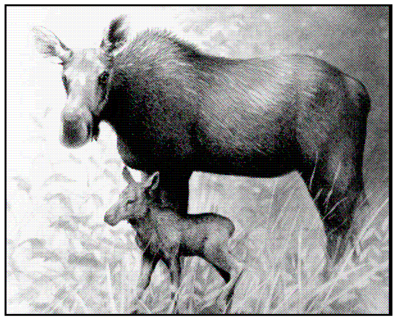

A population review of moose in the Kootenay Region

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Introduction

Moose (*Alces alces*) are found throughout much of interior British Columbia (Shackleton 1999), and are considered one of the most important game species in the province. Highest densities occur in the central and northern portions of the province. Moose generally occur throughout the Kootenay Region (Region 4) of southeastern British Columbia, with relative densities ranging from "few" to "plentiful" (Shackleton 1999). Higher densities are found in the East Kootenay (EK) compared with the West Kootenay (WK), with the exception of the Lake Revelstoke area in the northern WK, where the highest densities in the region likely exist (Poole and Serrouya 2003). Moose in North America have expanded in recent decades into areas considered previously unoccupied (Karns 1998), including coastal temperate rainforests of British Columbia (Darimont et al. 2005). Range expansion and increased populations also appear to be occurring in portions of the WK (R. Clarke, Fish and Wildlife Compensation Program: Columbia Basin [FWCP], unpublished data).

At the request of the British Columbia Ministry of Environment (MoE), Kootenay Region, I was tasked to review current and historic population information about moose in the Kootenay Region, including analysis of what is know about population dynamics that can be used to set harvest and conservation objectives and identify knowledge gaps. This report has the following objectives:

1. Critically review all population data and summarize historic and current population size, population density, and population trajectory information, drawing on all available sources of information. Focus on data from the Kootenay Region but if nearby areas are relevant to our regional understanding then present these too;
2. Summarize information on vital rates such as reproduction and mortality and present these measures across time;
3. Summarize harvest rate data comparing harvest numbers and population estimates; and
4. Summarize data for the entire region, or for ecological units, as appropriate.

Relevant ecology of moose

I present here a brief review of the relevant population ecology and dynamics of moose. Much of this information is summarized in various chapters in Franzmann and Schwartz (1998) and in Bowyer et al. (2003).

Subspecies

Three subspecies of moose occur in British Columbia: Alaskan (or Yukon or tundra) moose (*A. a. gigas*) in the far northwestern corner of the province, northwestern moose (*A. a. andersoni*) throughout much of the rest of the province, and Shiras (or Shira's or Shiras' or Yellowstone) moose (*A. a. shirasi*) in the extreme southeastern part of the province (Shackleton 1999). The border between Shiras' moose and northwestern moose in British Columbia is debateable. Cowan and Guiguet (1965) placed the range of Shiras moose fairly tightly as the Flathead Valley and adjacent Rocky Mountains south of Crowsnest Pass. Shackleton (1999) placed the boundary at the Trans-Canada Highway (TCH) to the north, and the east side of Kootenay Lake to the west. Bowyer et al. (2003) show Shiras moose range across all of southern British Columbia approximately south of the TCH. The outfitting organizations consider Shiras moose to occur in British Columbia south of the TCH with the Monashee Mountains (recently extended to the Okanagan valley) as the western boundary (C. Addison, Guide Outfitters Association of British Columbia, pers. comm.). Shiras moose are characterized as having the smallest body size and antlers of the North American moose (Bowyer et al. 2003). Mean body weights of adult cow moose captured in the 3 areas of the East Kootenay (Flathead, Upper Elk, and Spillimacheen valleys) as estimated by regression from body measurements (Hundertmark and Schwartz 1998) did not differ among areas ($F = 1.39$, 35 df, $P = 0.26$), and averaged 439 kg (K. Poole, unpublished data), greater than the supposed maximum body weight for bull Shiras moose (370 kg; Bubenik 1998).

Habitat and diet

Moose habitat varies widely across its holarctic range, including northern boreal forests, deciduous-dominated and mixed forests, mature coniferous forests, delta floodplains, and stream valley shrubs (Peek 1998). Floodplains and stream valley shrub areas often can be exceptionally productive, as they provide abundant forage biomass. Fire and logging have a great influence on the ecology of moose, removing overstory cover, but creating early seral habitats with higher levels of forage than mature stands. Production of browse generally peaks 15–30 years post disturbance (Peek 1998). Fire suppression can cause long-term changes in the vegetation community (Peek at el. 2001), affecting cover and forage availability.

Closed canopy forests characterize moose deep-snow habitat throughout much of their range (Peek 1998), but moose also concentrate in areas without substantial overstory where abundant food is available during winter (Bowyer et al. 2003, Poole and Stuart-Smith 2006).

Differences in habitat selection occur between cows and bulls, and between cows with calves and those without (Miquelle et al. 1992, Peek 1998). Cows with calves generally select habitats with higher security, while males select habitats with greater forage abundance.

Moose are primarily browsers, eating the stems and twigs of woody plants in winter, and the leaves and succulent shoots of shrubs and trees during the rest of the year. Their diet is catholic in North America, with over 220 species of plants recorded (Renecker and Schwartz 1998). Willows (*Salix* spp.), birch (*Betula* spp.), and alders (*Alnus* spp.) predominate the diet across North America. In recent studies on winter range in 3 areas in the EK, willow, red-osier dogwood (*Cornus stolonifera*), and saskatoon (*Amelanchier alnifolia*) made up 83% of browse events recorded (Poole and Stuart-Smith 2005).

Climate and winter range limitations

Moose populations are influenced by climate, and climate change has been potentially implicated in moose population declines in some areas, primarily through increased temperatures relative to thermoregulation thresholds (Murray et al. 2006). The southern range limit of moose may be determined by thermoregulatory restrictions and heat stress (Renecker and Schwartz 1998, Schwartz and Renecker 1998), such that recent and future population declines in southern areas may simply reflect a northward shift in the thermoneutral zone for this species (Murray et al. 2006).

The common paradigm is that snow depths likely limit moose distribution and density in many areas. In most areas, snow depth is probably the primary causative factor influencing late winter range distribution of moose (Peek 1998). Because of their size and relatively long legs, moose are less restricted by deep snow than other ungulates. Snow depths of greater than 50–70 cm are thought to impede moose movement and may be a critical threshold for the timing of movement from early to late winter range; movements are restricted at depths 70–90 cm, and depths >90 cm may cause serious difficulties for moose (Kelsall 1969, Hundertmark et al. 1990). All cow moose collared in a 2002–2003 study in the EK were considered migratory with seasonally distinct ranges that were probably driven by snow depths; some longer distance movements were observed (up to 30–65 linear km; Poole and Stuart-Smith 2006). In montane systems, elevation is inversely correlated with snow depth, and can be used as a surrogate to broadly model potential winter range (Poole and Mowat 2005). Within late winter range, moose select habitat primarily for the most available preferred forage (Poole and Stuart-Smith 2005).

Within the WK there is evidence that that snow depth limits moose through food availability, but not through restrictions on movement (Serrouya and D'Eon 2002). The Lake Revelstoke area has some of the deepest snow/sinking depths, yet some of the highest moose densities in the region. Serrouya and D'Eon (2002) suggest that if forage were tall enough and still plentiful at higher snow depth, the increased energy expenditure of movement through deep snow would be offset by increased forage. These authors suggest that moose were limited by willow abundance and distribution in winter, that is, the abundance of willow that is available above the snow.

Moose are relatively hardy of cold weather; the lower limit of the thermal-neutral zone of a moose is below –30ºC (Renecker and Hudson 1986). Depending upon season, heat stress may begin at –5ºC (winter pelage) to 14ºC (summer pelage).

Reproduction, productivity, and mortality

Most female moose produce their first calves at 2 to 3 years of age, but poor physical condition may delay this until age 4 (Schwartz 1998, Bowyer et al. 2003). Pregnancy rates of yearlings (which will give birth at 2 years of age) appear to be inversely related to carrying capacity (*K*) of the habitat. Pregnancy rates of adult moose are typically >70%, with singles or twins (very rarely triplets) produced. Twinning rates depend upon the nutritional status of cows (Franzmann and Schwartz 1985, Schwartz 1998, Bowyer et al. 2003). Reproductive senescence in female moose begins at about 12–13 years. Calves are generally born in late May. In a study in the EK, median dates of calving during 2002 and 2003 were 27–28 May (range 14 May–9 June; Poole et al. 2007).

Heard et al. (1997) sampled 1,198 reproductive tracts from cow moose in the Prince George area in central British Columbia from 1977 to 1995, and found pregnancy rates of 19%, 73%, and 80% for yearlings, 2-year-olds, and 3–19 year old moose, respectively. Cow moose 3–11 years of age averaged 85–90% pregnancy rate. The twinning rate was 14% in ≥2-year-old cows, increased with age up to 13 years, and was related to kidney fat mass. Fertility declined after age 13.

Male moose become sexually mature as yearlings, but because of their polygynous mating system, most reproductive contributions by males occur with maximum body weight and antler size (achieved at 7–11 years). Serum progesterone level tests of 48 adult cow moose captured during December–January in 2002–2003 showed that 14 of 16 cows were pregnant in the Flathead and Upper Elk valleys, and 11 of 16 were pregnant in the Spillimacheen Valley (Poole and Stuart-Smith 2004).

Survival rates for adults generally ranges between 75–94%, depending largely upon the degree of human harvest and predation (Van Ballenberghe and Ballard 1998). In populations in Alaska and Yukon, survival rates ranged from 88–95% (summarized in Bowyer et al. 2003). Survivorship decreases among moose >10 years of age (Gasaway et al. 1983).

During approximately 38 moose-years of monitoring on 48 individual adult female moose in the EK in 2002 and 2003, 8 deaths occurred, 7 of which took place between mid-April and early June (Poole and Stuart-Smith 2004). Although relocation frequency was not conducive to identifying cause of mortality, wolf predation was suspected in 1 case, and grizzly bear predation in 2 others. One moose was found intact within 2 days of death in mid-April 2003, with no obvious signs of predation or human-related injuries. Observation of femur or mandible marrow fat colouration and consistency did not suggest starvation as the cause of any moose mortality (7 moose examined). During 33 moose-years of monitoring of 30 collared male and female moose (roughly 40:60 split) in the Lake Revelstoke area starting in March 2004, 7 mortalities were recorded, 3 attributed to wolves, and 4 to hunting (R. Serrouya, pers. comm.). The 3 wolf mortalities occurred in late December, mid-March, and late March. Both studies noted above indicate roughly 0.80–0.82 annual adult (primarily or solely female) survival rates, which may be indicative of population decline.

Predators and parasites

Although controversy exists over whether predation can regulate populations of moose, large carnivores certainly are able to hold moose populations at densities well below carrying capacity (Messier 1994, Ballard and Van Ballenberghe 1998, Bowyer et al. 2003, Testa 2004). In many populations, predation is the primary source of mortality for neonates <6 weeks of age, with grizzly bears (*Ursus arctos*) and black bears (*U. americanus*) shown to be the most important source of calf moose mortality across North America (Ballard 1992, Ballard and Van Ballenberghe 1998). Wolf (*Canis lupus*) predation on young moose occurs more frequently during winter. Grizzly bears and wolves also kill adult moose; black bear predation on adults is not considered significant. Cougars (*Puma concolor*) may take both young and adult moose. Predation mortality on young moose in low-density populations tends to be additive (where mortality is in addition to other mortalities occurring within the population), whereas populations near carrying capacity exhibit higher levels of compensatory mortality (where one source of mortality is substituted for another; reviewed in Bowyer et al. 2003).

Moose can harbour numerous diseases, parasites and pests, the effects of which likely vary based on moose population density and physical condition (Lankester and Samuel 1998). Few of these pathogens are thought to have the potential to adversely affect populations of moose; in western Canada these may be limited to winter ticks (*Dermacentor albipictus*), liver flukes (*Fascioloides magna*), and tapeworms (*Echinococcus granulosus*). *E. granulosus* produce hydatid cysts that primarily reside in the lungs of infected moose, making them prone to predation.

Heavy loads of winter ticks can cause loss of hair through excessive grooming, chronic anaemia, decreased feeding time, and restlessness, and result in reduced fat reserves and reduced growth of young moose (Samuel 2004). Ticks may number upwards of 40,000–80,000 or more per moose on heavily infested individuals. The hair loss leads to the name “ghost moose” for animals with heavy infestations. Outbreaks of ticks appear to occur irregularly, and when they occur with severe weather or poor habitat may result in significant die-offs, mostly among calves. A major tick-related die-off in moose appears to have occurred in central interior and northeastern British Columbia in 1999 (H. Schwantje, BC MoE, pers. comm., in Samuel 2004), with a smaller die-off in 2002 (Samuel 2004). There is no evidence of significant hair loss in moose or tick-related die-offs in the Kootenays (H. Schwantje, BC MoE, pers. comm.).

Interspecific competition

The range of several native ungulates overlap with moose, but strong evidence for competitive interactions is limited (Boer 1998). Competition between caribou (*Rangifer tarandus*) and moose is thought to be slight (Bowyer et al. 2003), but high densities of moose could maintain wolf populations at high levels that could intensify predation on caribou (Bergerud and Elliot 1986, Seip 1992, Wittmer et al. 2005). Elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*) are sympatric with moose through portions of their ranges, but competition for food is not thought to be great, and in general habitat and dietary differences result in strong niche partitioning (Bowyer et al. 2003). However, limited evidence for exclusion of moose due to diffuse competition with deer and elk has been shown, with the greatest potential for dietary overlap and interspecific competition occurring during severe, nutritionally restrictive winters (Jenkins and Wright 1987, 1988). Maintenance of predator populations by sympatric ungulates may affect moose indirectly (Boer 1998).

Density dependence, sustained yields, and harvest rates

Population dynamics among moose and other large herbivores may be best explained by density dependence, as modified by predation, hunting, other mortality factors, and severe weather (Van Ballenberghe and Ballard 1998, Bowyer et al. 2003). Density dependence means that population growth rate should increase as the population is reduced (Bowyer et al. 2003). Influences of nutrition on reproduction and successful recruitment of young into the population have the greatest effect on population dynamics through density (Messier 1991). Quantity and quality of forage typically regulate moose populations at high densities (Messier 1991), while density-dependent mechanisms are less likely to affect adult survivorship. Examining moose demography in Michigan, Messier (1991) concluded that wolf predation and food competition (through increased moose density) were the primary factors driving variation in moose abundance, and snow accumulation had no quantifiable effect on moose numbers, either in a single season or during consecutive winters. This work, however, took place where snow depths rarely exceeded 70 cm. In south-central Alaska, Testa (2004) documented a moose population moderately affected by nutritional limits on its reproductive potential, but primarily limited in its capacity for growth by mortality from predation (grizzly bears and wolves). Maximal intrinsic rate of increase (r_{max}) may approach 0.35–0.40 without predators or a severe winter climate (Bowyer et al. 2003), but in reality rarely exceeds 0.15 (summarized in Van Ballenberghe and Ballard 1998, Hatter 1998).

Empirical studies suggest that sustainable harvest rates (primarily on bulls) may range from 5% of the population (in the presence of lightly hunted wolf and bear populations) to 10% (when predators are more heavily hunted) (Gasaway et al. 1992, Hatter 1998). Harvest rates of up to 25% may be sustainable when natural mortality is almost non-existent (Crête 1987, Fryxell et al. 1988). As populations approach carrying capacity, density dependent factors work to reduce the population rate of increase. The maximum sustained harvest probably occurs at about 60% of carrying capacity (Crête 1989). Empirical studies and modelling from central and northern British Columbia suggest that a harvest rate of about 7% per year (almost solely bulls) is sustainable under conditions of lightly harvested predator populations (Hatter 1998). In the Prince George area, with a full compliment of predators, an average 7% harvest rate (primarily, but not exclusively bulls) appeared to be sustainable (Heard et al. 1999; D. Heard, BC MoE, pers. comm., 2005). High bull ratios and low calf ratios are consistent with what one would expect in a lightly harvested, predator-limited population (Ballard 1992, Ballard and Van Ballenberghe 1998, Timmermann and Buss 1998).

Current provincial moose harvest management

Moose conservation and harvest management goals for central and northern British Columbia are detailed and discussed in Hatter (1998, 1999). One of the stated principles of the British Columbia wildlife harvest strategy (MELP 1996) is to maintain populations with bull ratios above 30 bulls:100 cows, ostensibly to maintain high productivity and avoid declines in pregnancy rates (Hatter 1998). Admittedly, no relationship between adult sex ratio and reproduction has been detected in British Columbia moose populations (Heard et al. 1997, Hatter 1998). For low-density populations (defined as <300 moose/1,000 km^2), maintaining 50 bulls:100 cows may provide a greater margin of safety from declines in reproduction (Timmermann 1992). The calf:cow ratio required to maintain a stable population in the absence of hunting has been estimated at about 25 calves:100 cows (at 6–9 months of age; Bergerud 1992), but may rise to 30–45 calves:100 cows in harvested populations depending on the adult harvest and natural mortality rates (Hatter and Bergerud 1991).

Harvest management in much of central and northern British Columbia involves a combination of passive (e.g., antler restrictions) and active (e.g., quotas) harvest controls (Hatter 1999). In a review during the mid-1990s, the moose harvest strategy that sustained the greatest hunting pressure, harvest density, and harvest rates, while maintaining desired hunting effort and post-season bull:cow ratios, was a strategy that included a general open season (GOS) for spike-fork or "immature" bulls and calves, combined with a limited entry hunting (LEH) season for mature bulls and cows (Hatter 1999). Under LEH, set numbers of tags are awarded to resident hunters based on a lottery or random draw. Similar patterns of harvest management are found in adjacent jurisdictions. Moose hunting in Alberta is regulated under an LEH system for antlered, antlerless, and calf moose (http://www.srd.gov.ab.ca/fw/hunting/ahg.html). Moose hunting in Washington is regulated by LEH draw for approximately 100 permits for either antlered or antlerless animals, with a lifetime restriction of 1 moose (http://wdfw.wa.gov/wlm/game/hunter/hunter.htm). In Idaho, moose hunting is also regulated by LEH permits, primarily for antlered moose, with a smaller number of antlerless moose permits available (http://fishandgame.idaho.gov/hunt/).

Aerial surveys of moose are conducted to estimate population size and age and sex structure. In British Columbia, the current standard to estimate population size is a stratified random block (SRB) design survey with sightability correction estimated from vegetation cover. Surveys are generally conducted in early winter (December or January) when complete snow cover pushes moose into concentrations on early winter range, and prior to movements into heavier cover that often occur by mid-winter. The area of interest is set to include all potential moose winter range within the study area, and sample units (SUs, also known as “blocks”) approximately 20 km^2 in size are established and assigned into strata based on expected high, moderate, and low moose densities based on past surveys, local knowledge, and habitat. To reduce variance, all high-density blocks, up to 50–75% of medium-density blocks, and a minimum of 4–5 low-density blocks are generally selected for survey.

The survey is conducted using a helicopter (generally a Bell 206B Jet Ranger) equipped with bubble windows. Each selected SU is flown along transects to provide full coverage of the block. All moose groups are circled to determine sex and age of each animal (Timmermann and Buss 1998). Oblique cover is estimated for each moose group observed as the percent vegetative cover (perhaps best described as screening cover) around the first animal seen in the group; this value is used to account for sightability of moose (Anderson and Lindzey 1996, Quayle et al. 2001). The population estimate is determined using programs to account for blocks not surveyed and sightability of moose.

One of the difficulties managing moose harvests at finer scales (e.g., guide/outfitter territories) is that population estimates are often generated on winter range, and do not reflect the spatial distribution of populations on fall hunting range. Moose in all 3 areas of an EK study were migratory (Poole and Stuart-Smith 2006). Thus, moose concentrated in valley-bottom habitat during winter generally disperse into upper tributaries for non-winter months. Since the dispersal pattern from winter range to summer and fall (hunting) range will vary among areas, there appears to be no simple answer to assigning winter population estimates to fall moose distribution among hunting subzones or comparatively smaller guide/outfitter territories. A proportional area approach may be the most equitable, whereby the area of all likely fall moose habitat in the broader study area is used to determine the split for the winter-derived estimate. Biogeoclimatic (BEC) zone mapping can easily be used to derive the area of likely fall moose habitat; areas unlikely to have harbour moose in the fall include most low-elevation areas in the Rocky Mountain Trench (primarily Ponderosa Pine [PP] and Interior Douglas-fir [IDF]), and high elevation Alpine Tundra (AT).

Kootenay Region

Research by Spalding (1990) suggests that moose were scattered in low numbers throughout much of the southern interior mountains of British Columbia during the early 19th century, and were locally abundant in some areas along the western slopes of the Rocky Mountains. As is common throughout much of their range (Thompson and Stewart 1998), moose distribution and numbers have generally expanded within portions of the Kootenays over the past 40–50 years. High numbers and increases have been most notable in areas associated with early seral habitat resulting from extensive logging, such as in the Elk Valley (Halko et al. 2000) and along the Revelstoke Reservoir (Poole and Serrouya 2003). Reduced snowpacks during the 1990s may have also contributed to the increases (through decreased costs of locomotion or increased food availability). In recent years, however, moose numbers appeared to have declined in some areas, including some management units (MUs) in the southern portion of the region (Halko et al. 2000). Hunter success rates are consistently low in some MUs (BC MoE, unpublished data), and calf numbers appear to be reduced (L. Ingham, FWCP, pers. comm.).

Moose hunting in the Kootenays was under GOS with antler restrictions until 1989 and any bull in 1990. There were also LEH permits for cow, calf or spike bull moose. In 1991, concerns about high numbers of hunters, high harvests, and reduced numbers of bulls resulted in cancellation of the entire GOS for moose, and a LEH system of harvest management was implemented for all moose. Some MUs are split into zones for allocation of tags (Fig. 1). For a broader assessment, MUs can be further amalgamated into 3 game management zones (GMZs) in the EK and 2 zones in the WK (Fig. 2).

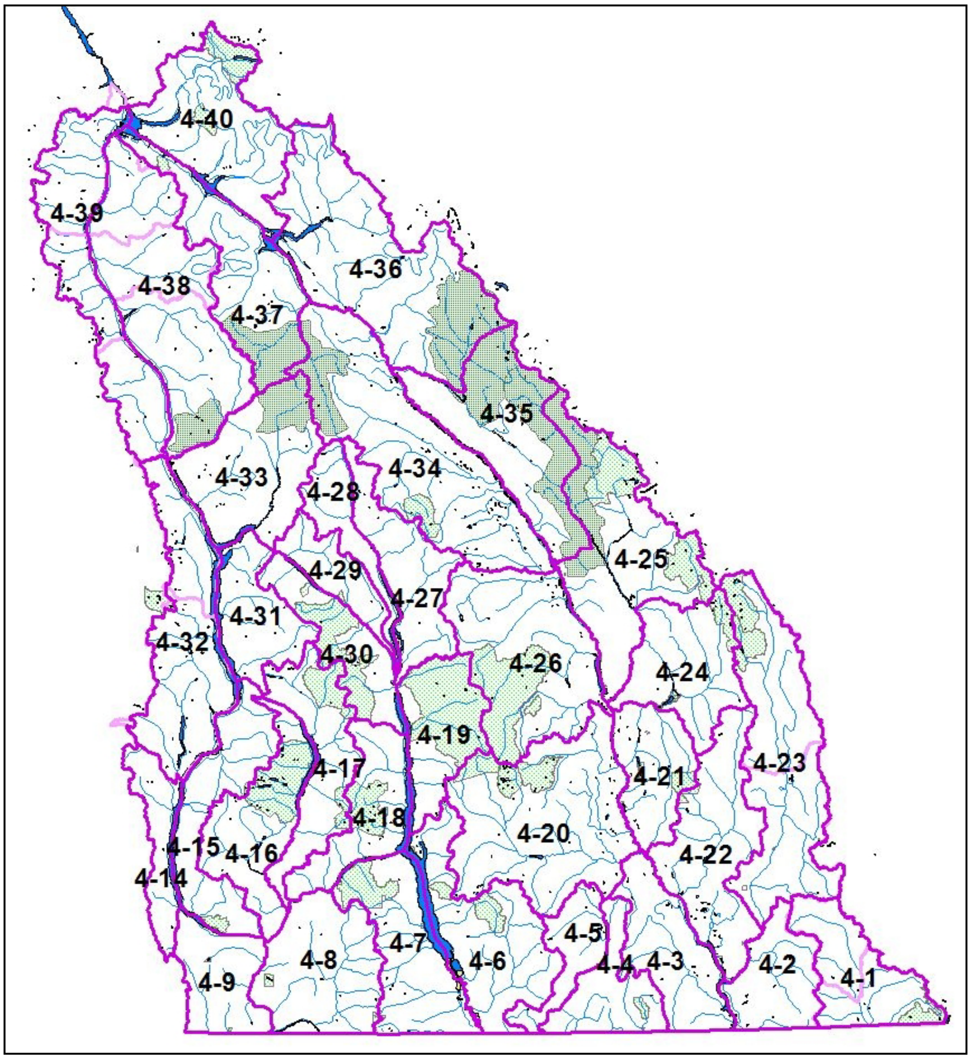

Figure 1. Location of management units (MUs; dark purple outline) in the East and West Kootenay, southeastern British Columbia. Five MUs are currently split into Limited Entry Hunting (LEH) zones (4-1, 4-23, 4-32, 4-38, and 4-39, shown by the light purple borders within MUs). National parks shown in darker green, provincial in lighter green.

Compulsory reporting for moose hunting in the Kootenays was instituted in 1991, whereby all successful hunters were required to report the location, date, and sex of the harvested animal, and to submit a tooth for aging. Tooth collections stopped in 2000. LEH tag allocations are assessed and reviewed on an annual basis, and adjusted according to estimated population size and hunter success over the previous 3 years.

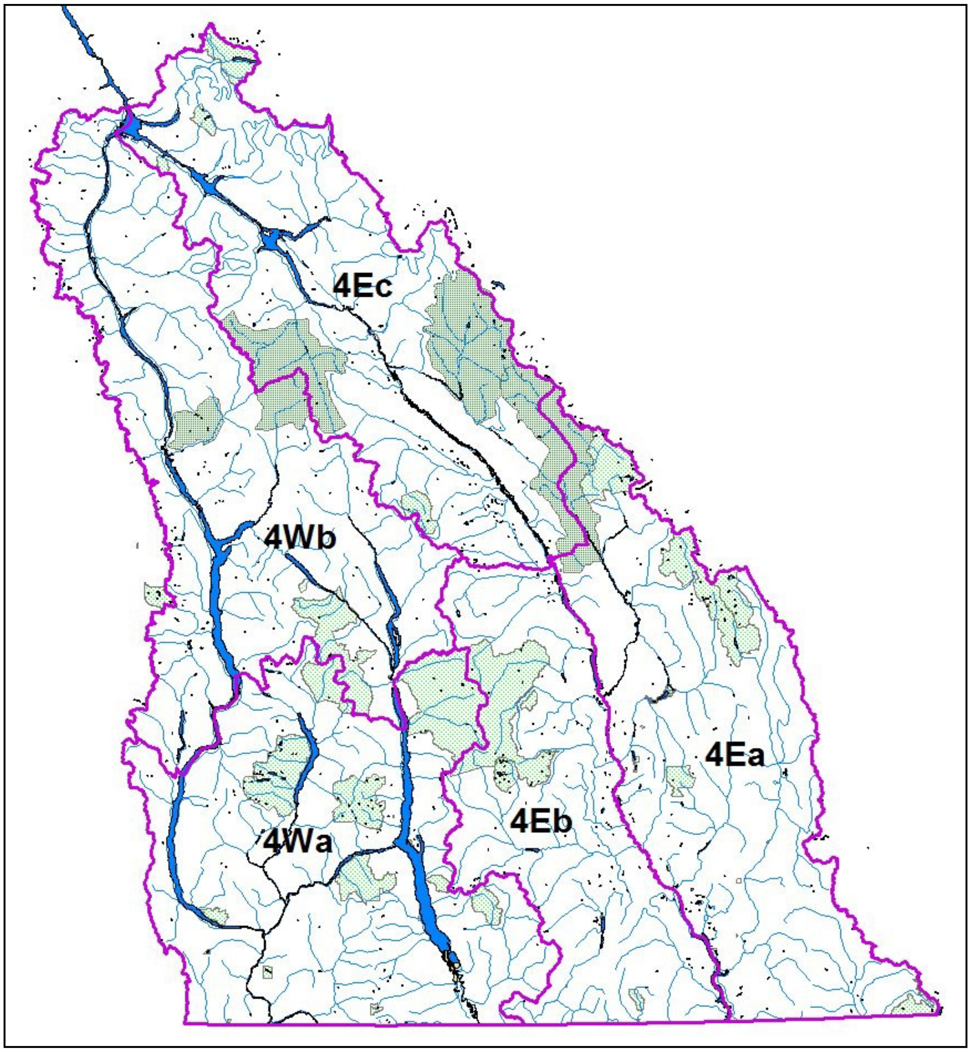

Figure 2. Location of game management zones (GMZs; dark purple outline) in the East and West Kootenay, southeastern British Columbia. National parks shown in darker green, provincial in lighter green. GMZ 4Ea (southeast EK): MUs 4-01. 4-02, 4-21, 4-22, 4-23, 4-24, and 4-25; GMZ 4Eb (southwest EK): 4-03, 4-04, 4-05, 4-20, and 4-26; GMZ 4Ec (north EK): 4-34, 4-35, 4-36, 4-37, and 4-40; GMZ 4Wa (south WK): 4-06, 4-07, 4-08, 4-09, 4-14, 4-15, 4-16, 4-17, 4-18, and 4-19; GMZ 4Wb (north WK): 4-27, 4-28, 4-29, 4-30, 4-31, 4-32, 4-33, 4-38, and 4-39.

The design of the LEH hunts in Region 4 has changed in recent years. Prior to 2004, a group of hunters could apply for a Group Hunt, whereby if one member of a group is drawn, each hunter in the group receives an authorization, and each may harvest an animal. Starting in 2004, all LEH moose hunts in the province are allocated under Limited Entry Shared Hunts, whereby if any member of a group is drawn, a group of 2 is allowed to take one moose only, and a group of 3 or 4 are allowed to take 2 moose, with any member of the group eligible to hunt and kill only 1 animal. Shared hunts resulted in an increase in participation in excess of available authorizations, often in the 30% range over the previous group hunt system (T. Szkorupa, BC MoE, pers. comm.).

Moose hunting is currently (December 2006) allowed in all MUs in the region, except for 8 MUs in the WK (4-08, 4-16, 4-17, 4-18, 4-19, 4-29, 4-30, and 4-33). All moose hunting in the Kootenay Region currently is by LEH permit, with a desired harvest rate of 15% of the estimated bull population in most MUs, 12% in MUs 4-38 and 4-39, 10% in MU 4-03, and 5% in MU 4-04 (T. Szkorupa, BC MoE, unpublished data). Up until 2006, cow-calf tags were only allocated in the Lake Revelstoke area (see below). Outfitting for non-resident moose hunting is provided by most guide/outfitters (G/O) operating in the Kootenay Region. Under a new provincial allocation policy, the guide/outfitter quota allocation will begin to change in 2007 from 1 or 2 permits to each outfitter, to a population-based system (T. Szkorupa, BC MoE, pers. comm.). Guide/outfitters are required to select bulls with a double brow tine.

With the exception of MUs 4-38 and 4-39, bull moose firearms seasons in the Kootenays currently run from 15 October or 25 October to 5 November or 15 November (12–32 days). Within MUs 4-38 and 4-39 (Lake Revelstoke area), the season is from 20 September to 31 October. Resident hunters holding an LEH permit may hunt moose with archery equipment beginning 1 September. In 2006, cow-calf permits were only allocated in MUs 4-38 and 4-39, where the season ran from 16 October to 30 November.

The greatest changes in allocation of permits in recent years have occurred in the Lake Revelstoke area (MUs 4-38 and 4-39). Detailed background on this area is provided in Poole and Serrouya (2003), and will be updated after completion of the census in January 2007 (Serrouya and Poole, in prep.). Briefly, large increases in moose population size (rate of increase = ~0.07–0.08) were detected through the 1990s and early 2000s. For a number of reasons (increased hunting opportunities for local residents, damage to western redcedar [*Thuja plicara*] plantations [D'Eon et al. 2002], increases in wolf numbers that may affect sympatric caribou herds), large numbers of both bull and cow/calf permits were allocated in 2003 through 2005 to reduce the population by about 25–30% (January 2006 partial survey; Serrouya and Poole, in prep.).

Methods

Population estimates

Moose population estimates by MU were obtained from MoE files for 1986, 1989, 1991, 1992, 1994, 2000, and 2006 (T. Szkorupa, BC MoE, unpublished data). These estimates were based on formal and informal survey data and anecdotal information (local knowledge; "best guesses"). I did not attempt to research the background or critically review surveys and estimates derived prior to the late 1990s. Surveys conducted since 2000 were used to update moose estimates for 10 MUs to 2006. For MUs where surveys had not been conducted since 2000, population estimates were derived from anecdotal information on bull moose numbers and the assumption that bulls made up about 35% of the population (approximate mean of recent survey data from the Kootenay Region).

I examined trends in calf:cow and bull:cow ratios over time, using published reports and a digital database supplied by MoE (21 surveys between 1985 and 2003; in part from Jalkotzy and Warkentin 2002). I also reviewed data summarized from extensive aerial surveys conducted from 1994–1997 in portions of the Upper Columbia Basin by FWCP (Tinker et al. 1997). Moose data from the FWCP surveys provided limited support for this review because moose were generally not the target species and sample sizes were small. Since the digital data supplied by MoE and FWCP were not corrected for sightability, all ratios were based only on observed animals. Surveys with <25 moose observed were excluded, as were surveys conducted outside of the December to early February time period. Surveys conducted in December were listed as the next year in the figures to provide yearly spacing among winters (thus 2001 means surveys conducted between December 2000 and early February 2001). I obtained additional ratio data from reports and digital database from annual surveys of the Elk Valley Coal Corporation (EVCC) mines in the Elk valley (MU 4-23). Most data came from surveys of the Fording mine area north of Elkford. Survey effort and coverage were not consistent among years. Elk Valley Coal Corporation survey data from prior to 1996 were not used because of low sample sizes and a large proportion of unclassified animals. Data from the EK were examined by year using a jackknife program to obtain annual means and standard deviations (http://www.stat.berkeley.edu/users/hhuang/STAT152/Jackknife-Bootstrap.pdf).

Trends of potential moose predators were summarized from Mowat (2006). Trend data were derived from hunter sample questionnaires, compulsory inspections, compulsory reporting, guide declarations, trapper kill data, and problem kill data.

I examined trends in climate data since 1969 from weather stations representing EK (Cranbrook) and WK (Castlegar). Data were obtained from monthly outputs similar to Environment Canada (2005). I examined snowfall and snow depth accumulation (summed for the winter and assigned to the year of the second half of the winter), and summer (May to September) rainfall as possibly having a direct or indirect effect on moose and their habitat (plant growth and nutritional quality during summer affect moose body growth and fat storage; Van Ballenberghe and Ballard 1998). I used Pearson correlation coefficients to compare these data with calf:cow ratios obtained from survey data, as population trend data were sporadic. I used data from the year of survey, and from the year prior to survey to examine potential time lag effects.

Harvest data

I obtained 2 sources of harvest data and hunter numbers and effort. The big game harvest data provided to MoE staff by John Thornton, British Columbia MoE, Victoria, is derived for resident hunters from resident hunter questionnaires and for non-residents from guide declarations. This dataset provides estimates by MU of the number of resident and non-resident hunters (hunters who actively hunted for moose), total hunter days, and estimated kill data broken up by sex and age class, where appropriate. The second source of data is from LEH survey estimates, which contains the results taken from the LEH survey. This dataset provides results summed by LEH subzone, and includes the number of tags available, and the estimated number of hunters, harvest, and days per kill. Thus, moose hunting data may be obtained from 2 questionnaires/data sources. Although cow-calf LEH tags were used in the Kootenay Region starting at least in the early 1980s, LEH tags for all bull moose hunting was not initiated until 1991. Thus, although the LEH survey may provide more accurate moose data (J. Thornton, BC MoE, pers. comm., May 2006), a blend of datasets is needed to examine trends starting in the early 1980s, and to combine resident and non-resident data. Data were summarized up to 2005 (the 2005–2006 hunting season) for the entire region and by GMZ where appropriate.

I obtained age data from tooth sections (Matson 1981) from 1980 to 1999 (T. Szkorupa, BC MoE, unpublished data), after-which the program was discontinued. I calculated mean tooth age by year for resident bulls, resident cows, and non-resident bulls. I also looked at the distribution of kills by age for resident bull and cow harvests summed from 1991 (the start of the LEH program) to 1999.

Harvest rates were calculated for 2 time periods, based on the 1996 to 2000 and 2001 to 2005 average annual harvest and the 2000 and 2006 population estimates, respectively, within each MU and GMZ.

Results

Population estimates

The moose population in the Kootenay Region was estimated to range from the 6,600 to 7,600 animals from the mid-1980s to mid-1990s, with a decrease to 4,000 moose in 2000 (Table 1, Fig. 3). The greatest declines took place in the 2 southern EK GMZs, and included all MUs in each GMZ (Table 2). Declines of 51–79% were estimated to occur in MUs 4-01, 4-03, 4-20, 4-21, 4-22, 4-23, 4-24, and 4-26 between 1994 and 2000 (Table 2). Surveys conducted in some MUs since 2000 and changes in perceived population size in other MUs resulted in an increase of nearly 50% in the regions' moose estimated population from 2000 to 2006, but still below levels estimated for the 1980s and 1990s. Most of the increases occurred in southeast EK and north WK (Table 1, Fig. 3).

Table 1. Moose population estimates by game management zone (GMZ) in the Kootenay Region 4, British Columbia. General area of the GMZ provided (e.g., SW EK = southwest East Kootenay). See text for source of data.

GMZ	1986	1989	1991	1992	1994	2000	2006
4Ea (SW EK)	3540	3540	3325	2715	3200	1315	2093
4Eb (SE EK)	2020	2020	1900	1855	2120	935	842
4Ec (N EK)	1080	1080	1455	1455	1340	850	886
4Wa (S WK)	150	215	250	250	250	275	550
4Wb (N WK)	610	460	375	375	725	635	1599
Total	**7400**	**7315**	**7305**	**6650**	**7635**	**4010**	**5970**

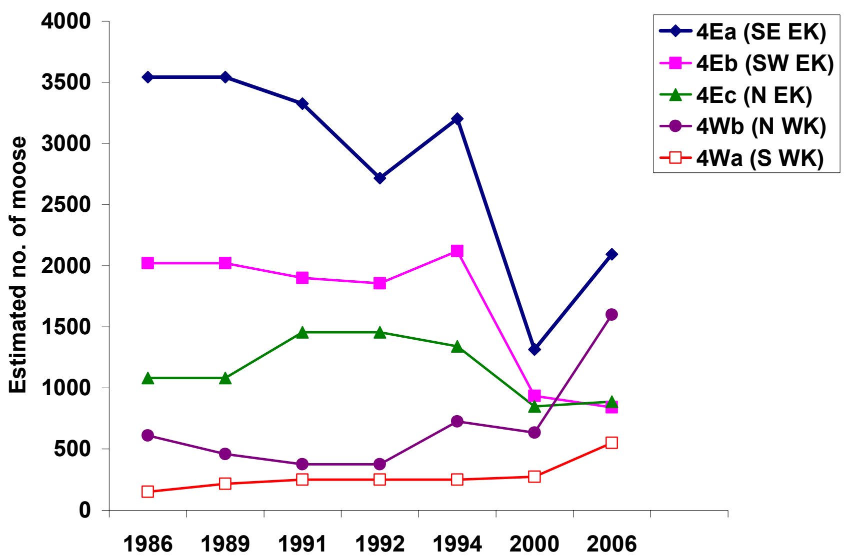

Figure 3. Moose population estimates by game management zone (GMZ) in the Kootenay Region 4, British Columbia (Table 1). General area of the GMZ provided (e.g., SW EK = southwest East Kootenay).

Table 2. Moose population estimates for 1986–2006 by management unit (MU) in the Kootenay Region, British Columbia. Game management zone (GMZ) shown in brackets. Data obtained from T. Szkorupa, BC MoE, Cranbrook, and represent a combination of survey-based estimates (in bold with* for 2000 and 2006; Tables 3, 4, and in text) and guesses based on anecdotal information.

MU (GMZ)	1986	1989	1991	1992	1994	2000	2006
4-01 (4Ea)	620	620	580	595	640	**185***	286
4-02 (4Ea)	200	200	190	190	240	**135***	211
4-03 (4Eb)	480	480	450	450	600	295	91
4-04 (4Eb)	260	260	255	205	280	185	57
4-05 (4Eb)	320	320	310	310	400	220	**291***
4-06 (4Wa)	120	120	120	120	120	120	157
4-07 (4Wa)	10	10	10	10	10	10	**100***
4-08 (4Wa)	5	10	30	30	30	30	**100***
4-09 (4Wa)	10	20	30	30	30	55	43
4-14 (4Wa)	5	5	10	10	10	10	57
4-15 (4Wa)							43
4-16 (4Wa)		10	10	10	10	10	10
4-17 (4Wa)		5	5	5	5	5	5
4-18 (4Wa)		5	5	5	5	5	5
4-19 (4Wa)		30	30	30	30	30	30
4-20 (4Eb)	440	440	415	370	360	135	**248***
4-21 (4Ea)	100	100	95	95	100	**35***	57
4-22 (4Ea)	440	440	425	425	480	**135***	**456***
4-23 (4Ea)	1800	1800	1675	1050	1400	**660***	831
4-24 (4Ea)	260	260	245	245	220	**80***	120
4-25 (4Ea)	120	120	115	115	120	**85***	131
4-26 (4Eb)	520	520	470	520	480	**100***	154
4-27 (4Wb)	30	30	30	30	30	30	71
4-28 (4Wb)	20	20	20	20	20	20	43
4-29 (4Wb)	5	5	5	5	5	5	5
4-30 (4Wb)	5	5	5	5	5	5	5
4-31 (4Wb)							43
4-32 (4Wb)	5	40	100	100	100	100	257
4-33 (4Wb)	5	10	15	15	15	15	15
4-34 (4Ec)	600	600	570	570	520	325	200
4-35 (4Ec)	120	120	115	115	120	75	57
4-36 (4Ec)	260	260	570	570	500	**315***	**226***
4-37 (4Ec)	60	60	120	120	120	75	**219***
4-38 (4Wb)	420	275	100	100	440	350	**640***
4-39 (4Wb)	120	75	100	100	110	110	**520***
4-40 (4Ec)	40	40	80	80	80	60	**184***
Reg 4 total	**7400**	**7315**	**7305**	**6650**	**7635**	**4010**	**5970**

I had limited access to data used to estimate moose numbers prior to 1997, thus it is difficult to detect trends in population based on robust survey data. Since the late 1990s, Halko and Hebert (1997), Halko et al. (2000), Poole and Serrouya (2003), and Poole (2005, 2006) conducted the only structured moose surveys (Table 3). FWCP conducted surveys of selected blocks in MUs 4-20, 4-22, and 4-03 in 2002, but it is unclear if survey areas were stratified and how blocks within each MU were selected for survey; these surveys do provide minimum counts in blocks surveyed and age and sex ratios (FWCP, 2002, unpublished data). FWCP also conducted reconnaissance-type total count surveys of all ungulates in MUs 4-36 and 4-40 in January 2005 (Ingham et al. 2005), and MU 4-37 in February 2006 (L. Ingham, FWCP, pers. comm.). Finally, FWCP recorded moose observations during a February 2004 block survey of MUs 4-07 and 4-08 designed for mule deer (Robinson et al. 2005; R. Clarke, FWCP, pers. comm.).

To summarize, updated estimates of moose population numbers were obtained for 10 MUs since 2000, including 5 from SRB surveys, 1 from a total count with sightability correction applied from vegetation cover measurements, 2 from total counts with a mean sightability correction applied, and 2 from counts of stratified random blocks (for deer) with sightability correction applied from measurements (Table 3). Only MU 4-22 has been surveyed twice during that period (discussed below).

Review of 2000 surveys

Halko et al. (2000) surveyed 9 MUs during their extensive coverage of the EK in 2000, which resulted in estimated populations 59% lower than MoE estimates from 1994 (Table 3). Surveys were conducted during a mild winter with low snowfall. Of these 9 MUs, only MU 4-22 has been surveyed subsequently (in 2006). While the block lay-out and stratification were not available (and therefore how the surveyed blocks were extrapolated to unsurveyed blocks within each stratum is unknown), a review of flight lines and survey effort suggest that estimates derived from the 2000 surveys should be considered low in most areas:

MU 4-22, Bull: Although direct comparisons among surveys are difficult, a stratified random block survey of MU 4-22 conducted in 2006 suggest that at least some of the 2000 estimates from Halko et al. (2000) may have been low, since the differences are beyond the rate of increase likely possible for moose in these areas. In January 2000, Halko et al. (2000) counted 76 moose during a stratified random block (SRB) survey of a 511-km^2 survey area in MU 4-22, and estimated 132 moose using the Wyoming moose model in Anderson and Lindzey (1996). Halko et al. (2000) thought the sightability estimate applied using the Wyoming model was too high, and proposed a "conservative management estimate" of 101 moose. In January 2006, Poole (2006) counted 179 moose and estimated 456 moose within a roughly comparable survey area in MU 4-22 (587 km^2) using the Quayle et al. (2001) British Columbia moose model. Although differences in detection probabilities between vegetation cover sightability models will result in slightly higher estimates for the 2006 survey, the main source of differences between the 2000 and 2006 estimates is likely related to survey design, rather than population increase.

I reviewed the flight lines for the Halko et al. (2000) survey of MU 4-22 (supplied by T. Szkorupa, BC MoE, unpublished data). First, it was apparent that Halko et al. (2000) did not survey to high enough elevations in most areas examined. Both the FWCP survey of MU 4-22 from 2002 and the 2006 survey (Poole 2006) detected moose in tributaries to the main Bull River drainage up to 1,700 m elevation, whereas most areas surveyed in 2000 appear to have been searched to far lower elevations, and sometimes consisted of a few transects up and down the valley bottom. In a winter of low snowfall, moose would have likely been distributed at higher elevations than found during winters of greater snow depth. Second, Halko et al. (2000) used an approximately 300–325 m transect spacing on flight lines in areas surveyed. In similar areas, Poole (2006) used approximately 180–200 m spacing between transects. Widely spaced transects in moderate to heavy cover will result in lower survey effort, and a greater proportion of moose missed within areas surveyed. Search effort reported by Halko et al. (2000) for MU

Table 3. Summary of moose inventories in the Kootenay Region, 1997–2006.

Area/MU	Date	Type[1]	Moose observed	Moose estimated	Calf:cow ratio	Bull:cow ratio	Reference
Goat R (4-06)	Jan 1997	SRB	38	60	10	66	Halko and Hebert 1997[2]
Mosquito Ck (4-32)	Jan 1997	SRB	48	106	26	78	Halko and Hebert 1997
Nancy Greene (4-09)	Jan 1997	SRB		10–20			Halko and Hebert 1997
4-01	Jan 2000	SRB	98	160	15	52	Halko et al. 2000[2]
4-02	Jan 2000	SRB	82	137	19	44	Halko et al. 2000
4-21	Jan 2000	SRB	27	37	35	50	Halko et al. 2000
4-22	Jan 2000	SRB	76	101	16	64	Halko et al. 2000
4-23	Jan 2000	SRB	336	584	21	62	Halko et al. 2000
4-24	Jan 2000	SRB	18	47	63	131	Halko et al. 2000
4-25	Jan 2000	SRB	43	46	10	110	Halko et al. 2000
4-26	Jan 2000	SRB	76	144	37	37	Halko et al. 2000
4-36	Jan 2000	SRB	160	202	29	29	Halko et al. 2000
4-38	Jan 2003	SRB	639	910[3]	23	80	Poole and Serrouya 2003
4-39	Jan 2003	SRB	639	740[3]	23	80	Poole and Serrouya 2003
4-07	Feb 2000, 2004	Total block	30	100	-	-	Robinson et al. 2005; R. Clarke, pers. comm.
4-08	Feb 2000, 2004	Total block	49	100	-	-	Robinson et al. 2005; R. Clarke, pers. comm.
4-36	Jan 2005	Total[4]	129	226	34	86	Ingham et al. 2005
4-40	Jan 2005	Total[4]	105	184	41	141	Ingham et al. 2005
4-05	Jan 2005	SRB	126	291	31	54	Poole 2005
4-37	Feb 2006	Total	74	219	38	156	Ingham unpublished data
4-20	Jan 2006	SRB	129	248	23	83	Poole 2006
4-22	Jan 2006	SRB	179	456	29	61	Poole 2006

[1] Estimates for total count surveys were calculated by extrapolating detection probabilities to vegetation cover observed for each moose group. “Total block” surveys indicate incomplete coverage for the MU, but full coverage within blocks surveyed. SRB = stratified random block.

[2] Halko and Hebert (1997) and Halko et al. (2000) estimated moose numbers using a combination of sightability corrections and “conservative management estimates” (assuming 70% sightability) when the sightability corrections were believed to be inaccurate.

[3] MUs 4-38 and 4-39 was re-surveyed in January 2007 (Serrouya and Poole, in prep.).

[4] Vegetation cover not recorded, therefore sightability correction applied based on rough mean of studies in the Kootenay (1.75).

4-22 was 1.57 minutes/km^2, less than half the effort used during the 2006 survey (3.8 min/km^2). The stratified random block survey technique with sightability correction applied assumes complete coverage of the block, with transect spacing adjusted to vegetation (Gasaway et al. 1986, Anderson and Lindzey 1996). These 2 reasons, along with some questionable survey area delineation (Demarchi et al. 2001), suggest that the main source of difference between the 2000 and 2006 estimates is related to survey design, rather than population increase. .

MU 4-01, Flathead: Survey effort of MU 4-01 in 2000 was 2.15 minutes/km^2 (Halko et al. 2000). Survey coverage within areas surveyed was reasonable in some areas (250 m spacing between transect lines), and wide within others (420 m spacing) (Fig. 4). Large portions of the central Flathead valley where considerable numbers of moose were observed during 1991 and 1992 surveys (which would presumably be considered high stratum blocks) were not surveyed during 2000 (Fig. 4). A large number of moose observed in 1991–1992 were located at elevations above areas surveyed in 2000. Finally, data from collared moose in 2002–2003 (Poole and Stuart-Smith 2004) indicates a wider distribution to the winter range than surveyed in 2000. These factors suggest the results of the 2000 survey are an underestimate.

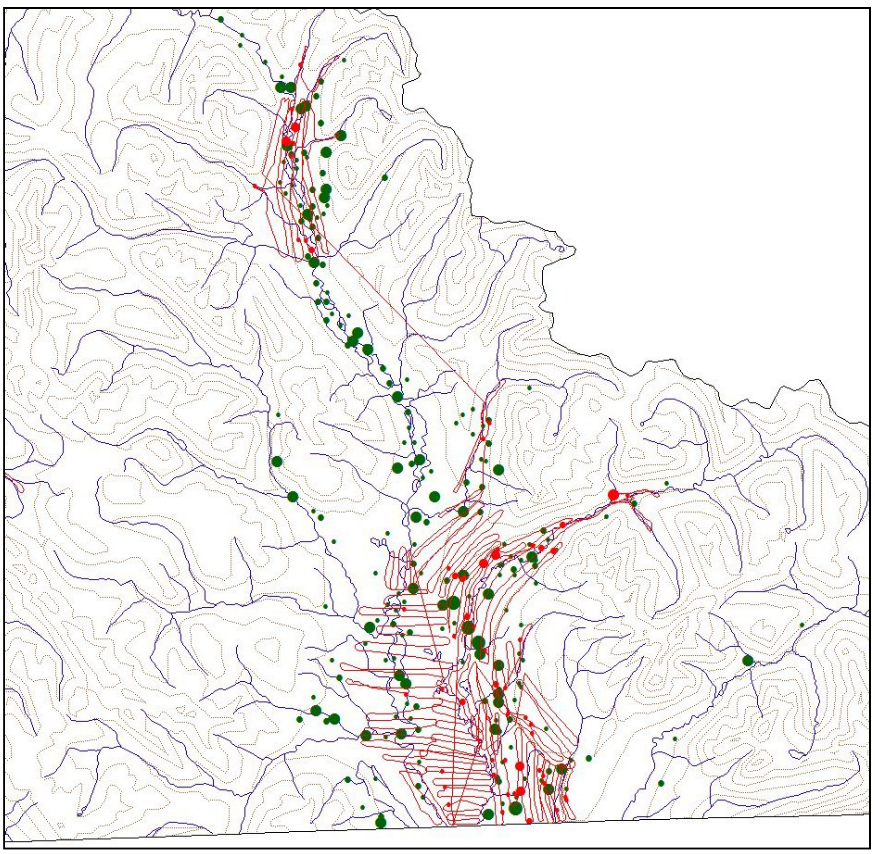

Figure 4. Moose observations from winters 1991 and 1992 (green dots; BC MoE, unpublished data) and 2000 (red dots; Halko et al. 2000), scaled to group size, and 2000 survey flight lines, Flathead Valley (MU 4-01), Kootenay Region, southeastern British Columbia.

MU 4-23, Elk: Survey effort in 2000 was 1.76 minutes/km^2. Compared with surveys conducted in 1991, 1992, and 1996, the 2000 survey coverage did not include a portion of the main Elk valley where large numbers of moose were observed. The 2000 survey may not have surveyed to sufficient elevation compared with the distribution of animals seen in earlier surveys, and is almost certain to be an underestimate.

MU 4-36, Blaeberry-Kinbasket (including the Donald Block): Survey coverage in 2000 appeared similar to areas covered in 1991–1992 (digital database) and 1995 (Ingham 1997), although survey effort was lower (1.65 min/km^2) compared with these earlier surveys (1.84–2.76 min/km^2), possibly resulting in an underestimate of moose numbers.

MU 4-02, Wigwam; MU 4-21, Wildhorse-Lussier; MU 4-24, White; MU 4-25, Upper Kootenay; MU 4-26, Dutch-Findlay: In many of these MUs the survey effort remains low (all but one <1.76 min/km^2) and the coverage of high elevation may not have been sufficient (many had only 3–4 passes along valley bottoms), likely resulting in an underestimate of moose numbers.

In summary, moose surveys flown either subsequent to (MU 4-22) or prior to (MUs 4-01, 4-23, 4-36) the Halko et al. (2000) surveys suggest that the 2000 survey coverage was often inadequate, with light survey effort, lack of coverage of presumed high-density blocks, and inadequate coverage of high-elevation areas that, especially during a low snow winter, likely harboured significant numbers of moose. Habitat change and winter snow depths would be expected to affect moose winter distribution over the span of 10–15 years, but it is unlikely that these changes alone would result in the significant changes in distribution assumed in the 2000 surveys. Interpretation of the 2000 surveys is further complicated by the somewhat arbitrary application of the sightability estimates derived from the moose models (Anderson and Lindzey 1996). Of the 9 MUs surveyed, sightability corrections were directly applied to calculate population estimates in 3 MUs, and altered in the other 6 MUs to lower figures than calculated from sightability estimates (Table 4).

Table 4. Moose population estimates from surveys of 9 management units (MU) in the East Kootenay, January 2000, conducted by Halko et al. (2000). Numbers in bold represent the estimates used by Halko et al. (2000).

MU	No sightability correction[1]	Conservative management estimate[2]	Anderson and Lindzey method[3]	Quayle et al. method[4]
4-01	123	**160**	184 (32)	166 (65)
4-02	105	**137**	460 (312)	241 (128)
4-21	32	42	**37** (8)	27 (7)
4-22	78	**101**	132 (33)	141 (23)
4-23	449	**584**	682 (?)	812 (49)
4-24	36	**47**	54 (29)	59 (112)
4-25	39	52	**46** (8)	57 (6)
4-26	109	142	**144** (23)	204 (8)
4-36	175	**228**[5]	239 (65)	262 (102)
Total	1146	1467	1978 (776)	1803 (134)

[1] Number of moose observed extrapolated to unsurveyed blocks (Halko et al. 2000).
[2] Conservative management estimates (CME) based on assumed 70% sightability (Halko et al. 2000), but incorrectly applied by multiplying the raw estimate by 1.3. CME is actually 77% sightability as calculated.
[3] Estimate derived from using the Anderson and Lindzey (1996) sightability model (Halko et al. 2000).
[4] Estimate derived from using the Quayle et al. (2001) sightability model (Demarchi et al. 2001).
[5] Errors in addition indicate the CME should be 228 moose, not the 202 presented in Halko et al. (2000), although "15% efficiency" was applied to obtain this CME.

Demarchi et al. (2001) conducted a thorough review of the Halko et al. (2000) surveys, including reanalysis of the data using the Quayle et al. (2001) model (Table 4). I did not redo these analyses. The overall pattern was a 23% increase in estimated moose numbers over the CME, and a 9% reduction compared with the Anderson and Lindzey (1996) calculations provided by Halko et al. (2000). However, because of questionable survey area selection and coverage within blocks, even with application of the British Columbia moose sightability model (Quayle et al. 2001), Demarchi et al. (2001) concluded that the survey results were likely underestimated. The 2006 survey of MU 4-22 supports this belief. Because of likely inconsistency among surveys conducted in 2000 (i.e., some MUs probably were covered better than others, as pointed out above) and likely differences in moose population growth among MUs since 2000, I suggest it is tenuous to broadly extrapolate the 3-fold increase observed in MU 4-22 to other MUs flown in 2000.

Review of FWCP surveys

As noted above, FWCP conducted surveys of selected blocks in MUs 4-20, 4-22, and 4-03 in 2002. Updated estimates for MUs 4-20 and 4-22 were produced from surveys conducted in 2006 (Poole 2006; Table 3). Few moose (35 in total, including 12 bulls, 15 cows, 5 calves, and 3 unknown moose) were sighted in MU 4-03 during an acknowledged hasty flight through portions of the MU (L. Ingham, FWCP, pers. comm.), thus it is difficult to use these numbers to generate updated estimates.

FWCP also conducted reconnaissance-type surveys of MUs 4-36 and 4-40 in 2005 (Ingham et al. 2005), and MU 4-37 in 2006 (L. Ingham, FWCP, pers. comm.). The intent of these surveys was a total count survey of "discrete" survey blocks, including areas <1,400 m elevation, in part to duplicate and compare with results from surveys conducted in 1991 (Bindernagel et al. 1991). Where percent vegetation (screening cover) was recorded (2006 only), I applied sightability corrections based on the updated British Columbia moose model (Quayle et al. 2001; Quayle, BC MoE, unpublished data).

MUs 4-36 and 4-40, Jan 2005: A total of 129 moose was observed in MU 4-36 and 105 moose in 4-40. Oblique vegetation cover was not collected. Sightability correction factors vary widely with habitat and snow conditions. In recent SRB surveys in the Kootenays, correction factors have varied from 1.4 to 2.1 (*in litt.*). If an arguably conservative correction factor of 1.75 was applied to the observed moose, then the estimated total numbers of moose in MUs 4-36 and 4-40 were 226 and 184, respectively, and of bull moose were 88 and 93, respectively (with the adult ratio applied to unclassified animals). Ministry of Environment had estimated 64 and 66 bulls, respectively, in 2006 based on a 1.25 sightability correction applied to the number of bulls observed (T. Szkorupa, BC MoE, pers. comm.).

The Donald Block is a portion of MU 4-36 south of the Bush Arm and north of Donald. FWCP has flown this area a number of times since 1991, including in December 1991 (Bindernagel et al. 1991), December 1995 (Ingham 1997), and January 2005 (Ingham et al. 2005). Halko et al. (2000) flew the Donald Block in 2000. Although effort varied somewhat among surveys, coverage was generally complete. Counts of animals observed in 1991 (255 moose) and 1995 (257 moose) suggest stable populations at that time. During the 2000 survey, 160 moose were counted using lower survey effort. The 2006 survey counted 102 moose, 40% of the numbers observed in 1995. Forest succession following the 1971 fire has resulted in increased conifer canopy cover in this area, leading to declining habitat quality (Ingham et al. 2005). Changes in sightability have likely also occurred, resulting in total counts that may not directly reflect changes in numbers of animals present. Regardless, survey data suggest fewer moose currently occur in the Donald Block compared with the early to mid-1990s.

MU 4-37, Feb 2006: MU 4-37 was flown in its entirety, and 74 moose were observed. Excluding 12 animals not classified, the bull:cow ratio was very high (156:100), and the calf:cow ratio was 38:100. Applying detection probabilities to the estimates of oblique vegetation cover, I estimated 219 moose, including 80 bulls. Many of the moose were reported in very thick cover (13 of 44 groups were in >40%

cover, and 8 groups were in >60% cover), and as a conservative measure I dropped vegetation cover estimates that were >80% to the next lower class to get the 219 estimate (otherwise it would have been considerably higher). Thus, the revised estimate of 219 moose for MU 4-37, including 80 bulls, is a great deal higher than the 2000 estimate of 75 animals, including 20 bulls (Table 2). MoE had estimated 48 bulls in 2006 based on the number of bulls observed with a 1.25 sightability correction applied (T. Szkorupa, BC MoE, pers. comm.).

MUs 4-07 and 4-08, Feb 2004: FWCP conducted random stratified block surveys in February 2000 and 2004 designed to estimate abundance of mule deer and white-tailed deer in MUs 4-07 and 4-08 (Robinson et al. 2005). Moose sightings were recorded, along with oblique vegetation cover. Twenty subunits (blocks) were surveyed each year, with some blocks surveyed both years. Survey effort was almost double in 2004 (10.3 hrs versus 19.6 hrs, respectively). Using the raw data (R. Clarke, FWCP, pers. comm.), I applied detection probabilities to the estimates of oblique vegetation cover to calculate the estimated number of moose observed within blocks surveyed. I used 2004 data, and added 2000 data from blocks not surveyed in 2004. Most moose observed were not classified, therefore it was difficult to estimate bull numbers or calf ratios from the survey data. I estimated very roughly bull numbers using the average proportion of bulls in most populations from other studies (~35%).

MU 4-07: Nine moose were observed and 10 estimated in 2000. In 2004, 30 moose were observed and 97 estimated. The large correction factor in estimated numbers is a result of heavy canopy cover for many sightings. Some valley bottoms branching off of Kootenay Lake were not surveyed, but likely harbour few moose. The 2004 estimate for MU 4-07 may be approximately 100 animals, with roughly 35 bulls.

MU 4-08: Five moose were observed and 6 estimated in 2000, and 45 were observed and 66 estimated in 2004. When combined these represent a minimum count of 49 moose, with an estimate of 70. Some areas of potential moose winter range were not surveyed (e.g., east shore of the Columbia River south of Castlegar), which suggest that a minimum of 100 moose (35 bulls) may occur within the MU. Moose observed in 8 blocks surveyed in both 2000 and 2004 increased from 3 (estimate 3.4) to 31 (estimate 47). Lower snow depths in 2004 likely resulted in moose being more widely distributed than in 2000; regardless, these surveys suggest numbers are likely increasing in this MU.

Density on winter range

Estimated densities of moose (corrected for sightability) within winter range are available for selected surveys conducted since 2000 (Table 5). I did not include results from 2000 surveys (Halko et al. 2000) because of suspected problems with the counts and inconsistent extrapolation of sightability corrections (as discussed above).

Table 5. Estimated density of moose on winter range in the Kootenay Region, 2003–2006.

Area	Date	Density (no./km^2)
MUs 4-38, 4-39 (Lake Revelstoke)	2003	1.58
MU 4-05 (Moyie River)	2005	0.77
MU 4-36 (North of Golden)	2005	0.27
MU 4-40 (Kinbasket East)	2005	0.41
MU 4-20 (St. Mary River)	2006	0.47
MU 4-22 (Bull River)	2006	0.78

Age and sex structure

Calf ratios varied widely among surveys and within years, but with the possible exception of higher ratios since 2000, there appeared to be little consistent trend to the data (Fig. 5). Data are variable, but in general calf ratios in GMZ 4Ea tended to be lower than those observed in 4Eb and 4Ec. Only 5 counts in the WK were conducted. Calf ratios averaged 29:100 cows among all surveys, 29:100 since 1999 (*n* = 20 surveys), and 32:100 from 2002 to 2006 in the EK (*n* = 10 surveys).

Bull ratios show a general increasing trend from 1990 through to present (Fig. 6). Most bull ratios were in the range of 25–45 bulls:100 cows in the early 1990s (*n* = 12 surveys), but appear to have steadily increased, such that the average bull ratio in the EK since 2002 was 90:100 (*n* = 10 surveys). There is no apparent trend in bull ratios among GMZs.

Data from amalgamated annual surveys conducted in the coal mine areas of the Elk Valley from 1996 to 2006 show a possible slight increasing trend in calf ratios in the past several years (Fig. 7). It is difficult to discern a pattern with bull ratios, although a declining trend since 2001 may be evident (Fig. 7). Calf and bull ratios from 1996 to 2006 averaged 18 and 63:100 cows, respectively. The maximum count for the Fording mine is also provided, but the trend of lower counts in recent years compared with in the mid-1990s may be more a reflection of survey effort, coverage, and sightability than actual population change.

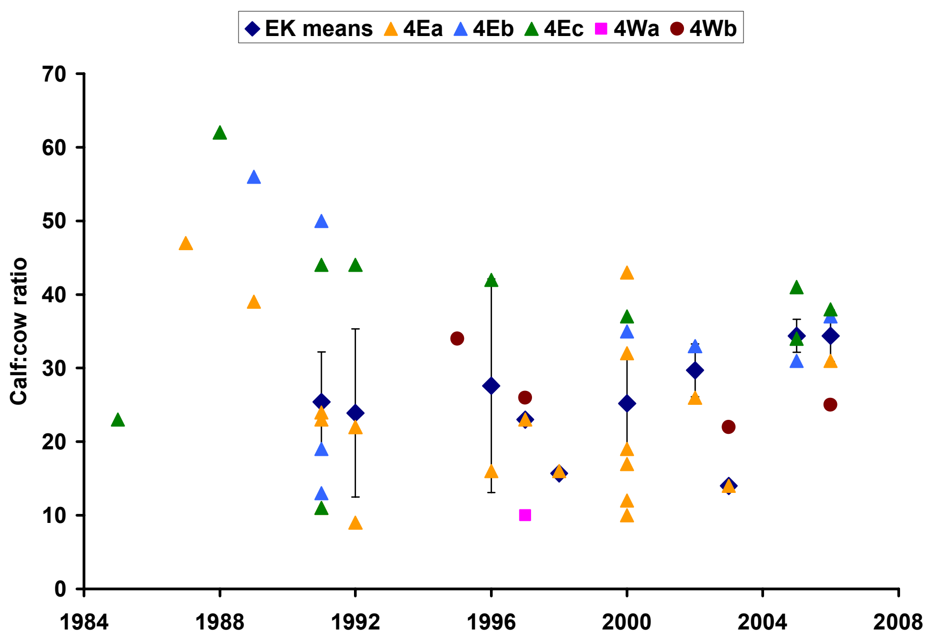

Figure 5. Calf:cow moose ratios derived from 43 moose surveys conducted during December to early February 1985 to 2006, Kootenay Region. Mean among years for the East Kootenay shown with 1 SD for data from 1991 on. Sources: published reports (Table 3), FWCP databases, and historic databases obtained from MoE. 1996 = December 1995 to February 1996.

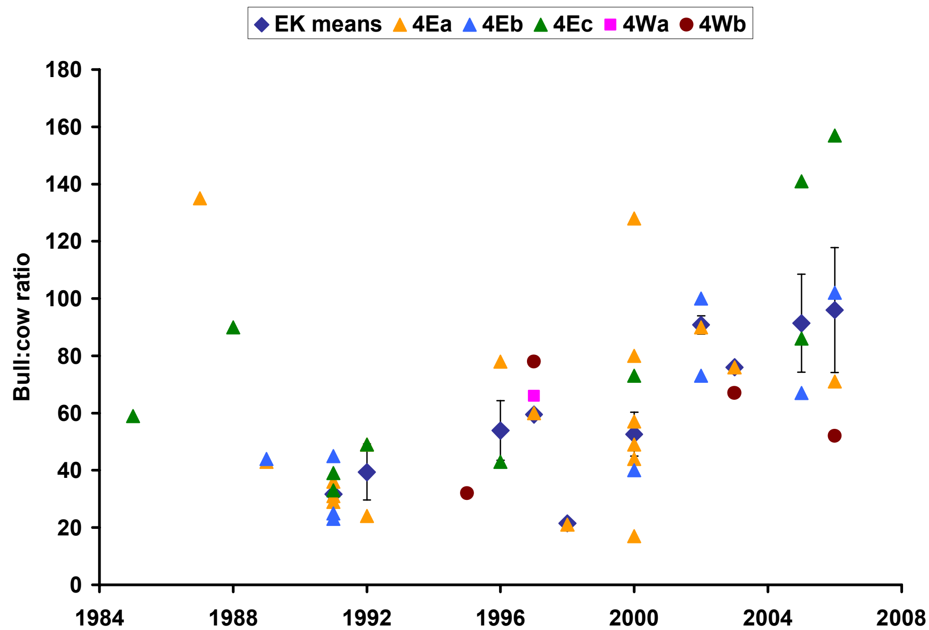

Figure 6. Bull:cow moose ratios derived from 43 moose surveys conducted during December to early February 1985 to 2006, Kootenay Region. Mean among years for the East Kootenay shown with 1 SD for data from 1991 on. Sources: published reports (Table 3), FWCP databases, and historic databases obtained from MoE. 1996 = December 1995 to February 1996.

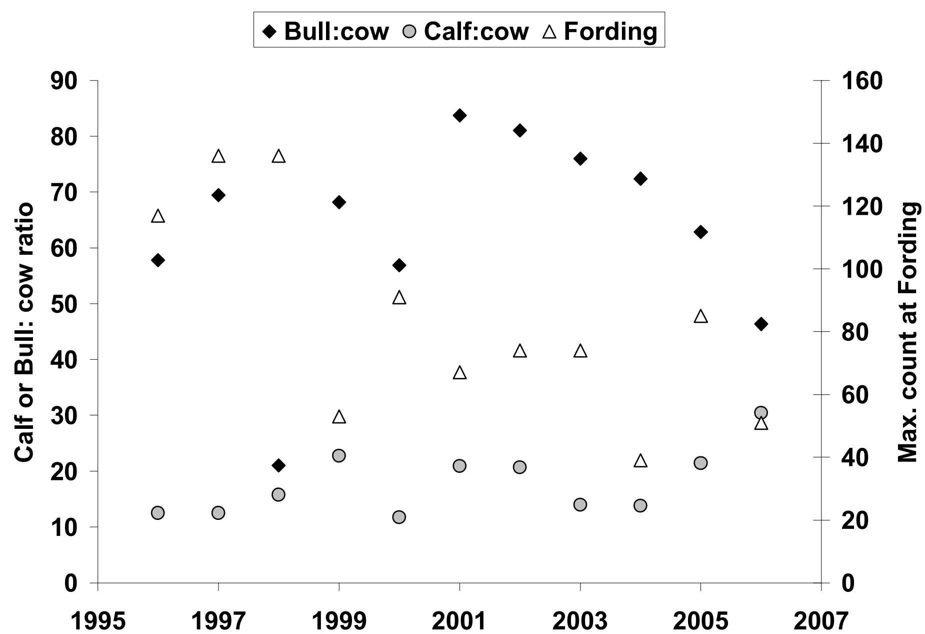

Figure 7. Bull:cow and calf:cow ratios derived from moose surveys conducted in Elk Valley Coal Corporation (EVCC) surveys (Fording, Line Creek, Coal Mountain, Elkview, Greenhills) during January–February of 1996 to 2006, Elk Valley. Annual sample sizes ranged from 65–141 moose (mean 111 moose); individual surveys ranged from 18–136 animals. The maximum annual count from Fording is provided. Sources: reports and databases from EVCC.

Nonhunting mortality

Cougar harvests and problems kills were relatively constant from 1976 to the early 1990s, increased to a peak in 1996–1998, and subsequently declined to lower levels by the early to mid-2000s (Fig. 8). Hunter effort for cougars changed little through 2000, and may have increased in recent years. Trends in numbers of problem cougars killed roughly mirror the harvest, suggesting both are rough but reasonable indices of population size. Wolf harvests were low through the 1980s, increased during the 1990s to peak in 1996 and 2002, and declined through to 2004 (Fig. 9); these statistics may reflect increased populations of wolves in the Kootenays beginning in the mid-1990s. No hunter effort data are available for wolves.

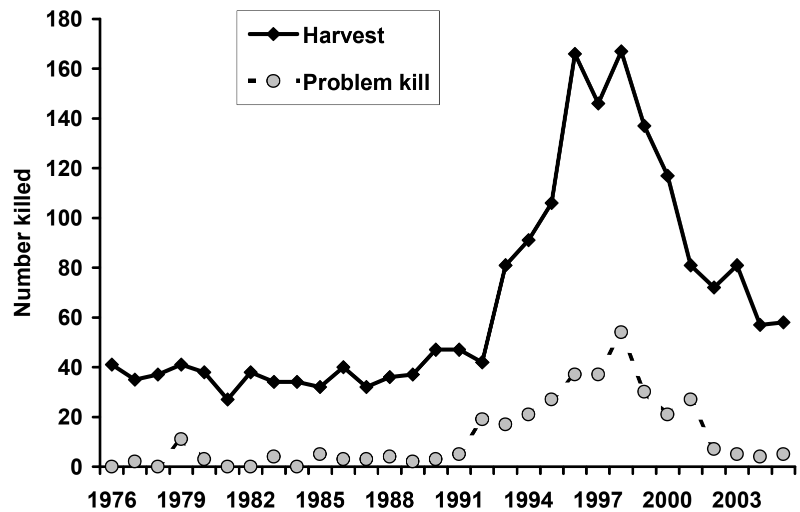

Figure 8. Cougar harvests and problem kills in the Kootenay Region, 1976–2005. 1997 = 1997–1998 harvest year.

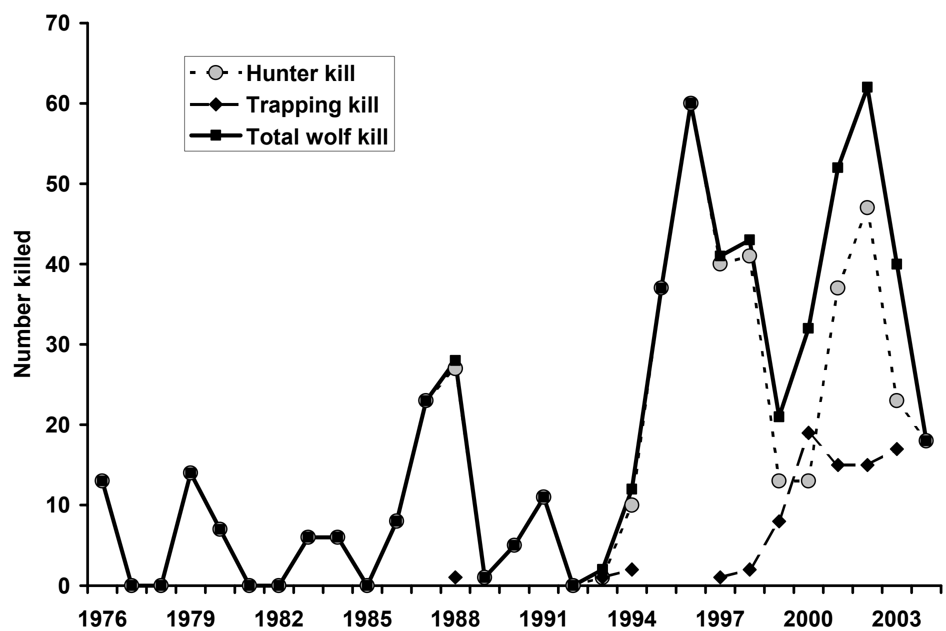

Figure 9. Wolf hunting and trapping harvests in the Kootenay Region, 1976–2004. 1997 = 1997–1998 harvest year.

Trends in populations of black bears and grizzly bears in the Kootenay Region are less clear. Numbers of black bears killed have declined slowly from the early 1980s to present, but both hunter success and days per kill (catch per unit effort) have remained relatively stable since the mid-1980s (Mowat 2006), suggesting no clear trend to the population (the declining harvest may be a result of declining interest). Grizzly bears harvest numbers in the Kootenays have varied considerably since 1976, but general increasing hunter success and decreasing days per kill (Mowat 2006) suggest populations may have increased over this time period, with a possible levelling since the late 1990s.

Vehicle-moose collisions on Kootenay highways resulted in an average of 22 moose kills per year between 1983 and 2002 (Fig. 10) (Sielecki 2004). Although there were roughly 3 times as many collisions in the EK compared with the WK over the 20-year period, the number of collisions in the WK has increased steadily since the late 1980s, whereas there was no obvious trend in numbers of collisions in the EK. Assuming equal increases in traffic volumes in both areas over time, the data suggest an increase in the numbers and distribution of moose in the WK.

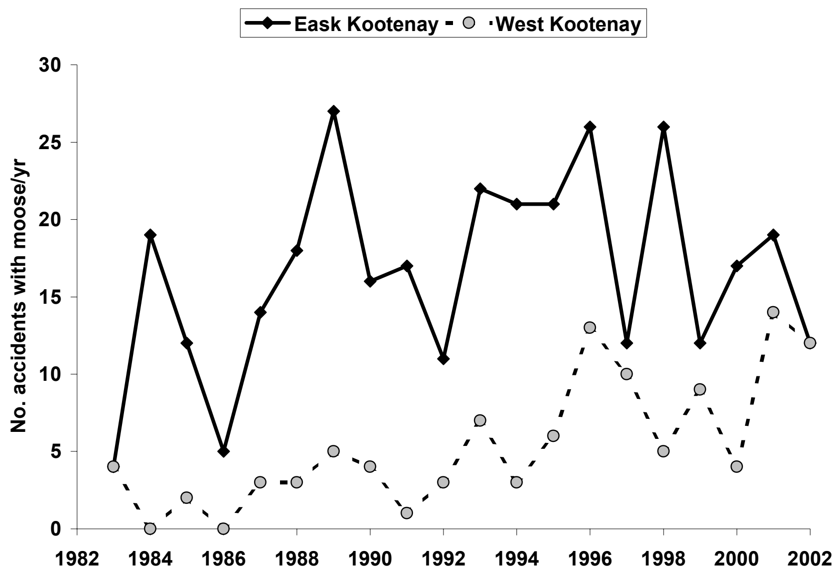

Figure 10. Number of vehicle-moose accidents annually in the East and West Kootenays, 1983–2002 (Sielecki 2004).

Weather data

Data from the past 35 years suggest snowfall and snow depths in both the EK and WK have declined from levels observed in the 1970s (Fig. 11). Both Cranbrook and Castlegar experienced high snowfall and accumulation in 1997 (winter 1996–1997), but in general, snowfall and snow accumulation has trended lower since about 2000, especially for snow accumulation at Cranbrook. Summer rainfall amount varied widely among years, but showed limited overall trend (Fig. 12).

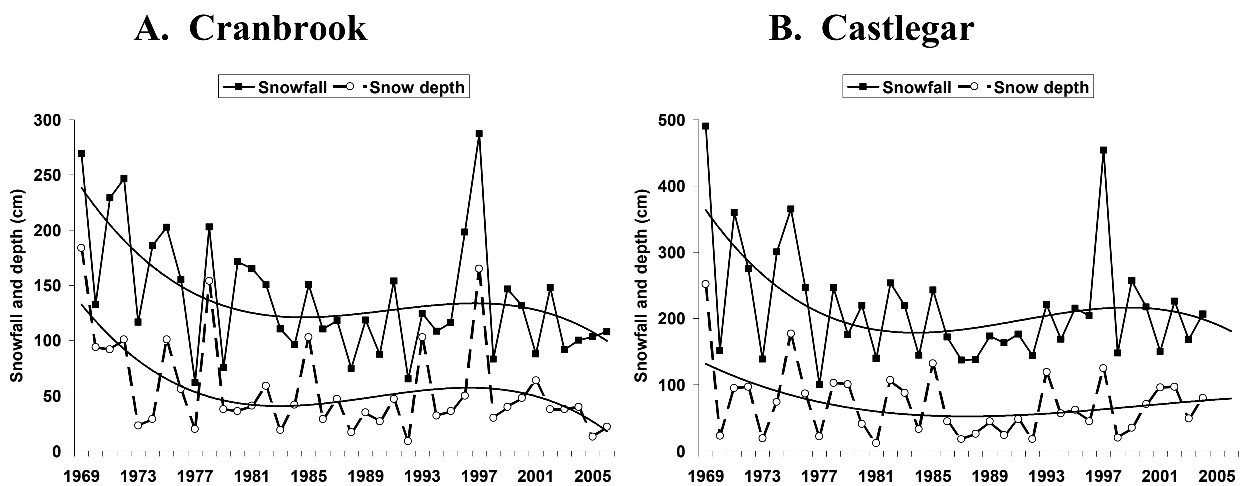

Figure 11. Snowfall (upper set of data and trend line) and snow depth accumulation for Cranbrook and Castlegar, 1969 to 2004–2006. Trend lines (3rd order polynomial) fitted in Excel. 1997 = winter 1996–1997.

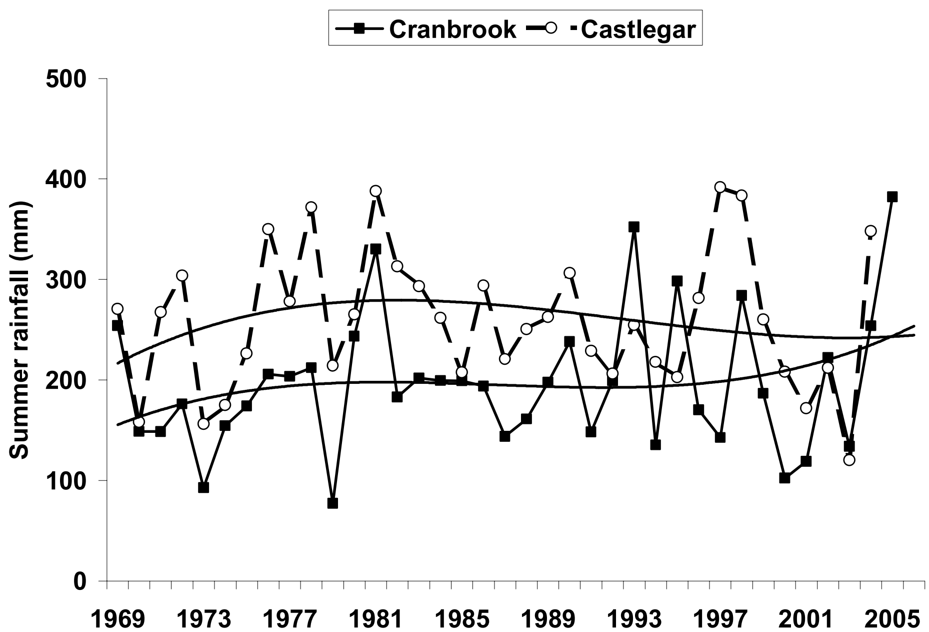

Figure 12. Summer (May to September) rainfall for Cranbrook (upper set of data and trend line) and Castlegar, 1969 to 2004–2006. Trend line (3rd order polynomial) fitted in Excel.

I used EK moose data only (n = 39) to examine possible correlations between snowfall, snow depth, and rainfall and calf:cow ratios, as sample sizes were extremely small for the WK (n = 4). No correlations approached significance ($r < 0.21$, $P > 0.21$). Comparisons with weather data from the year prior to the survey also resulted in poor fit to the data for all 3 climate parameters ($r < 0.12$, $P > 0.50$).

A multivariate regression analysis for the EK of dependent variable mean annual calf ratios and independent variables year, mean bull ratios, snow depth during the winter of survey, rainfall the previous summer, and cougar and wolf harvests the previous year (PROC GLM, 9 df, $F = 4.70$, $P = 0.12$) suggested a positive correlation with bull ratios ($P = 0.054$) and a negative correlation with wolf harvests ($P = 0.06$).

Harvest data

Moose tags allocated

Although a system of cow-calf LEH tags for residents was implemented as early as 1984, it was not until 1991 that bull LEH tags were implemented across the region. The number of resident LEH tags available for bull and especially cow-calf moose within the Kootenay Region has varied over time (Fig. 13). In addition to the numbers presented in these graphs, in 1989 an apparent one-time release of 544 calf tags occurred in the EK. In GMZ 4Wb, an additional 14 any sex/any age tags were allocated in 2000, and 10 antlerless/spike tags were allocated in 2002.

Numbers of bull tags in the region peaked in the mid-1990s at over 600 tags, and declined steadily through to the early 2000s (Fig. 14a). The highest numbers of cow-calf tags were released in the early

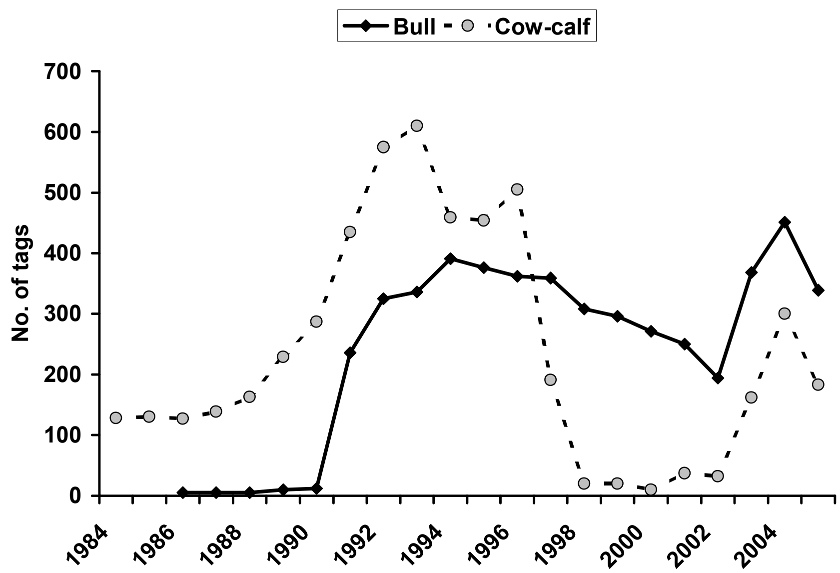

Figure 13. Resident moose Limited Entry Hunt (LEH) tags available for the Kootenay Region, 1984–2005. Data obtained from LEH surveys.

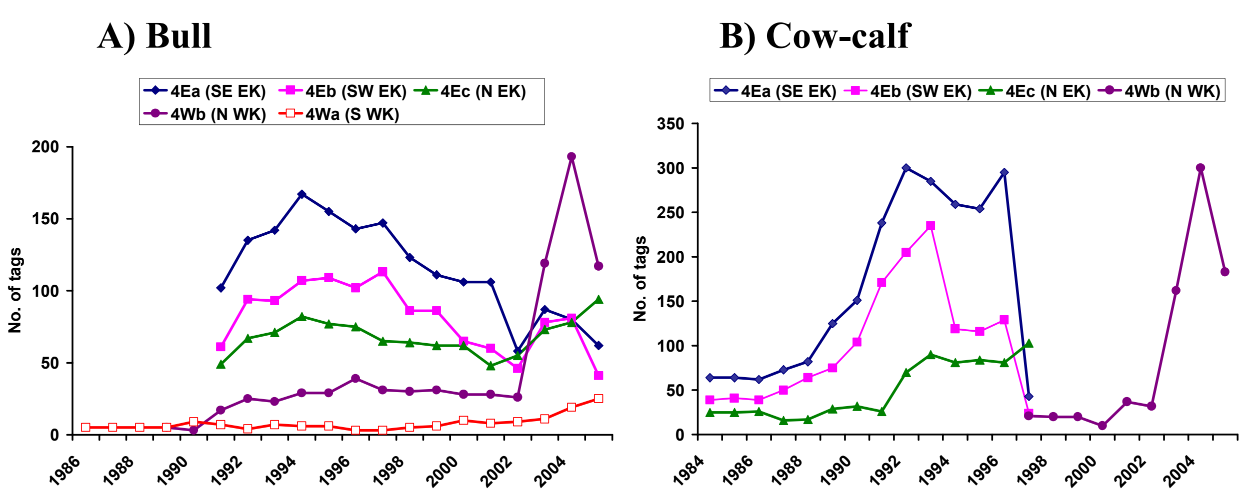

Figure 14. Resident moose Limited Entry Hunt (LEH) A) bull, and B) cow-calf tags available by Game Management Zone, 1984–2005. Data obtained from LEH surveys. Note that axes scales differ between figures.

1990s (peaking at 391 tags), and declined rapidly in 1997 and 1998 to 20 tags. The regional spike in the number of bull and cow-calf tags starting in 2003 came from efforts to reduce moose numbers in MUs 4-38 and 4-39 (Lake Revelstoke area; Poole and Serrouya 2003) (Fig. 14b). Tag allocation in the Lake Revelstoke area decreased in 2005, and returned to even lower levels for the 2006 season (T. Szkorupa, BC MoE, unpublished data). After 1997, no cow-calf tags were released in the EK.

On average across the region, resident hunters utilize (attempt to hunt) about 90% of bull permits and 80% of cow-calf permits.

Hunter numbers

Hunting for bull moose in the Kootenay Region prior to 1991 was under a GOS system, and resulted in 2,200–4,200 resident hunters annually (Fig. 15a). With the implementation of LEH tags for all bull moose hunting in the region in 1991, number of resident hunters declined to approximately 400–500 annually in the early to mid-1990s (Fig. 15b). Since peaking at 525 in 1995, the number of resident hunters declined to 254 by 2002. Increases subsequent to 2002 were primarily related to the tags available in the Lake Revelstoke area. The shared hunt rule initiated in 2004 also resulted in an increase in hunters. Since 1991, the number of non-resident hunters has increased from 6 to 68 annually (Fig. 15b).

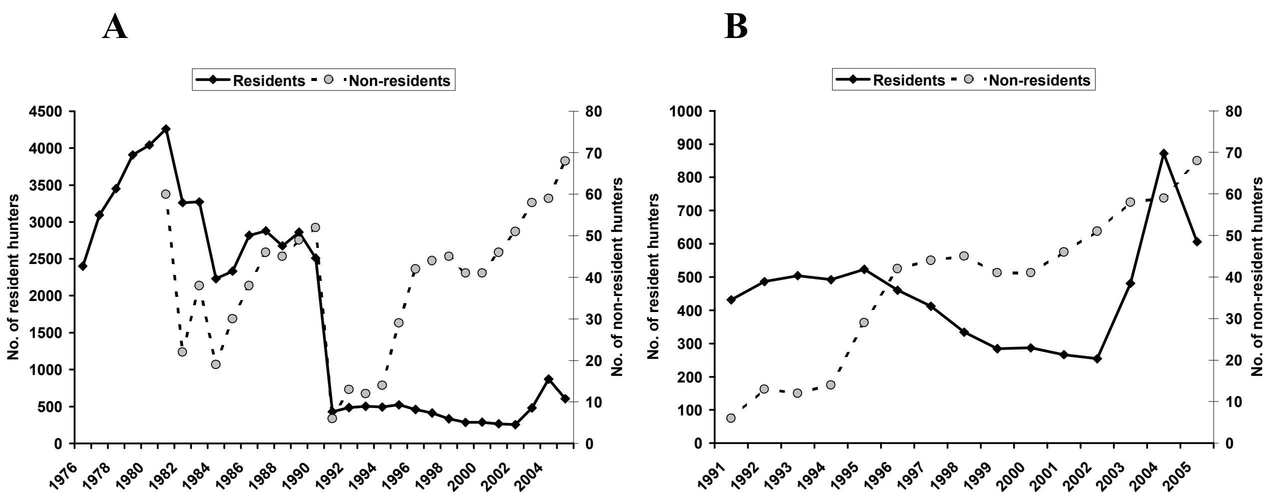

Figure 15. Numbers of resident (left axis) and non-resident (right axis) moose hunters in the Kootenay Region for A) 1976–2005, and B) 1991–2005 (when all moose hunting was by Limited Entry Hunts [LEH]), as determined from hunter sample questionnaires and guide declarations. Prior to 1991, bull moose hunting seasons were open; LEH was implemented for bull moose in 1991.

Mean number of days each hunter used to hunt moose generally declined until the early 1990s and subsequently remained relatively stable for both residents and non-residents, with a slight increase for residents in 2004 and 2005 (Fig. 16). Since 2000, moose hunters have averaged 4.9 and 5.6 days for residents and non-residents, respectively.

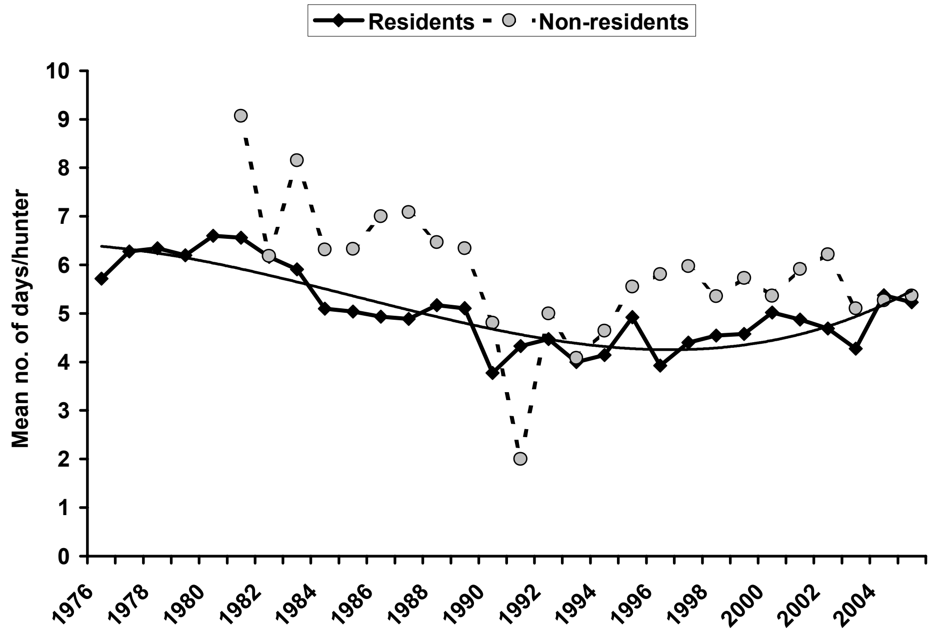

Figure 16. Mean number of days each moose hunter hunted per year, for residents and non-residents in the Kootenay Region, 1976–2005. Data from hunter survey questionnaires and guide declarations. Mean number of days for residents fitted with 3rd order polynomial trend line in Excel (r^2 = 0.76).

Harvest numbers

Prior to the start of LEH permits in 1991, up to 550 bull moose, 121 cow moose, and 134 calf moose were harvested annually by resident hunters (Fig. 17). Subsequent to 1990, all moose hunting in the region was by LEH tag, and although estimated harvest numbers differ somewhat between data sources, resident moose harvests roughly paralleled the number of permits issued within the region (Figs. 17, 18). Bull moose harvests peaked in the mid-1990s at just over 200 animals, and declined steadily to 2002 (Figs. 18), when the release of large numbers of permits in the Lake Revelstoke area (Fig. 14a) increased the overall harvest back to approximately 210 animals. With the exception of the recent increases in harvest in the Lake Revelstoke area, GMZs 4Ea and 4Eb have contributed the greatest proportion of the bull moose harvest in the region. Bull moose harvests in the 3 EK GMZs have generally declined since the mid-1990s.

Non-resident bull harvests increased from the early 1990s levels of 5–10 animals per year, to 41–44 bulls annually for 2003 to 2005. Comparing average bull harvests for 2001–2005, non-residents took approximately 17% of the annual moose harvest, and residents took 83%.

The cow-calf harvest peaked at about 200 animals in the late 1980s (Fig. 17) or early 1990s (Fig. 18), and declined dramatically in 1997–1998, coincident with a reduction in cow-calf tags (Fig. 14b). After 1998, cow-calf harvests were only permitted in the Lake Revelstoke area, where estimated harvests increased to approximately 140 animals in 2004 (Fig. 19b). From 1991 to 2002 (prior to the significant increase in tags allocated in 2003), the calf:cow ratio in the cow-calf harvest was 21 calves:79 cows. Hunter harvest data from the Lake Revelstoke area in 2003 to 2005 show a 25 calf:75 cow ratio.

Over the past 5 years, the combined resident and non-resident moose harvest was highest in the southern part of the region (Flathead, Wigwam, Elk and Bull valleys), west of the Rocky Mountain Trench in the EK (especially the Spillimacheen valley), and in the west side of the Upper Arrow Lakes and Lake Revelstoke area in the northern WK (Fig. 20).

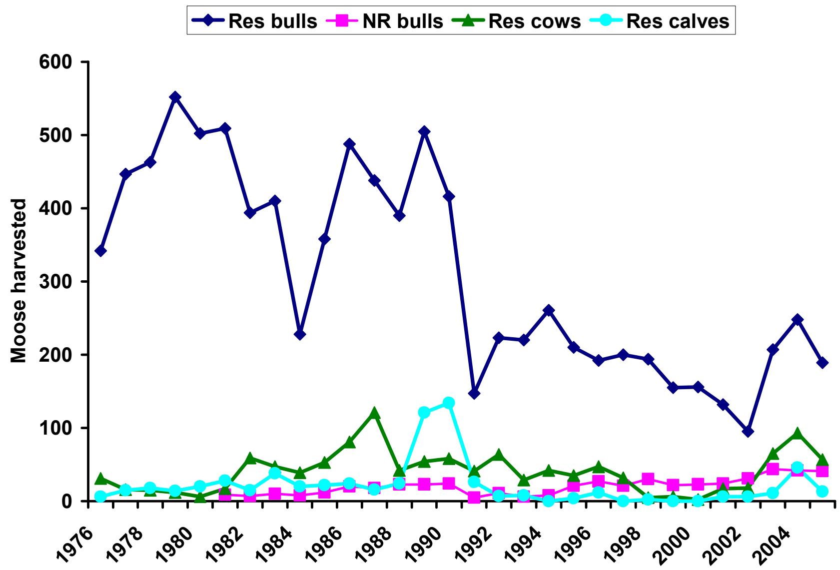

Figure 17. Resident (Res) bull, cow, and calf harvests and non-resident (NR) bull harvests for the Kootenay Region, 1976–2005, as determined from hunter survey questionnaires and guide declarations. Not included are 12 any sex/any age tags filled in 2000, and 8 antlerless/spike moose harvested in 2002.

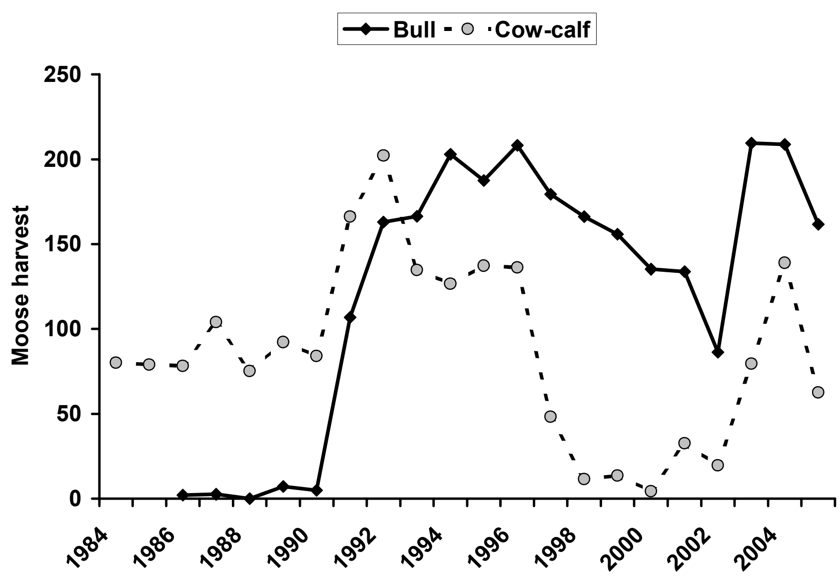

Figure 18. Resident bull and cow-calf moose harvest in the Kootenay Region as determined from Limited Entry Hunt (LEH) surveys, 1984–2005. Prior to 1991, most bull-moose hunting was open (Fig. 15), and not registered under the LEH system.

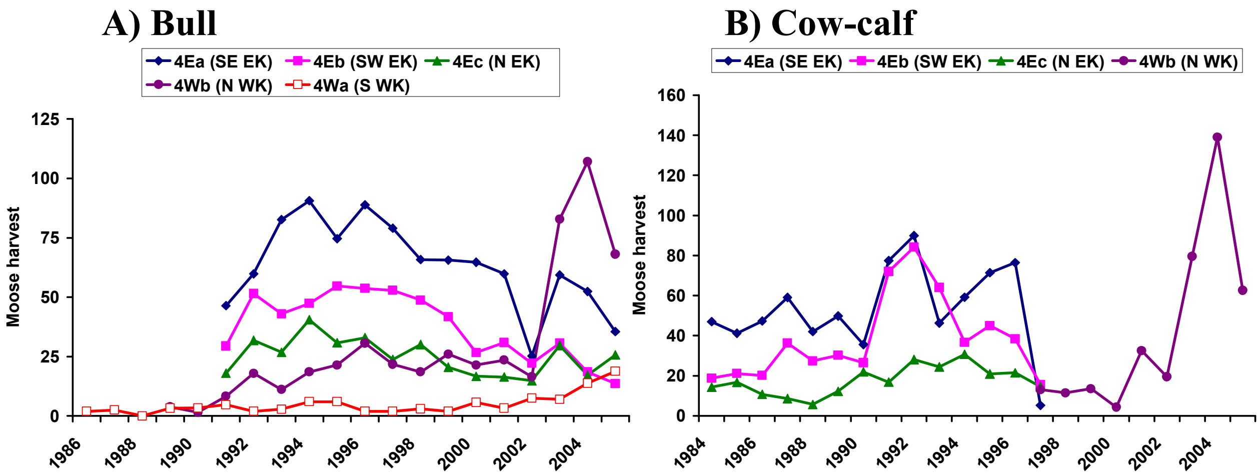

Figure 19. Resident bull (A) and cow-calf (B) moose harvest by Game Management Zone as determined from Limited Entry Hunt (LEH) surveys, 1984–2005. Prior to 1991, most bull moose hunting was open (Fig. 15), and not registered under the LEH system.

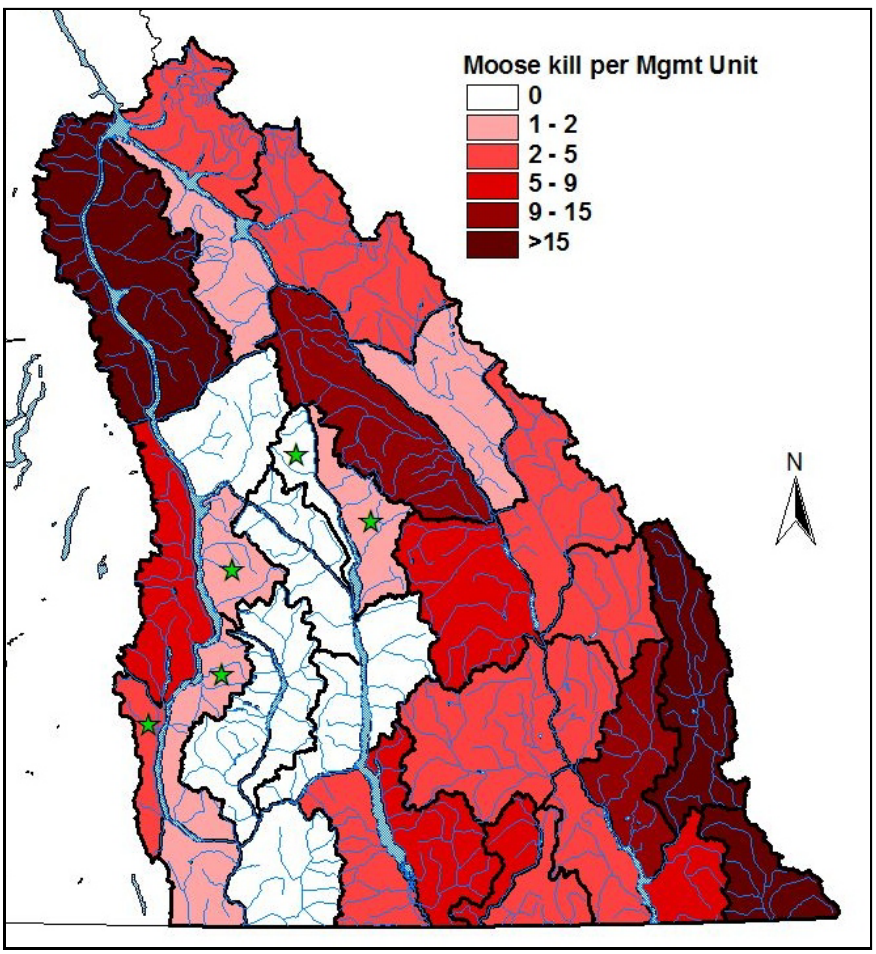

Figure 20. Average annual moose harvests (all age and sex classes) by management unit (MU) for resident and non-resident hunters combined, 2001–2005, Kootenay Region. Bull moose tags were first available for 5 MUs starting in 2005 (marked with green stars).

Hunter success

Overall hunter success (defined here as the number of animals harvested per hunter) increased significantly for non-resident hunters and slightly for resident hunters through to initiation of LEH tags in 1991 (Fig. 21a). (This calculation includes all moose age and sex categories for residents, since kills are not differentiated by age/sex category in the database). Subsequent to 1991, both resident and non-resident hunter success has remained relatively constant, averaging 50% and 64%, respectively, from 2001–2005 (Fig. 21b).

Region-wide, the resident hunter success for bull moose (defined here from LEH surveys as the estimated harvest relative to the number of tags allocated) has remained relatively constant since 1991 at 51% (range 44–57%; Fig. 22). During the early period when large numbers of cow-calf tags were available (1984–1997; 127–610 tags annually), hunter success was 22–30%. From 1998–2002, only 10–37 cow-calf tags were available annually within the region, resulting in higher hunter success but wide annual variation (43–88%). With the increase in tags in the Lake Revelstoke area (MUs 4-38 and 4-39), hunter success in 2003 and 2004 was 46–49%, but dropped to 34% in 2005.

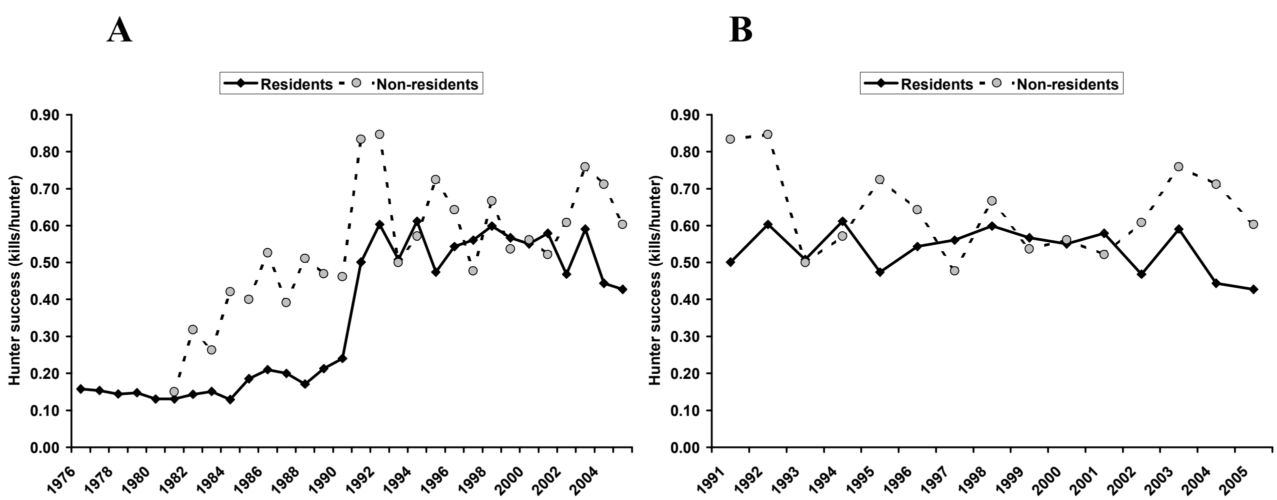

Figure 21. Moose hunter success (number of moose harvested per hunter) for resident and non-resident hunters in the Kootenay Region, A) 1976–2005, and B) 1991–2005 (when all moose hunting was by LEH). Data obtained from hunter survey questionnaires and guide declarations.

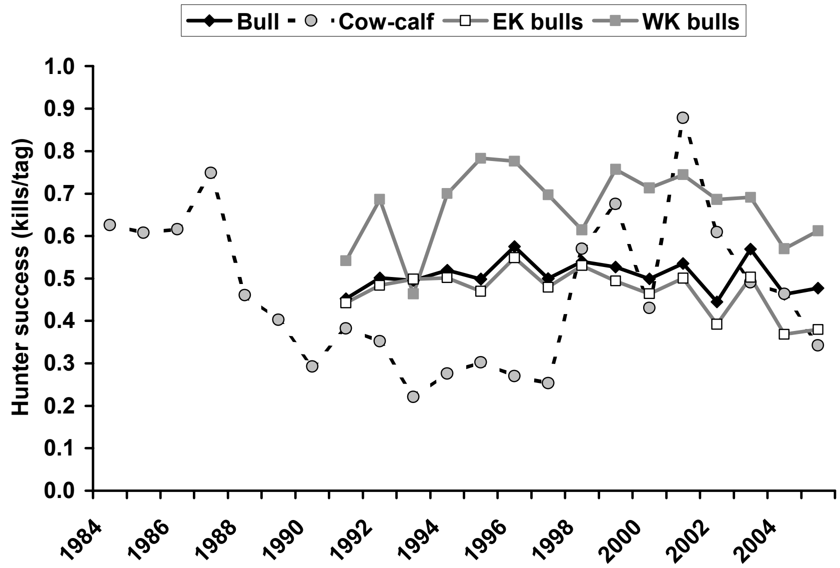

Figure 22. Resident hunter success (estimated kills per tags issued) for bull and cow-calf moose tags, Kootenay Region, 1984–2005. Data also presented for bull moose for EK and WK. Data obtained from Limited Entry Hunt (LEH) surveys.

The mean number of kills per days hunted (catch per unit effort; CPUE) increased steadily through the late 1980s for both resident and non-resident hunters, increased rapidly in the early 1990s (Fig. 23a), and has possibly trended slightly lower for residents from 1991–2005 (Fig. 23b). Data from the EK closely parallels the region averages, while WK data are generally higher but more variable. From 2001–2005, kills per 100 hunter days averaged 10.4 and 11.6 for residents and non-residents, respectively.

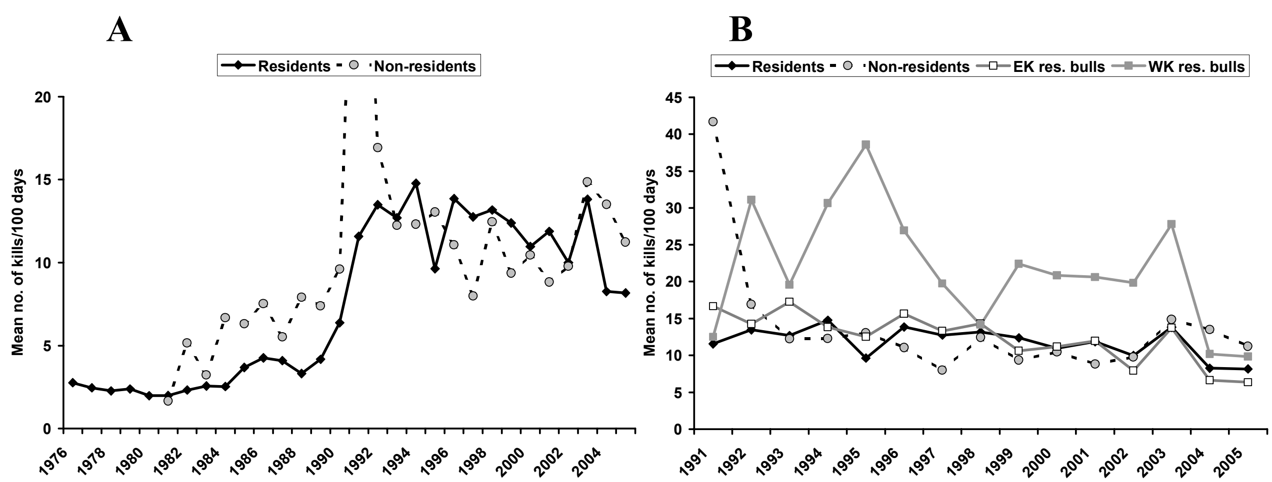

Figure 23. Mean number of kills per 100 days of hunting for resident and non-resident moose hunters in the Kootenay Region, A) 1976–2005, and B) 1991–2005 (when all moose hunting was by LEH). Data obtained from hunter survey questionnaires and guide declarations, except for data for EK and WK bulls shown in right figure, from LEH surveys. The value graphed off the top of the left figure for non-residents for 1991 was 41.7 kills/100 days (small sample size).

Various indices of hunter success (kills per hunter, kills per tag, kills per 100 days of effort) are related but show subtle differences, especially because the 2 data sources (general hunter questionnaires and LEH surveys) differ slightly in estimated totals of the various variables. Changes in regulations and numbers of tags allocated may affect indices of hunter success, such that it is difficult to directly relate hunter success to population size over long time periods. For example, the switch from resident group hunts to shared hunts in 2004 resulted in a drop in the number of kills per 100 days hunted (Fig. 23b), because more hunters were counted as actually hunting moose. Large differences in the numbers of bull and cow-calf permits allocated from the mid-1990s to 2002 (Fig. 13) may also influence these indices because of interference among hunters, lowering their hunting success. Although several studies have shown that hunter success provides a useful index of abundance, this outcome is not always the case (reviewed in Hatter 2001). Hatter (2001) found that hunter success underestimated the population rate of decline and may overestimate rate of increase. Thus, while hunter success can be considered as one means of tracking population trends, it should not be the only tool in the box.

Age of harvested animals

Mean age of bull moose harvested by resident hunters remained relatively constant during the 1980s and early 1990s ($\bar{x}$ = 3.8 years), and rose during the mid to late 1990s (Fig. 24). Mean age of cows increased during the 1980s, and levelled off in the 1990s ($\bar{x}$ = 5.6 years). Mean age of bulls harvested by non-residents during the 1990s was 5.4 years; small annual sample sizes (2–21 each year) precluded trend analysis of non-resident bull ages.

The age distribution of moose harvested by residents during 1991–1999 was more heavily skewed towards younger ages in bulls than cows (Fig. 25). Animals 1–4 years of age accounted for 60% of the bull harvest, and 40% of the cow harvest. The proportion of moose ≥7 years of age drops rapidly in the bull harvest (19% of the harvest), and less rapidly in the cow harvest (36%).

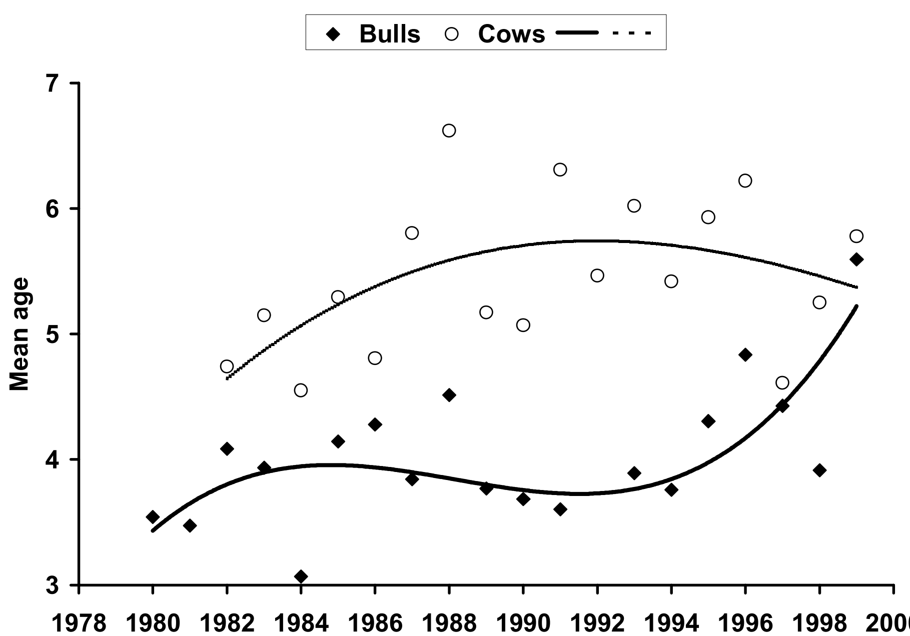

Figure 24. Mean age of moose harvested in the Kootenay Region by resident hunters, 1980–1999. Annual sample sizes for bull moose taken by resident hunters ranged from 46–177, and for cows 20-125 (<10 for 1998 and 1999). Mean age by year with fitted 3rd order polynomial lines in Excel) (r^2 = 0.47 and 0.27 for resident bulls [lower polyline] and cows [upper polyline], respectively).

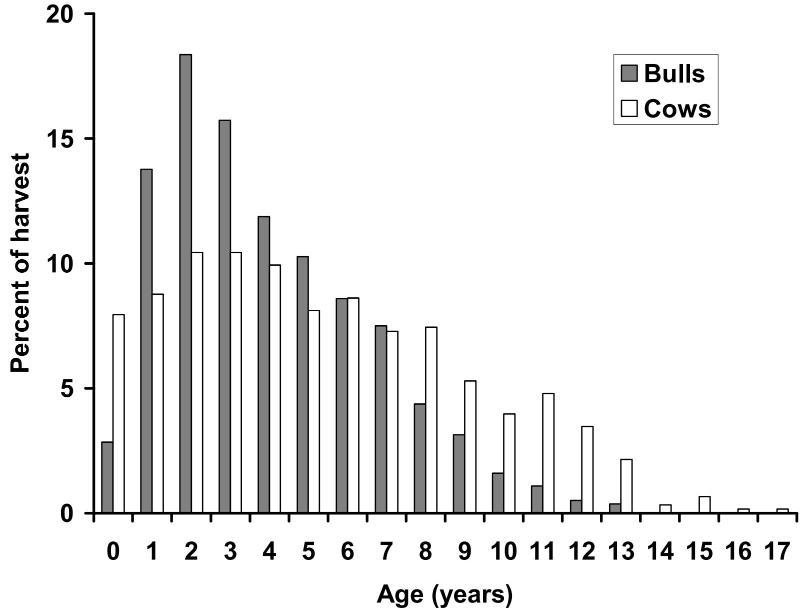

Figure 25. Distribution of age of harvested bull (*n* = 1373) and cow (*n* = 604) moose, Kootenay Region, 1991–1999.

Harvest rate

Estimated moose harvest rates declined in all GMZs between the late 1990s (range 2.5–7.9%) and early 2000s (range 2.0–4.8%), except for GMZ 4Wb, which increased from 5.5–8.7%, in part because of higher harvest levels used to reduce the Lake Revelstoke population (Table 6). Although the estimates of average annual harvest (as calculated from hunter questionnaires and guide/outfitter declarations) are likely relatively accurate, population estimates derived for 2000 may be significant underestimates in some cases, resulting in apparent higher, but false, harvest rates for that period. Of the 10 surveys conducted since 2000 that resulted in revised population estimates, population increases in individual MUs were significantly higher in 9 cases, resulting in an over doubling of the summed estimates (Table 7). In MUs where SRB surveys where conducted (4-05, 4-20, 4-22), the increases in population estimate between 2000 and 2005–2006 was 100% or higher in 5–6 years (Table 7), beyond the realistic increase in moose populations under moderate predation and hunting conditions (Bowyer et al. 2003).

Calculated harvest rates for 2001–2005 vary widely among MUs (Table 7). With the exception of MUs 4-38 and 4-39, calculated harvest rates >5% occurred in MUs that have not been surveyed since 2000. Again, as noted earlier, a number of these estimates were derived from surveys conducted in 2000 that may have underestimated population size. Therefore, the calculated harvest rates likely are biased high.

Table 6. Calculation of moose harvest rate by game management zone (GMZ) and region by comparing average annual harvest for periods 1996–2000 and 2001–2005 with population estimates derived in 2000 (BC MoE, unpublished data), and 2006 (updated data with recent surveys and revisions to MU estimates). General area of the GMZ provided (e.g., SW EK = southwest East Kootenay). See text for further discussion.

Parameter	4Ea SE EK	4Eb SW EK	4Ec N EK	4Wa S WK	4Wb N WK	Kootenay
Annual harvest						
1996–2000	93.8	48.4	37.6	6.4	38.4	224.6
2001–2005	77.6	23.6	21.6	14.0	140.2	277.0
Population estimate						
2000	1315	935	850	275	635	4010
2006	2093	842	886	550	1599	5970
Annual harvest rate						
1996–2000 harvest with 2000 estimate	7.1%	5.2%	4.4%	2.3%	6.0%	5.6%
2001–2005 harvest with 2006 estimate	3.7%	2.8%	2.4%	2.5%	8.8%	4.6%

Hunter success also varies widely among MUs (Table 7). A number of factors can affect hunter success, including access, population size, hunter effort, and habitat. Small sample sizes (low numbers of tags allocated) may result in wide fluctuations in success among years. Low hunter success may, but does not always indicate low population size relative to the number of tags allocated (Hatter 2001). For example, 179 moose were counted and 456 estimated during the 2006 survey of MU 4-22 (Bull River) (Poole 2006). This population should provide ample opportunity for harvest, yet hunter success for 2003–2005 was only 40%. In MU 4-40, 105 moose were counted (Ingham et al. 2005) and 215 were estimated in 2005, but average success during 2003–2005 was only 31%. Hunter success alone may not be a good indication of population size or trend.

Table 7. Moose harvest rate by management unit (MU), calculated by comparing average annual harvest for periods 1996–2000 and 2001–2005 with population estimates derived in 2000 (BC MoE, unpublished data) and 2006 (updated data with recent surveys), respectively. Resident hunter success (average number of bulls harvested relative to the number of permits available) provided for 2001–2005. Population estimate for 2006, harvest rates, and hunter success in bold provided for those MUs where population estimates have been recently updated. See text for further discussion.

	Annual harvest		Population estimate		Harvest rate (%)		Success (%)
MU	**1996–00**	**2001–05**	**2000**	**2006**	**1996–00**	**2001–05**	**2001–05**
4-01	17.0	16.0	185	286	9.2	5.6	64
4-02	6.2	8.2	135	211	4.6	3.9	47
4-03	11.8	2.6	295	91	4.0	2.9	17
4-04	5.2	3.8	185	57	2.8	6.7	26
4-05	11.0	7.2	220	**291**	**5.0**	**2.5**	**79**
4-06	6.0	6.4	120	157	5.0	4.1	58
4-07		3.5	10	**100**		3.5	100
4-08			30	**100**			
4-09	0.4	1.5	55	43	0.7	3.5	39
4-14		3.0	10	57		5.3	100[1]
4-15		1.5		43		3.5	50[1]
4-16			10	10			
4-17			5	5			
4-18			5	5			
4-19			30	30			
4-20	9.0	4.2	135	**248**	**6.7**	**1.7**	**66**
4-21	4.0	2.2	35	57	11.4	3.9	60
4-22	9.0	12.0	135	**456**	**6.7**	**2.6**	**35**
4-23	45.2	33.2	660	831	6.8	4.0	70
4-24	9.2	3.2	80	120	11.5	2.7	52
4-25	3.2	2.8	85	131	3.8	2.1	29
4-26	11.4	5.8	100	154	11.4	3.8	67
4-27		1.5	30	71		2.1	38[2]
4-28		0.0	20	43		0	0[3]
4-29			5	5			
4-30			5	5			
4-31		2.0		43		4.7	67[1]
4-32	5.2	7.4	100	257	5.2	2.9	71
4-33			15	15			
4-34	12.4	11.8	325	200	3.8	5.9	37
4-35	2.2	2.0	75	57	2.9	3.5	53
4-36	12.6	3.4	**315**	**226**	**4.0**	**1.5**	**19**
4-37	6.4	0.6	**75**	**219**	**8.5**	**0.3**	**63**
4-38	22.2	79.8	**350**	**640**	**6.3**	**12.5**	**69**
4-39	11.0	52.2	**110**	**520**	**10.0**	**10.0**	**57**
4-40	4.0	3.8	**60**	**184**	**6.7**	**2.1**	**34**

[1] Hunter success derived from 3 LEH authorizations for 2005.
[2] Hunter success derived from 4 LEH authorizations for 2005.
[3] Hunter success derived from 2 LEH authorizations for 2005.

Discussion

Population estimates

Estimated moose numbers in the Kootenay Region declined from 1986 to 1992, and increased by 1994 to roughly late 1980s levels (Table 1). Differences among GMZs were evident, with the greatest fluctuation in southeast EK (Fig. 3). The implementation of LEH permitting for moose hunting in the Kootenay Region in 1991 appeared to have a limited effect on moose population estimates, despite a 50% drop in bull harvests. However, reductions to bull harvests through the more conservative management system are reflected in the steady increase in the bull:cow ratio and mean age of harvested bulls since the early 1990s.

Estimated moose populations in the Kootenay Region declined during the later half of the 1990s; surveys of 9 MUs in the EK in 2000 suggested significant declines in most populations (Halko et al. 2000). Most declines where observed in the EK, while populations in the WK increased. However, problems with survey design and application of methods suggests that many of these EK populations were underestimated, and the survey results should not be considered reliable. Ten of 24 MUs in the Kootenay Region with reasonable moose populations have been surveyed to some degree since 2000, and all but one indicate considerably higher numbers than estimated for 2000 (Table 7). Some of these higher population estimates occurred concurrent with lower hunter success (Table 7).

Moose populations change over time as a result of a number of factors, including changes in habitat quality and quantity, predation, regulated hunting, non-hunting human-caused mortality, weather, and perhaps parasites (Bowyer et al. 2003). All of these factors can affect numbers, productivity, and recruitment. Habitat changes over time as a result of forest succession after fire events or logging can be expected. For example, the 1971 Sue Fire in the Donald Block area of MU 4-36 appears to have resulted in high densities of moose during the 1980s and 1990s (Bindernagel et al. 1991, Ingham 1997), but now 35 years later have show reduced habitat quality, and hence reduced moose densities (Ingham et al. 2005). Broad-scale logging in the Lake Revelstoke area may have increased forage and habitat quality, and partly contributed to significant increases in the population during the 1990s (Poole and Serrouya 2003). These areas may support reduced densities of moose as forest succession progresses.

Recent surveys suggest that moose numbers in several areas of the Kootenays are stable to increasing. Moose also may be expanding in range and numbers into previously un-occupied or low-density areas, as data from MU 4-08 suggest. Harsh winters, such as experienced during 1996–1997, may have increased over-winter mortality and reduced productivity and recruitment of moose. However, relatively mild winters with low snowfall during the past 5 years have likely contributed to higher moose recruitment, fuelling the expansion. None of the weather variables examined correlated well with calf ratios, but this may be a function of poor data for comparison. Messier (1991) found no measurable effect of snow accumulation on calf-cow ratios or moose numbers. Calf:cow ratios in the Kootenays appear to be stable or slightly increasing, after possibly lower levels in the late 1990s. Predator numbers are variable; stable to increasing bear populations, higher wolf numbers since the mid-1990s, and lower cougar populations in recent years. Since cougars are not thought to be significant predators on moose, overall predator pressure on moose populations in the Kootenays are likely higher than levels experienced prior to the mid-1990s, placing added natural mortality on some populations.

Moose are likely not stable or increasing in all areas of the region. Concerns about low numbers of anecdotal sightings, low calf counts, and poor hunter success in MUs 4-03 and 4-04 suggest that these populations may be declining. Moose populations in MUs 4-34 and 4-35 may also be declining. None of these MUs has been surveyed in more than 15 years.

Moose population changes in the Lake Revelstoke area (MUs 4-38 and 4-39) have been detailed elsewhere (Poole and Serrouya 2003; Serrouya and Poole, in prep.). Results of the 2003 survey (survey estimate of 1,650 moose) suggest that the population had likely doubled in the previous 8–10 years. Since the 2003 survey, 3 years of high numbers of bull and cow-calf LEH tags and resulting harvests rates approaching 16%, coupled with possible increased predation levels (R. Serrouya, pers. comm.), appears to have resulted in a 40–50% population decline (Serrouya and Poole, in prep.). Greatly reduced numbers of tags issued for 2006 are designed to stabilize the population at roughly 1,200 moose. A survey conducted in January 2007 (data analysis not finalized) should better establish current population levels.

The Revelstoke work points to an alternative method to track changes in population size. Pellet plots (Neff 1968) established in 2002 and 2003 in the Lake Revelstoke area have indicated changes in moose numbers that appear to mirror changes in the estimated population based on survey data and harvest rates (Poole and Serrouya 2003, Serrouya and Pavan, unpublished data). The cost of conducting annual pellet counts robust enough to detect change in population size is less (~$10,000) than the cost of a SRB survey (~$60,000). The pellet counts may be more robust to sightability issues, but do not provide composition data, and have limited spatial application.

Harvest data and rates

Evidence suggests that sustainable harvest rates for moose may range from 5–10% of the population depending upon predator levels and the relationship to carrying capacity (Gasaway et al. 1992, Hatter 1998). The sustainable harvest rate generally can be much greater at, for example 60% of carrying capacity, compared with 90% of carrying capacity. Most of the evidence for these rates comes from central and northern British Columbia and Alaska, under moderate to high-density populations, and where predominantly bulls are harvested. Differences among ecosystem and ungulate-predators dynamics within the Kootenay Region relative to areas studied may result in different sustainable harvest rates. However, evidence from the Lake Revelstoke area suggests that the population growth rate was 8% annually from the mid-1990s to 2003 under relatively light harvesting (10% growth rate if harvest was excluded; R. Serrouya, unpublished data). Under most moderate predation levels and in populations below carrying capacity, harvest rates of up to 5–7% of the total population (consisting primarily of bulls, but with some harvest of cows and calves) should be sustainable.

Surveys conducted since 2000 have shown an average of roughly 29–30 calves:100 cows, and upwards of 60–80 bulls:100 cows. These levels are above the 25 calves:100 cows suggested by Bergerud (1992) as necessary to maintain stable populations in the absence of hunting, and well above the bull ratios suggested as needed to sustain pregnancy rates in northern populations (Hatter 1998). Current MoE Kootenay Region policy in most cases is to produce a 15% harvest rate on the bull segment of the population (T. Szkorupa, BC MoE, pers. comm.). A 15% harvest rate is produced by allocating sufficient tags and quotas to residents and non-residents and accounting for the estimates of hunter success (kills per tag issued). Given bulls comprise roughly 30–40% of most populations, 15% bull harvest rate equates to approximately 4.5–6% harvest rate on the population. While harvest rates in many MUs within the Kootenay Region are below this level, all rates >5% occur in MUs that have not been surveyed since 2000, and may be inaccurate and biased low as a result of underestimated population size or actual population increases. These calculated harvest rates could be increased by up to 15–20% to account for losses due to wounding (e.g., a 5% harvest rate based on dead moose retrieved by hunters may in fact mean close to 6% loss for the population; Gasaway et al. 1983, Fryxell et al. 1988).

While male-only harvests work well for populations held well below carrying capacity by predation (Gasaway et al. 1992), where populations are near carrying capacity and the management objective is to maximize harvest, some harvest of cows and calves should be considered (Hatter 1998, Bowyer et al. 2003).

Summary, and research and monitoring requirements

In summary, moose numbers appear to have increased in many areas since levels estimated in 2000, and populations appear to be expanding into some areas of the WK, consistent with range expansion throughout much of western North America (Karns 1998, Darimont et al. 2005). Broad changes in moose numbers in the Kootenays over the past 2 decades likely have occurred, probably related to changes in habitat, predator densities, harvest rates and patterns, and winter severity. Population increases may have occurred in recent years in many areas, possibly as a result of relatively mild winters with low snowfall, and reduced harvest levels. Numbers of predators (primarily bears and wolves) have likely remained stable in some areas and increased in others over the past decade. Current harvest rates as calculated from the available data vary widely among MUs, likely in part a result of differences between population estimates and real population levels.

Surveys conducted since 2000 have resulted in updated population estimates for 10 MUs within the region (Table 3). Many of the remaining MUs have dated or non-existent population estimates. A stratified random block survey was conducted during winter 2006–07 north of Revelstoke (MUs 4-38 and 4-39), to update changes in the population as a result of liberal harvest levels aimed at reducing the population (Serrouya and Poole, in prep.). In addition, FWCP is planning a mule deer survey of MUs 4-07 and 4-08 that may shed light on recent changes in moose numbers and distribution in those areas (R. Clarke, FWCP, pers. comm.). I suggest priorities for future surveys should be based on where there are perceived declines in populations as based on anecdotal observations and consistently poor hunter success, or where the available data suggest high harvest rates (Table 8).

In addition to the EK MUs listed (Table 8), I suggest that inventory be conducted in 1 of the 5 WK MUs where moose hunting has recently been permitted (MUs 4-14, 4-15, 4-27, 4-28, 4-31) or in MU 4-33, which is adjacent to high density MUs and appears to have greater numbers of moose than the current estimate of 15 (R. Serrouya, pers, comm.). No inventory data are available from any of these MUs, bull and total population numbers are highly speculative, and monitoring over time may document changes in moose distribution and numbers for a suspected expanding population.

The Ministry of Environment is considering general open seasons (GOS) for moose in some areas of the region (T. Szkorupa, MoE, pers. comm.). Harvest in these situations is generally regulated by season length and antler restrictions. General open seasons in the Kootenays should be carefully monitored if implemented to ensure that the harvest is sustainable.

As noted in the introductory ecology section of this review, the taxonomy of moose in the Kootenay Region is unclear, specifically where the boundary between Shiras and northwestern moose occurs. Although in part an academic question, determination of the boundary between subspecies may help to target management in the region. Antler size may be one of the easiest methods to determine subspecies; collection of antler size and body data from residents and guide/outfitters could provide the basis for this analysis. These data could be coupled with DNA analysis of samples from harvested animals to see whether populations are continuous or discrete across suspected boundaries (D. Paetkau, Wildlife Genetics International, pers. comm.).

Aging of teeth from harvested moose was discontinued in 1999. Mean age of harvested bulls in the Kootenay region increased during the 1990s concurrent with implementation of LEH hunting and increases in bull:cow ratios. Mean age of harvested bulls may provide another parameter useful in assessing moose populations and measuring the impact of various management programs (Timmerman and Buss 1998), and the Ministry of Environment should consider re-instating this program for bulls.

While this document has focussed on the consumptive use of moose from a harvest perspective, non-consumptive values should not be ignored. Observations of moose enhances the value and enjoyment of the outdoor experience, and this should be reflected in the management of the resource.

Table 8. Suggested priorities for future moose inventories in the Kootenay Region.

Management unit	Priority	Last inventory	Type of inventory	Rationale
4-03	High	2002	Partial total count	Poor inventory; recent low hunter success; apparent population decline
4-04	High	Unknown		No inventory; recent low hunter success; apparent population decline
4-34	High	Unknown		No inventory; apparent population decline; high harvest rate
4-35	High	Unknown		No inventory; status unknown
4-01	Medium	2000	SRB[1]	Concerns that the 2000 inventory is biased low
4-02	Medium	2000	SRB	Concerns that the 2000 inventory is biased low
4-21	Medium	2000	SRB	Concerns that the 2000 inventory is biased low
4-24	Medium	2000	SRB	Concerns that the 2000 inventory is biased low
4-25	Medium	2000	SRB	Concerns that the 2000 inventory is biased low
4-26	Medium	2000	SRB	Concerns that the 2000 inventory is biased low
4-06	Medium			No inventory data; population appears to have increased

[1] SRB = Stratified random block.

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