Provincial Framework for Moose Management in British Columbia

Ministry of Forests, Lands and Natural Resource Operations

Fish and Wildlife Branch

Victoria, B.C.

February 2015

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Acknowledgements

The 'Provincial Framework for Moose Management in BC' was developed collaboratively with the Provincial Moose Management Technical Team including former employees (i.e. Mark Williams and Brian Harris, see page 11). This moose framework benefitted from input provided by the Provincial Hunting and Trapping Advisory Team including the BC Wildlife Federation and BC Guide Outfitters Association who provided detailed comments on earlier versions of the framework.

Executive Summary

This framework provides guidance and provincial direction for sustainable management of moose in British Columbia. Science-informed guiding principles and management objectives for sustainable use are outlined. Five management levers to assist in moose management are identified, including the legal authority to use each lever. The current status and monitoring/research on moose populations is reviewed. The plan proposes that regional moose action plans should be the key policy document for operational delivery of moose management actions, and a template for these plans is outlined. Ten appendices are included which provides information on specific topics related to moose management.

Introduction

The Provincial Moose Management Technical Team (see page 11) developed this provincial framework for moose management in BC. The purpose of the framework is to provide guidance on provincial direction for moose management, outline an approach for preparing regional moose action plans, and establish the scientific basis for making moose harvest management decisions.

Moose are widely distributed throughout B.C. and fulfill an integral role ecologically in the maintenance of predator/prey systems. Moose are culturally important to First Nations for social, food and ceremonial purposes, are an important hunted species for residents, and provide economic benefits to the guiding industry. In 2013 there were 33,107 licensed hunters that harvested an estimated 6,890 moose but these harvest levels are well below current hunter demand and historical levels (1981-90 average hunters = 41,651 and average harvest = 12,554, see Appendix 2).

Results from recent surveys (2011/12 to 2013/14) indicate moose numbers have also declined substantially in parts of the Central Interior of the province which has raised significant concern by wildlife managers, First Nations and stakeholders. The Ministry has committed to developing a provincial framework for moose management as a step towards understanding the factors that may have led to these declines and to develop recommendations for actions that will meet management objectives, as well as maintaining current harvest levels in the rest of the province. Regional staff will use this framework to maintain provincial consistency in management approaches where appropriate, and as guidance when consulting with stakeholders.

The provincial goal for moose management is to ensure moose are maintained as integral components of natural ecosystems throughout their range, and maintain sustainable moose populations that meet the needs of First Nations, licensed hunters and the guiding industry in B.C.

The objectives for moose management in British Columbia as established in this framework are to:

1. ensure opportunities for consumptive use of moose are sustainable;
2. maintain a diversity of hunting opportunities for moose;
3. follow provincial policies and procedures (e.g. provincial moose harvest management procedure) as guidance for regulatory options and management objectives; and
4. foster development of regional moose action plans where appropriate.

Management objectives need to be developed at the regional level to address different values and expectations from First Nations, resident hunters and non-resident hunters. While these objectives must reflect First Nation and stakeholder expectations, science must be used to ensure that use of moose is sustainable, and to indicate the consequences of various management options (see Appendices 1-8). To ensure stakeholders are aware of the consequences of various management options, and to identify trade-offs between competing objectives, a structured decision making approach should be considered prior to developing regional action plans and/or making major regulatory changes (see Appendix 9).

Guiding Principles

The guiding principles for moose management include:

1) In areas where moose are below management objectives, and where possible and appropriate, apply management levers (see "Identification of Management Levers" section) to meet management objectives.
2) Follow an adaptive management approach that will utilize "learning by doing" (Walters and Holling 1990[1]) as a process for improving moose management.
3) Manage for sustainable harvests through application of science-based principles and methods.
4) Follow the provincial polices and procedure (see http://www.env.gov.bc.ca/fw/wildlife/policy_procedures/index.html when developing management objectives and adhere to the inventory standards established by the Resources Information Standards Committee (RISC) when conducting surveys (see http://www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/ungulatesv2/unga_ml20_final.pdf).
5) Ensure that moose management actions consider caribou recovery objectives (http://www.env.gov.bc.ca/wld/speciesconservation/) and where appropriate address the implications of midterm timber supply decisions to moose (http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/mid-term-timber-supply-project/).
6) Consult with provincial stakeholders on the provincial management framework and advise on progress during implementation of regional management actions (see "Consultation").
7) Consult with regional stakeholders and First Nations on the regional management actions (see "Consultation").
8) Share information on moose management and management direction with First Nations, stakeholders, biologists and the public.

[1] Walters, C.J. and C.S. Holling. 1990. Large scale management experiments and learning by doing. Ecology 71:2050-2068

Summary of Moose Harvest Management Procedure

The moose harvest management procedure (Appendix 1) provides Ministry staff with direction on how to proceed when making decision or recommendations related to moose harvest management. A brief summary of the guidance provided from the procedure includes:

1) The primary spatial scale for moose management will normally be the population management unit (PMU). Currently, this is the Game Management Zone (GMZ, see Appendix 10).
2) Hunted moose populations will normally be managed to avoid declines and to ensure that the post-hunt bull:cow ratio remains above 30 bulls:100 cows. For low density moose population (< 200/1000 km^2), a minimum ratio of 50 bulls:100 cows is desired.
3) Formal management objectives should be developed for each PMU in consideration of land use commitments, species at risk conservation (e.g. recovery of Mountain Caribou), broader ecosystems considerations (e.g. numbers and densities of predators), and First Nation's needs.
4) Population assessment, aided by a computer model where appropriate, should be used to determine the maximum allowable mortality level that will enable provincial and population management unit specific objectives to be achieved.
5) The process for establishing the annual allowable harvest (AAH) for moose populations that are identified as a Category A under the Harvest Allocation policy.
6) Considerations for hunting regulations, including use of success rates for calculating LEH authorizations, provincial bag limits, and recommended season structures.

Identification of Management Levers

There are numerous potential management levers that may assist in moose management but only two are readily available to moose managers in the short term: hunting regulations and access management. Prior to implementation of any management levers, it is important to establish objectives and clearly defined performance measures (Appendix 9). The most accessible levers for wildlife managers are adjusting harvest levels through hunting regulation changes, including access restrictions (e.g. Access Management Areas, Motor Vehicle Closed Areas, Motor Vehicles for Hunting Closed Areas) as they may be authorized through the *Wildlife Act*. Science has shown that predator management, habitat enhancement and protection, other forms of access management (e.g. road deactivation) and First Nations harvest are also important management levers that can influence moose populations, and in many cases may have a much greater impact than hunting regulation changes.

Table 1 shows the management levers (i.e. actions that could be taken to assist with the achievement of moose management objectives) for B.C. While it is recognized that moose management needs to be considered within the context of multiple land use management, and that effective goals and objectives for moose should tie into multi-species and habitat management at the landscape level, those considerations are beyond on the scope of this framework. Recent work on cumulative effects, involving the Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations, offer an opportunity to identify and manage moose within a broader ecosystem context.

Table 1. Moose management levers (potential actions to assist with achievement of moose management objectives) for B.C.

#	Management Lever	Legal Authority to use Management Lever
1	Hunting Regulations	Authorized through *Wildlife Act*, supported by regulations and policy
2	First Nations Harvest	In the absence of a clear conservation concern, First Nations harvest will most likely be managed through agreements with First Nation governance bodies. Harvesting contrary to agreements may be enforced through the *Wildlife Act*.
3	Predator Management	Hunting and trapping of predators is authorized through *Wildlife Act*, although predator control to enhance ungulate hunting opportunities is not supported by current policy ("Control of Species Policy")[2]
4	Access Management	Access restrictions authorized through *Wildlife Act* supported by regulations and policy, also general recreation closures through the *Forest and Range Practices Act*
5	Habitat Enhancement and Protection	Numerous Acts involved, limited authority under *Wildlife Act*
6	Environmental Assessment and Mitigation	Provincial government staff review land-use applications and can influence mitigation measures to benefit moose (e.g. moose habitat supply through Timber Supply Reviews).

Current Population Status

Regional and Provincial Population Estimates

Regional and provincial moose population estimates are updated every three to five years, based on regional surveys, density extrapolations and expert opinion. The most recent compilation (2014) indicates a provincial estimate of 120,000 to 205,000 moose (http://www.env.gov.bc.ca/fw/wildlife/management-issues/index.html#ungulate_pop), and suggests that provincial moose numbers have declined by approximately 27,500 moose since 2011 (Appendix 2). These results are consistent with downward trends observed from recent area-specific surveys in central B.C. in 2012 and 2013 (see *Inventory* below).

Inventory and Monitoring

Adequate inventory and monitoring are critical to determining population status for moose. Stratified random block surveys provide estimates of population size, density and composition of the population whereas composition surveys provide only the sex/age information of the moose population (see RISC standards). Periodic resurveys using stratified random block can be used to assess population trends. Overall, the stratified random block surveys within select survey areas across the province indicate that moose population have declined (Table 2).

[2] The Control of Species Policy allows for the control of predators where there is a significant risk to property or human safety, or where they represent a threat to the viability or recovery of a species-at-risk.

Table 2. Moose population trends observed within select Management Units (MUs) of the province (current to 2012/13). It is important to note that surveys do not represent moose population trends throughout the entire Region, and that density estimates are not directly comparable between MUs.

MU	Previous Estimate	Previous density (#/km^2)	Bull/ cow ratio	Calf/ cow ratio	Recent estimate	Recent density (#/km^2)	Bull/ cow ratio	Calf/ cow ratio	Trend between estimates
8-06	2000/01	0.14	52	47	2012/13	0.30	24	27	+114
8-09	2008/09	0.19	28	40	2012/13	0.23	8	33	+21
8-11	1999/00	0.44	50	53	2010/11	0.85	26	32	+92
7-07 to 7-13, 7-15	2005/06	1.35	26	33	2011/12	0.68	30	28	-50
7-16, 7-23	2005/06	1.18	59	30	2011/12	0.63	66	25	-47
7-32	2004/05	0.93	59	37	2011/12	0.72	23	37	-23
7-44	1995/96	1.26	25	26	2012/13	0.98	20	38	-22
7-29, 7-38	2005/06	0.30	50	24	2012/13	0.41	45	29	+37
7-39 to 7-41	2006/07	0.56	62	21	2012/13	0.52	80	31	-7
6-04 to 6-06, 6-08, 6-09	2003/04	1.72	39	38	2011/12	1.37	32	37	-20
6-01, 6-02	1997/98	0.37	51	31	2012/13	0.37	54	19	0
6-03, 6-09, 6-10, 6-11, 6-15	1987/88	0.23	51	65	2012/13	0.23	62	35	0
5-02C	2000/01	0.62	21	45	2010/11	0.51	43	35	-17
5-04	2005/06	0.29	54	34	2011/12	0.17	40	28	-41
5-12	2001/02	0.58	44	48	2011/12	0.23	66	43	-60
5-14	2000/01	0.46	35	50	2012/13	0.25	31	38	-45
4-32	1996/97	0.27	78	N/A	2010/11	0.30	116	41	+10
3-29	1995/96	0.18	43	43	2012/13	0.33	54	27	+83
3-43, 3-44	2006/07	0.96	128	55	2012/13	0.35	54	37	-64

Monitoring:

Population:

Table 3 lists current priorities for stratified random block and composition surveys for the next five years. Criteria considered when prioritizing surveys included: (1) time since last survey; (2) is it part of an ongoing monitoring program?; (3) will it increase or maintain hunter opportunity?; (4) are there First Nations concerns?; and (5) are population management objectives being met?

Table 3. Proposed moose surveys over the next 5 years (see Appendix 10 for location of GMZ's).

Region	2013/14	2014/15	2015/16	2016/17	2017/18
8	8-23, 8-24, 8-15	8-01, 8-07, 8-14	8-05, 8-26	8-11, 8-09	8-08
7A	Comp GMZ 7Ob	SRB 7Ob Comp GMZ 7Ob	Comp GMZ 7Ob	SRB Parsnip Comp GMZ 7Ob	Reg 7A Comp GMZ 7Ob
7B	GMZ 7Pc, GMZ 7Pa	GMZ 7Pb, GMZ 7Pe	GMZ 7Pb, GMZ 7Pa	GMZ 7Pd GMZ 7Pc	GMZ 7Pa GMZ 7Pb
6	6-30 Kispiox	GMZ 6c composition	Nass	GMZ's 6d, 6e, 6f	604/605/606/608/609 BVLD
5	5-15D,5-02D	5-01, 5-02A	5-03	5-13A	5-04, 5-13B
4	4-38, 4-39	4-36	4-23	4-09	4-24
3	SRBS: 3-12 CS: 3-18, 19, 26, 32, 38	SRBS: 3-40 CS: 3-20, 39	SRBS: 3-31 CS: 3-29, 30	SRBS: 3-19 CS: 3-28, 36, 42	SRBS: 3-29, 30 CS: 3-18, 26, 32, 38

Harvest:

The ministry annually monitors the harvest of moose by resident (i.e. hunter sample) and non-resident hunters (guide declarations), and provides harvest estimates by management unit. First Nations harvest information on moose is largely unknown yet is critical to ensure optimized, sustainable use of moose in support of First Nation needs, recreational hunting and guide-outfitting. LeBlanc et al. (2011) in studying a First Nations moose hunt in Ontario state: "*Our results show provincial calculations may underestimate total harvests by up to 40%. This error could have significant implications for future moose populations, wildlife managers, and both provincial and First Nations hunters. The potential for such errors serves to highlight our call for provincial authorities to seek and engage First Nations perspectives and participation in moose management for the benefit of the entire community*."[3]

Compulsory inspection may be used to collect biological information such as age, antler configuration, tissue samples and reproductive tracts; and is periodically collected based on regional need for the information. The ministry previously used harvest data cards to collect teeth annually that allowed the age structure of the harvest to also be monitored. That program was discontinued approximately 10 years ago due to numerous concerns including: change in policy by Canada Post that would no longer allow for the mailing of teeth in envelopes, inadequate number of samples being collected for statistical analysis, sampling bias, and lack of regional capacity to age teeth.

Population Condition:

Birth mass, pregnancy rate, twinning, and birth date, have all been used previously as indices to describe density or weather-related effects on moose and therefore, provide reliable indices of population

[3] LeBlanc, J.E., B.E. McLaren, C. Pereira, M. Bell and S. Atlookan. 2011. First Nations moose hunt in Ontario: A Community's perspectives and reflections. Alces 47:163-174.

condition (Keech et al. 2000[4]. Boertje et al. 2007[5]). There is increasing concern that with climate change, pathogens may play a greater role in limiting moose populations along the southern distribution of their range especially where deer are abundant and act as reservoir hosts for parasites (Murray et al. 2006)[6]. In 2012, FLNRO initiated population condition monitoring of moose through the Wildlife Health Program (http://www.env.gov.bc.ca/wld/wldprogram.html). A total of 105 moose sera samples (72 from Kootenay, 33 from Thompson) were tested for antibodies (Johne's, Neospora, Parainfluenza-3 and Bovine Viral Diarrhea). The implications of the findings to moose population health are largely unknown at present as low numbers and regional gaps in information complicate interpretation. In addition, 27 moose fecal samples (Thompson Region) were tested for internal parasites and found gastrointestinal parasitism at low to moderate levels. Another 120 moose samples have been tested for chronic wasting disease since 2002, with no positives.

Applied Research:

Applied research is an essential component of adaptive management and likely will be necessary for determining causative factors in moose declines in the Central Interior, and to inform future management decisions. There are currently two applied research projects underway: (1) a 5-year provincially-coordinated field study of GPS-collared moose to assess their survival relative to their habitat use and anthropogenic disturbance (i.e. roads and cutblocks) (Kuzyk and Heard 2014[7]) and, (2) a retrospective modelling study in the Omineca to assess potential factors that may be contributing to the recent moose decline in that region. Funding proposals (e.g. Habitat Conservation Trust Fund; Land Base Investment Strategy) should address applied research priorities within the provincial framework and be applicable to management needs across regions.

Implications of Moose Management Actions on Mountain Caribou Recovery

There have been two experiments conducted in the province with an objective of reducing moose to low densities in order to reduce wolf densities and predation on mountain caribou. There are currently no confirmed plans to undertake further initiatives of reducing moose densities in order to promote caribou recovery. In the Parsnip area of the Omineca the effect of doubling the number of Limited Entry Hunt (LEH) permits (for both bulls and cows) and number of seasons and creating LEH subzones to reduce crowding by distributing hunters in space and time was tried in an effort to reduce moose

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[4] Keech, M.A., Bowyer, R.T., VerHoef, J.M., Boertje, R.D., Dale, B.W., Stephenson, T.R. 2000. Life-history consequences of maternal condition in Alaskan moose. J. Wildl. Manage. 64:450-462.

[5] Rodney D. Boertje, Kalin A. Kellie, C. Tom Seaton, Mark A. Keech, Donald D. Young, Bruce W. Dale, Layne G. Adams and Andrew R. Aderman. 2007. Ranking Alaska Moose Nutrition: Signals to Begin Liberal Antlerless Harvests J. Wildl. Manage. 71: 1494-1506.

[6] Murray, D.L., Cox, E.W., Ballard, W.B., Whitlaw, H.A., Lenarz, M.S., Custer, T.W. Barnett, T., and Fuller, T.K.2006. Pathogens, nutritional deficiency, and climate change influences on a declining moose population. Wildlife Monographs No. 166.

[7] Kuzyk, G. and D. Heard. 2014. Research design to determine factors affecting moose population change in British Columbia: testing the landscape change hypothesis. B.C. Ministry of Forests, Lands and Natural Resource Operations. Victoria, BC. Wildlife Bulletin No. B-126. 16pp.

densities (Steenweg 2011[8]). Another study to assess the effectiveness of reducing moose densities to help recovery mountain caribou was conducted in the Revelstoke area in the Kootenays (Serrouya 2013[9]). The Parsnip study area has not shown a response in caribou numbers, while there was a slight increase in caribou numbers in the Revelstoke study area. The Revelstoke study has established a population target of 500 moose for MU's 4-38 and 4-39 in 2009 and the population has been monitored through pellet transects and the population is now below 500. In response LEH permits have been reduced to 1 in each zone for 2013. The intent is to continue to evaluate the Revelstoke experiment by monitoring the caribou, moose and wolf population.

Role of Regional Moose Management Action Plans in Provincial Moose Management

The ecological conditions supporting moose population's varies substantially throughout the province[10] and stakeholders have different regional expectations for moose management. Consequently, previous attempts to develop a provincial-level moose management plan have not been effective. Regional moose management action plans, guided by this provincial framework, offers promise of a more useful approach for managing moose in BC, and will enable more effective engagement with First Nations.

Moose management action plans should be developed at the regional level where appropriate and should include Ministry staff, First Nations and stakeholders in their development. These plans should consider the issues presented in this provincial framework and the provincial harvest management procedure. The Omineca and Northeast Regions have begun developing regional action plans.

A standardized Table of Contents (TOC) for regional plans needs to be developed to ensure consistency in developing management approaches. The Kootenay Elk Management Plan for 2010 to 2014 (http://www.env.gov.bc.ca/kootenay/emp/Kootenay%20elk%20management%20plan%202010-14%20(final).pdf) should be considered as a template for developing a standard TOC. A standard TOC should include: (1) executive summary; (2) introduction; (3) public/stakeholder consultation process; (4) First Nations consultation process; (5) population management units; (6) moose management objectives; (7) management alternatives; (8) decision analysis; (9) recommended management direction; and (10) literature cited. The content of the plan should include a review and analysis current population trends, harvest trends, and landscape level changes at the Game Management Zone (GMZ) level (or other appropriate population management unit) that may be altering access and security cover for moose. Plans should be completed within a reasonable timeframe and contain management objectives and performance measures that acknowledge this provincial framework.

[8]Steenweg, R.W. 2011. Interactions of wolves, mountain caribou and increased moose hunting quota – primary-prey management as an approach to caribou recovery. M.Sc. Thesis, Univ. of Northern BC. 144 pg.
[9]Serrouya, R. 2013. An adaptive approach to endangered species recovery based on a management experiment: reducing moose to reduce apparent competition with woodland caribou. PhD Thesis. Univ. of Alberta. 220 pg.
[10]Eastman, D. and R. Ritcey. 1987. Moose habitat relationships and management in British Columbia. Swedish Wildlife Research Suppl. 1: 101-117

Regional staff contemplating reductions in moose hunting opportunities should address if hunting opportunities for other big game species may be enhanced, within conservation limits, to partially mitigate impacts to hunters.

Consultation[11] on moose action plans and regulations for moose, including consultation with First Nations, will take place at the regional level.

Team Members – Roles and Responsibilities

The Moose Management Technical Team (MMTT) will be led by the Fish and Wildlife Branch whose role is to lead and coordinate the development of the provincial moose framework, and where appropriate to coordinate regional moose recovery actions. All team members are expected to review the provincial framework and where required, assist with developing and reviewing future provincial moose management documents. If regional action plans are required, team members will lead or assist the process. All team members are encouraged to assist other members where possible.

Provincial Moose Management Technical Team (Branch and regional biologists)

Table 4 identifies the membership for the Provincial Moose Management Technical Team. Representatives occur in all regions of the province where moose are being managed for hunting. The work of the team is coordinated through the Fish and Wildlife Branch in Victoria.

Table 4. Provincial Moose Management Technical Team.

Area	Regions	Staff Representative
Branch	Fish and Wildlife Br.	Ian Hatter, Gerry Kuzyk
South	Cariboo	Becky Cadsand
	Thompson/Okanagan	Chris Procter Andrew Walker
	Kootenay/Boundary	Pat Stent
North	Northeast	Dan Lirette
	Omineca	Doug Heard
	Skeena	Conrad Thiessen

Provincial Moose Advisory Team

The Provincial Moose Advisory Team consists of PHTAT (Provincial Hunting and Trapping Advisory Team) which includes membership from: British Columbia Wildlife Federation; BC Trappers Association; Guide Outfitters Association of BC; Wild Sheep Society of BC and the United Bowhunters of BC.

[11] Consultation is defined for the purposes of moose management as a formal process which allows for reaction and response by stakeholders to wildlife management issues. It is a two-way form of communication that gives interested stakeholders the opportunity to explore wildlife management issues (e.g. ask and get answers to questions) and to make their views clearly known. Stakeholders are defined as those with a vested interest in moose management (e.g. for hunting or wildlife viewing).

Ministry of Forests, Lands and Natural Resource Operations Approval

Approval is sought for the Provincial Framework for Moose Management in British Columbia:

Director – Fish and Wildlife Branch

Resource Stewardship Division

Reviewed by:

Date: February 18, 2015

Signature:

Appendix 1. Provincial moose harvest management procedure

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

PROCEDURE MANUAL

VOLUME	SECTION	SUBSECTION	PAGE
4	7	01.07.3	1 of 6
SUBJECT			
Moose Harvest Management			

This Procedure Replaces:
None

Staff, Organizations Directly Affected:
Director
Regional Managers
Wildlife Management Staff
First Nations
Resident Hunters
Guide Outfitters

Policy Cross-Reference:
Ministry Policy Manual, Volume 4, Section 7
Subsections:
— 01.07 Game Harvest Management

Other Cross-References:
Ministry Policy Manual, Volume 4, Section 7
Subsections:
— 01.01 Allowable Harvest
— 01.02 Open Seasons
— 01.03 Harvest Allocation
— 01.05 Quota Allocation – Guided Hunting
— 01.06 Limited Entry Hunting
— 01.10 Resident Hunter Priority
— 01.11 Commercial Hunting Interests
— 04.01.3 Control of Species
— 13.01 Goal of Wildlife Management

Ministry Procedure Manual, Volume 4, Section 7
Subsections:
— 01.01.1 Allowable Harvest
— 01.02 Open Seasons
— 01.03.1 Harvest Allocation
— 01.05.1 Quota
— 01.05.2 Administrative Guidelines
— 01.06.1 Limited Entry Hunting

PREPARED BY	AUTHORIZATION		
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		DATE EFFECTIVE: March 1, 2010	REVISION NO.:

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

PROCEDURE MANUAL

VOLUME	SECTION	SUBSECTION	PAGE
4	7	01.07.3	2 of 6
SUBJECT			
Moose Harvest Management			

— 01.07.1 Big Game Harvest Management
— 04.01.3 Protecting Species at Risk From Other Species

Purpose:

To establish a sound and transparent approach for developing management objectives and harvest regulations for moose province-wide.

Definitions:

"allocation" – means the division of the annual allowable harvest (AAH) remaining after the legal rights of First Nations have been recognized and provided for, between resident hunters and guided hunters.

"allocation period" – means the five year period to which an allocation share applies, as defined in the Harvest Allocation Procedure.

"annual allowable harvest" (AAH) – means the number of moose that are allowed to be killed by resident hunters and guided hunters each year.

"**big game**" – means big game as defined in the *Wildlife Act*, RSBC 1996 c.488.

"big game stock assessment" – means the process of collecting, analyzing, and reporting demographic information for the purpose of determining the effects of harvesting on big game populations.

"director" – means director as defined in the *Wildlife Act*, RSBC 1996, c.488.

"game management zone" (GMZ) – means a grouping of management units based on geographical, ecological, and access criteria.

"management unit" (M.U.) – means a specific and legally designated land area denoted by the initials M.U. and a hyphenated number, e.g. M.U. 3-18 (B.C. Reg. 64/96).

"maximum allowable mortality" – means the number of animals, or animals in a particular class, that are allowed to be killed by humans each year, including First Nations' harvest for food, social, and ceremonial purposes, licensed hunting, and road/rail kill.

"population management unit" (PMU) – means the spatial scale at which a given big game population will be managed for hunting. This normally will be the geographic area that represents the year-round range of a big game population, while keeping interchange with other populations to a minimum.

DATE EFFECTIVE	REVISION NO.
March 1, 2010	

"regional section head" (RSH) – means a section head responsible for the management of fish and wildlife within a region, Regional Operations Branch, Ministry of Environment.

"sightability correction factor" – means a quantitative coefficient which is estimated or derived and applied to a survey population estimate to account for visibility or sightability bias of the observers.

"spike-fork moose" – means a bull moose having no more than two tines on one antler (includes tines on main antler and brow palms), but does not include a calf (i.e. a moose less than 12 months of age).

"wildlife manager" – means the Manager of the Wildlife Management Section, Fish and Wildlife Branch, Ministry of Environment, Victoria.

Procedure:

1 Population Management Units

1.1 Population Management Units (PMUs) will, unless otherwise stated, be equivalent to Game Management Zones (GMZs).

1.2 As specified in the Big Game Harvest Management Procedure, moose may be managed at smaller or larger spatial units, provided that the resulting units conform to the criteria outlined in the Big Game Harvest Management Procedure.

2 Management Objectives

2.1 Management objectives should be defined for each moose population management unit (PMU), and should take into consideration the big game management objectives described in the Big Game Harvest Management Procedure.

2.2 Unless formal population management objectives have been identified, hunted moose populations will be managed to avoid declines and to ensure that the post-hunt bull:cow ratio remains above 30 bulls:100 cows. For low density moose populations ($\leq$ 200/1000 km^2 of fall range, i.e. habitat currently or potentially used during the breeding season), a ratio of 50 bulls:100 cows is preferred.

2.3 Formal population management objectives will normally include a desired range in population density and bull:cow ratio. The lower range of the bull:cow ratio should not be below 30 bulls:100 cows, or 50 bulls:100 cows for low density moose populations ($\leq$ 200/1000 km^2 of fall range). Formal objectives should be developed in consideration of land use commitments, species at risk conservation, broader ecosystem considerations, First Nations needs, or other specified objectives; and approved by the Wildlife Manager.

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3 Harvest Strategy

3.1 Population Assessment

3.1.1 The maximum allowable mortality level should be determined through a big game stock assessment.

3.1.2 Population estimates from survey areas (e.g. Stratified Random Block) should be adjusted upwards using a sightability correction factor or relevant model wherever possible. Extrapolation of population estimates to the population management unit should be based on survey density, adjusted for habitat suitability of non-surveyed areas, and any other factors as deemed appropriate by the Regional Section Head (RSH).

3.1.3 The population assessment (aided by a computer model where appropriate) should be used to determine the maximum allowable mortality level that will enable the population objectives to be achieved over the allocation period.

3.2 Harvest Management Rules

3.2.1 For PMUs administered under the Harvest Allocation Policy and Procedure (i.e. allocated PMUs), the maximum allowable mortality level will, in general, be set to achieve the management objectives during the course of an allocation period.

3.2.2 The annual allowable harvest (AAH) for each allocated PMU will typically be calculated by:

a. estimating the maximum allowable mortality level through the big game stock assessment;

b. estimating or otherwise accounting for First Nations harvest of moose for food, social, and ceremonial purposes through the most appropriate means;

c. estimating or otherwise accounting for road/rail mortality where a substantive level of mortality is present; and

d. subtracting the First Nations harvest and the road/rail mortalities from the maximum allowable mortality.

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3.2.3 For allocated PMUs where there is insufficient information to perform a big game stock assessment, the AAH may be estimated from the historical average annual harvest of moose by licensed hunters, providing all available evidence suggests that the historic harvest has been sustainable.

3.2.4 It is recommended, but not required, that an AAH be established for unallocated PMUs.

3.2.5 In areas where there is a spike-fork moose harvest, the harvest of spike-fork moose should not exceed 50% of the total licensed bull moose harvest. The RSH may select a lower spike-fork moose percentage, if approved by the Wildlife Manager.

3.2.6 Season dates should fall within the bounds outlined in Table 1 of Appendix A.

3.2.7 Moose seasons in November may be adjusted in response to seasonal migration timing and hunting vulnerability.

3.3 Hunting Regulation

3.3.1 Numbers of LEH authorizations and guide outfitters' quotas should be set in accordance with the Harvest Allocation Procedure, Limited Entry Hunting Procedure, Quota Procedure, and Administrative Guidelines Procedure.

3.3.2 Success rates used to determine the number of LEH authorizations will reflect the most recent three years that were open to moose hunting. The spatial application of success rates will be by hunt zone.

3.3.3 Despite section 3.3.2, LEH success rates will be limited to a minimum of 5%. Higher minimum success rates may be applied in special circumstances where approved by the Director. LEH areas with consistently low success rates should be reviewed and other regulatory options considered.

4 Bag Limits

4.1 Normally, provincial and regional bag limits will be no more than one moose per hunter per year. The bag limit may be increased where required to achieve management objectives.

5 Regulation Review

5.1 The review of moose harvest regulations will follow the procedures outlined in the Big Game Harvest Management Procedure.

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APPENDIX A: Recommended Hunting Season Structure for Moose

Table 1. Season bounds (minimum/maximum season dates) for moose harvest seasons[1].

Class	Season Type	Season Bounds*
Spike-fork Bull	GOS	Aug 15 – Nov 30
Tripalm Bull‡	GOS	Aug 15 – Nov 30
10-point Bull‡	GOS	Aug 15 – Nov 30
Any Bull	GOS	Aug 15 – Nov 30
Any Bull	LEH Shared Hunt	Aug 15 – Nov 30
Cow/ Antlerless	GOS	Oct 1 – Dec 10
	LEH Shared Hunt	Oct 1 – Dec 10
Calf	GOS	Oct 1 – Dec 10
	LEH Age-Restricted	Oct 1 – Dec 10

* Start dates are in 5-day intervals
‡ Only for Region 7
GOS= General Open Season
LEH = Limited Entry Hunt

[1] Season dates represent outer bounds of seasons for each season type. It is expected that any open season will fall within the dates specified, but not that the entire date range is used in each region.

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Appendix 2. Provincial moose population and harvest estimates

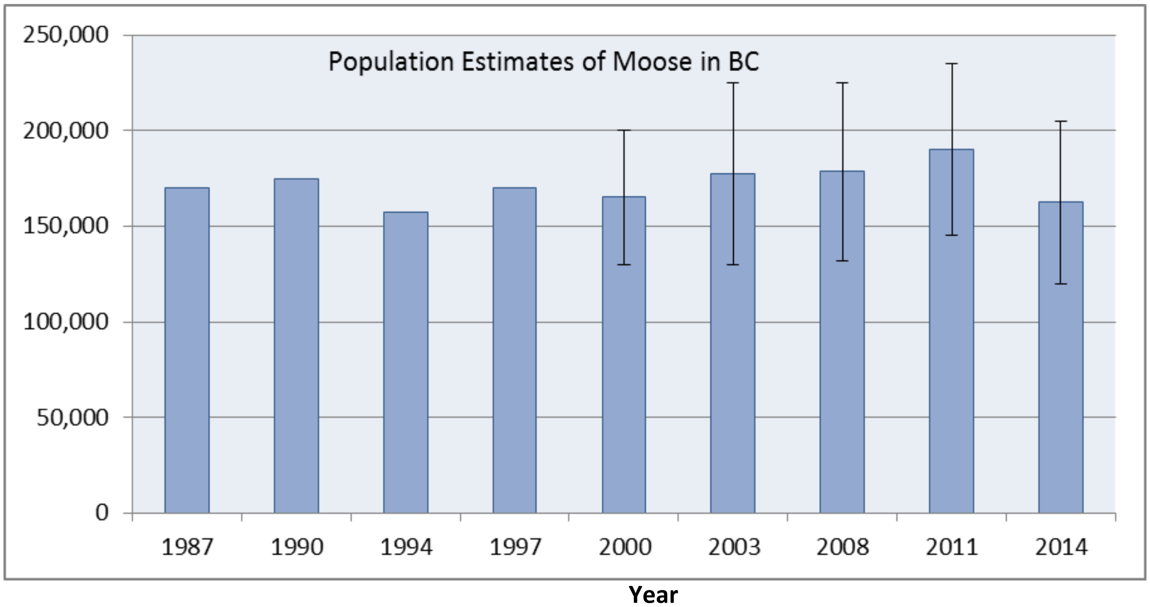

Figure 1. Estimated provincial moose population, 1987-2014. Estimates since 2000 include both a minimum and maximum estimate, as shown by the vertical error bar.

The provincial moose population estimates (Figure 1) are determined every three to five years using a combination of survey data and expert opinion. Lower and upper ranges in estimates were only reported from 2000-2014.

The provincial licensed resident and non-resident harvest estimates of moose are shown in Figure 2, and are taken from the provincial big game harvest statistics.

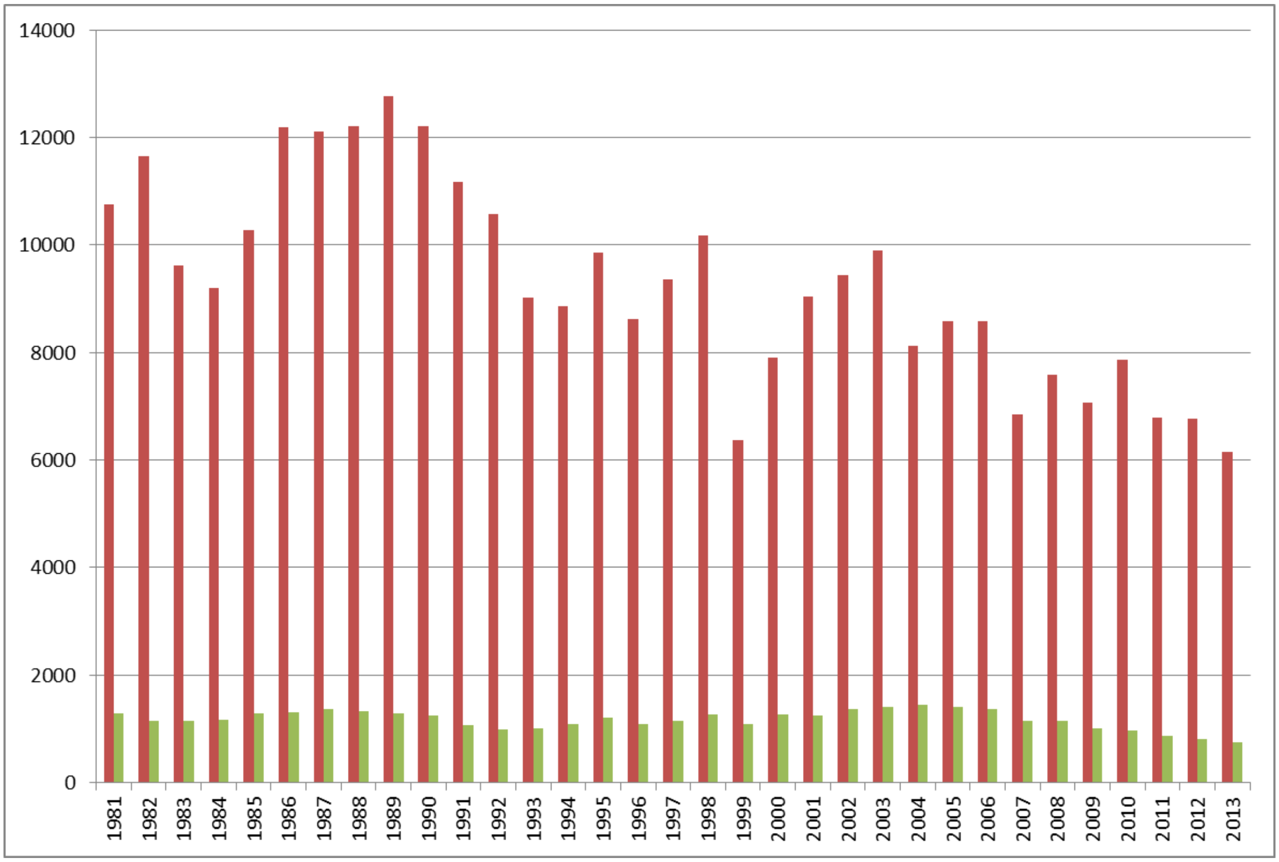

Figure 2. Provincial moose harvest, 1981-2013, for by resident (red) and non-resident (green) licensed hunters in British Columbia.

Appendix 3. Conceptual model of moose-wolf dynamics near Prince George, BC[12]

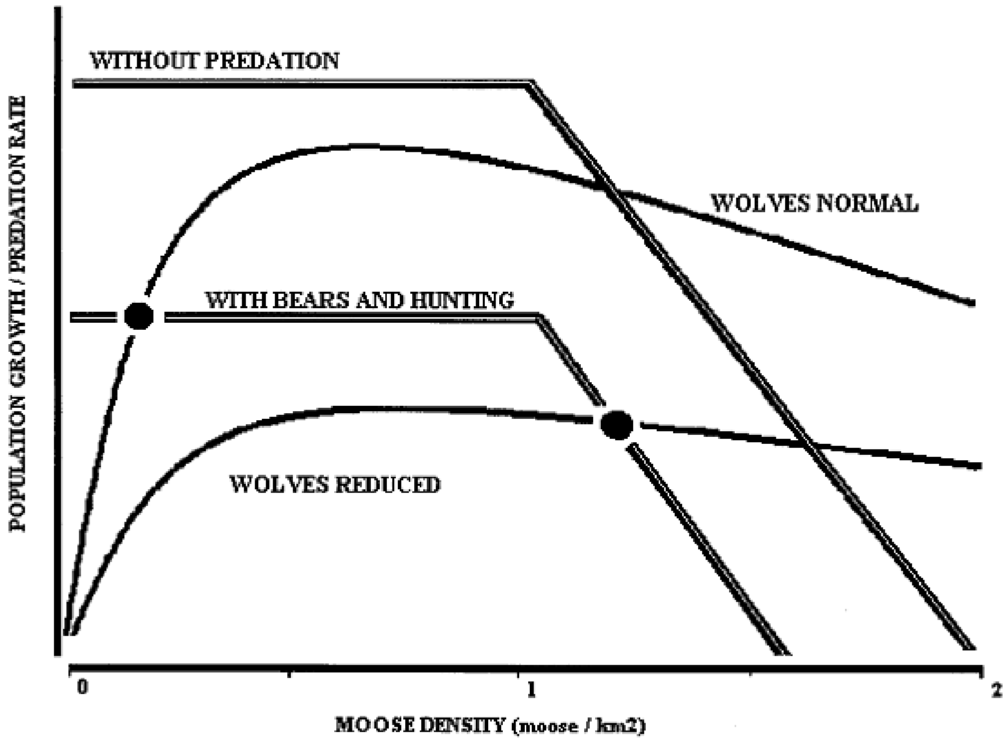

Figure 16. Conceptual model of moose-wolf dynamics. The double lines represent moose population growth rate without predation and with bear predation and hunting. The solid curves represent wolf predation rate on moose (the combination of wolf functional and numerical responses) where wolves exist at natural densities and where wolf densities have been reduced about 50%. Equilibrium conditions exist where the lines cross. A moose density of about 0.2 moose/km^2 would be expected around Prince George, but a moose density of 1.3 moose /km^2 can be maintained because wolf numbers are reduced below normal densities.

[12] from Heard, D.C., K.L. Zimmerman, G.S. Watts, S.P. Parry. 1999. Moose density and composition around Prince George, British Columbia, December 1998. Final Report for Common Land Information Base. Project No. 99004.

Appendix 4. Moose harvest management principles.

The moose harvest management principles outline below have been established to help inform the provincial moose harvest management procedure (Appendix 1), to define a set of best practices for managing moose populations, to provide guidance to regional moose action plans and to develop science-informed hunting regulations.

1. Maximum sustainable yield (MSY) is the maximum harvest that could be sustained from a population indefinitely. It is largely a theoretical concept with limited utility in practice as it is exceedingly difficult to quantify density dependence or carrying capacity, both of which may vary over time. Nonetheless, the concept of MSY and density dependence is still central to an understanding of sustained yield hunting.
2. Rather than managing for MSY, most wildlife agencies attempt to meld the biological, economic, social, and political considerations to provide the maximum sustained benefit of wildlife to society within an accepted risk of overexploitation.
3. The threshold post-hunt bull/cow ratio that can be accommodated without significantly impacting moose productivity and recruitment in BC is unknown. Most of the current research suggests that these effects are not measurable with post-season bull/cow ratios of 30 bulls:100 cows at moderate moose densities (see Appendix 5).
4. Generally, a moose population requires at least 25 calves per 100 cows to balance losses of adult moose from natural causes, including predation (Bergerud and Elliott, 1998). Higher calf/cow rates are required to support a sustainable hunter harvest.
5. In GMZ's where predators (bears, cougars, wolves) are common to abundant, the harvest by humans is largely additive to other sources of natural mortality. Conversely, where moose populations are largely regulated by food, the harvest by humans becomes more compensatory with changes in reproductive rates and other sources of natural mortality.
6. The sustainable number of moose that can be killed depends upon the population growth rate and the age and sex of the moose removed. In populations with high population growth rates bull-only harvests will yield fewer total moose harvested than when other sex/age classes are hunted. In low density or declining moose populations where predators are lightly harvested, the sustainable harvest may need to be limited to bull-only hunting.
7. The finite rate of increase for moose observed in northern boreal ecosystems, when wolf numbers were controlled, was approximately 15%/year (Van Ballenberghe and Dart 1982, Boertje et al. 1996), and the maximum sustained yield level for moose appears to occur at 60% of carrying capacity (K) (Crete et al. 1981). These parameters suggest a maximum harvest rate of 10 to 11% in these ecosystems, if moose are hunted unselectively. Estimates of sustainable harvest rates in B.C. by GMZ (Game Management Zone), averaged 5%, with the highest estimate at 9% (Hatter 1999). However, actual harvest rates would be higher as these harvest rates only included resident and non-resident hunting, and not harvests by First Nations and other non-reported mortalities (e.g. poaching) that may be substantial in many GMZ's.

8. In systems with lightly harvested predator populations, exceeding sustained yields can initiate a population decline that may continue due to high levels of predation and other factors (e.g. severe winters), even in the absence of hunting (Gasaway et al. 1983).
9. Harvest modelling studies of moose populations (e.g. Saether et al. 2001, Nilsen et al. 2005, Xu and Boyce 2010) have generally shown that:
    a. Attempting to manage for a MSY is inherently unstable and leads to population decline.
    b. To maximize yield of bulls, hunting of cows should generally be avoided unless calf survival is high (see also Appendix 6 and 7).
    c. To reach the MSY in number of moose killed, calves should be subject to intense harvest while bulls should be less intensively harvested. Female harvests should be very low.
    d. Bull only hunting, provided adequate bulls are retained to breed cows, reduces the likelihood of initiating further declines in moose populations subject to intensive predation by bears, wolves or both.
10. Local overharvesting (i.e., reducing moose population's below desired density objectives) through General Open Season (GOS) may be difficult to avoid, as harvest pressure is largely determined by access. Antler restrictions (e.g. spike-fork regulation) can help to reduce overharvesting and other regulatory measures (e.g. LEH zones, road closures) can assist to effectively distribute harvest and reduce the likelihood of localized overharvest.
11. Harvest opportunities are determined through management by population objectives. The primary population objectives for moose in B.C. include measures of adult sex ratio and density.
12. First Nations harvest needs to be considered and accommodated prior to calculation of the Annual Allowable Harvest (AAH) for resident and commercially guided hunters in BC. Licensed bull-only hunting, combined with harvest of cows and calves by First Nations, can resemble a selective harvest system of management (as current applied in the Omineca Region), except that numbers of cows and calves harvested are not regulated (Lynch 2006).
13. Population inventory and monitoring is an essential wildlife management activity for ensuring that management objectives are achieved, but see Boyce et al. (2012). While some harvesting may be managed and sustained without accurate or up-to-date inventory, these populations are typically managed by setting a lower AAH, to ensure that harvesting does not lead to a population decline. As the AAH generally tends to be more precautionary when information is lacking, increased inventory and monitoring efforts may lead to an increase in the AAH.

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Xu, C. and M. Boyce. 2010. Optimal harvesting of moose in Alberta. Alces 46: 15-35.

Appendix 5. Literature review on moose bull/cow ratios.

The establishment of minimum post-hunt bull/cow ratios, as defined in the provincial moose harvest management procedure (Appendix 1) has and continues to be controversial. The Ministry will continue to review new scientific literature, and to assess new survey data for evidence that post-hunt bull/cow ratios of 30 bulls:100 are impacting moose productivity and recruitment in BC. Until new research becomes available, BC's policy will continue to be to maintain post-hunt bull/cow ratios above 30 bulls:100 cows in moderate-to-high density areas, and above 50 bulls:100 cows in low density areas.

A brief summary of some of the published scientific information on this topic that was used to inform the provincial moose harvest management procedure is outlined below:

Thompson, R. 1991. An analysis of the influence of male age and sex ratio on reproduction in British Columbia Moose populations. MSc. Thesis. UBC. 45 pp.

- A study of the existing provincial data set on moose found "there was no evidence that reduction in the prime and senior-age bull social classes in a population resulted in reduced pregnancy rates or later conception timing. No evidence was found that greatly skewed sex ratios in favour of cows resulted in reduced pregnancy rates. No relation was found between bull/100 cow ratios and calf/100 cows in the winter inventory."
- Based on this work, the author stated "it appears that the effect of sex ratio is only evident at very low bull/cow levels, i.e., less than 20 bulls/100 cows."

Aitken, D.A. and K. N. Child. 1992. Relationship between in utero productivity of moose and population sex ratios: an exploratory analysis. Alces 28:175-187.

- A study of moose populations in the Omineca region looked at nine different measures of bull/cow ratios and nine different productivity indices. While fetal and twinning rates were correlated with some measures of bull/cow ratios, there were no correlations between pregnancy rate, fertilization rate or mean date of conception and the various measures of bull/cow ratios.

Boer, A.H. 1992. Fecundity of North America Moose: A review. Alces Supplement 1: 1 -10.

- A review of the scientific literature relating moose fecundity in North American to population density and range carrying capacity found that yearling pregnancy rates and twinning rates were highly variable and appeared to be sensitive indicators of moose population status relative to carrying capacity.
- Moose populations above, near and below K carrying capacity were estimated to produce 0.88, 1.06 and 1.24 calves/adult female at parturition and 0.18, 0.41 and 0.65 calves/yearling female, respectively.

H.R. Timmermann. 1992. Moose sociobiology and implications for harvest. Alces 28:59-77.

- This review paper stated "the minimum bull/cow ratios that will ensure the breeding of all receptive females is not known."
- The author noted that various statements on required bull/cow ratios for ensuring all cows were bred were "best guess", and that "nowhere in North America…have low pregnancy rates as a result of unbalanced sex ratios, been reported."

Heard, D., S. Barry, G. Watts, and K. Child. 1997. Fertility of female moose in relation to age and body composition. Alces 33:165-176.

- Another study of moose in the Omineca region showed that pregnancy rates were positively related to kidney fat mass (an index of nutritional status) and age, but not to population sex ratios, nor interactions among independent variables.
- Twinning rates were also positively related to kidney fat mass and age, while there was no relationship with population sex ratio or interactions among independent variables.

Laurian, C., J-P. Ouellet, R. Courtois, L. Breton and S. St-Onge. 2000. Effects of intensive harvesting on moose reproduction. J. of Applied Ecology 37:515-531.

- This is another Quebec study which tested the hypothesis that a balanced adult sex ratio is necessary for the full participation of ungulate females in reproduction and therefore high productivity.
- The number of calves per 100 adult females was not related to the percentage of adult males in the population.
- The authors suggested that the participation of young adult males (subadults) in reproduction in their harvested population may have compensated for the lower percentage of adult males, and thus productivity was unaffected.
- In the case of their low-density study, it appeared that 30% males in autumn were sufficient to ensure mating of all females in the population.

Tagquet, M., J-P. Ouellet, R. Courtois and C. Laurian. 1999. Does unbalanced sex ratio in moose affect calf size in fall? Alces 35: 203-211.

- This Quebec study tested to see if an unbalanced adult moose sex ratio affects calf size in the fall.
- While their study could not reject the hypothesis that calves are small in the fall when the adult sex ratio is unbalanced, the differences were found to be very small. Assuming that such events do occur, the authors suggested that the impact would be weak at the population level.
- The authors concluded that "in the short term, it does not appear necessary to take this phenomenon (i.e. biased sex ratios) into account in management plans, at least when bulls constitute > 30% at the time of the rut."

Solberg, E.J., A. Loison, T.H. Ringsby, B-E Saether and M. Heim. 2002. Biased adult sex ratio can affect fecundity in primiparous moose. Wildl. Biol. 8:117-128.

- This Norwegian study evaluated to what extent a decline moose recruitment rate could be a result of an insufficient number of males in the populations to fertilize all females.
- While there was a significant relationship between the population sex ratio and the probability of pregnancy among 2-year-old females, there was no relationship to the probability of pregnancy of older females.
- The authors concluded that biased sex ratio only affects first-time breeders, and therefore the effect of biased sex ratio on population recruitment rate may be limited.

Appendix 6. Evaluating moose harvest strategies through population modelling studies.

Numerous studies have developed population models to evaluate moose harvest strategies and formalize harvest management principles (e.g. Crête and Jordan 1981, van Ballenberge and Dart 1982, Schwartz 1993, Solberg et al. 1999, Saether et al. 2001, Nilsen et al. 2005, Xu and Boyce 2010, Boyce et al. 2012). These studies have generally shown that in order to maximize the number of animals to be harvested hunting should focus on bulls, or bulls and calves; whereas bull hunting combined with limited cow hunting maximizes the yield measured in terms of meat.

We developed a general moose population model for BC to explore the consequences of various harvest management approaches, including various harvest rates for bulls, cows and calves. We used an age-and sex-specific model similar to that developed by Nilsen et al (2005) which included density dependence in reproduction, as well as an adjustment for the effect of the adult breeding sex ratio on the pregnancy rates of young females as determined from empirical studies (Saether et al. 2001, Solberg et al. 2002). We used the maximum age-specific reproductive rates reported by Nilsen et al (2005) to evaluate density-dependent responses. We used the adult survival rates determined for moose on Isle Royale in Michigan (Peterson 1977), as opposed to those used by Nilsen et al. (2005) for moose in Norway, as we believe the Isle Royale rates are more representative of non-hunting adult moose survival rates in BC where wolves are common. Following the methodology described by Nilsen et al. (2005), we also determined the highest sustainable yield measured as the number of animals harvested, as well as the highest yield of meat. We considered that sustainable yields for moose in B.C. would differ primarily depending on calf recruitment rates as influenced by predators such as wolves, black bears, grizzly bears and cougars.

Our analysis was based upon a hypothetical moose population in B.C. occupying an area of 1000 km^2 with a maximum moose density (carrying capacity) of 2 moose/km^2. We assumed that predation was the most important cause of natural mortality (Bergerud and Elliott 1992), and that calves would display more variable mortality rates than adults (Gaillard et al. 1998). We built four models with summer calf survival rates of 40%, 50%, 60% and 70%. Differences in summer calf survival rates were assumed to be associated with differing levels of predation by wolves, grizzly bears, black bears and cougars. The lowest summer calf survival rate (40%) was assumed to result from high predation rates, while the highest survival rate (70%) was assumed to occur where predation rates were lower. We chose levels between 40% and 70% as a review moose calf mortality studies in Alaska and Canada indicated that summer calf survival is generally within this range (Osborne et al. 1991).

We considered seven scenarios for each model including: (1) no harvest; (2) 10% of the bulls harvested; (3) 20% of the bulls harvested; (4) 30% of the bulls harvested; (5) the maximum harvest of bulls subject to maintaining 30 bulls/100 cows with all sex/age classes harvested; (6) the maximum harvest of moose subject to maintaining 30 bulls/100 with all sex/age classes harvested; and (7) the maximum harvest of moose meat (based on relative weights of bulls, cows and calves) with all sex/age classes harvested subject to maintaining 30 bulls/100 cows.

Legend for Modelling Scenarios

Bull % HR = bull harvest/prehunt bulls	Bull harv = total harvest of males	Bull age = ave. age of males harvested
Cow % HR = cow harvest/prehunt cows	Cow harv = total harvest of females	B/C (postN) = posthunt bull/cow ratio
Calf % HR = calf harvest/prehunt calves	Calf harv = total harvest of calves	N (postN) = posthunt number of moose
Total % HR = total/prehunt moose	Total harv = total harvest of moose	

Model 1: summer calf survival = 70%

Scenario	Bull % HR	Cow % HR	Calf % HR	Total % HR	Bull harv	Cow harv	Calf harv	Total harv	Bull age	B/C postN	N postN
1	0	0	0	0.0	0	0	0	0	n/a	0.91	2000
2	10	0	0	3.2	64	0	0	64	4.8	0.55	1935
3	20	0	0	5.1	102	0	0	102	3.9	0.35	1898
4	30	0	0	6.2	124	0	0	124	3.2	0.23	1875
5	26.2	1.8	0.0	7.2	113	19	0	132	3.5	0.30	1706
6	23.7	0.0	35.9	13.7	66	0	113	179	3.6	0.30	1124
7	31.0	5.3	0.0	10.2	107	44	0	151	3.2	0.30	1333

Model 2: summer calf survival = 60%

Scenario	Bull % HR	Cow % HR	Calf % HR	Total % HR	Bull harv	Cow harv	Calf harv	Total harv	Bull age	B/C postN	N postN
1	0	0	0	0.0	0	0	0	0	n/a	0.91	1784
2	10	0	0	3.2	58	0	0	58	4.8	0.55	1727
3	20	0	0	5.1	91	0	0	91	3.9	0.35	1693
4	30	0	0	6.2	110	0	0	110	3.2	0.23	1672
5	24.7	0	0	5.9	99	3	0	103	3.6	0.30	1651
6	23.7	0	27.9	11.4	64	0	75	140	3.6	0.30	1088
7	29.0	3.8	0	9.0	93	30	0	124	3.3	0.30	1256

Model 3: summer calf survival = 50%

Scenario	Bull % HR	Cow % HR	Calf % HR	Total % HR	Bull harv	Cow harv	Calf harv	Total harv	Bull age	B/C postN	N postN
1	0	0	0	0.0	0	0	0	0	n/a	0.91	1501
2	10	0	0	3.2	48	0	0	48	4.8	0.55	1452
3	20	0	0	5.1	76	0	0	76	3.9	0.35	1423
4	30	0	0	6.2	93	0	0	93	3.2	0.23	1405
5	23.7	0	0	5.6	84	0	0	84	3.6	0.30	1416
6	23.7	0	17.2	8.8	61	0	38	99	3.6	0.30	1030
7	26.6	2.1	0	7.4	78	15	0	93	3.4	0.30	1157

Model 4: summer calf survival = 40%

Scenario	Bull % HR	Cow % HR	Calf % HR	Total % HR	Bull harv	Cow harv	Calf harv	Total harv	Bull age	B/C postN	N postN
1	0	0	0	0.0	0	0	0	0	n/a	0.91	1053
2	10	0	0	3.2	34	0	0	34	4.8	0.55	1018
3	20	0	0	5.1	53	0	0	53	3.9	0.35	996
4	30	0	0	6.2	65	0	0	65	3.2	0.23	979
5	23.7	0	0	5.6	58	0	0	58	3.6	0.30	990
6	23.7	0	2.6	6.0	54	0	4	54	3.6	0.30	923
7	23.7	0	0	5.6	58	0	0	58	3.6	0.30	990

Moose populations with high summer calf survival rates (Models 1 and 2) provide the most harvest management options, in that all sex/age classes may be harvested to achieve high sustained yields. Consistent with other studies, we also found the greatest yield in terms of total animals removed is achieved when both bulls and calves are harvested (All Models, Scenario #6). The greatest yield in terms of total meat is achieved with a high harvest on bulls, combined with a low harvest on cows (Models 1, 2 and 3; Scenario #7). The greatest yield in meat from moose populations with low summer calf survival rates (e.g. Model 4; Scenario #7) occurred with bull only hunting.

Figure 1 summarizes another analysis, independent of Models 1 through 4 above, and looks at the potential effect of cow harvest rate on increasing total yield when bulls and cows, but not calves, are hunted. When summer calf survival (scs) is within a range of 50 to 70%, increasing the cow harvest rate increased the total yield. For example, when scs =0.70 (summer calf survival rate = 70%), a 6% cow harvest rate provided the highest yield after which further increases in the cow harvest rate resulted in a decline in the total yield. When scs =0.60 (summer calf survival rate = 60%), a 4% cow harvest rate provided the highest yield. When scs = 0.50 (summer calf survival rate = 50%), a 2% cow harvest rate provided the highest yield. However, when scs = 0.40 (summer calf survival = 40%), the highest yield occurred from only harvesting bulls, i.e. including cow harvesting results in a lower harvest than achieved with bull-only hunting.

Figure 2 is similar to Figure 1, except that it shows the effect of cow harvest rate on the bull yield. For scs = 0.70 (summer calf survival rate = 70%), there is only a very slight increase in the bull yield from 111 with no cow hunting to 113 with a 2% cow harvest rate. When summer calf survival is lower than 70%, the highest bull harvest is achieved when there is no harvest of cows.

Summer calf survival rates for moose have not been well documented in BC. However, based upon known reproductive rates, and observed calf/cow ratios, it is likely that summer calf survival varies between 30 to 60%. This suggests that sustainable cow harvest rates in BC would range between 0% to 4% of the number of cows at the start of the hunting season. Heard et al. (1999) showed that a 2% kill of cows was sustained for over 20 years in the Prince George when hunters also shot 16% of the bulls and 9% of the calves.

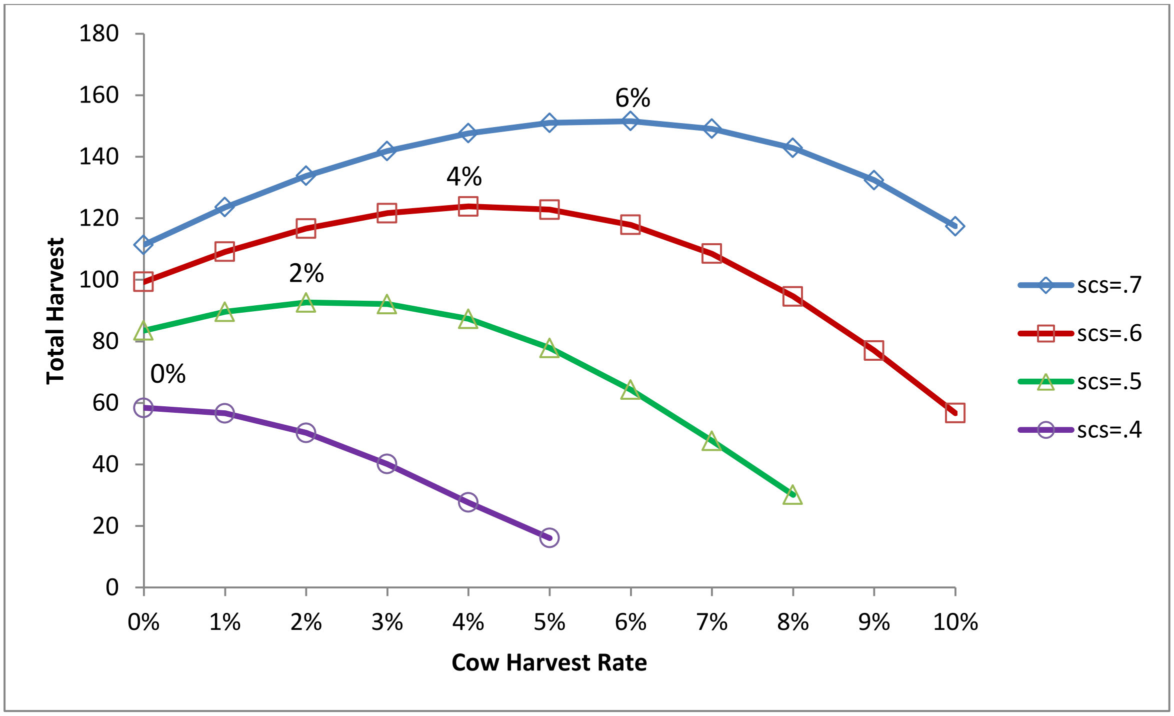

Figure 1. Influence of cow harvest rate on increasing the total harvest of bulls and cows under different levels of summer calf survival (scs, see text). Bulls and cows are harvested, but not calves.

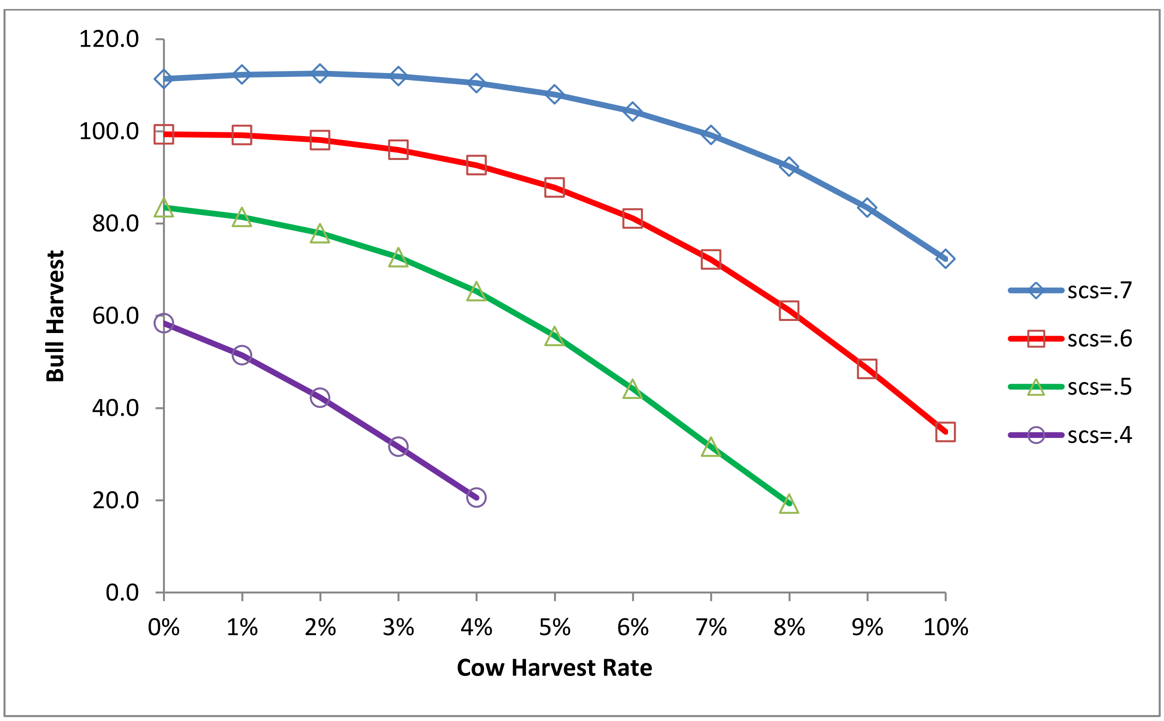

Figure 2. Influence of cow harvest rate on total harvest of bulls under different level of summer calf survival (scs). Bulls and cows are harvested, but not calves.

Environmental variation in calf survival or errors in population estimates were not explicitly modelled. However, general results from other modelling efforts for moose (e.g. Saether et al. 2001) have shown that environmental variation increases the risk of overharvest. Similarly, an overharvest may occur if the population size is over-estimated. Consequently, bull-only harvest can reduce the risk of a population decline when management uncertainty is high.

The modelling results described here support BC's current approach to limiting regulated hunting to bulls where predators are common and lightly hunted. It should be noted, however, that different models operating with different assumptions can produce different results (e.g. Messier 1996, Nielsen et al. 2005, Varley and Boyce 2006). Nonetheless, the model used here is in general agreement with van Ballenberghe and Dart (1982) who modelled moose populations in Alaska, and Xu and Boyce (1999) who modelled moose populations in Alaska. Empirical studies summarized by Gasaway et al. (1992) and Boertje et al. (1996) also suggest that bull-only moose hunting remains the only viable option for sustained yields where predators are lightly harvested.

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Appendix 7. Implications of hunting cow moose.

Hunting cow moose, at a low rate, is sustainable under most circumstances. In highly productive populations, hunting cow moose can increase both total yield and annual allowable kill of bulls. If the goal is to annually harvest the maximum number of moose, then both bulls and calves should be harvested, and harvesting cows should generally be avoided. If the goal is to harvest the maximum amount of meat each year, then intensive harvesting should be focused on bulls and calves with a low harvest of cows (see Appendix 6).

Managing for a sustainable harvest of cow moose is based on the premise that hunting mortalities are compensated for by either increased survival rates of the remaining individuals, increased reproduction or a combination of both factors. While the concept of compensation, as described in the literature, implies that changes in demographic processes must occur within the same year (e.g. Boyce et al. 1999), many wildlife managers view compensation of survival and reproduction to occur over several years.

An early description of complete compensation was described by Errington (1971) and occurred when hunting removed only the “doomed surplus”, with the result that there was no effect of hunting on year-to-year population size. For example, in Errington’s model, if 10% of the population was doomed to die (a 90% survival rate) and hunters killed 10%, there would be complete compensation such that the survival of the remaining individuals increases to 100%, with no change in population size. This model is more applicable to small mammals than it is for moose. Another model of sustained yield, more applicable to moose, assumes logistic population growth. In this case hunting reduces the population size below carrying capacity, to a new and stable number, with compensatory increases in survival and/or reproduction. Survival and reproduction increase because they are density-dependent, which is a necessary condition for logistic growth (Ricker 1958, Peek 1986).

However, these two “classical” explanations of sustained yield harvesting ignore some important details for hunting cow moose including:

1. Compensatory mortality or reproduction can operate as a consequence of seasonality (Boyce et al. 1999).
2. Hunting is almost always selective by sex, whereas the logistic growth model assumes that hunters remove individuals of both sexes in proportion to their abundance.
3. A change in population density does not affect all individuals equally. In fact, density effects in large mammals occur in a predictable sequence from juvenile survival, age of first reproduction, adult fecundity and adult survival (Bonenfant et al 2009, but see Nielsen et al 2005).
4. Moose populations have both sex and age structures where age-specific reproduction and mortality rates may or may not be density-dependent. Including age structure in models adds realism, but it also adds complexity. Complexity can be reduced by lumping age classes (e.g. up to 20) into stages with similar mortality factors, e.g., juvenile, adult, senior/senescence (Siler 1979). The benefit of incorporating age and stage structure is greater where there is a large difference between the age classes removed by hunters and those lost to natural

mortality. Age-specific natural mortality and hunting may be relatively similar in some ungulates e.g., sheep hunters selecting full curl rams and moose hunters select calves. However, natural and hunting mortality may also be very different where hunters do not select by age, e.g., bull moose hunting in much of BC where hunters kill mostly prime age moose that otherwise have low natural mortality rates.

Most moose population models currently used by wildlife managers to examine sustained yield hunting incorporate some or all of the above details and demonstrate that yield, in terms of numbers of moose harvested, depend on the hunter's selection of age and sex of animal. In these models, when only bulls are killed the overall density initially declines and both reproductive rates and calf survival rate increase, with male calves compensating for hunting losses and the female calves supplementing the number of females in the population. Eventually the population size and therefore calf recruitment, returns to what it was in the absence of hunting but with a lower sex ratio. Adding a cow hunting season to this situation (i.e., to a population previously subject to bulls-only hunting), has an effect similar to the logistic growth model. Overall density declines and calf recruitment increases with the male calves supplementing the number of bulls in the population and the female calves compensating for the losses from cow hunting. Eventually the population size stabilises at a lower density, calf recruitment remains higher than in an unhunted population and the sex ratio increases because there are more males and fewer females in the population. This is why killing cow moose may increase the sustainable bull kill where calf recruitment is moderate to high (see Saether et al. (2001), Nilsen et al. (2005), Xu and Boyce (2010), Boyce et al. (2012), Appendix 6 in this document).

The question remains "In B.C., where predators are common, what is the sustainable harvest rate that could be applied to cows, and will the cow harvest increase the male yield?" Some authors describe the cow kill to be "small" or "very low"(Saether et al 2001:175-177, Xu and Boyce 2010:26). If we assume that summer moose calf survival in BC ranges between 30% and 60%, then the model described in Appendix 6 suggests that the sustainable cow harvest rate may range between 0% and 4%; and that while cow hunting in some moose populations may increase total yield, it is generally unlikely to increase the bull yield, unless predators are managed at low densities. Heard et al. (1999) showed that a 2% kill of cows was sustained for over 20 years in the Prince George when hunters also shot 16% of the bulls and 9% of the calves. It is important to note that both wolves and bears are also harvested in this system (see Appendix 3 for a conceptual model of moose-wolf-bear-hunting dynamics in this system).

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Appendix 8. Adjusting the AAH based on post-hunt bull/cow ratios.

The provincial Moose Harvest Management Procedure states "unless formal management objectives have been identified, hunted moose populations will be managed to avoid declines and to ensure that the post-hunt bull:cow ratio remains above 30 bulls:100 cows." The 30 bulls:100 cows is not a target to achieve, but rather represents a minimum threshold or limit. Moose populations in B.C. are monitored by either periodic stratified random block or herd composition surveys. In general, most moose populations are not resurveyed more than once every five years.

Stochastic simulations, using the model described in Appendix 6 were used to develop a set of rules which may help to guide managers on how changes to Annual Allowable Harvest (AAH) could be made over a 5-year period to ensure that bull/cow ratios are maintained above 30 bulls/100 cows. In order to evaluate the model, it was necessary to establish performance measures that would determine if the harvest rules provided a satisfactory outcome. The performance measures used included: (1) the number of years (over a 100 year simulation) where the modelled bull/cow ratio fell below 30 bulls:100 cows; and (2) the CV of the bull harvest (over a 100 year simulation).

Assumptions included (in addition to those described in Appendix 6):

- Summer calf survival averaged 50%, but varied annually (CV = 15%)
- Surveys conducted once every 5 years, with CV (bull:cow ratio) = 20%
- Licensed harvest determined from the AAH with a CV = 10%
- First Nation harvest was non-selective with respect to sex/age of moose and was randomly set between 1 and 5% of the post-hunt population for each simulation.

The rule set for adjusting the AAH was:

- if bulls/100 cows >70, then AAH = AAH from previous allocation period x 1.3;
- If bulls/100 cows >65 and <70, then AAH = AAH from previous 5-year period x 1.25;
- If bulls/100 cows >60 and <65, then AAH = AAH from previous 5-year period x 1.20;
- If bulls/100 cows >55 and <60, then AAH = AAH from previous 5-year period x 1.15;
- If bulls/100 cows >50 and <55, then AAH = AAH from previous 5-year period x 1.10;
- If bulls/100 cows >45 and <50, then AAH = AAH from previous 5-year period x 1.05;
- If bulls/100 cows >40 and <45, then AAH = AAH from previous 5-year period x 1.00;
- If bulls/100 cows >35 and <40, then AAH = AAH from previous 5-year period x 0.95;
- If bulls/100 cows >30 and <35, then AAH = AAH from previous 5-year period x 0.90;
- If bulls/100 cows >25 and <30, then AAH = AAH from previous 5-year period x 0.85;
- If bulls/100 cows >20 and <25, then AAH = AAH from previous 5-year period x 0.8;
- If bulls/100 cows <20, then AAH = AAH from previous 5-year period x 0.5.

The results from the performance assessment from 10,000 Monte Carlo simulations indicated that the probability of the population bull/cow ratio dropping below 30 bulls/100 cows more than 10 times over a 100 year period was ~ 3%, and the average bull/cow ratio was 41/100. The probability of the harvest variation exceeded CV = 0.20 over 100 years was ~9%.

While more studies are needed, these results suggest that the AAH could be set by using periodic herd composition surveys in BC, which are much more economical to conduct than stratified random block surveys. If herd composition surveys are used, the target bull:cow ratio should be ~40 bulls/100 cows in order to ensure that actual bull/cow ratios does not drop below the minimum threshold of 30/100.

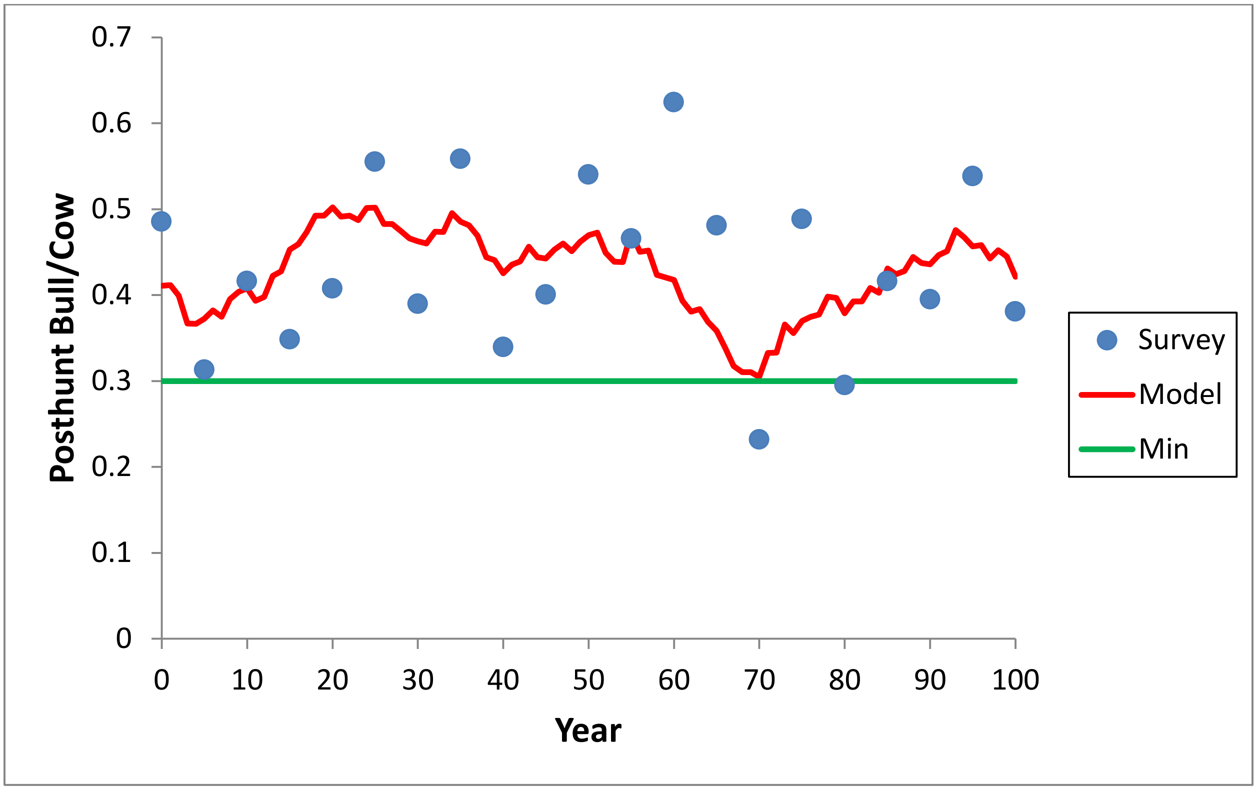

Figure 1. Example simulation of applying harvest rules to adjust the AAH based on surveyed bull:cow ratios. Surveys were conducted once every 5 years to measure bull/cow ratios (blue dots) and were subject to measurement error. The actual (modelled) bull/cow ratio is shown by the red line. The minimum threshold (min) for the bull:cow ratio is 30 bulls/100 cows. The average bull/cow ratio, from applying the harvest rules, was 43 bulls/100 cows.

Appendix 9. Incorporating SDM into wildlife management.

Wildlife management in North America, including British Columbia, has undergone a significant paradigm shift over the last 20 years. Traditionally, wildlife management was focused primarily on the analysis and insights from the biological sciences and expert opinion to make decisions. More recently, increased stakeholder interest in wildlife and their expectations for direct participation in management decisions have necessitated integration of traditional wildlife management practices with the human dimensions of wildlife. One of the ways we are attempting to "make complementary use of biological and social science for wildlife management in BC" is through Structured Decision Making.

What is SDM?

Structured Decision Making (SDM) is a common-sense framework that formalizes the steps of good decision making, emphasizing the integration of scientific, socioeconomic and other technical analysis with value-based information. It also recognizes that "hard decisions" require trade-offs, and that decisions need to be communicated in a transparent and thoughtful manner. The SDM framework has proven to be a useful tool for integrating biological assessments with stakeholder values and interests, and thereby improve wildlife management decisions in BC.

There are six steps to the SDM process as outlined below:

1. Define the problem and the issues (also called framing the decision context).
2. Define objectives (sometimes called end points) and evaluation criteria (sometimes called performance measures).
3. Develop alternatives or options.
4. Estimate the consequences – these are the social, economic and environmental/biological consequences of each option as measured against the objectives and evaluation criteria.
5. Evaluate the trade-offs and select an option.
6. Implement the option – monitor and re-evaluate (the "adaptive management cycle").

In SDM, "objectives" are endpoints or interests, i.e. things people care about. Objectives are not targets – which are largely value judgments.

SDM outlines clear roles and responsibilities for the analyst (e.g. the scientist, economist, and policy specialist), the decision maker and stakeholders, as outlined below:

1. The decision maker needs to approve the decision context, and approve the objectives, evaluation criteria, and alternatives before the analyses begin. The decision maker also has the responsibility for assessing the trade-offs and making the final decision.
2. Stakeholders help clarify the problem by providing their perspective, but most importantly, they provide value-based input into the evaluation criteria and alternatives. They also state their preferences for options and trade-offs based on their values.
3. The analyst's job is to explain the key technical issues to both the decision maker and stakeholders, and to provide technical input. Their primary role is the objective analysis of the

consequences associated with each management option, typically shown in the Consequence Table.

Consequence tables (CT's) have proven to be a very effective communication tool for SDM. The CT is a table where the objectives are listed in the first column, along with the evaluation criteria in the second column, and the options or alternatives are listed in the remaining columns. The following example is for a hypothetical moose population with different expectations for harvest.

Table 1. Consequence Table for a hypothetical moose population with different expectations for harvest.

End Points (Objectives)	Evaluation Criteria (Performance Measures)	What's Better	Alt A Low Harvest	Alt B High Harvest	Alt C High & increase KCC	Alt D High & increase inventory
Conservation	Average expected abundance	Higher	10,000	8,000	9,000	8,000
	Probability of falling below B/C threshold	Lower	10%	40%	40%	5%
First Nation Needs	First Nation's sustenance harvest		500	500	500	500
Socio-economic costs/benefits	Average annual hunter harvest	Higher	500	800	800	800
	Probability of hunting moratorium	Lower	5%	20%	20%	3%
	License Fees	Lower	$45	$45	$100	$100
Management Costs	Program Costs	Lower	$50K	$50K	$225K	$200K

Note: KCC refers to habitat carrying capacity

As some CT's can be quite complex, it is a good idea to simply the CT, in order to expose the key trade-offs that need to be made for a decision. A number of techniques can be used to simplify the CT, such as looking for redundancy, sensitivity and dominance. This helps to expose and focus the discussion on the key trade-offs that need to be made.

Three Case Studies

1. Hunting Stakeholder Committee Meetings

Experience with Structured Decision Making really began with our traditional hunting stakeholder groups. In the past these meetings have been very challenging as various stakeholder groups have brought forward competing interests for the use of wildlife, which we really had no way to adequately resolve. SDM was used as a way to enable us to accommodate these multiple competing objectives in the decision process.

One experience was with moose management occurred in the Cariboo Region. Typically, the regional manager will deal with a number of guide outfitter appeals each year, as a result of the decisions that come out of these meetings. Two meetings were held to work through a SDM process for moose regulation setting. While not everyone was happy with the outcome, they did feel that their values and interest had been considered, and there were no appeals.

2. Kootenay Elk Management Plan

The Kootenay elk management plan (http://www.env.gov.bc.ca/kootenay/emp/emp.htm) is an example where SDM was used to develop management direction statements over a five year period. Ministry of Environment (MoE) staff in the Kootenay Region, in consultation with First Nations, stakeholder groups, staff from other ministries and the general public used SDM to assess and make recommendations for elk management in seven Population Management Units (PMU's). CT's were developed for each PMU. There were six objectives focused on population management, hunting and viewing opportunities, management and enforcement, ecosystem health, and agriculture. A total of 22 evaluation criteria were developed and five management options were analyzed. After considerable debate, this plan was supported by all stakeholders and it has reduced the controversy around elk management in the Kootenay Region.

3. Big Game Harvest Management Procedures.

SDM language and process has been put directly into the "big game harvest management procedure" which stipulates the use of SDM, CT's, consultation guidelines, and a process for conducting a trade-off analysis.

Lessons Learned

Problems have occurred most often with stakeholders when we the SDM process has been hurried. Some key learning's regarding stakeholder acceptance and support of SDM include:

1. Involve stakeholders early enough to provide critical input on decision framing.
2. Involve stakeholders often enough to ensure that the process appears/is transparent.
3. Involve stakeholders actively enough so that they provide useful input to objectives, evaluation criteria, and alternatives.
4. Have stakeholders state their preferences for the trade-offs that will be made in a decision.

Learning More about SDM

Additional information on using SDM is available on the website: http://structureddecisionmaking.org/ developed by Compass Resource Management, a team of research and consulting professionals dedicated to improving both the quality of policy and management decisions and the decision making capacity of citizens, organizations and governments.

Appendix 10. Game Management Zones in British Columbia.

British Columbia Game Management Zones	
GMZ #	GMZ Name
1a	Southern Vancouver Island
1b	Northern Vancouver Island
1c	Kingcome/Knight Inlet
2a	South Coast
2b	Fraser Valley
3a	West Fraser
3b	Nicola
3c	Bonaparte
3d	North Thompson
4Ea	Fernie
4Eb	Cranbrook
4Ec	Golden
4Wa	Nelson
4Wb	Revelstoke
5a	Quesnel Highland
5b	Cariboo
5c	North Chilcotin
5d	South Chilcotin
5e	Central Coast
6a	Queen Charlotte
6b	North Coast
6c	Bulkley Valley/Lakes District
6d	Upper Skeena
6e	Stikine
6f	Atlin
7Oa	Upper Fraser
7Ob	Prince George
7Oc	Mcleod Lake
7Od	Omineca
7Oe	Upper Finlay
7Pa	South Peace
7Pb	North Peace
7Pc	Northeast Rockies
7Pd	Liard
7Pe	Fort Nelson
8a	Similkameen
8b	Okanagan
8c	Monashee
8d	Kettle

GMZ Name	Code	MU's
Southern Vancouver Island	1a	101-108
Northern Vancouver Island	1b	109-113
Kingcome/Knight Inlet	1c	114-115
South Coast	2a	205, 212-216
Fraser Valley	2b	201-204, 206-211, 217-219
West Fraser	3a	315-316, 332-333
Nicola	3b	312-314, 318-320,326
Bonaparte	3c	317, 327-331
North Thompson	3d	334-346
Fernie	4Ea	401-402, 421-425
Cranbrook	4Eb	403-405, 420,426
Golden	4Ec	434-437, 440
Nelson	4Wa	406-409, 414-419
Revelstoke	4Wb	427-433, 438-439
Quesnel Highland	5a	515-516
Cariboo	5b	501-502
North Chilcotin	5c	510, 512-514
South Chilcotin	5d	503-506
Central Coast	5e	507-509, 511
Queen Charlotte	6a	612-613
North Coast	6b	603, 610-611, 614-616
Bulkley Valley/Lakes District	6c	601-602,604-606, 608-609
Upper Skeena	6d	607, 617-618, 630
Stikine	6e	619-624
Atlin	6f	625-629
Upper Fraser	7Oa	701-705, 717-718
Prince George	7Ob	706-713, 715
McLeod Lake	7Oc	714, 716, 723-726
Omineca	7Od	727-730, 738
Upper Finlay	7Oe	737, 739-741
South Peace	7Pa	719-722, 731
North Peace	7Pb	732-735, 744-746
Northeast Rockies	7Pc	736, 742-743, 750, 757-758
Liard	7Pd	751-754
Fort Nelson	7Pe	747-749, 755-756
Similkameen	8a	803-807
Okanagan	8b	801-802, 808-811, 821-822, 826
Monashee	8c	823-825
Kettle	8d	812-815