratio

In the absence of hunting, adult sex ratios can range widely, from 100 bulls per 100 cows (Peterson 1977: Isle Royale) to 29 bulls per 100 cows (Miquelle et al.1992: Denali Park) depending on area-specific life-history strategies. Generally, naturally regulated populations will have sex-ratios near parity whereas populations with bull-only harvests exhibit more female biased sex-ratios. In Alaska, ratios of 5 to 12 bulls per 100 cows have been reported for areas experiencing intense hunting pressure (Bishop and Rausch 1974). Yukon aerial survey results from mostly harvested areas average 64 bulls per 100 cows and range from 27 to 117 per 100 adult cows depending on survey year and area (Environment Yukon, *unpublished data*).

In Yukon, harvest restrictions are considered when post-hunt adult sex-ratios fall below 30 bulls per 100 cows, in part to ensure no impact of low bull numbers on reproductive success. This approach is consistent with other jurisdictions with low-density moose populations (Alaska: Young and Boertje 2008, British Columbia: Hatter 2009) and available literature (Schwartz et al. 1982, Timmermann 1987, Thompson 1991, Aitkin and Child 1992, Timmermann 1992, Schwartz and Hundertmark 1993, Schwartz 1998, Laurian et al. 2000, Environment Yukon, *unpublished data*). However, there is currently no clear evidence of a minimum bull-cow ratio that will ensure that there is no effect on timing of breeding and birth, offspring sex-ratio, and survival.

2.6.6 *Disease and parasites*

Currently, there are no active surveillance programs to assess the range and frequency of diseases and parasites affecting Yukon moose; however, passive disease surveillance has detected evidence of disease and parasites, or exposure to pathogens, in individual animals (Appendix 1). Despite this, no population level effects of any disease or parasite infection have been identified in Yukon moose.

Winter ticks (*Dermacentor albipictus*) have been found on a few road-killed moose in south-central Yukon. Prior to ~1990, it was believed the Yukon climate was too cold and dry for winter ticks to become established. Ticks may have arrived in Yukon on elk introduced from Alberta in the early 1990s, on imported horses, and/or from mule deer expanding northward from British Columbia. A recent study on the origin of Yukon winter ticks was inconclusive (Leo et al. 2014).

However, winter ticks may also be expanding northward as a result of climate change (Kutz et al. 2009; also see Section 2.5). In Yukon, ticks have been found as far north as Carmacks; in the Northwest Territories, they occur as far north as Norman Wells. Climatic conditions greatly affect tick survival. Warmer and shorter winters, as predicted under climate change scenarios, could favour tick survival and increased abundance (Del Giudice et al. 1997), thereby increasing the likelihood and frequency of transmission to moose. Heavy tick infestations are a concern as they can have serious negative physiological consequences (Musante et al. 2007) that may affect survival and reproductive success of individual moose; however, population level effects are unknown.

3 Management guidelines

3.1 Population monitoring

Yukon-wide priorities for moose population inventory and monitoring are established after consideration of the availability of harvest information for all users, historic and current harvest levels, access levels, current and anticipated land use activities, and habitat availability. These factors are weighed together with social, financial, and political considerations to produce annual and multi-year survey schedules. Generally, moose populations do not exhibit large changes in population size from year to year. Therefore, MMUs are not surveyed more frequently than every 5 years as this is the amount of time it takes to detect if a population has changed in size and trend. To date, Environment Yukon inventories have covered 33 areas at least once, covering approximately 150,000 km^2 or about 30% of the territory (Figure 3). Some high priority areas, primarily near Yukon communities, have been regularly monitored for moose since the early 1980s.

Aerial counts provide some of the most reliable estimates of population numbers and trends (Ronnegard et al. 2008). In Yukon, intensive population surveys of moose in high priority areas are conducted in early winter because moose are most visible at that time of year due to shallow snow covering and

the tendency of moose to aggregate during and after the rut. Information from these surveys is used to estimate moose abundance, trends from previous surveys when available, population composition (number of calves, yearlings, bulls and cows), and distribution. In addition, selected populations are also surveyed, with less intensive techniques, in early winter to estimate area-specific variation in recruitment (number of calves and yearlings per 100 cows). Lastly, aerial surveys in late-winter are used to identify important habitat types during a critical period when food resources are most limited and may be difficult to access because of snow cover. Moose are difficult to observe at this time of year so not all important areas can be identified.

3.2 Population management

There has been gradual shift for management agencies towards maintaining and restoring intact ecosystems (Schwartz et al. 2003). This philosophy is consistent with wildlife management principles in Yukon, in that over most of the territory, moose are managed within their natural range of variation. The management of human activities, including harvest (3.3) and land use, are the primary tools for moose management in Yukon. Other moose management tools that have been used in the past or in other jurisdictions include and large-scale predator control and habitat enhancement (Appendix 2); neither has been nor is currently used as an ongoing management tool in the Yukon.

Management of human activities provides the most practical, cost-effective and socially acceptable tools for moose management. For example, hunting regulations are intended to allow for sustainable harvesting opportunities while ensuring the long-term welfare of local and regional moose populations. Management decisions and restrictions with respect to harvest are intended to:

- Prevent moose populations from declining below their historical densities (i.e., natural range of variation);
- Recover those populations that have declined;
- Maintain acceptable adult sex-ratios.

3.3 Harvest

3.3.1 Harvest allocation

Opportunities for moose harvest are shared by all users. More intensive management actions are considered in areas where the total harvest by all users exceeds sustainable levels (needed to prevent the population from declining), where the management goal is to recover a moose population that has declined, or where adult sex-ratios approach minimum recommended levels. In these cases, a maximum Annual Allowable Harvest (AAH) will be established for MMUs to meet management objectives.

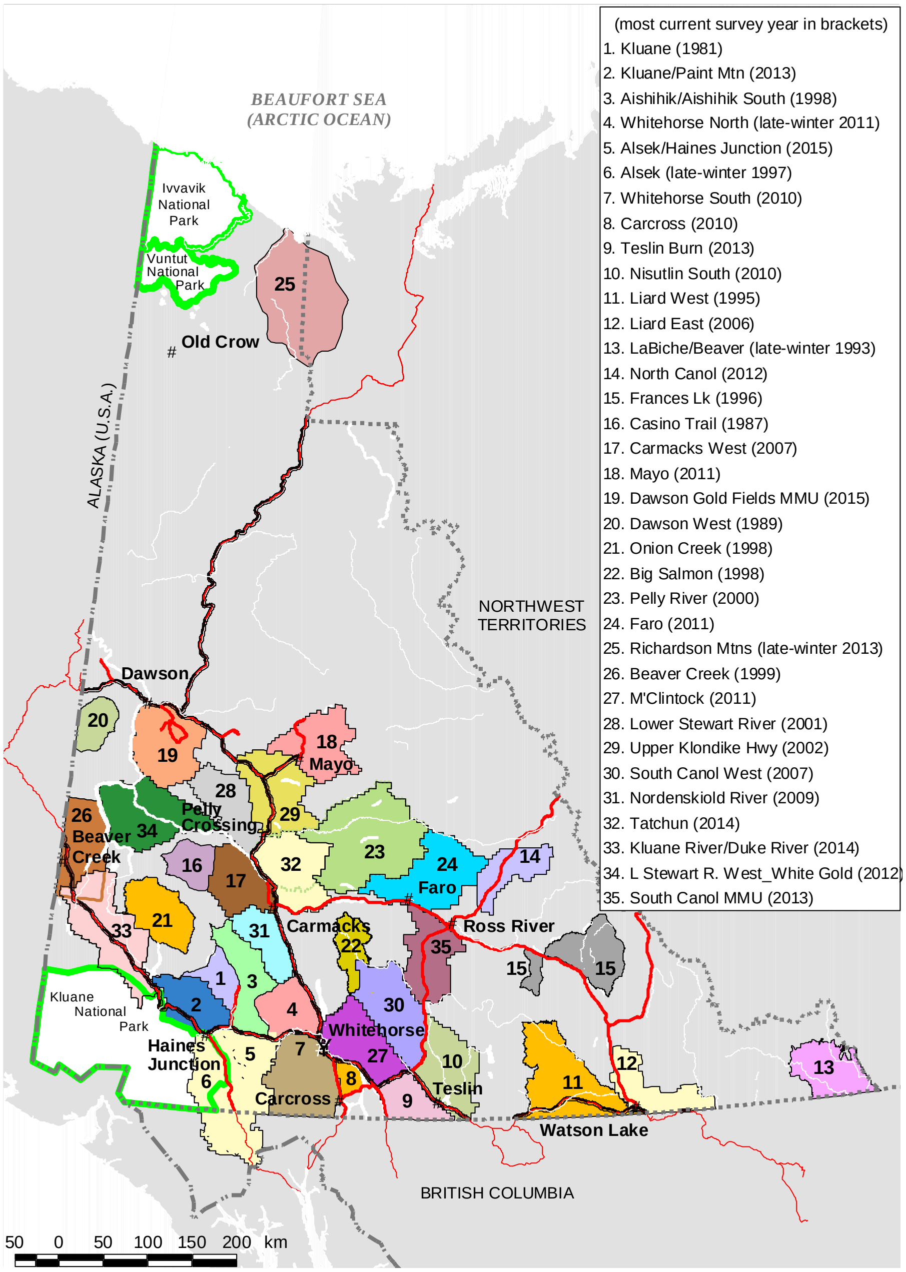


Figure 3. Moose census survey areas in Yukon – 1981-2015.

In areas outside of the Inuvialuit Settlement Region, the principle of sharing the allowable moose harvest among all Yukoners is recognized in government policy and First Nation allocation priority is described in the *Umbrella Final Agreement* (UFA). Specific sharing or allocation formulas, if they exist, are identified in individual Yukon First Nation final land claim agreements. The licenced harvest allocation is shared between residents and non-residents. In the Inuvialuit Settlement Region, the Inuvialuit have the preferential right to hunt for food all species of wildlife (except for migratory non-game birds and migratory insectivorous birds) on the North Slope (*Inuvialuit Final Agreement as Amended*, 2005).

3.3.2 Harvest monitoring and reporting

Reliable information on the annual moose harvest by all hunters is a cornerstone of effective population management. Environment Yukon has kept records of the annual moose harvest reported by licenced hunters in each GMS since 1979. Harvest is assigned to specific GMSs based on the location of the kill. Harvest rates are evaluated at the population level (i.e. the MMU). All successful licenced moose hunters must complete a compulsory report for their harvest and submit to an Environment Yukon office no later than 15 days after the end of the month in which the moose was killed. Additional reporting conditions may apply in some areas (see current Yukon hunting regulations summary on Environment Yukon's website).

First Nation moose harvest information is unavailable for many areas in the Territory. This information is valuable for assessing the sustainability of harvest levels and to meet conservation objectives identified in Chapter 16 (Fish and Wildlife) of the UFA. Some First Nations governments collect voluntary information or field observations while others provide Environment Yukon with GMS-specific annual harvest data to assist in management within their Traditional Territory.

Yukon First Nation final agreements provide for and assume harvest reporting by all hunters will be acquired to manage wildlife effectively. Where First Nation harvest is not available, it is estimated based on the level of licenced resident harvest pressure and any available local information.

3.3.3 Harvest management considerations

Moose hunting in Yukon is recognized as a culturally and economically important and environmentally sound activity. Harvest management should support the subsistence, recreational, cultural, and economic opportunities associated with hunting while ensuring the total harvest remains sustainable. In Yukon, the harvest of moose is considered to be mostly additive to other sources of adult mortality (Gasaway et al. 1992), meaning that hunters are harvesting moose in addition to the number that would die of other causes. That means harvest can become an important risk factor, particularly where moose are at low density (Gasaway et al. 1983).

Yukon moose populations are part of a predator-limited system where harvest represents a very small proportion of overall mortality (Appendix 2; also see Boertje et al. 1996), however, it may cause a population to decline if not managed carefully. Harvest strategies in Yukon should employ the *Precautionary Principle* to ensure populations do not decline below their natural range of variation (i.e., densities with little or no human-caused mortality), particularly in areas where bears and wolves are naturally regulated (i.e., areas with limited human caused mortality; Hayes and Harestad 2000). Once a population has declined from overharvest, it may continue to decline from other factors such as weather and predation in the absence of hunting (Gasaway et al. 1983).

It is important to recognize that once a population has declined below its natural range of variation, even complete hunting closures may not result in population increases (Hayes et al. 2003). Growth rates in populations that have significantly declined may be reduced or nil because of the time-lag in the numeric response of wolves to decreasing moose numbers (i.e., a decrease in moose numbers doesn't immediately result in a decrease in wolf numbers; Gasaway et al. 1983) and the density-independent nature of grizzly bear predation (i.e., bear predation does not depend on the density of moose; Boertje et al. 1988, Ballard et al. 1990). Recovery can take decades (Gasaway et al. 1983, Ballard and Larsen 1987), meaning there may be long periods during which there are no surplus moose available for harvest (Larsen et al. 1989, Gasaway et al. 1983). Recovery also comes with many biological, social, regulatory, and economic challenges; for example, frequent monitoring to assess recovery rates may not be economically feasible.

Recognizing that harvest can cause populations to decline and the many challenges in recovering moose populations in Yukon, harvest by all users in an MMU should not exceed recommended levels if the objective is to maintain or recover the population (Figure 4).

3.3.4 Harvest rate recommendations

Knowledge of what constitutes a sustainable harvest rate is critical. Computer simulation models were used to evaluate different harvest management strategies and help guide harvest rate recommendations (Czetwertynski 2015). These models incorporated all available information on recruitment and mortality from across Yukon. This data provides information on the variation in survival and reproduction in Yukon so that predictions are realistic and specific to the areas where most harvest occurs (i.e. because most surveys are conducted in areas of high hunting pressure, Figure 3).

Simulation models used reproductive and mortality rates recorded during aerial surveys of Yukon moose populations between 1981 and 2012. The initial population for all simulations was set at 500 individuals and projected 5 years into the future with a constant harvest rate. This approach is most consistent with current management where sustainable harvest rates are estimated based on the most current survey results. A range of harvest rates were applied to moose populations with adult sex-ratios ranging from 30 to 70 adult bulls per 100 adult cows. A harvest rate was considered sustainable if 5-year projections resulted in an *average* stable or increasing population trend and 95% of simulations resulted in adult sex-ratio of at least 40 adult bulls per 100 adult cows. This target sex ratio used for simulations adheres to the precautionary principle, recognizes the uncertainties surrounding population projections, reduces the risk of initiating a population decline, and is intended to prevent populations from reaching the threshold of 30 adult bulls per 100 adult cows.

Sustainable harvest rates for moose populations were calculated based on the number of bulls in the population (when this information is known) or as a proportion of the total population (when no survey information is available). **The harvest rate recommendations outlined here are applicable to all of Yukon's surveyed or unsurveyed MMUs; however, population-specific harvest rate recommendations should be developed where detailed population-specific information is available and where a specific management need exists.**

Sustainable harvest rates in surveyed MMUs

Estimates of the number of adult bulls in the population are available for MMUs that have been surveyed. Model results indicate that a harvest of 10% of the adult bull population in a MMU should maintain an adult sex-ratio of at least 40 bulls per 100 cows and maintain stable or increasing moose populations for sex ratios between 30 and 70 adult bulls per 100 adult cows. A bull harvest of 10% of the adult bull population corresponds to 2.2 to 3.3% harvest of the total population depending on the initial adult sex-ratio.

Sustainable harvest rates in MMUs that have not been surveyed

In unsurveyed MMUs, sustainable harvest rates are estimated based on case studies of populations in Yukon where trend and harvest information are available. Specifically, harvest rates were related to moose density. This approach is consistent with previous harvest guidelines (Environment Yukon 1996, based on Gasaway et al. 1992) but uses substantially more Yukon-based information to generate conclusions:

- Less than 110 moose per 1,000 km^2: No sustainable harvest.
- 110-145 moose per 1,000 km^2: a bull only harvest rate of up to 2% of total estimated population size.
- 145 – 180 moose per 1,000 km^2: a bull only harvest rate of 2-3% of total estimated population size.
- More than 180 moose per 1,000 km^2: a bull only harvest rate of 3% of total estimated population size.
- More than 350 moose per 1,000 km^2: higher harvest rates may be sustainable but will require a case-by-case assessment of the MMU, given current harvest pressure, potential harvest pressure given access, population trend, etc.

Results are summarized in a decision tree (Figure 4). Estimates of moose density in unsurveyed MMUs are based on densities in similar adjacent areas, habitat availability, harvest pressure, and local information.

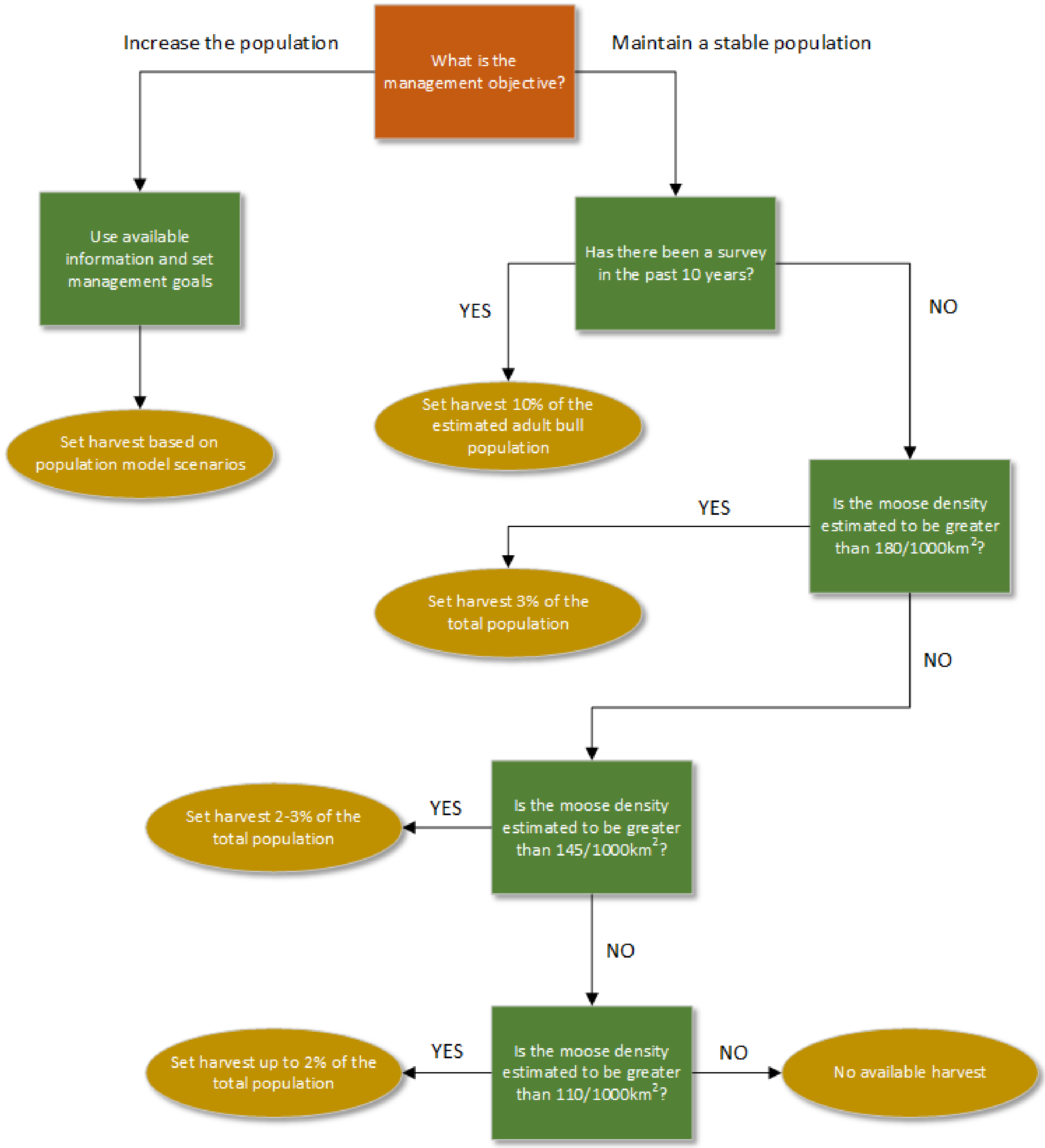


Figure 4. Decision Tree for setting harvest rates for Moose Management Units (MMUs) in Yukon. Harvest rates greater than those specified in the tree should not be considered sustainable unless there is supporting biological data.

Effects of a cow vs bull harvest

Population models (Xu and Boyce 2010) and field data (Gasaway et al. 1992, Boertje et al. 1996) in northern populations where predators are lightly harvested consistently find that bull-only harvest is the only viable option to harvest moose optimally over time. When a cow is hunted, not only is an individual animal removed from the population, but there is a loss of reproductive capacity as she will no longer be contributing calves to the population. Typically for large herbivores, adult female survival contributes the most to population growth rate (Gaillard et al. 2000). **Cow harvest should be avoided to minimize risk of population declines in Yukon**.

Model results indicate that over a 10 year period (the reproductive time span of a cow), the population impact of harvesting 1 cow is equivalent to the population impact of harvesting 3 bulls. In areas where sex of the harvest is known, cow harvest is multiplied by 3 to provide an estimate of total bull harvest used to evaluate the harvest rate in a moose population. As a result, the harvest of cows reduces the number of moose that can be sustainably hunted in an MMU.

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APPENDIX 1

Bacterial, parasitic, and viral infections detected in Yukon moose to 2012.

Bacterial diseases	**Parasites**	**Viruses**
Actinomycosis (lumpy jaw)	*Taenia krabbei* (moose measles)	Infectious bovine rhinotracheitis (based on positive serologic tests)
	Taenia pisiformis	Bovine respiratory syncytial virus (based on positive serologic tests)
	Echinococcus granulosus (hydatid disease)	Papillomas (warts)
	Cysticercus tenuicollis (larval form of tapeworm *Taenia hydatigena*)	
	Moniezia sp.	
	Onchocerca cervipedis (leg worm)	
	Wherdikmansia sp.	
	Nematodirella alcidis	
	Taenia pisiformis	

APPENDIX 2

Other management tools

Habitat enhancement – Although studies have not found habitat to be a significant limiting factor for northern moose populations (Gasaway *et al*. 1992), habitat enhancement offers a more socially acceptable alternative to predator control for the recovery and enhancement of moose populations. In their review of predator control studies in Alaska, the National Research Council (1997) recommended that habitat enhancement be investigated.

Fire is the primary natural disturbance in Yukon's boreal forest and moose can benefit if the regenerative pathway results in early successional deciduous species. The presence and quality of moose browse available after a fire depends on many factors including fire severity, composition of the pre-fire vegetation community, depth of the organic horizon in the soil, weather patterns, fire behavior, and topography (Epting and Verbyla 2005, Johnstone and Chapin 2006). If the successional pathway creates browse for moose, there is a time-lag before shrubs are established and also a climax period after which coniferous species begin to dominate. The intermediate stage where moose benefit from additional shrubs on the landscape occurs between ~11 and 30 years post-fire (Maier *et al.* 2005).

In Yukon, fire suppression zones are ranked and managed by Wildland Fire Management. Generally, fires are not suppressed unless human settlements or infrastructure require protection. Global climate change is predicted to increase the frequency and severity of large forest fires across the boreal forest (Price *et al.* 2013) which will likely lead to increased moose forage distributed across the landscape. Prescribed burns are not a primary management tool for moose in Yukon because the landscape does not have a history of fire suppression, human induced alterations to the environment are already increasing the proportion of the landscape burned, species other than moose may be negatively affected (i.e., Northern Mountain caribou, which are a species at risk), and there is no guarantee that moose numbers will increase as a result of the treatment.

Large-scale predator control – As per the *Yukon Wolf Conservation and Management Plan* (Government of Yukon 2012), there is strong public opposition from Yukoners to using large scale government sponsored wolf control programs as an ungulate management tool. These types of programs are costly, have only short term impacts unless they are intensive and maintained indefinitely, and lack community involvement.

Predator control programs where wolf and/or bear numbers are substantially reduced can temporarily elevate moose densities above naturally regulated low numbers and provide additional animals for harvest (Boertje *et al.* 2010). However wolf numbers will return to pre-control numbers within 3-5 years after control ceases (Hayes *et al.* 1991, Hayes and Harestad 2000). The commonly held view that moose numbers will increase and remain high without sustained removal of a wolves has not been supported by scientific studies conducted in the Yukon. Achieving higher moose densities with wolf

control requires significant annual reductions in wolf numbers (approx. 50-80% of the population) over large areas.

Localized reductions in wolf numbers may not increase moose densities because harvested wolves may be compensated for by immigration and reproduction of dispersing wolves from areas with lower wolf harvest rates (Adams *et al.* 2008), and because wolves in smaller packs have higher kill rates (prey killed/wolf/unit time) than wolves in larger packs (Hayes *et al.* 2000). Some areas may require significant reductions in bear numbers in addition to wolf control for moose populations to increase (Larsen *et al.* 1989, Ballard *et al.* 1991). Currently, wolf-bear-prey systems are not fully understood and it is clear that no single pattern or model fully explains these interactions because “variations in weather, habitat conditions, and behavior of predators and prey guarantee that outcomes will be varied, difficult to predict, and difficult to interpret” (National Research Council 1997).

To be consistent with the National Research Council’s (1997) suggested standards and guidelines, predator control programs should take the form of adaptive management experiments (with clear predictions) and provide quantitative results of management actions. Actions should include identifying the relative influence of limiting factors on the target moose population (including harvest by all user groups), evaluating population trend (stable, increasing, or decreasing), and quantifying the carrying capacity of the habitat. These recommendations should be the standard to ensure that sound science is incorporated into any government sponsored predator control program (Van Ballenberghe 2006) intended to meet local demands for moose hunting opportunities.

Finally, any predator control program specific to wolves must respect the *Yukon Wolf Conservation & Management Plan* (Government of Yukon 2012) (and any periodic revisions to that plan). Specifically, wolf harvest may be used as a community-based management tool to reduce local predation on moose, but it is subject to a number of criteria, including verifiable harvest reporting for moose and wolves, a harvest management plan for all users, and an agreed upon, collaborative approach to program design, implementation and evaluation. The use of wolf reduction, for the purpose of increasing moose numbers to the upper range of natural variation or recovering moose populations that have declined from overharvest, is limited in the Yukon.