To the reader:

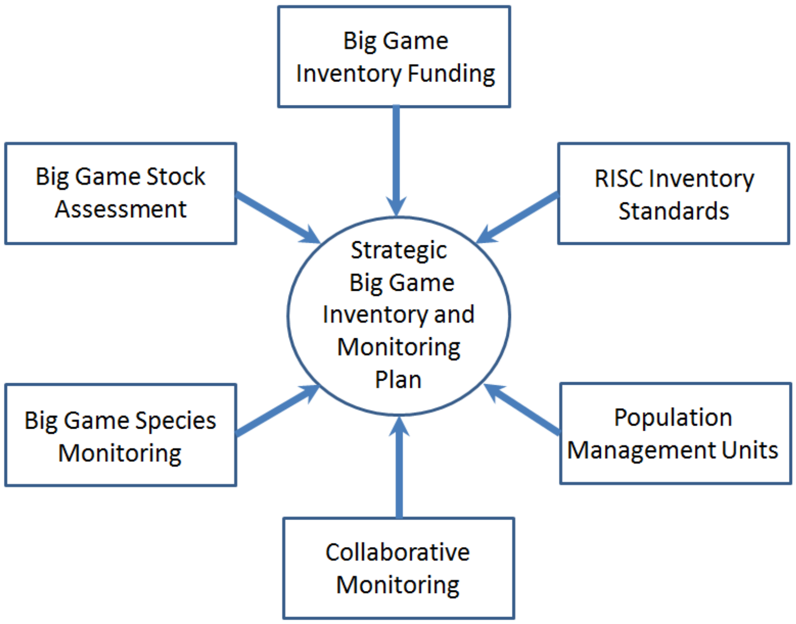
In December 2017, Nature Wise Consulting produced a report titled "Towards a Big Game Inventory and Monitoring Strategy for British Columbia: Background Report" for the Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

This report provides recommendations to government for a strategic approach to big game inventory and monitoring in British Columbia. It summarizes the latest science and most up-to-date methods for monitoring big game species, and highlights linkages between monitoring, objective-setting and management decisions.

The Province will carefully consider the recommendations in this report. Implementation of actions will depend on government priorities, budgetary constraints and legal, social and economic factors. Successful delivery of big game inventory and monitoring in BC will require the commitment and cooperation of partners across the Province.

The report does not represent an official position or program of government and may support discussions with Indigenous peoples and stakeholders in the development of specific regional inventory plans.

Towards a Big Game Inventory and Monitoring Strategy for British Columbia: Background Report



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Prepared for:

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I thank all the members of the Big Game Population Inventory and Monitoring Working Group who provided expertise, information, suggestions and discussions that greatly assisted in developing the report. This working group consisted of 18 employees from the Ministry of Forests, Lands and Natural Resource Operations including the Branch office in Victoria; as well as the Coast, the South and the North areas of British Columbia. Gerry Kuzyk and Stephen MacIver from the Fish and Wildlife Branch represented the Branch office perspective. Sean Pendergast and Bill Wilton of the West Coast Region along with Darryl Reynolds of the South Coast Region provided the Coast Area viewpoint. The South Area was represented by Gerad Hales, Chris Procter and Andrew Walker from the Thompson/Okanagan Region; Albert Chirico and Tara Szkorupa from the Kootenay/Boundary Region; and Becky Cadsand and Nicola Dodd from the Cariboo Region. The following individuals provided the North Area perspective: Conrad Thiessen and Krystal Dixon and from the Skeena Region; Shelley Marshall and Michael Klaczek and from the Omineca Region; and Michael Bridger and Chris Addison from the Northeast Region.

Dr. Jenny Feick assisted with the literature review and Executive Summary, contributed to the analysis in Section 7 and Appendix J, and carried out the technical editing of the final draft of the report according to guidance in the on-line version of the "“British Columbia Forest Science Program Style Guide and Authors Manual” (2008). She also provided technical assistance with the content and structure of the final draft of the report.

I obtained the relative abundance and distribution maps for deer, elk, moose, caribou, bison, mountain goat, bighorn sheep, thinhorn sheep, American black bear and grizzly bear from the big game brochures funded by the Habitat Conservation Trust Foundation. The wolf and cougar distribution maps are from the species management plans developed for the Ministry of Forests, Lands and Natural Resources. Dr. Tony Bubenik created the pen and ink drawings of ungulates, which appear throughout the report. These drawings were found in the Hunting and Trapping Regulation synopses during the 1980s and early 1990s; and are used with the permission of the B.C. Fish and Wildlife Branch.

Executive Summary

This report summarizes and provides a long-term perspective for how the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) could implement a provincially coordinated effort to support and enhance big game inventory and monitoring in British Columbia (B.C.). The history of inventory and monitoring in B.C., with some notable exceptions, has largely been prioritized in reaction to management issues and concerns. A more structured, adaptive approach that connects inventory and monitoring to decision making through management objectives will help to resolve this.

The mandate, foundational to the recommendations for inventory and monitoring, comes from three sources: the Ministry's Service Plan (FLNRO 2014e); the Provincial Wildlife Program Plan (MOE 2008); and strategic advice to the Minister of Forests, Lands and Natural Resource Operations (Morris 2015). The scope includes those native big game populations (i.e. deer, elk, moose, caribou, bison, mountain goat, mountain sheep, bear, wolf, cougar, lynx, bobcat, and wolverine) that are being managed for both conservation and sustainable use.

The goal is "to enhance the use of big game population inventory and monitoring to facilitate a structured, adaptive approach to management decisions that achieves desired management outcomes. To facilitate achieving this goal, the report:

1. establishes a set of principles for big game inventory and monitoring;
2. describes key components for inventory and monitoring that will help ensure big game populations in B.C. are sustainably managed, and meet a variety of management objectives;
3. develops a vision or future state for what a big game inventory and monitoring program would look like if additional resources became available; and
4. provides recommendations for improving big game inventory and monitoring consistent with this vision.

The seven principles for big game inventory and monitoring are:

1. inventory and monitoring must be conducted to evaluate the effectiveness of big game management actions relative to objectives;
2. monitoring enables periodic assessments on the status of big game populations;
3. inventory and monitoring contribute directly to the value of information for big game management;
4. in an adaptive management setting, monitoring provides the feedback loop for learning about big game populations, and how to better achieve management objectives;
5. inventory and monitoring methods must adapt to environmental changes that affect big game populations;
6. inventory and monitoring provide data necessary to calculate the annual allowable harvest of big game populations; and
7. inventory and monitoring must be efficient and cost-effective given limited staff and budgets.

Key interrelated components for big game inventory and monitoring include:

1. big game inventory funding;
2. big game inventory standards;
3. Population Management Units;
4. collaborative monitoring;
5. big game species monitoring; and
6. population monitoring for big game stock assessment.

The 12 most pressing issues affecting the ability of big game inventory and monitoring to inform management decisions in B.C. include:

1. variable funding for big game inventory;
2. lack of an approved big game inventory funding plan to guide expenditure of funds;
3. out-dated inventory guidance, e.g. Resource Inventory Standards Committee (RISC) manuals;
4. incomplete documentation of completed inventories in the Species Inventory (SPI) database;
5. lack of designated Population Management Units (PMUs) to guide inventory priorities;
6. lack of designated Big Game Monitoring Areas (BGMAs) to monitor key big game populations;
7. lack of regional big game species management plans that establish management objectives;
8. lack of integrated inventory and harvest data systems that support big game stock assessments;
9. inadequate big game harvest data system;
10. insufficient understanding and/or application of new wildlife techniques by staff;
11. lack of population monitoring to support adaptive management approaches; and
12. unrealized opportunities to leverage investment for big game inventory and monitoring.

Key recommendations and actions to address these issues include:

1. Optimize funding levels to support big game inventory and monitoring,

Action #1.1: Ensure dedicated long-term funding for big game inventory and monitoring.
Action #1.2: Formally approve the Big Game Inventory Fund 5-year Plan.

2. Dedicate resources to support RISC inventory and monitoring,

Action #2.1: Create a Big Game Inventory and Monitoring Unit to perform the following functions:

a) update RISC population inventory and monitoring standards;
b) assist wildlife biologists with project and data management in order to ensure all big game inventories are conducted to RISC standards and inventory results are being entered in SPI;
c) review the RISC inventory submission process to assess whether big game inventory data submission requirements to the SPI data system are being met;
d) review current mechanisms in retrieving species inventory information to assess whether the information meets client needs;
e) maintain a current provincial summary list of inventories for each big game species extending from 1980 to present;
f) produce annual summary reports of big game inventory and monitoring projects in B.C.; and

g) provide regional support for developing regional big game species management plans, conducting inventories, and assisting with big game stock assessments.

3. Address gaps in PMUs, BGMAs and regional management plans for big game species

Action #3.1: Develop PMUs for all big game species in B.C.
Action #3.2: Develop BGMAs for high priority PMUs.
Action #3.3: Develop regional management plans for all big game species.

4. Build a data system to integrate harvest and inventory data by PMU

Action #4.1: Investigate the potential to incorporate PopR into B.C.'s hunting transformation project.
Action #4.2: Improve the functionality of B.C.'s big game harvest data system through the hunting transformation project.

5. Invest in staff training for big game inventory and population modelling

Action #5.1: Train wildlife staff in new inventory techniques as RISC standards are updated.
Action #5.2: Update the big game stock assessment manual to include Bayesian modelling and Statistical Population Reconstruction (SPR), and distribute to wildlife staff.
Action #5.3: Hold periodic population modelling training workshops to train/re-train wildlife biologists in new big game stock assessment methods.
Action #5.4: Train wildlife staff on how to incorporate Adaptive Resource Management (ARM) into wildlife management decision-making to reduce key uncertainties.

6. **Foster collaborative big game monitoring**.

Action #6.1: Develop partnerships with First Nations, other government agencies, traditional stakeholders and citizen-science volunteers to collaborate on inventory and monitoring initiatives.
Action #6.2: Expand the use of smartphone technology to enable hunters to record their observations of big game.
Action #6.3: Develop programs, relationships, or agreements with First Nations to enable annual reporting of their harvest.

The vision for what an ideal big game inventory and monitoring program would look like is *British Columbia achieves desired wildlife management outcomes through a structured, adaptive approach to management decisions facilitated by enhanced use of big game population inventory and monitoring*.

Implementing this vision could involve three phases:

Phase One– a Big Game Inventory and Monitoring Unit is established to work collaboratively with headquarters and regional staff on big game inventory and monitoring activities. FLNRO develops an objective and structured approach to determine the funding requirements for a fully operational Big Game Inventory and Monitoring Program that will meet management needs.

Phase Two - a comprehensive annual provincial inventory and monitoring budget is developed and funding sources identified and secured.

Phase Three - on-the-ground implementation is underway for all six of the report's key recommendations and corresponding 12 actions and 78 species-specific recommendations. An integrated management system for automatic compiling, analyzing and reporting of population inventory and harvest data by PMU is implemented. Collaborative big game monitoring projects with First Nations, other government agencies, stakeholders, and citizen-science volunteers are underway.

Table of Contents

List of Figures

List of Tables

1. Introduction

With its significant size and diverse ecosystems, British Columbia (B.C.) (Figure 1) supports one of the largest **big game**[1] species assemblages in North America (Table 1). This rich big game fauna comprises a key feature of the province's "supernatural image" that draws tourists and hunters from around the world. The Ministry of Forests, Lands and Natural Resource Operations (FLNRO) holds responsibility for the **conservation** of big game. Along with the Ministry of Environment (MOE), FLNRO carries provincial, national and international obligations for ensuring the sustainability of **wildlife use**.

The conservation status of most big game species in B.C. is secure, both provincially and globally (Table 2). The Convention on International Trade in Endangered Species of Wild Fauna and Flora or CITES (https://cites.org/) is an international convention that controls the movement of animals and plants that are, or may be, threatened by international trade. Seven big game species in B.C. are listed in Appendix II of CITES (Table 2) for "look alike" reasons in order to protect wildlife populations at high risk in other parts of the world. These species require a **non-detriment finding** (NDF) to demonstrate they are being sustainably managed. Both FLNRO and the MOE share in the responsibility to meet the province's obligations under CITES. The Committee on the Status of Endangered Wildlife in Canada or COSEWIC (http://www.cosewic.gc.ca/eng/sct5/index_e.cfm) is a committee of experts that assesses and designates which wildlife species are in some danger of disappearing from Canada. COSEWIC has identified six big game species in B.C. as endangered, threatened or special concern (Table 2). The B.C. Conservation Data Center or CDC (http://www.env.gov.bc.ca/cdc/) in MOE assesses and assigns the status of provincial wildlife and has placed 11 big game species on the yellow list (secure), seven on the blue list (special concern) and three on the red list (threatened or endangered). The Conservation Framework (http://www.env.gov.bc.ca/conservationframework/) provides the provincial approach for maintaining the rich biodiversity of B.C (MOE 2009). The Framework has assigned three big game species a conservation priority of 1 (highest priority) and nine species a priority of 2 (next highest priority) under Goal 2: prevent species and ecosystems from becoming at risk.

With the exception of those species that are known or presumed to be extirpated (e.g. Dawson caribou, Vancouver Island wolverine), or imperiled (e.g. southern mountain and boreal caribou populations), big game populations in B.C. are managed for both conservation and **sustainable use**. The provincial goal for harvested big game species is to ensure all hunted and trapped big game populations are maintained as integral components of natural ecosystems throughout their range, and to ensure sustainable use that meets the harvest of First Nations, licenced hunters, trappers and the guiding industry (MOE 2008) in that order. To help ensure this goal is achieved, the Fish and Wildlife Branch develops **big game status report**s, **big game management statement**s, and **big game management plans** (Table 3); conducts **big game inventories**; and creates **big game harvest management policies and procedure**s (Table 4).

[1] Definitions for terms in **boldface** appear in the Glossary.

For many First Nations, resident and non-resident hunters, big game hunting continues as a very important cultural and traditional activity and provides a source of food and other animal products. Although difficult to quantify, statistics for viewing and hunting of big game in B.C. show its significance. For example, B.C. resident hunter expenditures are estimated at nearly $230 million annually (Responsive Management 2013), and past studies suggest 94% is spent in the hunting of big game (Reid 1997). The guide-outfitting industry facilitates the hunting of big game by non-residents, generating $115 million of economic activity annually, and directly employing more than 2,000 people (GOABC 2014).

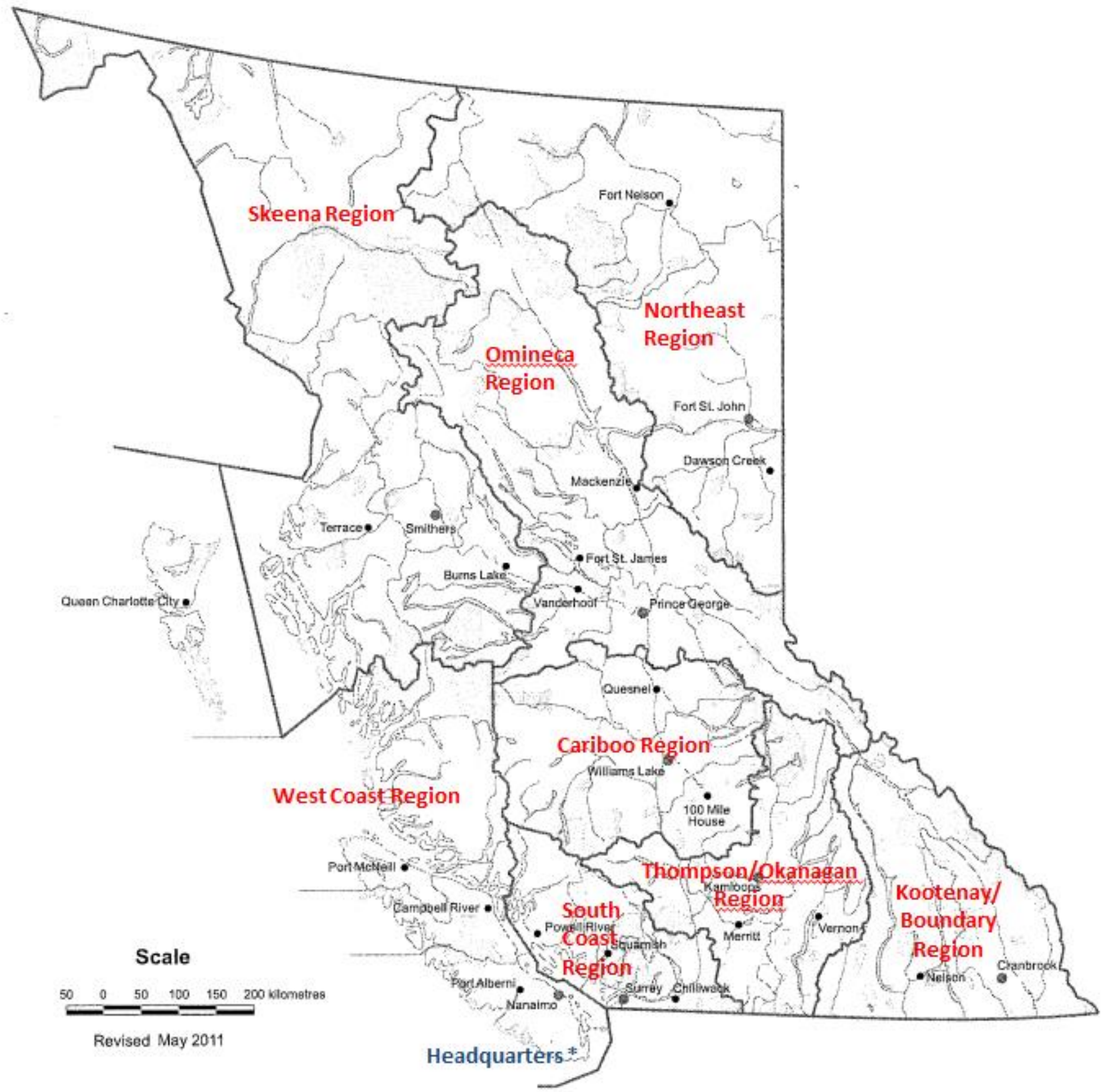
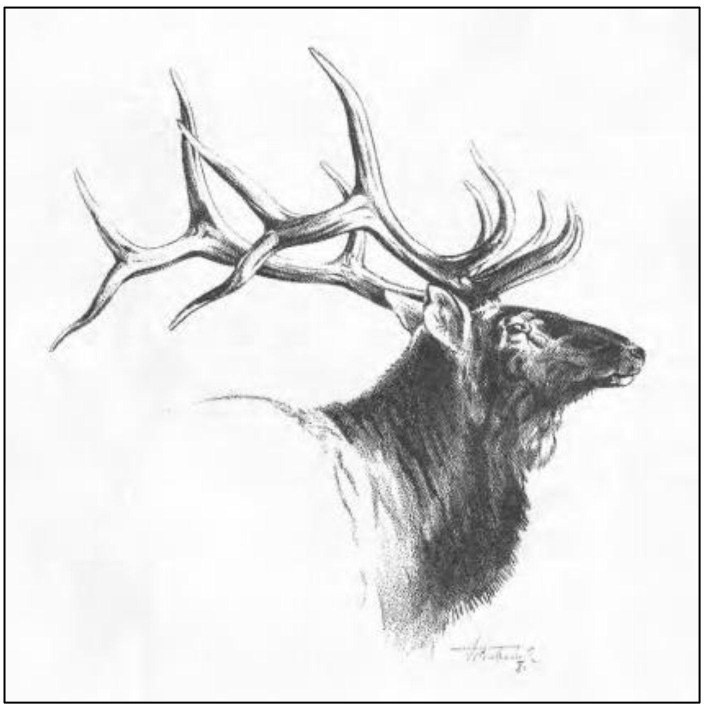


FIGURE 1. Map of British Columbia showing regional boundaries for the Ministry of Forests, Lands and Natural Resource Operations.

Wildlife management agencies in North America consider conducting inventory of big game populations one of the most important wildlife management activities. However, limited budgets preclude intensive inventory or monitoring for most big game populations in B.C. Yet inventory is critical to ensure that big game species are sustainably managed and that B.C. continues to meet its obligations under CITES and other international commitments. The value of inventory and monitoring is expected to increase as big game populations become more intensively managed to address conservation concerns and increasing demand for consumptive and non-consumptive use. **Big game inventory** and **big game monitoring** are defined below:

Big Game Inventory: A **survey** that documents one or more **population parameters** at one point in time. The population parameters may include: (1) **absolute abundance** and **relative abundance**; (2) **sex/age composition**; (3) **recruitment rates**; and (4) **juvenile survival rates** and **adult survival rates**. As an inventory is focussed on a "snapshot" in time it generally is not sufficient to determine trends in population parameters or the causation of trends.

Big Game Monitoring*:* An inventory (survey) repeated through time to determine changes or trends in population parameters. **Surveillance monitoring** is designed to document the change in one or more population parameters over time, e.g. moose population trend in an area over a specific number of years. **Targeted monitoring** is designed to document how big game populations respond to specific **management actions** (e.g. elk harvest rate or habitat enhancement) or environmental stressors (e.g. severe winter weather).



Note: This report is for discussion purposes only. It does not represent a position or program of government.

2. Scope and Goal of the Report

The scope of the Recommendations for a Strategic Big Game Inventory and Monitoring Strategy encompasses those native big game species currently managed for both conservation and sustainable use. It does not address inventory or monitoring needs for fallow deer (a non-native species), or imperilled populations of caribou whose needs are addressed through recovery plans and strategies.

The mandate for developing a strategic plan for big game inventory and monitoring comes from three sources: (1) the service plan for the Ministry of Forests, Lands and Natural Resource Operations (FLNRO);

Ministry's Service Plan (FLNRO 2014e)

Goal 2: Coordinated and sustainable management, use and stewardship of B.C.'s natural capital

***Performance Measure** 4*: Quality of resource monitoring data used for resource stewardship decisions

(2) the Provincial *Wildlife Program Plan*;

Provincial *Wildlife Program Plan* (MOE 2008)

Use Goal: Provide and manage sustainable uses of wildlife

Strategy: Conduct ongoing inventory, monitoring and assessment of wildlife populations to ensure sustainable use

Activity: Develop a long-term funding strategy and identify resources for **big game stock assessment** (e.g. inventory, harvest, **population modelling**)

and (3) from strategic advice to the Minister of Forests, Lands and Natural Resource Operations from Mike Morris, Parliamentary Secretary to the Minister of Forests, Lands and Natural Resources Operations.

***Getting the Balance Right: Improving Wildlife Habitat Management in British Columbia* (Morris 2015)**

Develop a wildlife management program that recognizes the intrinsic and extrinsic value of all provincial wildlife. That program should consider wildlife population levels and wildlife population objectives, including for species at risk.

Complete wildlife inventories:

a) develop a comprehensive wildlife inventory program
b) develop a real-time reporting system for hunters and trappers to report harvest results
c) include First Nations harvest results

The history of big game inventory and monitoring in B.C., with some notable exceptions, has largely been prioritized in reaction to management issues and concerns, and has lacked a structured approach. As issues and demands become more complex on the land base, a structured a strategic approach is warranted. The recommendations in this report builds upon adaptive management principles to support decision making in **big game management** by emphasizing the use of inventory and monitoring to connect decisions to **management objectives**. Figure 2 shows how decisions affect the status of a big game population to achieve a population objective. Inventory and monitoring assess the status of the population and also influence the decision. The decision may also influence the objective indirectly.

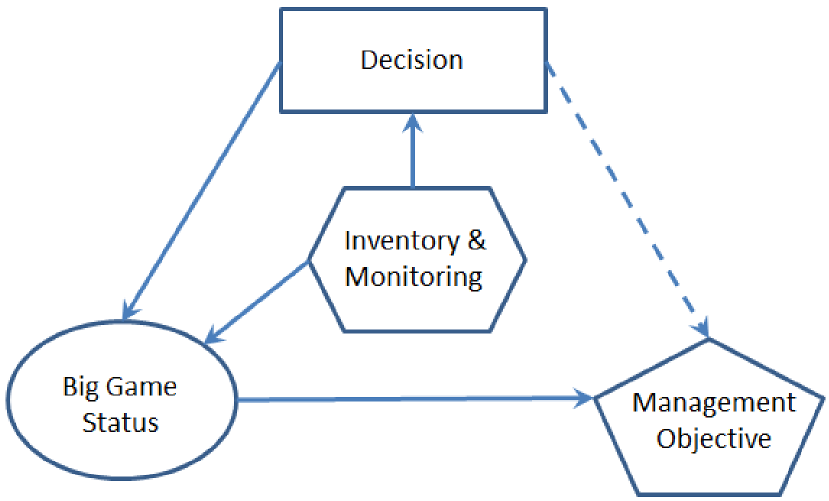


FIGURE 2. Schematic of big game species decision problem (adapted from Conroy and Peterson 2013).

Conroy and Petersen (2013) outline three basic components in a **structured decision making (SDM)** process[2]: (1) explicit quantifiable objectives (e.g. bear population size), (2) developing management alternatives or actions that can be taken to meet the objectives (e.g. harvest regulations), and (3) the use of models that incorporate inventory and monitoring data to predict the effect of management actions (e.g. models predicting population size from various harvest regulations). This report also links inventory and monitoring with population modelling for big game stock assessment.

Inventory and Monitoring Goal

The goal of a Big Game Inventory and Monitoring Strategy is to enhance the use of population inventory and monitoring to facilitate a structured, adaptive approach to management decisions that achieves desired wildlife management outcomes.

To achieve this goal, this report:

1. establishes a set of principles for big game inventory and monitoring;
2. describes the key components for inventory and monitoring that will ensure B.C.'s big game populations are sustainably managed, and meet a variety of management objectives and human needs;

[2] Both MOE and FLNRO recognize six core steps in SDM that also include clarifying the decision context, estimating consequences (Consequence Table), and evaluating trade-offs (Gregory et al. 2012).

3. develops a vision or future state for what a big game inventory and monitoring program would look like if additional funding became available; and
4. provides recommendations for improving big game inventory and monitoring consistent with this vision.

TABLE 1. List of big game species in B.C. (*denote species not covered in this report)

Big Game Species[3]	Scientific Name
Fallow deer	*Dama dama**
Black-tailed deer	*Odocoileus hemionus columbianus*
Mule deer	*Odocoileus hemionus hemionus*
White-tailed deer	*Odocoileus virginianus*
Rocky Mountain elk	*Cervus elaphus*
Roosevelt elk	*Cervus elaphus roosevelti*
Moose	*Alces americanus*
Dawson caribou	*Rangifer tarandus dawsoni* (extinct)*
Caribou (southern mountain population)	*Rangifer tarandus pop. 1**
Caribou (boreal population)	*Rangifer tarandus pop.14**
Caribou (northern mountain population)	*Rangifer tarandus pop. 15*
Wood bison	*Bos bison athabascae*
Plains bison	*Bos bison bison*
Mountain goat	*Oreamnos americanus*
Bighorn sheep	*Ovis canadensis*
Dall's sheep	*Ovis dalli dalli*
Stone's sheep	*Ovis dalli stonei*
American black bear	*Ursus americanus*
Grizzly bear	*Ursus arctos*
Wolf	*Canis lupus*
Cougar	*Puma concolor*
Canada lynx	*Lynx canadensis*

[3] The wolf is also managed as a Class 3 furbearer (moves between and among traplines, but generally not vulnerable to over-trapping). Canada lynx, bobcat and wolverine are also managed as Class 2 furbearers (also move between and among traplines, but potentially vulnerable to over-trapping, and thus regulated regionally in consultation with trappers.

Bobcat	*Lynx rufus*
Wolverine, *luscus* subspecies	*Gulo gulo luscus*
Wolverine, *vancouverensis* subspecies	*Gulo gulo vancouverensis* (extinct)*

TABLE 2. Conservation Status of Big Game Species in B.C.[4]

Big Game Species	Global Status	CITES[5]	COSEWIC Status	Provincial Status[6]	BC List	CF Priority	Provincial Estimate
Fallow deer	G5			SNA	Exotic	6	*na*
Black-tailed deer	G5			S5	Yellow	6	130,000
Mule deer	G5			S5	Yellow	6	135,000
White-tailed deer	G5			S5	Yellow	6	145,000
Rocky Mountain elk	G5			S5	Yellow	5	50,000
Roosevelt elk	G5T4			S3S4	Blue	2	6,700
Moose	G5			S5	Yellow	6	160,000
Dawson caribou	G5TX		XX	SX	Extinct	Extinct	0
Caribou (southern)	G5T2Q		E	S1	Red	2	1600
Caribou (boreal)	G5TNR		T	S2	Red	1	1325
Caribou (northern)	G5T4T5		E/SC	S3	Blue	2	17,500
Wood bison	G4T2Q	App. II	T	S2	Red	1	450
Plains bison	G4YT			SX	Red	2	1,200
Mountain goat	G5			S3	Blue	1	52,000
Bighorn sheep	G4			S3?	Blue	3	6,600
Dall's sheep	G5T5			S2S3	Blue	2	450
Stone's sheep	G5T4			S4	Yellow	2	13,000
American black bear	G5	App. II	NAR	S5	Yellow	6	140,000
Grizzly bear	G4	App. II	SC	S3?	Blue	2	15,000
Wolf	G4G4	App. II	NAR	S4S5	Yellow	3	8,500
Cougar	G5	App. II	DD	S4	Yellow	4	6,000

[4] Status designations and Conservation Framework (CF) priority were determined from the BC Species Ecosystems Explorer (http://www.env.gov.bc.ca/atrisk/toolintro.html). This link also indicates the year of status designations.
[5] See CITES (https://www.cites.org/) for designation of Appendix (App.) II species.
[6] See http://www.env.gov.bc.ca/atrisk/red-blue.htm for explanations of conservation status ranks.

Canada lynx	G5	App. II	NAR	S5	Yellow	4	*na*
Bobcat	G5	App. II	*na*	S5	Yellow	4	*na*
Wolverine, *luscus*	G4T4		SC	S3	Blue	2	3,500
Wolverine, *vancouverensis*	G4TH		*na*	SH	Red	2	<10

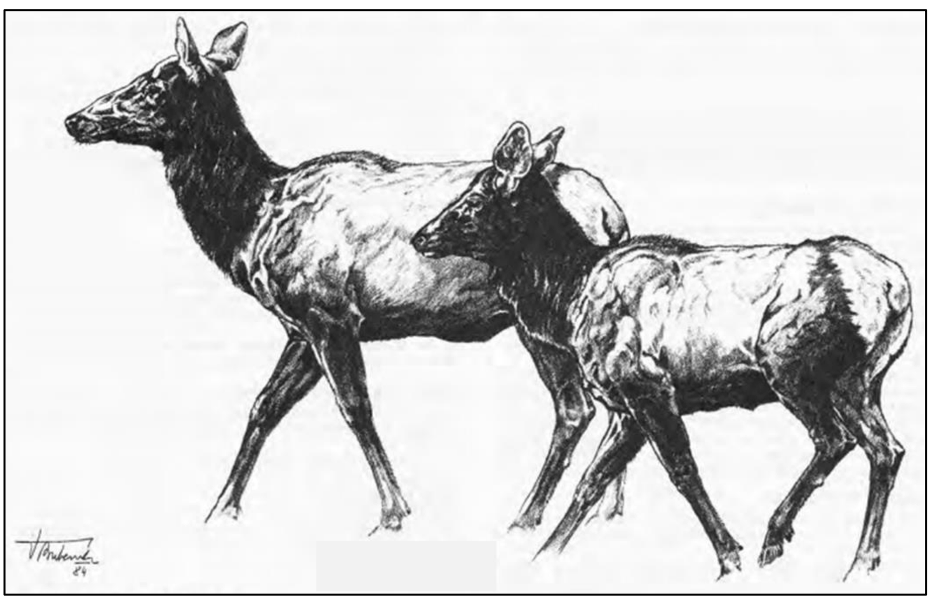
TABLE 3. Big Game Species Management Plans or Status Reports for B.C.

Big Game Species	Management Plan or Status Report Links
Deer	*http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=wcC2WYRQGx1qpsFtJwCybCnmptJRJpMWQjVLTVXJwy5QFkFgLqWJ!-1678131715?subdocumentId=2383*
Mule deer	*http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/kb_mule_deer_managementplan.pdf*
White-tailed deer	*http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/white_tailed_deer_prov_review.pdf*
Rocky Mountain elk	http://www.env.gov.bc.ca/kootenay/emp/Kootenay%20elk%20management%20plan%202010-14%20(final).pdf
Roosevelt elk	*http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/roosevelt_elk_management_plan_draft_July_2014.pdf*
Moose	*http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/provincial_framework_for_moose_management_bc.pdf*
Caribou (northern mountain population)	*http://www.env.gov.bc.ca/wld/speciesconservation/nc/index.html* *http://www.forrex.org/sites/default/files/forrex_series/fs22.pdf*
Wood bison	*http://www.wildlifecollisions.ca/docs/bcbisonmanagementplan2000.pdf*
Plains bison	*http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_plains_bison_e.pdf*
Mountain goat	*http://www.env.gov.bc.ca/wld/documents/recovery/management_plans/MtGoat_MP_Final_28May2010.pdf*
Bighorn sheep	*http://www.env.gov.bc.ca/wld/documents/statusrpts/b99.pdf* *http://www.env.gov.bc.ca/wld/documents/statusrpts/b98.pdf*
Dall's sheep	*http://www.synergyecology.ca/docs/Demarchi2004Status_thinhorn_BC.pdf*
Stone's sheep	*http://www.synergyecology.ca/docs/Demarchi2004Status_thinhorn_BC.pdf*
American black bear	*http://www.env.gov.bc.ca/eirs/bdp/index.html (preliminary plan)*
Grizzly bear	*http://www.env.gov.bc.ca/wld/grzz/* *http://www.env.gov.bc.ca/wld/documents/recovery/ncgbrt_final.pdf*

Wolf	*http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/grey_wolf_management_plan.pdf*
Cougar	*draft plan*
Canada lynx	*draft plan*
Bobcat	*draft plan*
Wolverine	*http://www.env.gov.bc.ca/wld/documents/techpub/b60/b60_1.pdf* *https://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=A18B84C4-1*

TABLE 4. Harvest management policies and procedures for big game species in B.C.

Wildlife Policy and Procedures	Link
Harvest Allocation Policy	4 7 01.03
Game Harvest Management Policy	4 7 01.07
Harvest Allocation Procedure	4 7 01.03.1
Big Game Harvest Management Procedure	4 7 01.07.1
Southern Interior Mule Deer Harvest Management Procedure	4 7 01.07.2
Moose Harvest Management Procedure	4 7 01.07.3
Mountain Goat Harvest Management Procedure	4 7 01.07.4
Bighorn Sheep Harvest Management Procedure	4 7 01.07.5



3. Inventory and Monitoring Principles

This report proposes the following set of seven principles for big game inventory and monitoring based on the literature and input from the Big Game Inventory and Monitoring Working Group: (1) inventory and monitoring must be conducted to evaluate the effectiveness of big game management actions relative to objectives; (2) monitoring enables periodic assessments on the status of big game populations; (3) inventory and monitoring contribute directly to the value of information for big game management; (4) in an adaptive management setting, monitoring provides the feedback loop for learning about big game populations, and how to better achieve management objectives; (5) inventory and monitoring methods must adapt to environmental changes that affect big game populations; (6) inventory and monitoring provide data necessary to calculate the annual allowable harvest of big game populations; and (7) inventory and monitoring must be efficient and cost-effective given limited staff and budgets.

3.1 Principle 1 – Managing Big Game Populations by Objectives

> *Principle 1: "*Inventory and monitoring must be conducted to evaluate the effectiveness of big game management actions relative to objectives*."*

To manage big game populations, B.C., like many other jurisdictions, uses a "management by objectives" approach. Targeted monitoring forms an essential component of this management approach, e.g. monitoring the buck:doe ratio of a mule deer population with a depressed adult sex ratio to determine if regulatory changes were effective in achieving the objective of at least 20 bucks:100 does.

Lyons et al. (2008) and Conroy and Peterson (2013) define objectives as specific outcomes or performance measures that guide decision-making and are used to evaluate the success of management actions. Two types of objectives used include: **fundamental objectives**, the results or values that decision makers and stakeholders care most about; and **means objectives**, ways of achieving the fundamental objectives. For example, some wildlife managers and hunters care about **hunter opportunity**, hunter density, bull harvest, trophy potential and hunter success. These are fundamental objectives. An example of a means objective that can be used to help assess the achievement of these fundamental objectives is the post-hunt adult sex ratio. **Desired wildlife management outcomes** are outcomes from wildlife management actions that achieve fundamental objectives. The relationship between fundamental objectives, management actions and desired wildlife management outcomes are illustrated in the examples below:

Example #1: the fundamental objectives for mule deer harvest management might be to enhance hunter opportunity and harvest. The management actions are to implement hunting regulations that provide hunting opportunities, in which hunter expectations for harvest are met, while maintaining buck:doe ratios that meet adult sex ratio objectives. The desired wildlife management outcome is mule deer populations with **healthy** buck:doe ratios and hunting opportunities that satisfy the needs of hunters.

Example #2: the fundamental objective for wolverine conservation and management might be to ensure all wolverine PMUs have viable, self- sustaining populations that support hunting and trapping opportunities. The management actions are to implement hunting and trapping regulations that limit the harvest to self-sustaining levels, and to regulate environmental practices that ensure wolverine habitats and their prey species are conserved. The desired wildlife management outcome is healthy wolverine populations that satisfy the needs of First Nations, stakeholders and the public.

Population management objectives for big game are often stated in terms of means objectives as they are quantifiable, and can be measured through inventory and monitoring. The primary (default) population management objective for all big game populations is to maintain post-hunt numbers at or near current levels unless stated otherwise in species harvest management procedures (FLNRO 2010c). For ungulates, a secondary population objective is to maintain minimum post-hunt adult sex ratios (Table 5), as outlined in species-specific harvest management procedures (FLNRO 2010b, 2014a, 2014b, 2014c), and the *Wildlife Harvest Strategy* (MELP 1996). Thus, population inventories are an important part of the management objectives setting process (Figure 3).

TABLE 5. Post-hunt adult sex ratio objectives for select big game species in B.C.

Species	Adult Sex Ratio Objective	Source
Mule deer	minimum 20 bucks:100 does	*Southern Interior Mule Deer Harvest Management Policy* (FLNRO 2014a)
Elk	minimum 20 bulls:100 cows	*Wildlife Harvest Strategy* (MELP 1996)
Moose	minimum 30 bulls:100 cows	*Moose Harvest Management Procedure* (FLNRO 2010b)
Caribou	minimum 35 bulls:100 cows	*Wildlife Harvest Strategy* (MELP 1996)

Note: This report is for discussion purposes only. It does not represent a position or program of government.

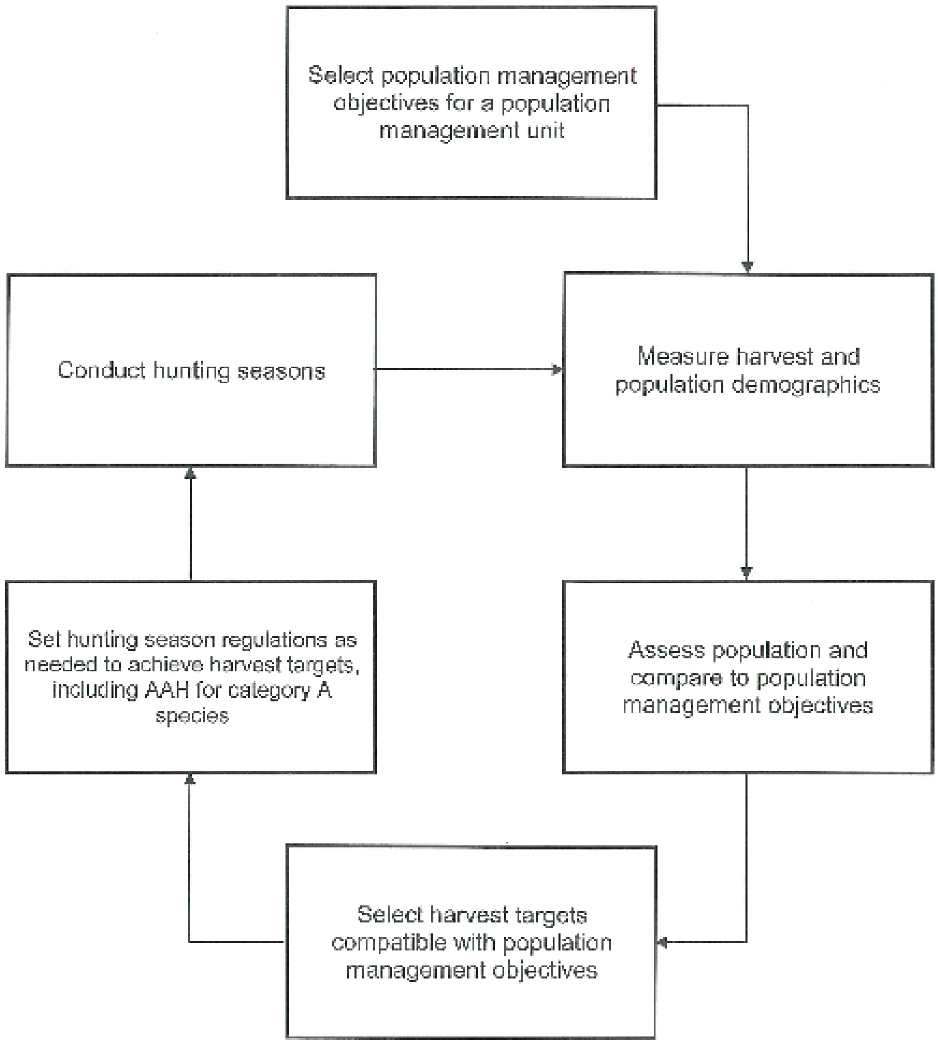


FIGURE 3. Population management objectives setting process used to manage big game populations in B.C. (FLNRO 2010c).

3.2 Principle 2 – Determining Big Game Population Status.

*Principle 2: "*Monitoring enables periodic assessments on the status of big game populations.*"*

The province-wide population status of ungulates is assessed every three years, and periodically for other big game (http://www.env.gov.bc.ca/fw/wildlife/management-issues/index.html#ungulate_pop).

Surveillance monitoring is an important activity for assessing big game population status. While monitoring is needed for conducting status assessments, it is not sufficient to determine the causes of demographic change. Conroy and Peterson (2006) note that surveillance monitoring data is typically analyzed retrospectively, and potential explanatory relationships tend to be correlative and confounded with other factors. Thus, a complete assessment of big game status often combines monitoring with population modelling to better understand the causes of demographic change in a big game population.

3.3 Principle 3 – Value of Information

"Inventory and monitoring contribute directly to the ***value of information*** *for big game management."*

A general premise is that obtaining more scientific information, e.g. more inventory and monitoring, will reduce uncertainty and lead to better decisions (Conroy and Peterson 2013). While science should inform decision making, many other factors influence decisions (Feick 2000). However, even when economic or other social factors over-ride the effect of scientific information in decision making, a science-informed process will improve understanding of the issue within the management agency.

The value of information can be measured relative to the level of management certainty it provides. Clearly, without any information, there would be no management certainty for decisions. Even a low, initial level of investment in information (e.g. harvest monitoring) is required to provide the critical minimum information for management (Figure 4). Intermediate levels of information (e.g. abundance and sex/age composition surveys) will produce substantial gains. To optimize management certainty, wildlife managers should set their inventory information targets at least at an intermediate level of information. The investment in inventory beyond this point may result in diminishing returns for wildlife management.

Value of information analysis has been used in fisheries management to quantify the expected increase in fishing yield due to reducing uncertainty about stock abundance (Maxwell et al. 2015). A similar finding can be expected for big game harvest management.

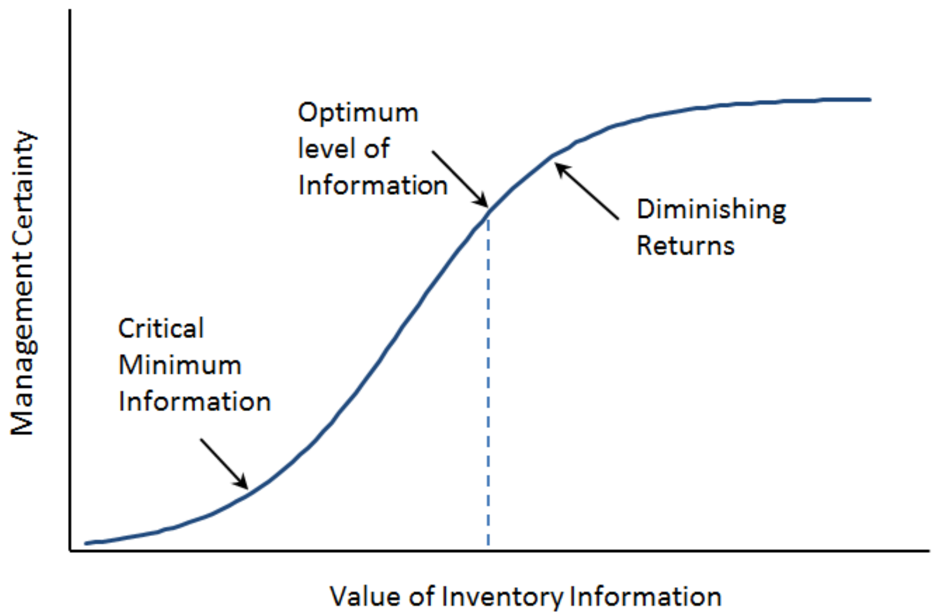


FIGURE 4. Hypothesized relationship between inventory information and management certainty (adapted from Mace et al. 2001).

A concept closely tied to the value of information is the **expected value of perfect information (EVPI)**. EVPI expresses how much would be gained in the management system if the best information possible was collected to inform a decision. More specifically, it is the difference between the best we could do under perfect knowledge about the system and the value of the best decision, given imperfect knowledge (Conroy et al. 2008). In the context of structured decision making for big game management, EVPI = expected value of a decision if the current population status was known with certainty – expected value without knowing the current population status. For example, if the objective value is estimated in terms of population size or number of animals harvested, EVPI would let a decision maker know how many more animals would be in the population or how many more could be harvested if the information were known (Conroy and Peterson 2013).

Although largely a theoretical concept, EVPI can be useful as it casts the need for information in terms of decision making. From this standpoint we ought to be willing to pay up to EVPI (but not more) to reduce uncertainty, via additional research and monitoring (Conroy et al. 2008). Thus, the EVPI would be low where the need for management certainty is also low (e.g. a lightly hunted white-tailed deer population where only bucks are hunted). It would be a poor decision to pursue intensive inventory and monitoring solely for this purpose. Conversely, the EVPI from conducting intensive inventories would be much higher where the need for measurement certainty is high (e.g. a heavily hunted mountain goat population where both sexes are harvested). Conroy et al. (2008), Conroy and Peterson (2013) and Canessa et al. (2015) provide examples of calculating EVPI associated with conducting an inventory.

3.4 Principle 4 – Adaptive Resource Management.

"In an adaptive management setting, monitoring provides the feedback loop for learning about the big game populations, and how to better achieve management objectives."

Adaptive Resource Management (ARM) is a systematic approach for improving resource management decisions by learning from management outcomes (Conroy and Carroll 2009, Williams and Brown 2012, Conroy and Peterson 2013). An ARM approach involves exploring alternative ways to meet management objectives, predicting the outcomes of these alternatives based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn about the effect of management actions, using the results to update knowledge with **Bayes' rule**, and then adjusting management actions (Figure 5).

Under ARM, big game monitoring data serves two purposes. First, it provides an estimate of the current system state (e.g. population size and sex/age composition). Second, it provides a means of monitoring the responses of the system to management (i.e. the feedback loop).

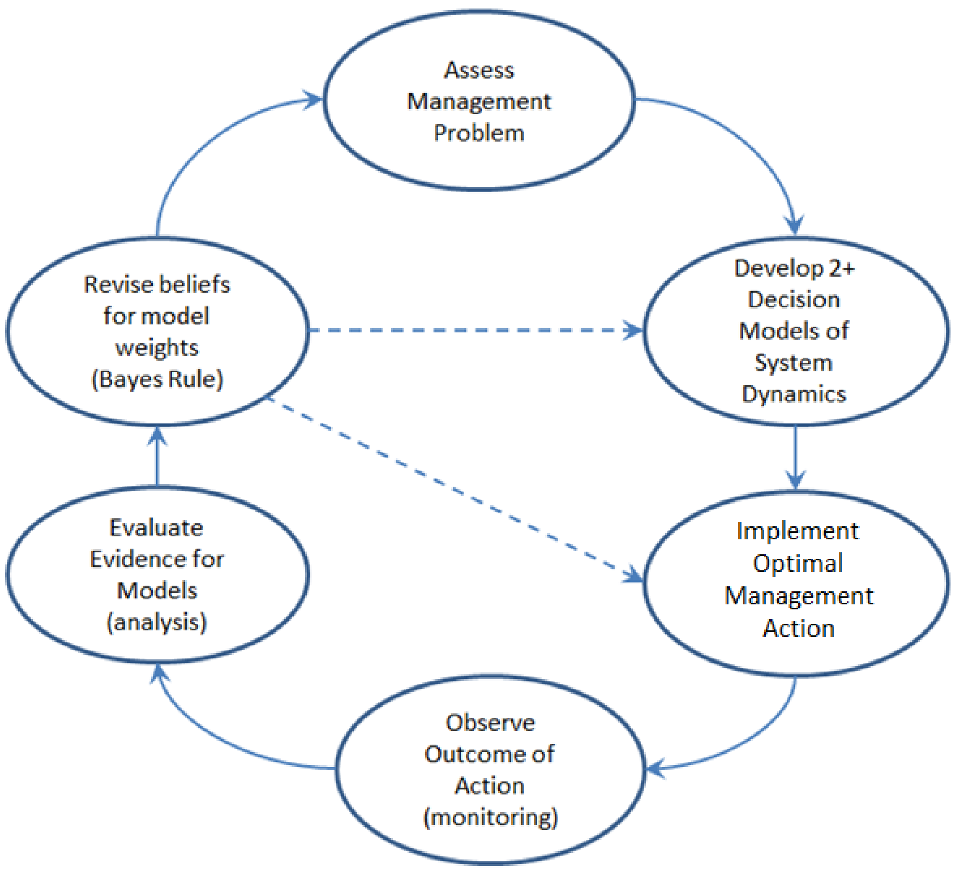


FIGURE 5. Diagram of adaptive resource management process (adapted from Conroy and Peterson 2013). Dashed arrows represent modifications as system leaning proceeds.

A related concept to ARM is **adaptive harvest management (AHM)**. AHM is the application of adaptive resource management to the objective of **sustainable harvest**. It thus uses the same ARM process (Figure 5) for updating the relative evidence for competing models and implementing management actions (usually annual adjustments of harvest rate). Most examples of successfully implementing AHM are for waterfowl populations (Johnson et al. 1993, Nichols et al. 2006, Conroy 2010). To date, AHM has not been implemented to support big game management in B.C., in part because of the inability to maintain annual funding for population monitoring to evaluate outcomes (e.g. post-hunt population size and composition) and to make annual adjustments to management actions (e.g. adjusting the AAH).

Both ARM and AHM can be intensive, long-term and costly endeavors. However, they have great potential to resolve key uncertainties associated with management actions for big game that are often highly controversial and debated among biologists, stakeholders and the public. Appendix A provides an approach for how optimal harvest rates of mountain goats could be determined using AHM.

3.5 Principle 5 – Adapting to Climate Change.

*Principle 5: "*Inventory and monitoring methods must adapt to environmental changes that affect big game populations*."*

Climate change has emerged as an enduring, significant, and complex problem affecting wildlife and their habitats throughout the world (Inkley et al. 2009). In North America, moose populations across much of the southern part of their range are in decline, presumably because of changing climate patterns (Murray et al. 2006, Lenarz et al. 2009). Kuzyk and Heard (2014) discuss testing the "landscape change hypothesis" for moose declines in central B.C. that coincided with a large scale, climate-change-induced mountain pine beetle outbreak. There is also growing concern that climate change is affecting pacific salmon escapement returns that may be adversely affecting the viability of coastal grizzly bear populations (Boyce et al. 2015).

Nichols et al. (2011) examined ways in that climate change is expected to exacerbate uncertainties in wildlife management. They also considered wildlife harvest management and considered problems anticipated to result from climate change and potential solutions. They concluded that an adaptive resource management approach, with a strong focus on monitoring, will be required for managers trying to deal with the uncertainties of climate change. Conroy et al. (2011) also stressed the importance of using an adaptive management framework to mitigate the effects of climate change on wildlife.

Climate change also poses a significant challenge to current inventory methods that must be executed under specified environmental conditions. For example, inventory standards for aerial moose winter surveys note that moose observability is highest when temperatures are -10° C or colder and surveys should be flown within 0.5 to three days after at least five cm snowfall with greater than 30 cm of snow on the ground (RISC 2002). Similarly, aerial snow tracking surveys for wolves must be conducted within two to three days following a fresh snowfall of at least 5-10 cm (RISC 1998). Since the early 2000s, these conditions have been less dependable, which hampered the ability to conduct numerous big game surveys in B.C. This issue is especially problematic for moose where inventory and monitoring are critical components for resolving numerous contentious management concerns in B.C. (G.Kuzyk, pers. comm. Jan. 2016).

3.6 Principle 6 – Calculating the Annual Allowable Harvest.

*"*Inventory and monitoring provide data necessary to calculate the annual allowable harvest of big game populations.*"*

The *Wildlife Allocation Policy* (http://www.env.gov.bc.ca/fw/wildlife/harvest_alloc/) stipulates that all **Category A species** (Table 9) require the calculation of an **Annual Allowable Harvest (AAH)**. While numerous methods exist to calculate the AAH, most all of these methods rely on inventory data.

Figure 6 shows that with a low level of management information, there is a broad potential range of estimated allowable harvest. A **precautionary approach** in response to this uncertainty is to set recommendations safely below the "best estimate" of the AAH in order to avoid unintentionally exceeding the true value and over-harvesting. There is a progression towards reduced uncertainty in setting the AAH through harvest monitoring, use of anecdotal data (e.g. observations from hunters, guide outfitters and trappers), population inventory, and population monitoring. Uncertainty is reduced most when research on ecosystem understanding is also included. Ecosystem understanding, within the context of setting the AAH, refers to adjusting species harvest levels to either maintain or achieve desired ecosystem outcomes, e.g. harvesting moose populations to manipulate predator-prey relationships between wolves and caribou (Serrouya et al. 2015a, 2015b). The progression towards reduced uncertainty is likely not as linear as indicated in Figure 6. Some information, such as absolute abundance surveys, can greatly reduce uncertainty when combined with a big game stock assessment that includes other information.

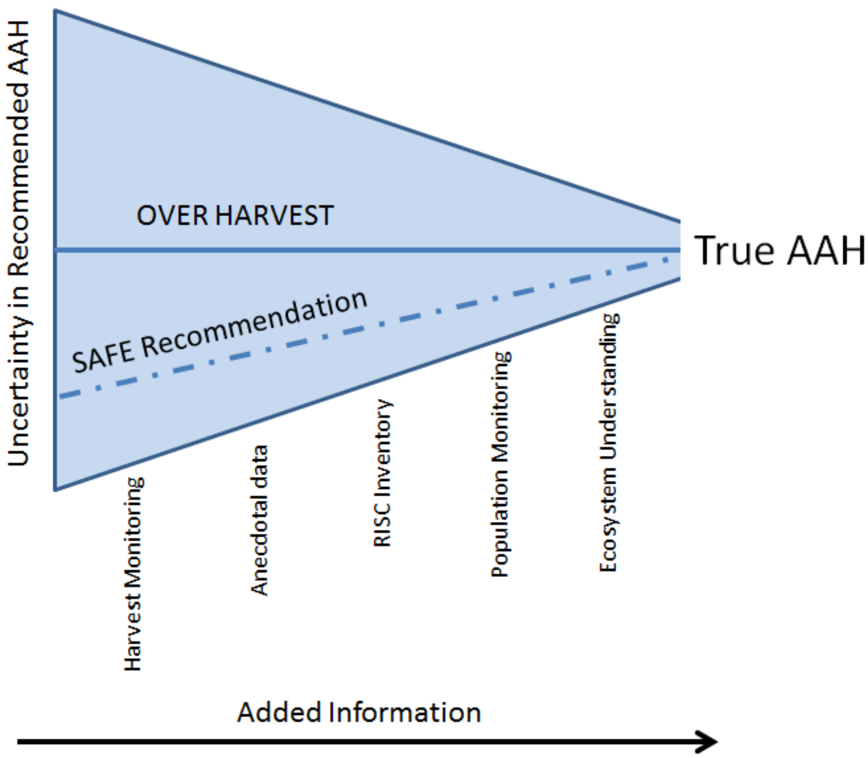


FIGURE 6. Reducing uncertainty in the AAH with added information (adapted from Mace et al. 2001).

3.7 Principle 7 – Conducting Efficient and Cost-Effective Inventories.

*Principle 7: "*Inventory and monitoring must be efficient and cost-effective given limited staff and budgets.*"*

Inventory and monitoring should be sufficient, but not excessive, to determine if management objectives are being achieved. The investment in population inventory and monitoring can be viewed as an optimization problem with costs competing for alternative management needs such as habitat management (Possingham et al. 2012). Figure 7 shows the theoretical optimal allocation of resources for monitoring and management given a fixed total budget. Management efficiency starts low and increases rapidly as the proportion of the budget spent on monitoring increases but additional management benefits rapidly diminish as further funds are spend on monitoring. The expected gain from managing also increases rapidly as a greater proportion of the budget is spent on management, but then declines as additional funds are spent on monitoring. The optimal percentage of the budget to spend on big game management occurs where the expected gain from managing is greatest. Thus, the cost of conducting inventory and monitoring should also be placed within the broader context of other wildlife (and other) management needs (McDonald-Madden et al. 2010).

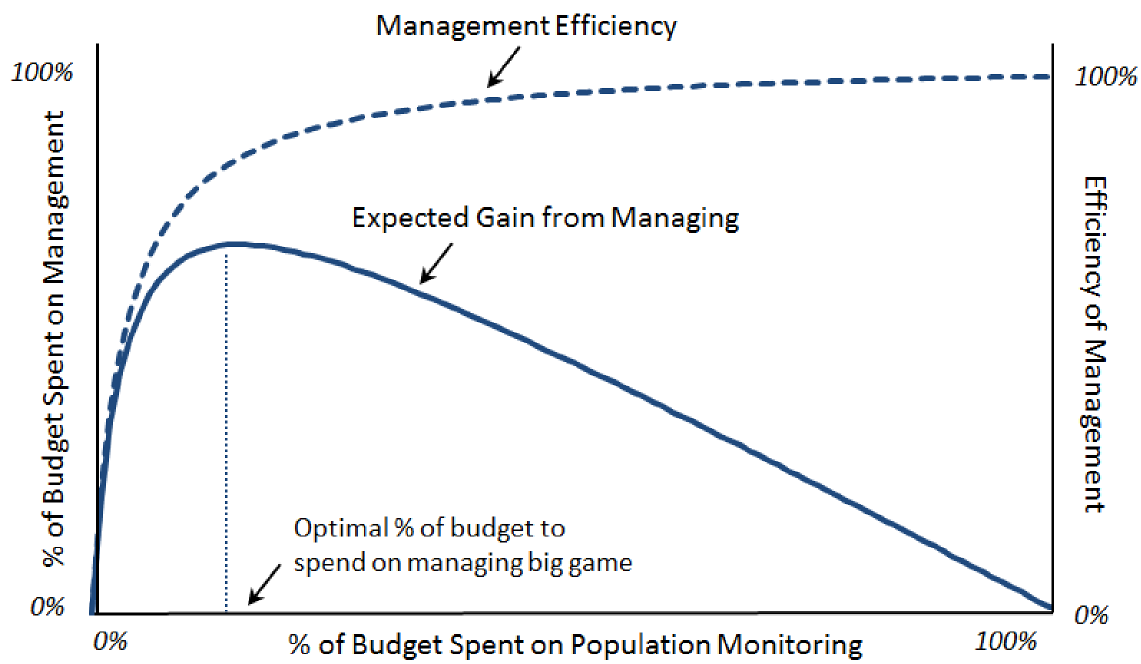


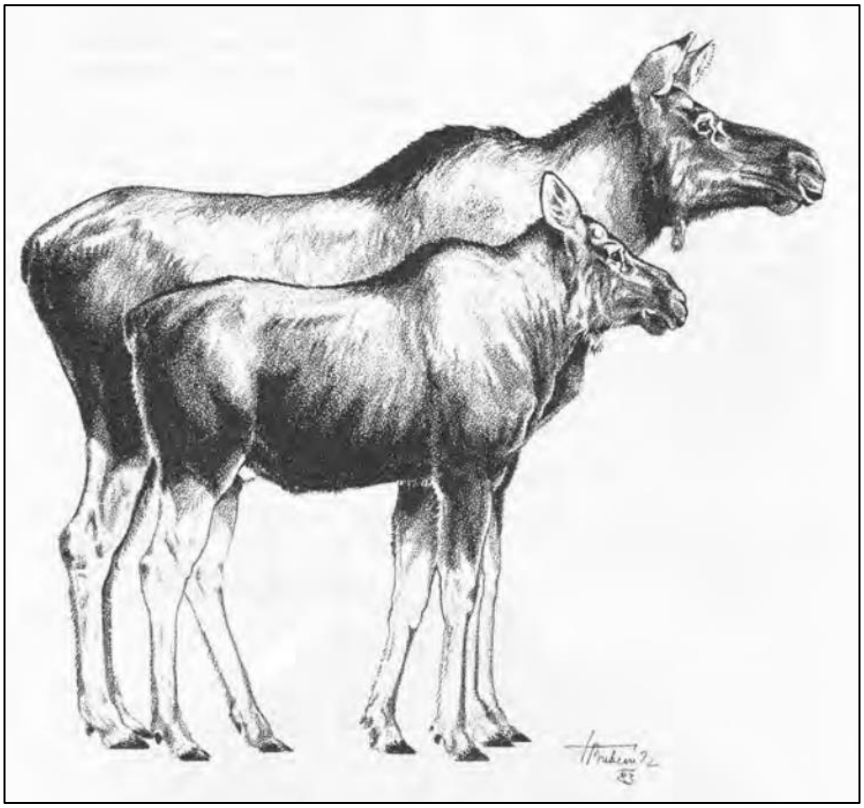
FIGURE 7. The optimal allocation of resources to monitoring and management given a fixed total budget for both (adapted from Possingham et al. 2012).

If the management objective is to maintain a stable population (i.e. fluctuating within a range of natural variation), then assessing population trend through indices of relative abundance may be sufficient; and an estimate of absolute abundance is not required. Similarly, if the objective is to maintain a minimum of 30 bulls:100 cows then only herd composition surveys to measure sex/age composition are required. Sample size should be sufficient, but not excessive, to achieve the intended level of **accuracy** and **precision** of the survey (Table 6).

TABLE 6. Recommended levels of accuracy and precision for ungulate inventory in B.C. (RISC 2002)

Level	Confidence Interval	Allowable Error	Intended Use
1	90%	± 15%	Inventory Development, Population Research, Inventory of Red/Blue listed species
2	90%	± 25%	Intensive Population Management, Inventory of Yellow-listed species
3	90%	± 50%	Less Intensive Management

Given the large number of big game populations in B.C. it is neither possible nor prudent to collect high quality inventory and monitoring data for all populations. It is much more important and efficient to collect high quality data for a few populations of a species where the information is required for management than collecting poor data for all populations, which would have minimal utility for management.



4. Big Game Inventory and Monitoring Components

This report identifies six essential components for a big game inventory and monitoring project (Figure 8). These include: (1) a big game inventory funding model; (2) inventory standards for conducting surveys; (3) explicit designation of **population management units (PMUs)** for setting objectives; (4) **collaborative monitoring** with First Nations, stakeholders and the public; (5) establishing big game species monitoring protocols; and (6) population modelling for big game stock assessment.

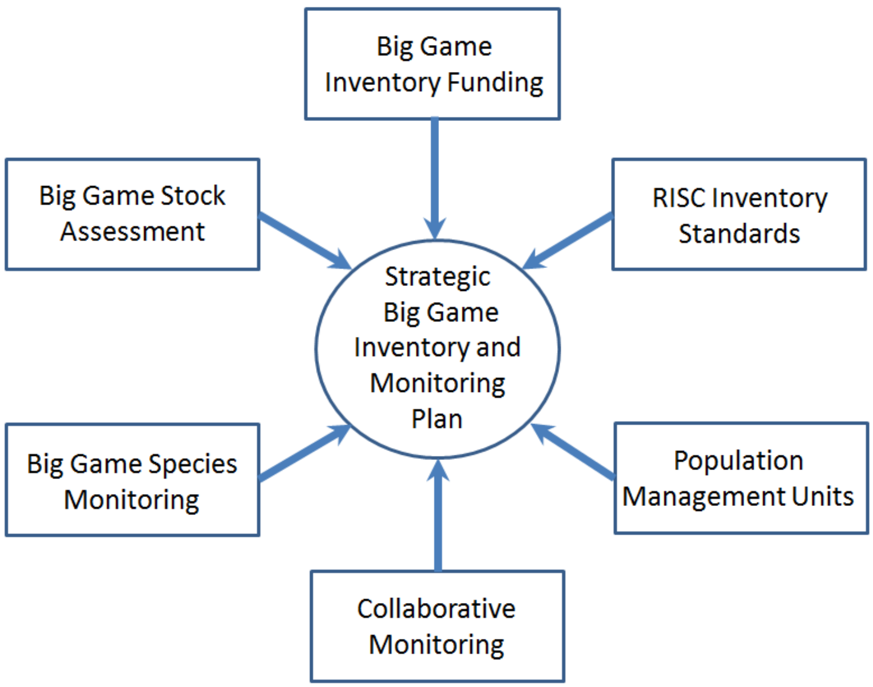


FIGURE 8. Big game inventory and monitoring components.

4.1 Big Game Inventory Funding

The success of a big game inventory and monitoring project depends on a stable, reliable and adequate level of annual inventory funding. While some regional base funding is available each year, special project initiatives generally comprise the largest proportion of big game inventory funds[7]. Special project initiatives that have supported big game inventory from the mid-1990s to the mid-2000s include the Common Resource Inventory Initiative (CRII), the Common Land Information Base (CLIB), Forest Renewal BC (FRBC), and FIA (Forest Investment Account). Currently (2015/16), the Land Base Investment Strategy (LBIS) is the major provincial funding source (FLRNO 2014d). LBIS with a focus on "optimized, sustainable use of wildlife to support First Nations needs, recreational hunting and an

[7] Some regions also have access to additional inventory funds through HCTF (http://www.hctf.ca/) and initiatives such as the BC Hydro Fish and Wildlife Compensation Programs in the Coastal, Columbia and Peace Region (http://fwcp.ca/).

economically viable guide industry" (http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/land-based-investment/2015-16_lbis_strategy.pdf). Strategic direction for LBIS funding comes from the FLNRO's service plan goals and objectives (https://www.for.gov.bc.ca/mof/serviceplans.htm), annual regional and provincial work plans that identify key priorities and projects, and other government commitments and specific initiatives. In 2014/15 and 2015/16 LBIS funded $750K towards big game inventory annually.

a) Big Game Inventory Fund 5-Year Plan

The *Big Game Inventory Fund (BGIF) 5-year Plan* (FLNRO 2015b) outlines a transparent, repeatable and objective approach for prioritizing big game inventories for funding through the LBIS (or other funding initiatives). The goals and priorities of the BGIF are to:

1. Provide inventory information that optimizes sustainable use of big game to support First Nations' harvesting interests, licenced hunting opportunities and the guiding industry in B.C.
2. Ensure coordinated management of regional and provincial priorities for big game inventories to improve the quality and integrity of resource data available for science-informed decision making.
3. Conduct priority big game inventory projects that have been reviewed for technical soundness, and that are both robust and comparable over time and among areas.
4. Conduct big game inventories that incorporate the goals and objectives of provincial harvest management procedures and regional species inventory plans.
5. Conduct "repeated surveys" on representative big game populations throughout the province.
6. Ensure inventory data results and reports are properly documented and accessible in a provincial government database.

Previous BGIF project proposals that were eligible for funding were ranked by a technical review team according to performance measures that reflected the objectives in the plan (Table 7). Weighting was also applied to the performance measures to reflect annual provincial priorities. Project proposal requests have exceeded $1M and thus not all inventories have been funded (e.g. the 2015/16 request was $1.2 M with an additional $0.6 M requested through other funding sources). The review team has therefore made recommendations on those surveys that should be funded, based on the results of a technical ranking process. Those recommendations were forwarded to the Directors of Resource Management (DRM) committee in 2014-15 and 2015-16, who made adjustments to ensure the funded surveys also reflected the priorities of regional business plans.

Apps (2010) developed an inventory and monitoring priority-setting tool specifically for grizzly bears in B.C. It has not been adopted within the BGIF model, in part because the BGIF priority-setting tool focuses on big game inventories for ensuring sustainable use while the Apps tool is single-species focussed, and uses criteria related to 'species at risk' and recovery status. Species at risk projects are eligible through other LBIS funding envelopes. The Apps tool also requires PMUs as the basis for funding, which are only available for some big game species. Finally, the Apps tool does not address changing inventory priorities as reflected through annual regional business plans. These regional priorities drive provincial big game inventory priorities.

TABLE 7. Big Game Inventory Fund proposal submission form, 2015/16

Name of Proposal:
Submitted by:
Region:
Species:
Area - LEH zone(s) or MU(s):
Amount requested:

1) **Inventory Need:** Please describe the rational for the inventory need and the implications if this survey is not conducted (*briefly in 2-3 sentences*)

2) **Regional Ranking:** Please give a number rank to this proposal in relation to other proposals submitted by your region (*e.g. if you are submitting 3 proposals rank as 1, 2 and 3 with 1 being the highest rank*).
Regional Rank:

3) **Funding Considerations:**
   a. Are you seeking additional funds outside of this request?
   b. If so, how much?
   c. Is additional funding confirmed?

4) **Information Gain:**
   a. Is this a Category A species, allocated under the Harvest Allocation policy, which requires calculation of an AAH?
   b. What is the survey history of the area (*briefly describe in 1-2 sentences*)? Please provide the years when previous surveys were done.

5) **Hunter Opportunity:**
   a. Is this survey required to maintain or increase current licensed hunter opportunity?
   b. What sort of increase in licensed hunter opportunity could result from completing this inventory? Or, is the survey needed to maintain current seasons or number of LEH permits?
   c. How big of an area will the inventory results apply to (*e.g. MUs, LEH zones*)?
   d. How much does that area contribute to licensed hunter opportunity?
   e. What is the resident and non-resident interest in this hunt?

6) **First Nations:**
   a. Is there a First Nations concern with the wildlife population to be surveyed?
   b. Is the survey needed to provide information that will help in FN consultations or address concerns?

7) **Population Management:**
   a. What are the regional or provincial management objectives for the population? (*e.g., 30:100 bull:cow post hunt ratio for moose or minimum hunted population of 50 adult mountain goats.*)
   b. Are these objectives being met? If not, how significant is the concern that they are not being met?
   c. What is the nature and degree of concern that the population may currently be overharvested?

b) Tracking Big Game Inventories

A tracking system that documents completed big game inventories and identifies future inventory priorities for funding facilitates efficiency and effectiveness. The *Big Game Inventory Fund (BGIF) 5-year Plan* (FLNRO 2015b) recommends that each region have a current 5-year regional inventory plan to prioritize their inventory requirements for addressing regional business needs, and that these needs should be compiled into a provincial list. This list would assist the provincial prioritization of inventories for upcoming fiscal funding, as well highlighting immediate big game inventory needs that exceed current funding levels. Another advantage of an annual provincial list of inventory needs is to be able to utilize end-of-fiscal funding as many big game inventories can be conducted during this time period (Feb. – Mar.).

To help ensure continued inventory funding to support big game management, wildlife biologists need to showcase the results of their annual inventory projects. The BGIF 5-year plan recommends that biologists complete inventory project summaries annually, and that these be compiled into an annual BGIF report for public distribution.

Appendix B provides a simple spreadsheet template for tracking inventories for big game monitoring. The template could be used to highlight where big game monitoring areas are currently due for resurveys, as well as where resurveys are now overdue.

c) Annual Funding Requirements

As noted in ‘Principle 7 – Conducting Efficient and Cost-effective Inventories’, inventory and monitoring should be sufficient, but not excessive, to determine if management objectives are being achieved. While population inventory is considered an essential activity in wildlife management, inventories also compete for funding to support other management actions such as habitat management and protection.

The annual funding requirements for big game inventory and monitoring is not known, nor can it likely be rigorously quantified through analysis. Annual inventory requests through the BGIF have approached $2M and these have largely supported ungulate inventories, as few carnivore inventory projects are submitted to the BGIF. Numerous other internal and external sources of funding also support big game inventory.

Having a stable annual budget to would facilitate planning of big game inventory needs. Some of the criteria to establish a funding target include the value of inventory information for management (Sect. 3.3), the potential for collaborative monitoring (Sect. 4.4), the number of big game monitoring areas established (Sect. 4.5), the cost of various species inventory protocols (Sect. 5), and the capacity for both headquarters and regional staff to deliver big game inventory and monitoring projects.

4.2 Big Game Inventory Standards

Big game inventory and monitoring depend on having well developed and standardized big game inventory methodologies in place, a central repository system for the collection of data, and systematic reporting of survey results that are readily available to managers. The Province’s **Resources Inventory**

Standards Committee (RISC) (https://www.for.gov.bc.ca/hts/risc/pubs/tebiodiv/index.htm) provide big game inventory standards.

a) Resources Inventory Standards Committee (RISC)

The Resources Inventory Standards Committee (RISC) developed a suite of 42 manuals that provide methodological standards for species inventory and assessment in B.C., including both operational and strategic-level inventories of wildlife, population monitoring studies and the assignment of status rankings for species. Table 8 shows the manuals applicable to big game inventory in B.C. In addition to the species group manuals (for ungulates, bears, wolf and cougar, and medium sized territorial carnivores), other essential manuals include *Species Inventory Fundamentals*, *Live Capture and Handling Guidelines*, *Wildlife Radio-Telemetry*, and *Quality Assurance Standards for Wildlife Inventory*.

The *Species Inventory Fundamentals Manual* provides essential guidance for conducting any big game inventory as it outlines the process of setting up a species inventory project, and discusses project design through to data collection, storage and analysis. Key concepts covered include survey intensity, sampling design, accuracy, precision, **bias**, sampling effort, and data analysis, all which apply to any big game survey.

Each species group inventory manual follows a standardized format providing protocols for inventory to determine species presence, distribution, relative abundance and absolute abundance. Inventory methods for ungulates also cover the collection of sex/age composition data. Additional topics covered in each manual include factors to consider when developing a survey program, sampling methods for collecting data, and statistical methods for developing population estimates, or estimating changes in population parameters. A set of field data forms and coding instructions accompany the majority of the manuals.

b) Project and Data Management

Good project and data management leads to successfully initiating, conducting and reporting an inventory. Project and data management is thoroughly reviewed in Species Inventory Fundamentals – Errata No. 4 (RISC 2011).

The Provincial Species Inventory Data System (SPI) is the centralized provincial data system for species inventory (Lepp 2000, http://www.env.gov.bc.ca/wildlife/wsi/index.htm). From this website, clients can access links that describe RISC inventory methods, data format, data templates, and report structure required to complete a data submission. Data templates form a critical component of project management as they provide a mechanism to enter data collected into provincial databases. This ultimately results in software applications that provide easy access for clients to the data and information.

For an inventory project to be considered complete, the following are required (http://www.env.gov.bc.ca/wildlife/wsi/submission_overview.htm):

1. Report(s) that provide important information about the project.

2. Survey data formatted in one of the appropriate data templates.
3. Spatial data formatted in one of the appropriate spatial data templates.
4. Other supporting documents such as photos, graphics, and analysis worksheets.

TABLE 8. RISC big game inventory standards manuals

Series	Manual Title	Date	Download Files
1	*Species Inventory Fundamentals (Version 2.0)*	Nov '98	[PDF]
1	*Species Inventory Fundamentals,* ***Errata***	Aug '11	[PDF]
3	*Live Animal Capture and Handling Guidelines For Wild Mammals, Birds, Amphibians and Reptiles Version 2.0*	Feb '97	[PDF]
5	*Wildlife Radio-Telemetry (Version 2.0)*	Jun '98	[PDF]
21	*Inventory Method for Bears (Version 2.0)*	May '98	[PDF]
25	*Inventory Methods for Medium-Sized Territorial Carnivores - Coyote, Red Fox, Lynx, Bobcat, Fisher, and Badger (Version 2.0)*	Jun '99	[PDF]
25	*Inventory Methods for Medium-Sized Territorial Carnivores - Coyote, Red Fox, Lynx, Bobcat, Fisher, and Badger:* ***Errata No. 1***	Apr '07	[PDF]
32	*Aerial-Based Inventory Methods for Selected Ungulates (Version 2.0)*	Mar '02	[PDF]
32	*Aerial-based Inventory Methods for Selected Ungulates: Mule Deer. Addendum to Aerial-Based Inventory Methods for Selected Ungulates (Version 2.0)*	Jul '13	[PDF]
33	*Ground-Based Inventory Methods for Selected Ungulates (Moose, Elk and Deer) (Version 2.0)*	Mar '98	[PDF]
33a	*Ground Based Inventory Methods for Ungulate Snow-track Surveys (Version 1.0). Addendum to Ground Based Inventory Methods for Selected Ungulates (Moose, Elk and Deer) (Version 1.0)*	Jul '06	[PDF]
34	*Inventory Methods for Wolf and Cougar (Version 2.0)*	May '98	[PDF]
N/A	*Quality Assurance Standards for Wildlife Inventory Projects (Version 2.0)*	Mar '09	[PDF] [DOC]

c) Data and Information Security

The *Species and Ecosystems Data and Information Security Policy and Procedures* identify categories of species and ecosystems data and information that are deemed secure. This includes data and information that: pertains to species and ecosystems susceptible to persecution or harm; is proprietary in nature; is protected by federal and/or provincial statute; or whose disclosure poses a risk to government interests. The procedures that the Province will accept and release secure species and ecosystems data and information are outlined in these documents (http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/ecosystems/secure-data-and-information).

4.3 Population Management Units

Many North American jurisdictions manage their big game species using population objectives (e.g. population size, sex/age ratio), which are tied to spatially delineated PMUs. The PMU is normally the area that represents the year-round range of a big game population. PMUs are thus also the basic unit for population inventory, monitoring and assessment.

PMUs have been established for all populations of wolverines (Lofroth and Ott 2007), grizzly bears (Apps 2010), and Roosevelt elk (FLNRO 2014f) in B.C. PMUs are currently being developed for all Category A species (Table 9) using standardized criteria (Poole 2015a). Poole (2015a) delineated PMUs for bighorn sheep, mountain goat and moose in the Kootenay Region based on these criteria (Figure 9). If PMUs were developed for non-Category A species this would facilitate their management by population objectives.

The default PMU is the **Game Management Zone (GMZ)** when species-specific PMUs have not been identified (FLNRO 2010c). GMZs do not work as PMUs for many big game species since they do not meet the criteria listed below. This report recognizes the PMU designation outlined by Poole (2015a) as a key supporting document.

The following criteria have been developed to help establish PMUs (Poole 2015a):

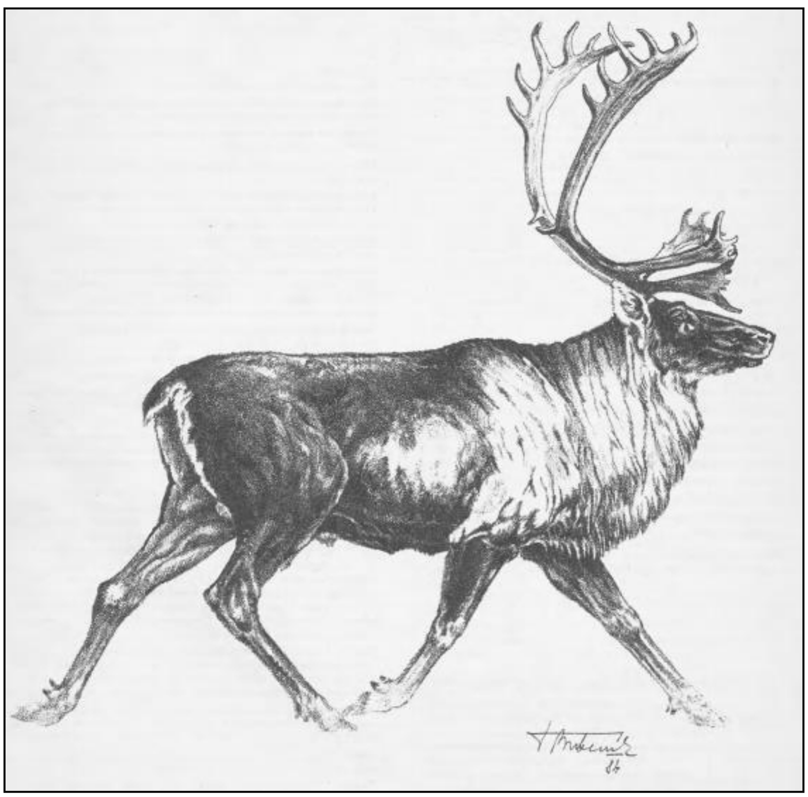
- A PMU is defined as a geographic area that represents the year-round range of a big game population, including all of its seasonal ranges. A PMU should be delineated so as to minimize interchange (emigration and immigration) with other populations.
- A population is defined as a “biological unit ... …where it is meaningful to speak of a birth rate, a death rate, a sex ratio and an age structure in describing the properties of the unit”. The popular concept portrays a group of intermixing animals with a discrete boundary, having little contact with other such groups. These may be termed local populations or subpopulations, the complex of which can be referred to as a metapopulation.
- PMUs are most easily identified for wildlife populations comprised of discrete populations separated by large fracture zones (e.g. mountain sheep, mountain goat, and caribou).
- PMUs are less easily distinguished for populations having a more contiguous distribution and where there are few or no barriers to movement over large geographic areas (e.g. moose). For these populations, PMUs may also need to consider the ecological characteristics of the landscape.
- PMUs are not required to follow regional boundaries, i.e., a PMU may contain WMUs or LEH zones from two or more adjacent regions.

TABLE 9. Category A and non-Category A species in B.C.

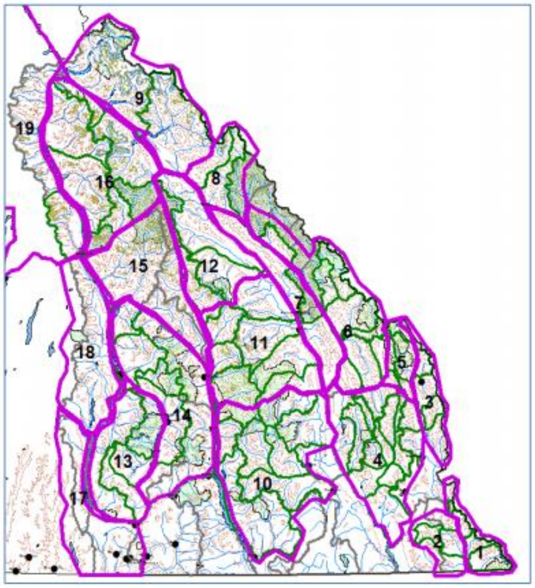
Category A species[1]	Non-Category A species[2]
Mountain goat (Regions 3,4,5,6N,6S,7b,8)	Black-tailed deer
Bighorn sheep (Regions 3,4,8)	Mule deer
Thinhorn sheep (Region 6N)	White-tailed deer
Moose (Region 3,4,5,6N,6S,7A,8)	Rocky Mountain elk
Roosevelt elk (Regions 1,2)	American black bear
Rocky Mountain elk (Region 7B), antlerless	Wolf
Caribou (Regions 5,6N)	Cougar
Bison (Region 7B)	Canada lynx
Grizzly bear (Regions 1,3,4,5,6N,6S,7A,7B,8)	Bobcat

[1] Category A species: a big game species, population, or class allotted through the *Harvest Allocation Policy*, see http://www.env.gov.bc.ca/fw/wildlife/harvest_alloc/

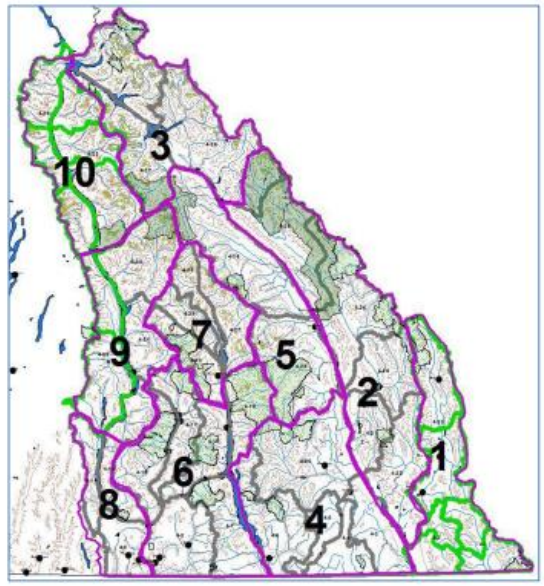
[2] Non-Category A species: a big game species not allocated under the *Harvest Allocation Policy*.



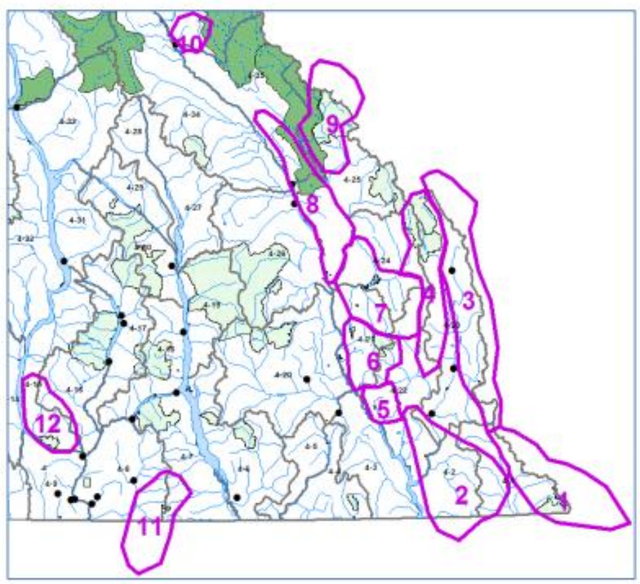
Note: This report is for discussion purposes only. It does not represent a position or program of government.



Mountain Goat PMUs



Moose PMUs



Bighorn Sheep PMUs

FIGURE 9. PMUs for mountain goats, moose and bighorn sheep in the Kootenay Region (Poole 2015a).

Note: This report is for discussion purposes only. It does not represent a position or program of government.

4.4 Collaborative Monitoring

The provincial *Wildlife Program Plan* (MOE 2008) identifies two key objectives that mandate collaborative monitoring: 1) to improve wildlife management through effective engagement of First Nations; and 2) to improve wildlife management through the effective engagement of stakeholders, clients and the public. Morris (2015) recommended harnessing "the wisdom, talent and expertise of BC **Wildlife practitioners** in wildlife/habitat management" by developing "a program that utilizes the knowledge, wisdom and experience of long term wildlife tenure holders and wildlife practitioners including resident hunters".

a) First Nations

First Nations play a unique and evolving role in wildlife management in B.C. stemming from their many significant historical, cultural and economic links to wildlife. The New Relationship (http://www2.gov.bc.ca/gov/content/governments/aboriginal-people/new-relationship affirmed that changes will occur in how the B.C. Government and First Nations collaborate on wildlife management (MOE 2008).

First Nations currently collaborate with the monitoring of their own harvests in several areas of the province, and participate directly with FLNRO staff on numerous big game inventories. The *Big Game Inventory Fund 5-year Plan* (FLNRO 2015b) includes First Nation harvest surveys as eligible for funding.

First Nations are increasingly involved in monitoring big game populations. In the Northeast, the Doig River Band collaborates with Ministry staff on the monitoring of bison and moose populations (B. Cadsand, pers. comm. March 2016). The Nisga'a Lisims Government undertakes wildlife population assessments and inventories in the Nass Area. These assessments are directed by the Nass Wildlife Committee, and include moose and grizzly inventories in the Nass watershed (http://www.nisgaanation.ca/stock-assessments). The Tsilhqotin Stewardship Council supports a moose collaring program and elk management plan development (http://www.tsilhqotin.ca/PDFs/Newsletter/Christmas%202014%20TNG%20Newsletter.pdf).

b) Traditional Stakeholders

The B.C. Fish and Wildlife Branch's traditional stakeholders for big game management include the B.C. Wildlife Federation (BCWF), the Guide Outfitters Association of BC (GOABC) and the B.C. Trappers Association (BCTA). Many other organizations value wildlife. The BCWF's affiliated clubs have and continue to assist with monitoring big game populations. A few examples include annual surveys of bighorn sheep in the Okanagan, black-tailed deer surveys on Vancouver Island, and mule deer surveys in the Peace. These monitoring efforts provide significant value if stakeholders follow standardized survey protocols. The GOABC has a Wildlife DNA Collection Program (http://www.goabc.org/wildlife-dna-program.aspx) to assist wildlife managers, and its members regularly provide assistance on big game surveys as well. The BCTA has a long history of collaborating with the BC government to help document the status of furbearers. Trappers have participated in an annual BC trapper questionnaire from 1989-1993 where a sample of 1000 trappers were randomly selected each year to measure trends in furbearer abundance based on qualitative perceptions from trappers and a quantitative catch per unit effort index (RISC 1999).

Wildlife managers may also use hunter observations to monitor trends in big game populations. Ericsson and Wallin (1999) found that hunter observation of moose (moose seen per hunter day) in Sweden reflected moose population size and reproductive rate, and could be used to monitor population fluctuations. They indicated that if calibrated, hunter observation indices could also be used to estimate local moose populations and thus provide an alternative or supplement to more costly aerial survey monitoring methods. Solberg and Saether (1999) reported similar findings in Norway but cautioned that the index (moose per hunter day) in their study tended to overestimate population size when hunting success was high, indicating that factors influencing hunting success may also affect the probability of detecting moose. The availability of smartphones to collect hunter observation data has sparked considerable interest in the use of hunter observations to track trends in big game populations. Alberta (http://www.biology.ualberta.ca/moose/) and Washington State (http://wdfw.wa.gov/viewing/moose/app_instructions.pdf) currently have programs in place, and the technique is being piloted in B.C. as well (C. Thiessen, pers. comm. Mar. 2016).

c) Citizen-science Volunteers

Citizen-science volunteers collect and/or process data as part of a scientific inquiry. This may include hunters, trappers, guide-outfitters, naturalists, other organizations and individuals. Projects that involve citizen science are becoming increasingly common in ecology and the environmental sciences (Silvertown 2009). Citizen science for wildlife population monitoring is also increasing rapidly. Conrad and Hilchery (2011) attribute this increase to growing public concern about anthropogenic impacts on natural ecosystems, and the inability of governments to undertake adequate inventories due to lack of resources.

Wildlife management agencies benefit from having a pool of volunteers who are willing to help collect data that their agencies do not have the time or financial resources to undertake. One example is the Citizen Wildlife Monitoring Project (CWMP), which organizes citizen-science volunteers to monitor and document wildlife using remote cameras (see http://www.conservationnw.org/what-we-do/wildlife-habitat/wildlife-monitoring). The CWMP extends from the Washington Cascades to the Kettle Crest to southern B.C.

Including citizen-science volunteers to assist with big game inventory and monitoring in B.C. would enable significant expansion of big game monitoring efforts and information to inform decisions. However, to ensure credibility (validity and reliability of results) volunteers need to know standardized inventory protocols, and to receive sufficient training and guidance in the field from experienced practitioners before initiating inventory and monitoring activities.

4.5 Big Game Species Monitoring

Wildlife management agencies in North America conduct inventory and monitoring of harvested big game populations as core activities, but limited revenues preclude intensive monitoring for most big game populations. Depending on intensity, harvest has the potential to influence most big game population parameters, including sex ratios, age structure, and population abundance (Caughley 1977). Agencies do not manage all big game species in the same way, and certain management objectives require more intensive monitoring of population demographics than others. Different sex/age components of a big game population also exert different effects on population trends. For example, adult male survival generally has little effect on overall population trend, whereas even small changes in adult female survival can greatly influence a population trend. Because of the high annual variation due to varying environmental influences, production and survival of juveniles often accounts for the majority of the annual variation in population trend (Gaillard et al. 2000).

Management objectives largely driven by both biological and socio-political needs determine the parameters to be monitored. For most ungulate species, adult male:adult female and juvenile:adult female ratios are the most common population demographic collected by wildlife management agencies, along with population density or trend. For carnivores, population density or trend is the most important as it is generally impractical to monitor sex and age ratios.

Few monitoring studies in B.C. or elsewhere have incorporated monitoring of adult survival, generally because of the lack of annual variation in survival rates, high cost of telemetry-based mortality studies, and limited inventory budgets. However, the importance of monitoring adult and juvenile survival is now receiving increasing attention for both ungulates (White and Bartmann 1997, Hurley et al. 2015), and large carnivores (Interagency Grizzly Bear Study Team 2012, McLellan 2015) as population responses are most sensitive to changes in survival rates (Starfield and Bleloch 1991). White and Bartmann (1997) argued that the population variables that change most from year-to-year should be monitored more intensively, rather than the variables that change little. For mule deer, they suggest that the most variable parameter is over-winter fawn survival, and propose a monitoring system for mule deer where survival is estimated annually and recruitment and density less frequently. They outline a strategy where this could be accomplished with little additional cost by shifting resources from estimating juvenile recruitment to estimating juvenile over-winter survival.

Greater monitoring effort is also required when management objectives attempt to harvest populations at or near the **maximum sustained yield (MSY)**, or provide liberal male-only seasons. In these cases, managers need more information to avoid unintended consequences such as undesired population declines or very low adult male:adult female ratios (Keegan et al. 2011). Conversely, management approaches such as conservative male only seasons can be monitored less frequently or with less intensive methods because there is much less risk that the population will be adversely affected.

The biology of the big game species and its population status also influence monitoring needs. Populations of small size and low intrinsic rates of increase, such as many mountain goat or grizzly bear populations, require more intensive monitoring. Similarly, populations at the geographic limits of their ecological tolerance, such as mule deer in the Peace River valley that experience periodic extreme winter weather conditions (Baccante and Woods 2010), require more detailed monitoring if they are to be intensively managed.

Table 10 provides recommendations by Keegan et al. (2011) for mule deer monitoring in response to increasing harvest rates. Wildlife managers can apply this concept to most other big game species as well. Appendix C provides recommendations for monitoring requirements related to hunting regulation changes in B.C.

TABLE 10. Recommended population parameters to monitor, and frequency of monitoring needed for mule deer (from Keegan et al. 2011)

Population parameter	→ Increasing harvest rates →			
Harvest	A	A	A	A
Population trend	P	B	A	A
Sex and age composition	P	B	A	A
Population abundance		P	P	A[1]
Fawn survival	If concerns[2]	If concerns	If concerns	If concerns
Adult female survival	If concerns	If concerns	If concerns	If concerns
Examples				
Doe harvest	None	Light	Moderate	Heavy
Buck harvest	Very limited	Limited	Open entry	Open entry 2-pt + very limited adult

A = monitor annually; B = monitor every 2-3 yr; P = monitor at least once every 5 yr; If concerns = investigate if monitoring data suggest concerns over population health (e.g., trends indicate declining population, very low productivity or recruitment, etc.).

[1] If low density population; otherwise B.

[2] If population trend, abundance, or productivity rates show declining trends, agencies may choose to intensively investigate production and survival of juveniles, or adult survival. Most frequently, most annual variation in changes in abundance is driven by high annual variability in production and survival of juveniles (Gaillard et al. 2000), so this demographic should be evaluated first.

a) Big Game Monitoring Areas

Ideally, a **big game monitoring area (BGMA)** should include the entire population, i.e. conform to PMU boundaries. If only a sample of the PMU proves logistically feasible to monitor, then the area selected should be representative of the population to which the survey results will be extrapolated, i.e. the population parameters (density, sex/age structure, recruitment and mortality rates) within the monitoring area should provide an unbiased sample of the true values (Appendix D).

BGMAs may include surveillance monitoring, targeted monitoring or both. Surveillance monitoring areas need to be maintained for monitoring long-term trends, while targeted monitoring areas may be more transient, as they are focussed on monitoring the results of specific management actions. For example, farmers may be concerned with current levels of elk depredation on their crops. This requires monitoring elk abundance so that increased harvest rates on cow elk (the management action) is appropriate for achieving an established objective for elk population size. In many cases, it is likely that a BGMA will serve both purposes – to monitor population parameters over time, and to also assess responses of the population to specific management actions (e.g. Buckley Valley-Lakes District moose monitoring area).

b) Population Monitoring Parameters

Monitoring parameters may include **occupancy** (presence-absence), relative abundance, absolute abundance or density, sex/age composition (i.e. adult males, adult females and juveniles), and demographic rates (i.e. juvenile survival rate, adult survival rate, recruitment rate). Most big game inventories traditionally focussed on estimates of abundance, and in the case of ungulates, sex/age composition. However, increasing effort is now being on placed on monitoring survival rates (Table 10).

c) Survey Frequency

How often to repeat surveys for monitoring depends on the variability in population estimates, monitoring objectives, and funding availability (Thompson et al. 1998). In general, surveys should take place more frequently for big game populations that undergo large changes in numbers. Monitoring objectives that specify detecting a smaller rate of change (e.g. to detect a ± 10% change versus ± 25% or ± 50% change) over a specified time period will also require greater survey frequency. Usually, it is difficult to statistically detect changes over a short time because of imprecision in survey estimates. For example, Gasaway and Dubois (1987) indicate that with confidence intervals of ± 20%, a population must increase or decline about 20% to detect a significant ($p<0.05$) change in abundance. If the population is increasing at 3.7% per year, then five years would be required between surveys to detect a significant difference. Finally, funding constraints and changing priorities almost always limit the number of re-surveys that can be conducted. Conducting too many surveys over a short time may waste time and money.

In general, resurveys in BGMAs may be required annually, every second or third year, once every five years, or once every 10 years. The re-survey schedule for absolute abundance and/or sex/age composition should reflect the value of information associated with conducting the survey. For example, surveying a lightly hunted elk population, where only six point bulls are harvested may only need to be surveyed once every 10 years as it will offer a relatively low value of information, while surveying a population that is moderately hunted (including some antlerless harvest) will provide a higher value of information and may need repeating once every five years. Relative abundance surveys are usually conducted more often as survey costs are much less and the analytical methods used (e.g. trend analysis) depend more on annual estimates. Wildlife biologists annually conduct black-tailed deer spotlight counts within monitoring areas on Vancouver Island as costs are low and information gain can be relatively high (Jones and Mason 1983, Hatter and Janz 1994).

Gasaway et al. (1986: 61-66) provide an excellent review for detecting statistical changes in absolute abundance or sex/age composition between two surveys. They also point out that if you do not detect a significant decline, then you should determine if the null hypothesis can be accepted with a tolerable probability of committing a Type 2 error (i.e. the probability of concluding no change in abundance when a change occurred). This involves calculation of **statistical power** ($1- \beta$), or the probability of rejecting a false null hypothesis[8]. Gasaway et al. (1986:65) also discuss planning surveys to detect specified population changes and provide a formula for estimating the required precision from a second survey after the first survey has been completed.

d) Harvest Monitoring

In addition to population monitoring parameters, Keegan et al. (2011) also note the importance of harvest as a monitoring parameter (Table 10). In B.C., key harvest parameters include total harvest, harvest by sex/age class (i.e. males, females and juveniles) and effort (days spent hunting) for all big game species; and age-at-harvest for select species (see Table 11). Annual hunter surveys conducted by the Biometrics Unit of the Fish and Wildlife Branch[9] enable calculation of estimates of these parameters by hunter residency group (i.e. resident and non-resident hunters).

Three of the main challenges with harvest monitoring in B.C. include acquiring accurate and precise estimates of harvest and effort at various spatial scales (e.g. WMU, PMU, Region and Provincial); timely reporting of harvest statistics to update population assessments and inform hunting regulation development; and estimation of other sources of human-caused mortality, including harvest by First Nations.

One monitoring parameter that is commonly calculated from harvest statistics is catch-per-unit effort (CPUE) or kills per hunter day, which may be used as an index of abundance. CPUE offers a readily accessible and thus tempting source of data when no population inventory data exists. Appendix E reviews the use of CPUE and outlines the conditions when CPUE may be used as a trend index.

4.6 Population Modelling for Big Game Stock Assessment

Big game stock assessment is defined as the process of collecting, analyzing, and reporting demographic information for the purpose of determining the effects of harvesting on big game populations. The field of wildlife management identifies population modelling for big game stock assessment as an increasingly important tool as it provides a way to apply an objective, structured approach for establishing the AAH for Category A species and determining sustainable harvest levels for non-Category A species (Griffiths and Hatter 2011). The provincial *Wildlife Program Plan* (MOE 2008:53) states that "The big game inventory program will be expanded to include big game stock assessments to ensure maximum utilization of big game inventories." Key means to achieve this include to "develop a big game stock assessment improvement plan for priority harvested species" and to "develop a long-term funding strategy and identify resources for big game stock assessment (e.g. inventory, harvest, population modelling)." The *Big Game Harvest Management Procedure* (FLNRO 2010c) provides general guidance for how stock assessment will utilize inventories on population trends, abundance and sex/age

[8] See RISC (1998a) for a more information of power analysis, including available software that may be used to conduct a power analysis.

composition in combination with legal harvest, other human-caused mortality, and demographic rates to improve big game harvest management. Griffiths and Hatter (2011) provide an introductory guide to population modelling for big game stock assessment which provides important guidance for the Strategic Big Game Inventory and Monitoring Strategy.

Most big game stock assessment models are a form of **integrated population modelling** (IPM), which is now becoming the choice for modelling population dynamics of harvested wildlife (Schaub and Adadi 2011). An IPM provides a unified analysis of population inventory, harvest and demographic data. The modelling framework can be implemented through least squares, maximum likelihood, or Bayesian estimation approaches. Big game stock assessment models that employ an IPM approach typically include stage-based or age-based models. Other big game modelling approaches include recruitment-mortality and regression models. While not strictly a big game stock assessment model, habitat-density extrapolation models have also been used in B.C. to estimate big game population numbers. Each of these approaches is briefly reviewed below. Table 11 provides recommendations for population modelling approaches for each big game species in B.C. and the required inventory and harvest data to facilitate a big game stock assessment.

a) Stage-Based Models

Stage-based models recognize different stages in an animal's life history. In big game stock assessment the model is usually described by equations for three stages (i.e. adult females, adult males, and juveniles). Thus they are ideally suited to big game inventories that collect both abundance and sex/age composition data (e.g. moose: bulls, cows and calves, deer: bucks, does and fawns). The White-Lubow likelihood model (White and Lubow 2002) and the Cooper-Hilborn-Unsworth Bayesian model (Cooper et al. 2003) are two common modelling approaches that utilize a stage-based model structure. Both of these models are reviewed by Griffiths and Hatter (2011) and have been applied to big game populations in B.C. Appendix F provides a case study for using a Bayesian modelling approach for evaluating harvest to achieve mule deer management objectives in B.C.

b) Age-Based Models

Age-based models include all age-classes in an animal's life history (e.g. grizzly bears may live to 30 years or more and thus both males and females may each have up to 30 age-classes in an age-based model). As inventories cannot distinguish individual adult age-classes for most big game species, they are less frequently used in big game stock assessment. However, recent advancements in **statistical population reconstruction (SPR)** have renewed interest in this modelling approach (see Appendix G). SPR enables the reconstruction of cohorts through time based on age-at-harvest and hunter-effort information and supplemented with inventory data on abundance and adult survival.

c) Recruitment-Mortality Models

Hatter and Bergerud (1991) developed the recruitment-mortality model (also known as the *RM* equation) that related the finite rate of population change (λ) to adult mortality and juvenile recruitment:

$$\lambda = \frac{(1 - M)}{(1 - R)}$$

where λ is the finite rate of increase, M is the adult mortality rate and R is the juvenile recruitment rate.

The *RM* equation can be used to ascertain an estimate of λ from a single late winter survey providing an estimate of *M* is available. For example, if a late winter (March) moose inventory found 30 calves per100 cows and the annual adult cow mortality rate, including both natural and hunting mortality, was 10% (e.g. based on a radio-collared sample of adult cows), then the finite rate of change for female moose can be estimated as:

$$\lambda = \frac{(1 - 0.10)}{(1 - 0.13)} = 1.035$$

where *R* = (30/2)/[(30/2)+100] = 0.13, assuming that 50% of the calves are female. DeCesare et al. (2012) and Hervieux et al. (2013) expanded the model's capability to include long-term trend monitoring with annual measures of precision.

The *RM* equation has received limited use in big game stock assessment in B.C., mainly because empirical estimates of adult mortality rates (*M*) have not been available, and because most ungulate surveys are conducted in early or mid-winter and thus do not provide an annual estimate of *R* (i.e. they do not include the effect of winter survival of juveniles on annual recruitment). However, as moose and elk inventories start to focus more on monitoring winter calf survival and annual adult survival rates, in addition to six month recruitment, this method will likely gain greater utility (see Appendix H).

d) Habitat-Density Extrapolation Models

Fuhr and Demarchi (1990) used a habitat-based approach to estimate grizzly bear abundance from an estimate of the habitat carrying capacity, i.e. the number of bears the habitat in a particular area should be capable of supporting. A step-down process that incorporated evaluations of current habitat condition and past human-caused mortality was then applied to the carrying capacity estimates. Estimates were also calibrated against existing survey-based estimates of abundance in the Flathead and Hart Ranges. This approach has gone through several iterations. Peek et al. (2003) thoroughly reviewed this approach and recommended several improvements.

FLNRO (2012b) developed a cougar range map based on the distribution of capable deer habitat, documented kill locations and expert opinion. Broad ecosystem inventory (BEI) mapping (RISC 1998f) and associated habitat capability ratings for white-tailed deer and mule deer were used to estimate the potential range of cougars at a provincial scale.

Lofroth and Krebs (2007) developed a habitat quality rating system for wolverines, using existing wolverine distribution, wolverine food, ecosystem mapping, and human development data. They used the habitat quality rating system, with empirically derived estimates of wolverine density in two study areas in B.C., to predict wolverine distribution and abundance at a provincial scale.

e) Regression Modelling Approaches

Kuzyk and Hatter (2014) modified the regression approach of Fuller (2003), referred to as the “ungulate biomass regression model”, to estimate wolf densities from an ungulate biomass index at a regional scale. The ungulate biomass index was derived from regional ungulate population estimates, which in turn were derived from ungulate inventories. The equation for estimating the relationship between wolf density and ungulate biomass was:

$$y = 5.40x - 0.166x^2$$

where y = wolves/1,000 km2 and x = ungulate biomass/km^2. Kuzyk and Hatter (2014) concluded that the ungulate biomass regression model was useful to estimate the abundance of wolves for management purposes when precise estimates are not required. The regression equation only works when prey biomass regulates wolf populations. It does not work when wolves are heavily exploited or recovering from previous over-exploitation.

Mowat et al. (2013b) used a regression approach that related interior grizzly bear densities from abundance surveys to environmental and anthropogenic variables including precipitation, vegetation, ruggedness, human density and livestock density. Their regression model was then used to predict grizzly bear densities for other areas where data existed for the input variables. Mowat et al. (2013b) concluded that their model predictions could be used to assess grizzly bear population status, set limits for total human-caused mortalities, and for conservation planning.

TABLE 11. Recommended population modelling approaches for big game stock assessment in B.C.

	Big Game Species[1]																		
Model[2]	DEBT	DEMU	DEWT	ELRO	ELRM	MOOS	CARI	SHEB	SHES	SHED	GOAT	BISO	BEAG	BEAB	WOLF	COUG	BOBC	LYNX	WOLV
Stage	✓	✓	★	✓	✓	✓	✓	✓	★	★	✓	★	✓						
SPR							★		✓	★	★		✓		★	★			
RME	✓	✓	★	★	✓	✓	✓	★			★	★							
HDE													✓	✓	✓	✓	★	★	★
RMA													✓	★	✓				

✓ *model has or is currently being used* ★ *model is recommended for use*

	Population Inventory Data						Harvest Data[3]		
Model[2]	Absolute Abundance	Relative Abundance	Sex/Age Composition	Adult Survival Rate	Juvenile Survival Rate	Recruitment Rate	Kill	Age-at-Harvest	Effort
Stage	✦	(✦)	✦	✦	✦		✦		(✦)
SPR	✦	(✦)		✦			✦	✦	✦
RME			(✦)	✦	(✦)	✦	✦		
HDE	✦						✦		
RMA	✦						✦		

✦ *required data (inventory or harvest) for model* (✦) *supplemental data (inventory or harvest) for model*

[1] DEBT = black-tailed Deer, DEMU = mule deer, DEWT = white-tailed deer, ELRO = Roosevelt elk, ELRM = Rocky Mountain elk, MOOS = moose, CARI = caribou, SHEB = bighorn sheep, SHES = Stone's sheep, SHED = Dall's sheep, GOAT = mountain goat, BISO = bison, BEAG = grizzly bear, BEAB = American black bear, WOLF = wolf, COUG = cougar, BOBC = bobcat, LYNX = Canada lynx, WOLV = wolverine

[2] Stage =Stage-based (i.e. adult male, adult female, juvenile), SPR = statistical population reconstruction (i.e. cohort based), RME = recruitment-mortality equation, HDE= habitat-density extrapolation, RMA = regression modelling approach

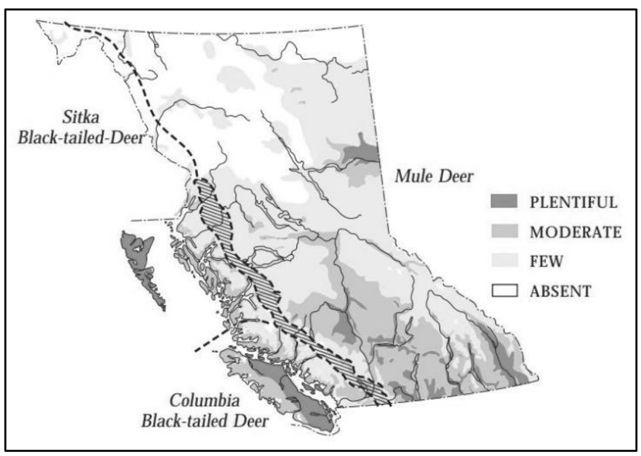
[3] Kill = kill by sex/age class (i.e. adult male, adult female, juvenile), Age-at-Harvest = kill by age-class (e.g. 1.5 year-old, 2.5 year-old, etc.), Effort = hunter days or trapper days.

5. Species Monitoring Statements with Recommendations

The following species monitoring statements provide an overview of available species management plans and status reports, species inventory standards, the status of species PMUs, and current monitoring efforts. Recommendations to further improve inventory and monitoring are provided as determined from literature reviews in academic journals, status reports, and management plans; and through discussions with the advisory group for this report(see Acknowledgements). The Fish and Wildlife Branch should periodically update these recommendations as more information becomes available to ensure that inventory and monitoring activities continue to reflect provincial and regional priorities.

5.1 Black-tailed deer

No provincial black-tailed deer management plan for B.C. exists. A preliminary deer management plan that included black-tailed deer was developed over 35 years ago (MOE 1980a). It is now outdated and provides little management direction for black-tailed deer inventory and monitoring. Kuzyk et al. (2012) summarized the status of black-tailed deer from 1981-2013.



Inventory of relative abundance of black-tailed deer populations using roadside spotlight counts during spring (April and May) has a long history of use in the South Coast and West Coast Regions (Jones and Mason 1983, RISC 1998c). These surveys are often supplemented with both spring and summer sex/age composition surveys. By combining the deer/km index with fawn recruitment and harvest data, Hatter and Janz (1994) were able to model deer population abundance and adult survival trends in the Nimpkish Valley on northern Vancouver Island from 1970 to 1990. Other methods for inventory of black-tailed deer have included pellet group counts or mark-re-sight methods for either relative or absolute abundance, but these techniques tend to be less reliable and cost-effective than spotlight counts (RISC 1998c). More recently, Kelly and Reynolds (2015) used remote cameras to calibrate a trail-counter located on a migration corridor to provide a trend index of a wintering deer population near Pemberton, B.C.

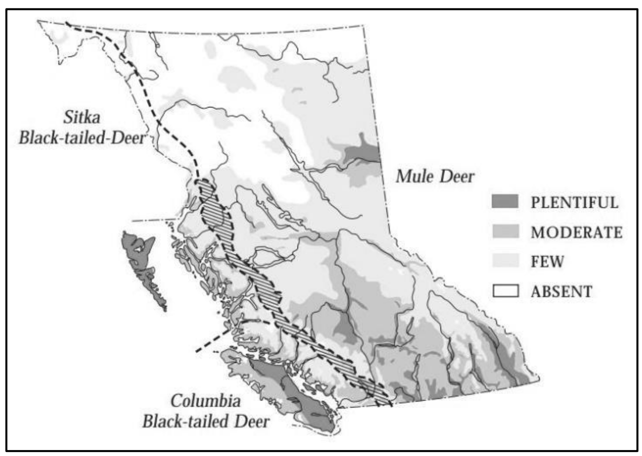
Catch per unit effort (CPUE), or kills per hunter day, has been widely used to monitor black-tailed deer trends in areas without inventory. Hatter (2001) assessed the reliability of CPUE to estimate rate of change in black-tailed deer on northern Vancouver Island. CPUE underestimated the population rate of decline, and may have overestimated rate of increase. While CPUE can be used to determine general population trends under certain conditions (Appendix E), CPUE should not be used to estimate the population rate of change unless the relationship between CPUE and abundance is known. Given the large number of black-tailed deer populations in B.C., most populations will likely continue to be monitored from CPUE data.

Recommendations:

1. Develop black-tailed deer PMUs for all regions in B.C. where they occur.
2. Expand the use of deer spotlight counts to BGMAs within high management priority PMUs.
3. Investigate the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
4. Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of black-tailed deer abundance (see Hilborn and Walters 1992: 104-155).

5.2 Mule deer

No provincial mule deer management plan for B.C. exists. A preliminary deer management plan that included mule deer was developed over 35 years ago (MOE 1980a). It is now outdated and provides little management direction mule deer inventory and monitoring. A regional mule deer management plan was recently developed for the Kootenay-Boundary Region (FLNRO 2014g). Kuzyk et al. (2012) summarized the status of mule deer from 1981-2013.



Inventory standards for mule deer have been developed for both aerial and ground based surveys (RISC 1998c, 2002, 2013). Due to low **detection probabilities** aerial survey techniques have generally been unsuccessful for estimating absolute abundance.

In Idaho, mule deer monitoring focuses on estimating total population size by PMU at 5 year intervals, conducting periodic sex/age composition counts (primarily fawn:doe ratios), and measuring adult female survival and winter fawn survival rates through radio-telemetry (Hurley 2014). The inclusion of survival rates into monitoring has also allowed numerous other important management questions to be answered, e.g. how deer survival rates are influenced by spring and autumn phenology (Hurley et al. 2014), and whether predator removal will increase mule deer populations at a management scale (Hurley et al. 2011). Keegan et al. (2011) provide a comprehensive review of methods for monitoring mule deer populations.

In the Kootenay-Boundary region, mule deer monitoring focuses on measuring the population growth rate (λ) through inventories of juvenile recruitment and adult female survival, as this approach is believed to be more cost-effective and reliable than repeated SRB surveys using a **sightability model** (FLNRO 2014g). Mule deer are surveyed for sex/age composition in the early spring from ground counts and late fall from aerial counts in the Thompson/Okanagan, Cariboo and Northeast Regions. The number of deer observed per km of road is also used as an index of population size.

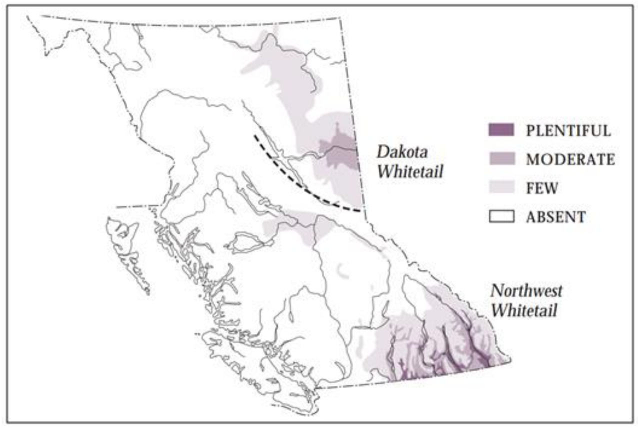
Quayle and Hatter (1990) developed a **winter severity index (WSI)** for 14 mule deer management areas (PMUs) based on monthly air temperature and snowfall data collected from provincial climate stations. Baccante and Woods (2010) showed a strong relationship (R^2 = 0.59) between spring fawns:100 does and this WSI, with higher fawn recruitment occurring during milder winters. They suggested that the WSI could be used to determine if mule deer populations were increasing or declining, assuming that 30 fawns:100 does was required for population stability.

Given the large number of potential mule deer PMUs in B.C., it is neither efficient nor practical to monitor all mule deer populations using RISC inventory standards. Monitoring through harvest data (e.g. CPUE) with focused inventory efforts in selected PMUs will likely be sufficient for most management decisions.

Recommendations:

1. Review and develop mule deer PMUs for all regions in the province where they occur.
2. Initiate a monitoring scheme similar to that used by Idaho as a trial within one mule deer PMU in the southern interior.
3. Develop a mule deer sightability model that can be used to more accurately measure deer population size from aerial surveys over forested habitats.
4. Investigate in training and the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
5. Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of mule deer abundance (see Hilborn and Walters 1992:104-155).
6. Consider adopting provincial monitoring of winter severity through a standardized WSI, similar to that developed by Quayle and Hatter (1990).

5.3 White-tailed deer



No provincial white-tailed deer management plan for B.C. exists. A preliminary deer management plan that included white-tailed deer was developed over 35 years ago (MOE 1980a). It is now outdated and provides little management direction for white-tailed deer inventory and monitoring. Kuzyk et al. (2012) summarized the status of white-tailed deer from 1981-2013 and some information for B.C.'s approach to white-tailed deer management is available at:

http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/white_tailed_deer_prov_review.pdf.

PMUs have not been developed for white-tailed deer populations.

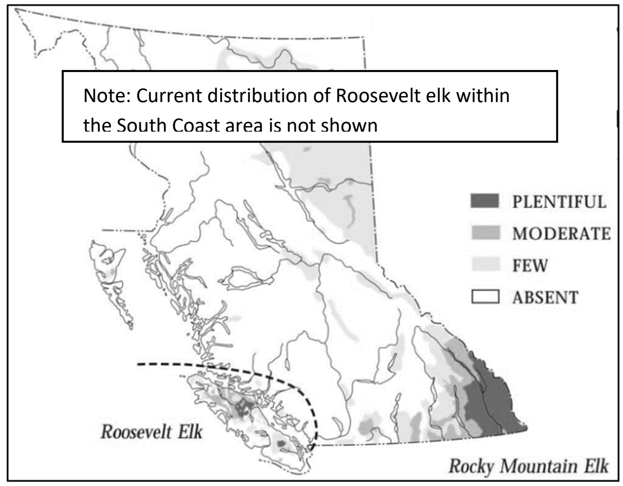
RISC inventory standards have been developed for both aerial and ground based surveys (RISC 1998c, 2002) although aerial survey techniques have generally been unsuccessful to estimate absolute abundance.

With some exceptions (e.g. Kootenay-Boundary and Northeast Regions), B.C. has placed little emphasis on monitoring white-tailed deer, as most deer populations prove resilient to moderate levels of hunting pressure. This is supported by the findings from other jurisdictions, particularly those in eastern North America, where liberal hunting seasons do not control white-tailed deer numbers (Brown et al. 2000, Riley et al. 2003). Winter weather patterns are considered to be the key population driver (Verme 1968, Patterson and Power 2002), although wolf predation may also be an important contributing factor for some populations (Mech et al. 1987). Diseases such as epizootic hemorrhagic disease may be locally significant in southern B.C. (Schwantje 2012).

Recommendations:

1. Develop white-tailed deer PMUs for all regions in the province where they occur.
2. Investigate the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
3. Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of white-tailed deer abundance (see Hilborn and Walters 1992: 104-155).
4. Investigate other indices for monitoring white-tailed deer populations, such as the number of white-tailed deer observed per hour on mule deer or elk surveys.
5. Consider adopting provincial monitoring of winter severity for white-tailed deer through a standardized WSI, similar to that developed by Quayle and Hatter (1990).

5.4 Roosevelt elk



A comprehensive provincial Roosevelt elk management plan has been prepared (FLNRO 2014f). The plan presents a synopsis of current management objectives and strategies for elk that will direct management from 2014 to 2024. Kuzyk et al. (2012) summarized the status of Roosevelt elk from 1981-2013.

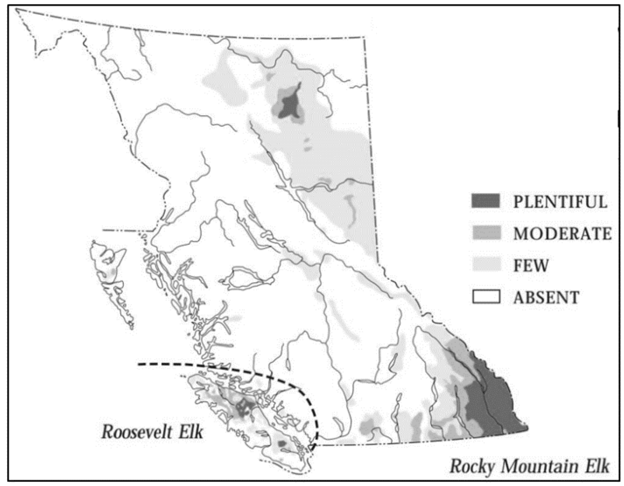
A total of 157 Roosevelt elk PMUs have been delineated including 113 PMUs in the West Coast Region and 44 PMUs in the South Coast Region. Priority PMUs are generally surveyed every one to two years, with less frequent monitoring (every three to five years) for other PMUs. Priority PMUs for inventory are defined as those with large hunted populations, where a new hunt is anticipated, where populations have been recently translocated, which are of particular interest to First Nations, and where high levels of illegal or unregulated hunting are suspected.

Roosevelt elk are one of the most intensively monitored big game species in the province due to their localized distribution and high demand for hunting. Roosevelt elk are most commonly inventoried by aerial surveys conducted in late winter or early spring using RISC inventory standards (RISC 2002). Surveys focused primarily on estimating population size, sex/age composition and age-class distribution of bulls. A subjective SCF of very low to very high is assigned to each survey to estimate the total population size within a PMU. This SCF is based on a number of criteria including weather conditions, canopy cover, ground snow conditions, proportion of range that was surveyed, time of day, and group size (FLNRO 2014f). Ground based inventories (RISC 1998) to gather further information on elk numbers and composition are occasionally also conducted.

Recommendations:

1. Ensure current inventory funding is maintained or increased to support current intensive management efforts and maintain current levels of survey intensity.
2. Consider research to further improve aerial survey estimates of sightability on elk winter ranges.
3. Where required, contemplate revisions to proposed PMU targets, objectives and strategies based on First Nations and stakeholder consultation and monitoring results.

5.5 Rocky Mountain elk



A preliminary elk management plan that included both Roosevelt elk and Rocky Mountain elk was prepared in 1981 (MOE 1981), but is now outdated. A provincial Rocky Mountain elk management plan is currently under development (G. Kuzyk, pers. comm. Jan. 2016). A regional elk management plan has been developed for the Kootenay Region (FLNRO 2010d). This management plan extended from 2010 to 2014, and is currently being updated (T. Szkorupa, pers. comm. Jan. 2016). Kuzyk et al. (2012) summarized the status of Rocky Mountain elk from 1981-2013.

With the exception of the Kootenay Boundary Region, elk PMUs have not been developed. Seven Kootenay elk PMUs were developed through the Kootenay elk management plan (FLNRO 2010d).

Inventory standards are well developed for Rocky Mountain elk, and are reviewed in the RISC aerial-based ungulate survey manual (RISC 2002). The method of choice are winter aerial-based SRB surveys using a sightability model (Unsworth et al. 1994) to estimate population abundance and sex/age composition. Recent winters with milder temperatures and reduced snow packs have made it increasingly more difficult to initiate and/or complete aerial SRB surveys. In addition, SRB elk surveys may not be suitable within agriculture zones where elk movement between adjacent blocks can confound survey results (M. Bridger, pers. comm. Mar. 2016).

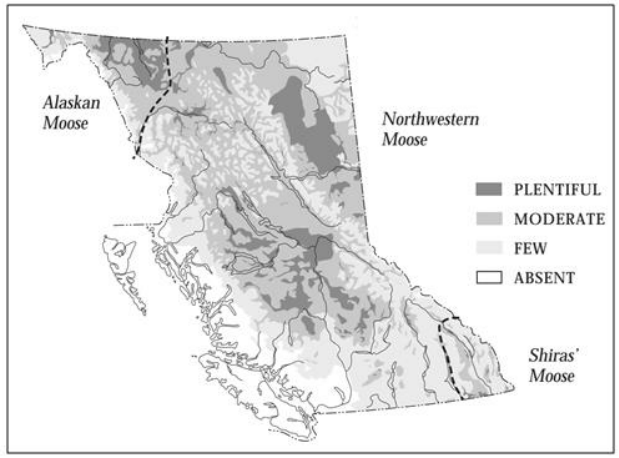
With the exception of antlerless elk in the Northeast Region, elk are not a Category A species, and thus calculation of an AAH, while desirable, is not required by policy. Most hunting focuses on bulls, and thus estimates of population trend and sex/age composition may work for most management purposes; e.g. the Kootenay Region is investigating the use of recruitment (calf:cow ratio) and survival rates from radio-collared cow elk to estimate population trends (see Sect 4.6c).

Recommendations:

1. Develop Rocky Mountain elk PMUs for all regions in the province where they occur.
2. Establish one or more population monitoring areas within high priority elk PMUs.
3. Ensure current inventory funding is maintained or increased to support intensive management efforts within high priority elk PMUs.
4. Investigate more suitable survey methods for surveying elk within agricultural areas.
5. Promote research on cost-effective methods to estimate elk population trends that do not require intensive helicopter survey sampling and that are less reliant on specific environmental conditions (e.g. temperature, snow cover) for surveying.

6. Investigate the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.

5.6 Moose



A provincial moose management framework (FLNRO 2015a) provides provincial direction for moose management, outlines an approach for preparing regional moose action plans, and establishes the scientific basis for making moose harvest management decisions.

Moose PMUs have been delineated for most areas of the province, and with some exceptions closely align with GMZs (Appendix I). Hatter (1999) summarized post-season densities and sex and age ratios for moose by GMZ within central and northern B.C. from 1994 to 1996.

Inventory standards (RISC 2002) highlight the importance of stratified random block surveys with corrections for sightability to provide estimates of moose population size, although distance sampling has also been successfully used in the Northeast Region (e.g. Thiessen 2010, Peters et al. 2010). Wildlife biologists use herd composition surveys extensively throughout the province for monitoring adult sex ratios and calf recruitment. In the Kootenays, biologists use these surveys to assess the effectiveness of harvest regulations (e.g. spike-fork seasons) on bull:cow and spike bull:cow ratios (Stent 2012). Big game stock assessment models that use inventory, harvest and other demographic data are routinely used to determine moose population size and trends; but some assessments are limited due to unknown levels of First Nations' harvest and lack of area-specific demographic rates.

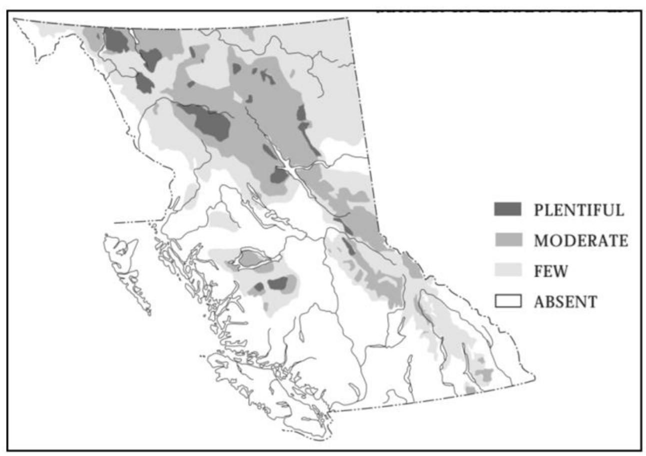
Recent winters with milder temperatures and reduced snow packs have made it increasingly difficult to initiate and/or complete aerial moose surveys. Given climate change, these conditions will likely continue. Thus, wildlife biologists and technicians urgently need to develop techniques to determine moose population trends that are less reliant on specific environmental conditions (e.g. temperature, snow cover) for monitoring. Kuzyk and Heard (2014), suggest that the best approach would involve collaring a large sample of six-month old calves. This work should be done in collaboration with the provincial moose research program which in 2015/16 had 167 active collars within five study areas (Kuzyk et al. 2015).

Results from surveys from 2011-12 to 2013-14 indicated moose numbers declined substantially in parts of the central interior of the province. This raised significant concern among wildlife managers, First Nations and stakeholders; and highlighted the need to improve surveillance monitoring (FLNRO 2015a). The current provincial moose research initiative outlines the importance of targeted inventories and monitoring within five provincial moose study areas to help understand the factors that may have led to these declines (Kuzyk and Heard 2014, Kuzyk et al. 2015).

Recommendations:

1. Finalize determination of moose PMUs for all regions in the province.
2. Ensure current inventory funding is maintained to support the provincial moose research program (Kuzyk and Heard 2014).
3. Update the RISC aerial survey standards to include methods using distance sampling (Buckland et al. 2001, Laake et al. 1993).
4. Promote research on new inventory methods that are less reliant on specific environmental conditions (e.g. temperature, snow cover) for monitoring moose population trends, including maintaining an adequate sample of radio-collared cows and calves.
5. Repeat and expand the moose status assessment by PMU (Hatter 1999), including PMUs in southern B.C., to help assess moose inventory and monitoring priorities.
6. Investigate options to determine area-specific, updated demographic parameters to improve population modelling efforts.
7. Explore opportunities to implement a Moose Survey App for hunters to record their sightings via their smart phones, as currently being used in Alberta (http://www.biology.ualberta.ca/moose/) and piloted in the Skeena Region (see Sect 4.4b.).
8. Support First Nation moose harvest surveys so that this information can be included in provincial big game stock assessments.

5.7 Caribou



The B.C. Government recognizes three ecotypes of caribou – mountain caribou, northern caribou and boreal caribou (Table 1). For status assessment purposes, COSEWIC has identified four **designatable units** in B.C., including Southern Mountain, Central Mountain, Northern Mountain and Boreal (COSEWIC 2011). COSEWIC lists the Southern Mountain and Central Mountain populations as endangered, the Boreal population as threatened and the Northern Mountain population as special concern (COSEWIC 2014). Due to conservation concerns, hunting only occurs within some of the Northern Mountain herds. No management plan exists for the hunted herds within the Northern Mountain population.

The B.C. Government identifies the caribou herds recognized by COSEWIC (2011) as the PMUs for caribou in B.C.

Inventory standards highlight the importance of aerial-based total counts of caribou within PMUs, preferably those using collared caribou for mark-resight to correct population estimates (RISC 2002).

Caribou spread widely over remote and large landscapes, making ground-based inventories largely impractical. All herds have been surveyed, but up-to-date survey information is lacking for many herds.

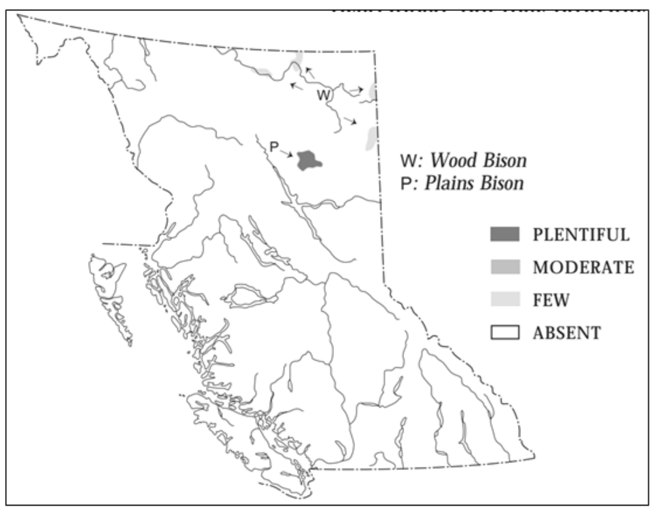
Harvest management has and continues to utilize a “5-point bull regulation”, which focuses hunting on older bulls and precludes younger bulls, cows and calves from being harvested. Consequently, hunting is generally not considered to be a management concern, and there has been relatively little inventory need for determining levels of sustainable use. All caribou are aged through **compulsory inspection** and some information on adult male survival rates is available through radio-telemetry studies (e.g. McNay and Voller in prep.). Thus, potential exists to estimate the number and trends of the hunted bull component through SPR (see Sect. 4.6b).

Recommendations:

1. Due to their high conservation concern, develop an inventory schedule outlining survey frequency and recommended survey methodology for all caribou herds in B.C., including hunted herds within the Northern Mountain population.
2. Consider undertaking additional adult bull mortality studies using GPS radio-collars to support SPR analyses for the Northern Mountain population.
3. Conduct a SPR analysis to estimate the number and trends of mature bulls within the Northern Mountain population.

5.8 Bison

Both plains bison and wood bison occur within Northeast Region. Plains bison have been designated as nationally threatened, while wood bison are designated as special concern, and are also listed as a CITES Appendix II species. There is both a provincial management plan and a national recovery plan for wood bison (Harper et al. 2000, Gates et al. 2001); and a national status report for plains bison (COSEWIC 2004).



Bison herd ranges have been delineated and correspond to bison PMUs. Wood bison PMUs include Nordquist, Etthithun Lake and Nahanni. The Plains Bison PMU is located within the Pink Mountain area.

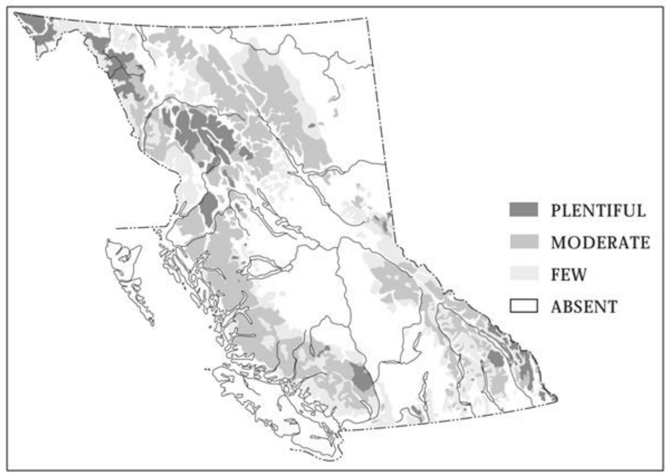
Inventory standards highlight the importance of aerial-based total counts of bison within PMUs, preferably using collared animals for mark-resight to correct population estimates (RISC 2002). All bison PMUs have been surveyed and are periodically re-surveyed.

Most of the management of bison has focused on trying to prevent hybridization between plains and wood bison as well as between wild bison and farmed bison; and addressing public health and human safety concerns. Hunting has been used as the primary management tool to address these concerns.

Recommendations:

1. Periodically determine the size, seasonal distribution and demographics of each bison population.
2. Promote and support the use of First Nations and citizen-science volunteers to assist in conducting road-side sex/age composition surveys in northeastern B.C.

5.9 Mountain goat



Approximately one half of the world's mountain goats are found in B. C., therefore the Province has a global responsibility to ensure their long-term persistence. Mountain goats are sensitive to harvest, and potentially also to climate change and human-caused disturbance. For these reasons, a provincial mountain goat management plan was prepared and provides guidance on provincial direction for mountain goat conservation (MGMT 2010). Kuzyk et al. (2012) summarized population and harvest trends of mountain goats from 1987 to 2011.

Mountain goats are a Category A species and thus PMUs have been delineated for most areas of the province.

Inventory methods have traditionally relied on aerial surveys to count the entire mountain goat population with corrections for sightability using marked animals (RISC 2002) or from logistic regression methods (Rice et al. 2008, Poole 2015b). Poole et al. (2011) estimated mountain goat population size using DNA obtained from fecal pellet and hair samples. DNA mark-recapture estimates will become increasingly more common for intensively managed populations. Ground-based composition surveys may work for small, isolated populations that are road accessible.

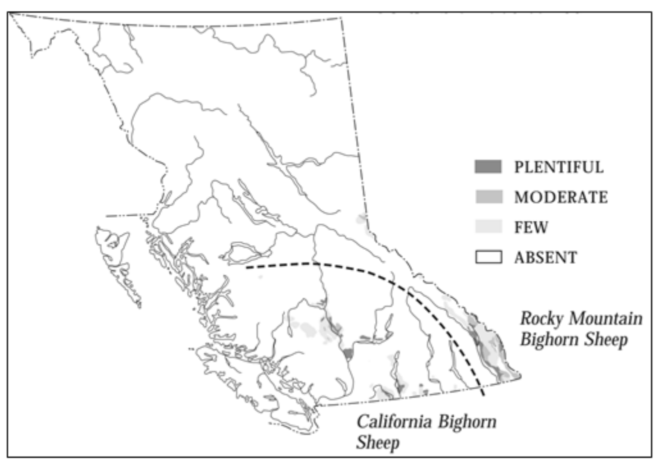
Parts of B.C. have out-dated, poor, or no inventory data on mountain goats, especially the northern and coastal areas. With the inadequate level of inventory in these areas, the probability of detecting localized loss of mountain goats is low. Local goat surveys are needed unless harvest has little impact on population numbers. Côté and Festa-Bianchet (2003) advise annual monitoring of hunted populations, but this approach is not feasible given the large number of goat populations in the province. The mountain goat management plan recommends that all hunted populations of an estimated 50–100 adults should be monitored at least every three years to ensure sustainable harvest, and that other areas should be monitored every five to six years (MGMT 2010).

There is considerable uncertainty regarding sustainable harvest rates for mountain goats. The *Mountain Goat Harvest Management Procedure* (FLNRO 2014b) states that mountain goat populations with less than an estimated 50 adults should not be hunted, that the AAH should typically be calculated by applying a harvest rate of not more than three per cent of the estimated population size, and that these rates should be adjusted depending on the percentage of female goats in the harvest. These harvest rules highlight the importance of ensuring that mountain goat populations are regularly inventoried. Mountain goats are considered a good candidate species for both AHM (see Sec. 3.4, Appendix A) and SPR (Appendix G).

Recommendations:

1. Finalize determination of mountain goat PMUs for all regions in the province.
2. Update the RISC inventory standards for mountain goats to include mark-recapture methods using fecal and hair DNA.
3. Determine optimal sustainable harvest rates using an adaptive management approach within one or more goat PMUs (Appendix A).
4. Consider establishing monitoring areas for mountain goats where there is concern with high levels of human-caused disturbance and/or hunter harvest.
5. Promote monitoring of accessible small, localized mountain goat populations through collaborative monitoring.
6. Consider the application of SPR for estimating mountain goats over larger areas than a PMU where inventory information is lacking.

5.10 Bighorn sheep



Two ecotypes of bighorn sheep exist in B.C. The Rocky Mountain bighorn sheep occurs in the eastern portions of the Kootenay Boundary Region with isolated herds near Chase, Spences Bridge, and the Narraway and Belcourt drainages. The California bighorn sheep occupies the dry valleys and mountains of the Thompson, Okanagan, South Cariboo and South Chilcotin. Regional and/or herd-specific management plans are in various stages of development. A provincial status report summarized the conservation status of Rocky Mountain bighorn sheep (Demarchi et al. 2000a), and another status report summarized the status of California bighorn sheep (Demarchi et al. 2000b). Kuzyk et al. (2012) summarized population and harvest trends of bighorn sheep from 1987 to 2011.

Bighorn sheep herd ranges have been delineated and generally correspond to bighorn sheep PMUs. A Provincial Wild Sheep Registry has been established to track the information on herd population status, ranges, and management concerns (D. Demarchi, pers. comm. Jan. 2016). Disease transmission from domestic sheep and goats to wild sheep can be fatal to bighorn sheep with long term population consequences and is the highest priority issue for wild sheep conservation and management throughout North America (Porter 2014, Brewer et al. 2014).

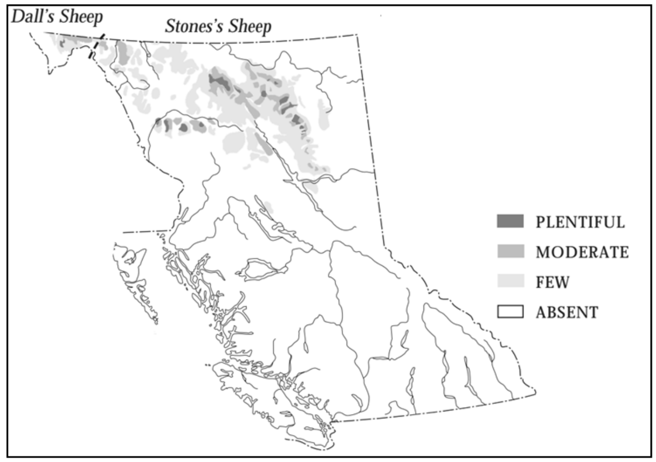
Inventory standards highlight the importance of aerial-based total counts of wild sheep within PMUs, preferably using collared sheep for mark-resight or a **sightability correction factor (SCF)** to adjust population estimates for **visibility bias** (RISC 2002). Adult males are classified as Class I, II, III, or IV on the basis of horn curl (Geist 1971). Some bighorn sheep ranges are easily accessible by road, thus enabling ground-based inventories.

Harvest management has and continues to focus on the harvest of either "three-quarter" or "full curl" rams, although any ram LEH seasons are also in effect for some populations. All wild sheep are aged through compulsory inspection (MELP 1996). Bighorn sheep are a Category A species. Thus an AAH is required to be calculated for each PMU, which necessitates total count surveys. The *Bighorn Sheep Harvest Management Procedure* (FLNRO 2014c) notes that where sufficient population-specific demographic information exists, a big game stock assessment that utilizes a population-specific population model should be performed to determine the AAH.

Recommendations:

1. Maintain and update the Provincial Wild Sheep Registry as new information becomes available.
2. Prioritize inventory and monitoring needs of wild sheep herds near domestic sheep farms.
3. Consider more extensive radio-collaring and monitoring of sheep to help define bighorn sheep metapopulations and movement corridors among sub-populations.
4. Develop bighorn sheep sightability models for B.C. that can be used to both accurately and precisely measure bighorn population size from aerial surveys (see Bodie et al. 1995).
5. Investigate training citizen-science volunteers to ensure ground-based surveys within road accessible areas are conducted to RISC standards.

5.11 Thinhorn sheep



Two subspecies of thinhorn sheep live in B.C.: Dall's sheep in the St. Elias Mountains of extreme northwestern B.C.; and Stone's sheep in the northern mountains and plateaus. As three-quarters of the world's Stone's sheep are found in B.C., the Province has a global responsibility to ensure their long-term persistence. A provincial status report summarizes thinhorn sheep conservation status (Demarchi and Hartwig 2004), and a Stone's sheep action plan has been prepared (GOABC 2007). The need for a provincial management plan has been identified as a high priority (WSF 2014), and is currently being developed (G. Kuzyk, pers. comm. Mar. 2016). Kuzyk et al. (2012) summarized population and harvest trends of thinhorn sheep from 1987 to 2011.

Thinhorn sheep PMUs have been delineated through the Provincial Wild Sheep Registry that tracks information on herd population status, ranges, and management concerns (D. Demarchi, pers. comm. Dec. 2015). PMUs may undergo additional refinement as research continues to be conducted to delineate the spatial genetic structure of thinhorn sheep populations (Worley et al. 2004, B. Jex, pers. comm. Jan. 2016).

Inventory standards highlight the importance of aerial-based total counts of thinhorn sheep within discrete mountain blocks, preferably with the application of a sightability correction factor (RISC 2002). Ground-based inventories are largely impractical due to the remoteness and large landscapes occupied by thinhorn sheep.

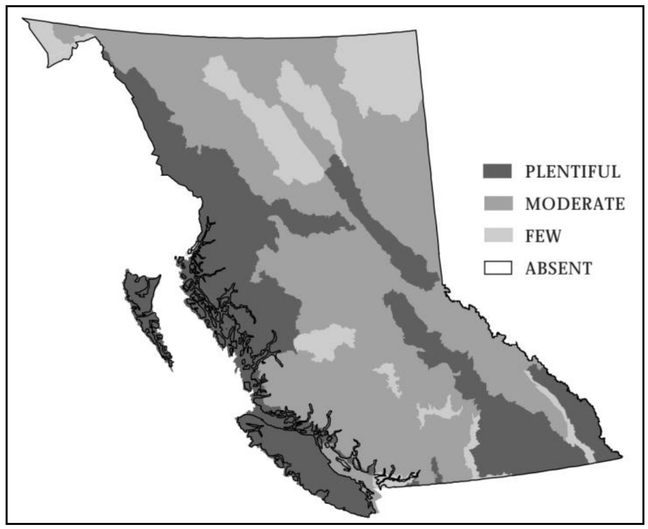
Despite numerous sheep surveys that have been conducted, parts of their range continue to have out-dated, poor, or no population inventory information. The draft *Thinhorn Sheep Harvest Management Procedure* (FLNRO 2013) notes that when sufficient population-specific inventory and demographic information is not available, a harvest age structure model may be applied.

Harvest management has and continues to focus on the harvest of full curl rams and all sheep are aged through compulsory inspection (Demarchi and Hartwig 2004). While this harvest strategy has been thought to prevent over-harvest, Douhard et al. (2015) caution that excessive harvest of full curl rams may have undesirable long-term consequences of reducing both the harvest and the horn size of rams, and recommend limiting the harvest of mature rams. Hengeveld and Cubberley (2011) provide some information on adult male survival rates. Thus, there is potential to estimate mature ram numbers, trends and harvest rates through SPR. Hatter (1994) used SPR to estimate mature ram numbers and trends in the Muskwa-Kechika area from 1978 to 1993 using CAGEAN statistical software (Deriso et al. 1985).

Recommendations:

1. Develop thinhorn sheep PMUs for Skeena, Omineca and Northeast regions, and establish population monitoring areas within high priority PMUs.
2. Promote ground-based monitoring of accessible small, localized thinhorn sheep populations by First Nations and stakeholders where possible.
3. Undertake additional adult male mortality studies using GPS collars to support SPR analyses.
4. Conduct an updated SPR analysis to estimate the number and trends of mature rams in both the Skeena and Northeast Regions from 1978 to 2015.

5.12 American black bear



A preliminary American black bear management plan was prepared in 1980 (MOE 1980b), and is thus outdated. As with all *Ursidae*, the Appendix II of CITES lists American black bear.

PMUs for this species have not been delineated.

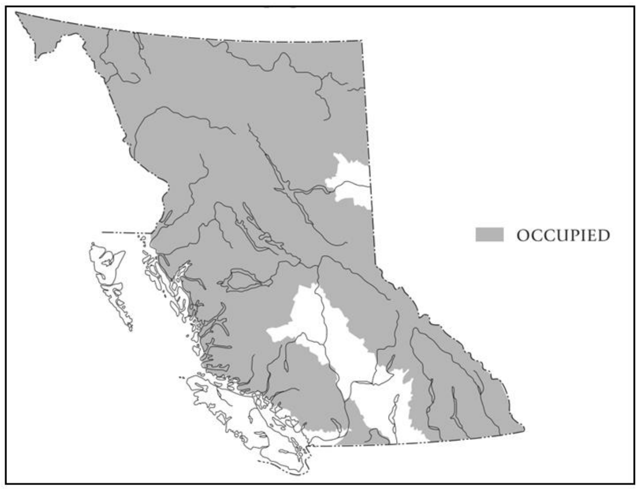
American black bear densities and population estimates in B.C. are generally derived from a habitat-based extrapolation model (Fuhr and Demarchi 1990). RISC population-based inventory standards have been developed for American black bears, and follow the same standards as for grizzly bears (RISC 1998). While there have been some research studies on American black bears to estimate densities (e.g. Mowat et al. 2002), few inventories have been conducted to support population management. This is because American black bears are widely distributed, numerous, and generally lightly hunted (MELP 1996). Consequently, inventories for this species are generally not cost-effective for population management. The primary management concern for American black bears relates to conflicts with humans (Ciarniello 1997).

B.C., like most jurisdictions in North America, uses numerous harvest-monitoring statistics for American black bears (e.g. kill per unit effort, proportion of females in harvest, and total harvest trend) in lieu of population inventory for harvest management. The West Coast Region collects information on the ages of harvested American black bears, which may be useful for estimating male bear abundance and trends through SPR (Appendix G).

Recommendations:

1. Develop American black bear PMUs for all regions in the province.
2. Maintain the population monitoring focus on American black bears through the collection of analysis of harvest statistics.
3. Consider estimating regional American black bear population size through existing information and expert opinion.
4. Investigate the potential to utilize SPR for estimating adult male American black bear numbers and trends on Vancouver Island.
5. Explore opportunities for developing and implementing a large carnivore sighting app for hunters on their smart phones in order to record their sightings of American black bears.

5.13 Grizzly bear



A Future for the Grizzly: British Columbia Grizzly Bear Conservation Strategy (http://www.env.gov.bc.ca/wld/grzz/grst.html) was drafted in 1995.Much of the information contained in this document is now out-of-date but some updates are available (FLNRO 2010a).The Province's approach to grizzly bear management, including its inventory and monitoring program has undergone two independent scientific reviews (Peek et al. 2003, Boyce et al. 2015). As with all *Ursidae*, the grizzly bear is listed in Appendix II of CITES and the Province has produced a non-detriment report (Austin and Fraser 2004). The comprehensive *Grizzly Bear Harvest Management Procedure* is also available (FLNRO 2012a).

Fifty-seven grizzly bear PMUs (referred to as GBPUs) have been developed that are used for conservation and harvest management purposes (http://www.env.gov.bc.ca/fw/wildlife/ management-issues/docs/grizzly_bear_faq.pdf)). Management objectives have or are currently being developed for these PMUs that address many of the recommendations from the second independent scientific review (Boyce et al. 2015).

B.C. pioneered the use of hair-snag DNA sampling to estimate grizzly bear densities through capture-recapture methods (Mowat and Strobeck 2000, Boulanger et al. 2004), and this has become the primary tool for grizzly bear population inventory (RISC 1998d). Mowat et al. (2013b) recognized that field-based estimates of grizzly bear density (i.e. hair snag DNA mark-recapture) will never be available for more than a small portion of GBPUs, and used a modelling approach to relate grizzly bear density to measures of ecosystem productivity and mortality for interior and coastal ecosystems in North America. This regression approach, combined with field inventories and expert opinion, has been used to estimate grizzly bear population abundance within each GBPU (Hamilton 2012). Several monitoring programs have been established in B.C., most notably in the Flathead (Mowat et al. 2013a, McLellan 2015). The Southern Rockies GBPU also has a monitoring program that was specifically established to address concerns of potential excessive human-caused mortality (Mowat et al. 2013a).

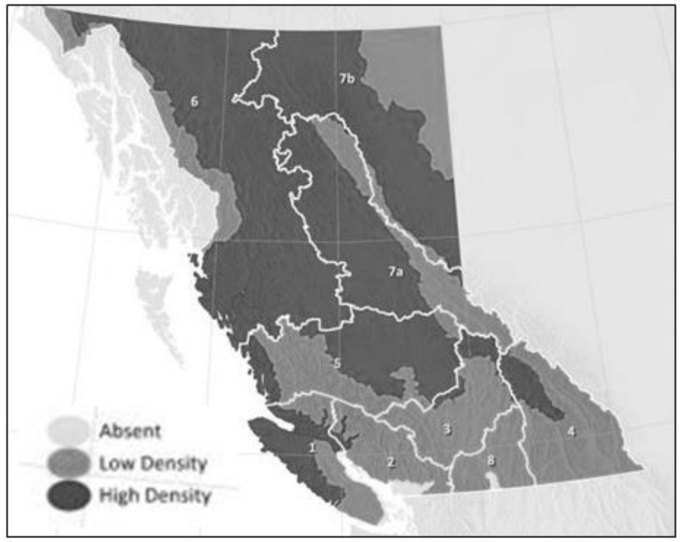
All known human-caused mortalities of grizzly bears are documented through compulsory inspection. The information collected from compulsory inspection includes mortality location, gender, skull measurements and tooth extraction for aging. Measures of effort are available (kill/hunter day) and some information on human-caused mortality rates, including unreported mortality rates, are available for the Flathead in southeastern B.C. (McLellan 2015). Hatter (2016) used these data sets to construct SPR models to estimate male grizzly bear population size, trends and harvest rates within three SPR grizzly bear regions (Appendix G).

B.C. also has a comprehensive population inventory and monitoring strategy for grizzly bears (Apps 2010). Inventory and monitoring priorities were established using a structured rating system reflecting the relative need for population inventory for each GBPU specific to objectives for estimating (1) abundance, (2) distribution and connectivity, and (3) population monitoring. A decision support tool was used where GBPU scores for each objective were derived on the basis of 10 criteria. A combined score for each objective was then established based on a weighted average among criteria scores specific to each objective. This approach provided a provincially consistent ranking method that ensures future efforts are directed to areas where the least is known about grizzly bear abundance, trend and distribution relative to apparent management need. The decision support tool is used to help rank HCTF proposals for funding grizzly bear inventory and monitoring projects.

Recommendations:

1. Review the decision support tool developed by Apps (2010) to determine if it requires updating, refinement and more input to reflect inventories for sustainable use; and if another workshop should be held to assess the opinion-based scores that are currently being used to rank GBPUs for inventory.
2. Determine key priorities for hair snag DNA mark-recapture inventories that will help to improve the regression model of Mowat et al. (20113b), and its use for extrapolating densities to GBPUs.
3. Implement the recommendations in Hatter (2016) for improving future SPR models for grizzly bear numbers and trends.
4. Review and consider adopting the recommendations in the recent scientific review of grizzly bear management in B.C. pertaining to inventory and monitoring, many of which align with current management direction, e.g. establish population trend monitoring procedures in areas where long-term population declines or significant fluctuations are suspected (Boyce et al. 2015).
5. Explore opportunities for developing and implementing a large carnivore sighting app for hunters on their smart phones in order to record their sightings of grizzly bears.

5.14 Wolf



The wolf is managed both as big game and a Class 3 furbearer. A wolf management plan (FLNRO 2014h) provides provincial direction for wolf conservation and management. The wolf management plan notes that improved harvest monitoring, combined with an assessment of the effect of current harvest rates on wolf populations, will likely be required in order for B.C. to maintain its CITES non-detriment finding for wolves; and recommends improving the accuracy and precision of provincial and regional wolf population assessments through research and inventory. The wolf management plan also recommended a two-zone management strategy where wolves are managed more intensively within livestock and caribou recovery areas, and less intensively elsewhere in the province.

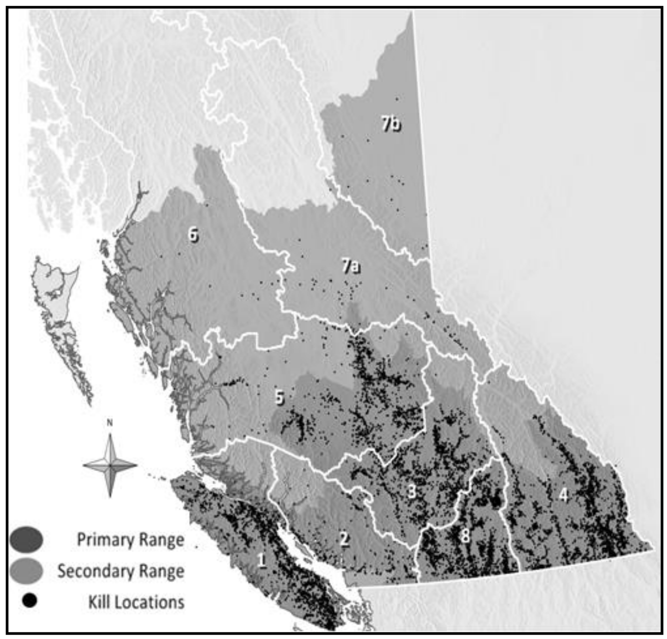
In contrast to ungulates, bears and felids; wolf PMUs are unlikely to be of significant management value. Rather, establishing wolf population monitoring areas in conjunction with large predator-prey system monitoring will likely provide more useful information for management. The most comprehensive wolf population monitoring in B.C. has occurred in the Nimpkish Valley on northern Vancouver Island (Atkinson and Janz 1994), north of Revelstoke in southern B.C. (Serrouya 2013) and in the Muskwa-Kechika area of northeastern B.C. (Elliott 1984a, 1984b). Currently, there is limited inventory or monitoring of wolves other than some woodland caribou recovery areas in B.C.

RISC-based survey methodologies generally consist of aerial snow-tracking, radio-telemetry, or a combination of aerial snow-tracking and radio-telemetry (RISC 1998), More recently, low-cost methodologies that hold considerable promise for monitoring wolves in B.C. have been developed and should be included as RISC standards (e.g. Ausband et al. 2010, van Oort et al. 2010, Rich et al. 2013, Ausband et al. 2014). Rich et al. (2013) provides a method for estimating occupancy and predicting numbers of wolf packs using hunter surveys. While these methods work for smaller monitoring areas (e.g. < 20,000 km2), Kuzyk and Hatter (2014) noted that there are no standardized, cost-effective methodologies for providing reliable estimates of wolf abundance for management at a large spatial scale. They developed an ungulate biomass regression model (see Sect 4.6) to estimate regional wolf abundance in B.C., which may be sufficient for most management purposes, provided that wolves are not heavily exploited or recovering from previous over-exploitation.

Recommendations:

1. Update the RISC inventory standards for wolves based on more recently developed, cost-effective survey methods (e.g. Ausband et al. 2010, van Oort et al. 2010, Rich et al. 2013, Ausband et al. 2015).
2. Contemplate implementing three long-term wolf monitoring studies in B.C., including one each in the Coast, Southern Interior, and Northern areas.
3. Consider establishing other wolf monitoring areas within intensive wolf management zones (i.e. livestock and caribou recovery areas) using recently developed, cost-effective survey methods (see recommendation #1).
4. Explore opportunities for developing and implementing a large carnivore sighting app for hunters on their smart phones in order to record their wolf sightings.
5. Work with the BCTA to develop a detailed trapper return survey for wolves.

5.15 Cougar



A draft provincial cougar management plan has been prepared, but has not been finalized (FLNRO 2012b). As with all *Felidae*, the cougar is listed in Appendix II of CITES.

Cougar PMUs have not been established. As deer and elk are the primary prey for cougars, PMUs for cougars will likely be based on combinations of deer and elk PMUs.

Cougars are secretive animals and difficult to survey. However, they may be inventoried for relative abundance using aerial track counts in interior areas with open forest cover, or using ground-based track counts along logging roads. Aerial track surveys using probability sampling, or radio-telemetry studies are recommended for determining absolute abundance (RISC 1998b). More recent survey methodologies are now incorporating DNA spatial capture-recapture models to estimate cougar densities (Russel et al. 2012). This approach is currently being piloted in the Kootenay and West Coast regions. Clawson (2010) used SPR from harvest-at-age and hunter effort data, combined with radio-telemetry results of natural and harvest mortality rates, to estimate cougar abundance and trends in northeastern Washington.

Accurate population estimates for cougars are generally not feasible and are not a prerequisite for successful management (CMGWG 2005). However, in their absence, reliable indices of population trends are essential. The draft cougar management plan notes that indices including animal control kills, total harvest, catch per unit effort, proportion of females in the harvest, mean age of harvested cougars, size of ungulate populations and expert opinion may all be used but need to be validated with independent inventory information when and where there are opportunities (FLNRO 2012b).

Recommendations:

1. Develop cougar PMUs for all regions in the province.
2. Update the RISC manual on inventory methods for cougar to include protocols for conducting spatial DNA capture-recapture.
3. Maintain support to B.C.'s current pilot studies in order to determine the cost-effectiveness of estimating cougar densities using spatial DNA capture-recapture inventory.
4. Collaborate with hunters to investigate the utility of other cougar monitoring indices (e.g. number of cougars treed by hounds per hunter day).
5. Improve the collection of harvest age data (including removing the second upper premolar for cementum aging to confirm cougar aging by other techniques) during compulsory inspection.
6. Investigate the utility of SPR for cougar abundance within larger SPR regions where auxiliary data on natural mortality rates are available.

5.16 Canada lynx and Bobcat

Canada lynx and bobcat are managed both as big game and as Class 2 furbearers, and are listed on Appendix II of CITES, due to their pelts being indistinguishable from those of endangered cat species from other continents ("look-alike" species). Draft provincial plans for both Canada lynx and bobcat have been prepared, but have not been finalized (Apps et al. 2011a, 2011b). PMUs have not been established. Wildlife researchers suspect that climate change may pose problems for Lynx and research is underway in the U.S.A. (Butcher nd), Ontario (Koen 2014, Peers 2014) and B.C. (Dyck 2015) to determine their climate sensitivity.

While numerous direct inventory methods are available to monitor Canada lynx and bobcat populations including snow-track counts, telemetry studies and DNA mark-recapture (RIC 1999, 2007), these methods are generally either expensive or only applicable to relatively small study areas. As with other furbearers, inferences of population trend generally come from monitoring of harvest levels and age-and-sex composition (Apps et al. 2011a, 2011b). These are most cost-effectively carried out by monitoring trapper returns and fur-trader transactions, supplemented by either compulsory inspection or **compulsory reporting** (Table 12).

TABLE 12. Compulsory inspection and reporting requirements for Canada lynx and bobcat in B.C.

2014-16:	Compulsory Inspection	Compulsory Reporting
Hunters	Canada lynx: Region 4	Canada lynx: Regions 3, 5, 6, 7A, &b and 8 Bobcat: province-wide
Trappers	Canada lynx: MUs 1-14, 1-15, Region 2	Canada lynx: Region 4 and 8 Bobcat: MUs 1-14, 1-15, Region 2, 4 and 8

Within B.C., trappers are required by law to pay royalties on pelts regardless of whether the pelts are marketed or kept for personal use. These records are tracked by the Provincial Wild Fur Data System, and are the primary source of monitoring information for these species in the province. The only harvest that is not potentially captured by this system are those pelts kept for personal or ceremonial use by First Nations. Fur traders are also required to measure and record pelt lengths (nose to base of tail) of Canada lynx, although this has not been a requirement for bobcats. This data can be used to infer population age structure and recruitment (Apps et al. 2011a).

The disadvantage of relying on trapper returns for monitoring Canada lynx and bobcat harvest is that they are subject to a variety of response and non-response biases (Poole and Mowat 2001). Apps et al. (2011a, 2011b) note that decisions to liberalize Canada lynx harvest should be coupled with an appropriately high confidence in monitoring methods and resulting data. This may include, for example, monitoring of snowshoe hare populations and Canada lynx reproduction, as well as the quality, effectiveness, and regional distribution of habitat to support long-term stable Canada lynx populations.

Apps et al. (2011a, 2001b) provide a number of recommendations to improve population monitoring for Canada lynx and bobcat. These include a detailed trapper return survey that should be completed and submitted at the end of each season, improved compulsory reporting for hunter harvest, collecting a random sample of female Canada lynx carcasses, and prey population monitoring.

Recommendations:

1. Work with the BCTA to develop a detailed trapper return survey for Canada lynx and bobcat that would be completed and submitted at the end of each season.
2. Review and consider adopting the other monitoring recommendations by Apps et al. (2011a, 2011b).

5.17 Wolverine

B.C. may be the continental centre of abundance for wolverines (Hatler and Beal 2003) and thus the province has provincial, national and international responsibilities for their conservation. The *Preliminary Mustelid Management Plan for British Columbia* was prepared but is outdated (MOE 1979). A wolverine management strategy for B.C. was prepared in 1989 (Hatler 1989). The wolverine is managed both as big game and a Class 2 furbearer. Trappers harvest 200-300 per year, while harvest by hunters is incidental at only a few animals a year. Wolverines are a climate sensitive species (Copeland et al. 2010, McNay et al. 2011, McKelvey et al. 2011).

A total of 74 wolverine PMUs were established by Lofroth and Ott (2007). Population estimates were developed for each PMU using empirically derived estimates of wolverine density in combination with a habitat quality rating system based on wolverine distribution, wolverine food, ecosystem mapping, and human development data (Lofroth and Krebs 2007).

RISC standards have been developed and include snow tracking, bait/scent stations, live capture/telemetry and DNA mark-recapture (RISC 1999). However, wolverines naturally occur at low density and with current RISC standards it is difficult and generally not cost-effective to obtain accurate inventory information, particularly over the large areas required for their management (Hatler and Beal 2003). However, Parks Canada is currently investigating new methods for estimating wolverine populations in Canada's national parks (see http://www.pc.gc.ca/eng/pn-np/mtn/conservation.aspx).

The most significant and cost-effective source of information about wolverine population trends in B.C. has and will likely continue to come from trappers through contributing harvest data and specimen material; and responding to provincial questionnaires and interviews (Hatler 1989). Lofroth and Ott (2007) note that monitoring and reporting could be improved to provide better data on the female component of the harvest, a metric that should be integrated into annual harvest monitoring. Hatler (1989) also recommended that skulls of wolverines be collected routinely to provide continuing information on the sex and age composition of the harvest in various areas under varying conditions.

Recommendations:

1. Work with the BCTA to develop a detailed trapper return survey for wolverine that would be completed and submitted at the end of each season. In addition to recording the location, sex/age composition, effort and kill information also consider the submission of skulls for information on the sex and age composition of the harvest.
2. Consider updating the wolverine status assessment for each PMU as conducted by Lofroth and Krebs (2007) once there is sufficient new information.
3. Consider establishing three long-term trend monitoring areas for wolverines including one each within the Coast, South and North FLNRO Areas, potentially using camera traps and collaborative monitoring (e.g. citizen-science volunteers, other government agencies).

6. Vison – What would an ideal big game inventory and monitoring program look like?

British Columbia achieves desired wildlife management outcomes through a structured, adaptive approach to management decisions facilitated by enhanced use of big game population inventory and monitoring.

By 2025, big game inventories are strategic and proactivethrough a more structured, adaptive approach connecting inventory and monitoring to decision making which achieves desired wildlife management outcomes.

Big game inventory budgets are transparent and defendable; and inventory funds are sufficient, but not excessive, to acquire the necessary information for management. A tracking system documents completed inventories and identifies future inventory projects for funding. The calculation of the AAH for Category A species is science-based and defendable, as it is founded on inventory data.

A Big Game Inventory and Monitoring Unit performs a variety of functions, including updating inventory standards, assisting with project and data management, providing regional support for conducting inventories and big game stock assessments, and preparing reports.

First Nations, other government agencies, stakeholders, and citizen-science volunteers contribute their expertise and time to big game collaborative monitoring activities. Investing in this greatly expands the number of big game populations monitored.

Wildlife biologists use updated RISC inventory standards and the most cost-effective and state-of-the-art survey methodologies. This includes new inventory methods that allow populations to be surveyed, regardless of survey conditions. All big game inventory results are reported and entered into the Province's SPI database. The Big Game Inventory and Monitoring Unit annually prepares summary reports of big game inventory and monitoring projects, which the public can easily access.

Each region has a management plan or statement for each of its big game species. These plans create management objectives, summarize inventory and harvest information, establish monitoring schedules, and set management direction over a five to ten year period. Species-specific PMUs, with monitoring schedules, are identified in each of these plans, and BGMAs are established in higher priority PMUs.

Wildlife staff receive periodic training in new inventory methods and big game stock assessment techniques. Staff also use an integrated analysis system, such as **PopR**, to help them efficiently explore their harvest, inventory and monitoring data; and to run state-of-the-art statistical software to generate analyses and reports.

Trained wildlife staff apply adaptive management to improve big game management decisions and to learn from management outcomes. Sufficient and stable inventory budgets guarantee that population monitoring provides the information essential to do adaptive management. Climate change continues to affect big game populations in unpredictable ways, but using an adaptive management approach helps deal with these uncertainties.

7. Issue Analysis, Recommendations and Actions

The vision of what an ideal big game inventory and monitoring program would like is to *British Columbia achieves desired wildlife management outcomes through a structured, adaptive approach to management decisions facilitated by enhanced use of big game population inventory and monitoring.* This section gives an overview of the issues that impede realization of this vision, and provides key recommendations and actions to resolve these issues.

7.1 Issue Analysis

Discussions with the Big Game Population Inventory and Monitoring Working Group, along with personal knowledge based on work experience and the literature review, informed the identification of the following twelve issues that interfere with achieving the vision for an ideal big game inventory and monitoring program. The issues are: variable funding; lack of an approved big game inventory funding plan; out-dated inventory guidance; incomplete documentation of inventories; lack of designated PMUs; lack of designated BGMAs; lack of regional big game species management plans; lack of integrated data systems; inadequate big game harvest data system; insufficient understanding and/or application of new wildlife techniques; limited application of adaptive management approaches; and unrealized opportunities to leverage investment.

Issue #1: Variable funding. Sufficient funds are required for staff to acquire the optimum level of inventory information (See Figure 4 on Value of Information) necessary to inform big game management decisions (Archibald et al. 2014). Big-game inventory and monitoring budgets within the B.C. Government vary annually. Previously, most inventory funds came from special funding initiatives (e.g. CRII, CLIB, FIA) that had specific objectives not directly related to big game management objectives. Governments only maintain special funding initiatives for a set period of time.

Issue #2: Lack of approved big game inventory funding plan. The BGIF 5-year plan outlines a transparent, repeatable and objective approach for prioritizing big game inventories for funding through the LBIS. As of March 2016, this report has not been approved by the DRM committee or Government Executive, and thus has not been officially implemented.

Issue #3: Outdated inventory guidance. Most RISC inventory manuals have not been updated since 2002 and many require revisions to incorporate new inventory methods. For example, 'Inventory Methods for Wolves and Cougar, (Version 2.0)' does not include cutting edge techniques such as spatial DNA mark-recapture. The 'Aerial Based Inventory Methods for Selected Ungulates (Version 2.0)' also needs updating to include innovative inventory methods where current environmental conditions (e.g. lack of snow, warm temperatures) have made existing RISC aerial inventory standards unsuitable.

Issue #4: Incomplete documentation of completed inventories. Lack of staff capacity prevents officially reporting many completed RISC inventories, including entering data and summary reports into the SPI data system. This compromises the use of inventory information to evaluate objectives, inform management decisions, and meet the needs of clients (i.e. First Nations, other government agencies, traditional stakeholders, and the public). Currently, there is no tracking system to document completed inventories and identify future inventory priorities.

Issue #5: Lack of designated PMUs. The fundamental unit for setting objectives for and managing big game populations is the PMU. As of March 2016, only some big game species in B.C. (e.g. Roosevelt elk, grizzly bear, and wolverine) have had PMUs defined. Lack of designated PMUs impedes setting management objectives at the population level.

Issue #6: Lack of designated BGMAs. Only a few BGMAs have been established. Consequently, wildlife biologists monitor very few big game populations in B.C. Monitoring within designated BGMAs enables biologists to determine if wildlife population objectives have been met within PMUs.

Issue #7: Lack of regional big game species management plans. Regional species management plans and management statements establish management objectives, summarize inventory and harvest information, establish monitoring schedules, and set management direction. Yet few of these important guidance documents exist as of March 2016.

Issue #8: Lack of integrated data systems. B.C.'s big game data systems are not integrated. Two discrete systems exist, one for big game inventories (SPI), and another for big game harvest. Wildlife staff find it difficult and time consuming to extract the information they need from these two source to conduct big game stock assessments. Other jurisdictions benefit from having integrated data systems. The University of Montana in collaboration with Idaho Fish and Game and South Dakota Game, Fish and Parks has developed an integrated analysis system called PopR to help wildlife agencies explore their harvest, inventory and monitoring data; and to run analyses and generate reports (see http://popr.cfc.umt.edu/).

Issue #9: Inadequate big game harvest data system. Wildlife staff use annual harvest statistics such as hunter effort and hunter success to interpret big game population trends and provide auxiliary information for stock assessments. Concerns with B.C.'s big game harvest data system include difficulties in: acquiring accurate and precise estimates of harvest and effort at various spatial scales; timely reporting of harvest statistics to update stock assessments and inform hunting regulations; and documenting all sources of human-caused mortality, including harvest by First Nations.

Issue #10: Insufficient understanding and/or application of new wildlife techniques. Wildlife staff must maintain knowledge of and skill in applying new inventory and population modelling techniques as these develop. Insufficient understanding of new techniques impedes wildlife staff from applying the best available science to inform big game management decisions.

Issue #11: Limited application of adaptive management approaches. ARM, with a strong focus on monitoring, offers the best approach for dealing with uncertainties in natural resource management like the effects of climate change and hunting on big game populations. Yet wildlife staff apply ARM on a limited basis as they lack the mandate and resources to conduct big game monitoring to adjust management actions. Wildlife staff may also lack sufficient technical knowledge to apply ARM.

Issue #12: Unrealized opportunities to leverage investments. The B.C. Government no longer has the capacity to rely solely upon internal professionals for its resource inventory and monitoring needs (Morris 2015). Great potential exists to increase big game monitoring activities with minimal additional cost through effective engagement of First Nations, other government agencies, stakeholders, and the public. Investing in new technology, such as the use of smartphones to record hunter observations of big game, also offers opportunities to obtain additional data relevant to population monitoring.

7.2 Key Recommendations and Actions

Key recommendations to address the concerns raised in the issues analysis and to achieve this report's vision include: increase funding to support big game inventory and monitoring, dedicate resources to support RISC inventory and monitoring, address gaps in PMUs, BGMAs and regional management plans for big game species, build a data system to integrate harvest and inventory data by PMU, invest in staff training for big game inventory and monitoring, and foster collaborative big game monitoring. Specific actions to implement these recommendations appear under each key recommendation below.

The key recommendations and corresponding actions address all issues identified in Section 7.1 of this report. The detailed analysis appears in Appendix J. Table J3 in this appendix identifies how each of the key recommendations and actions relates to the issues, and Table J4 shows how each issue is addressed by a specific recommendation and corresponding action.

Recommendation #1: Optimize funding levels to support big game inventory and monitoring.

Action #1.1: Ensure a dedicated long-term funding budget for big game inventory and monitoring that meets information needs for management.

Action #1.2: Formally approve the *Big Game Inventory Fund 5-year Plan*.

Recommendation #2: Dedicate resources to support RISC inventory and monitoring activities.

Action #2.1: Create a Big Game Inventory and Monitoring Unit within FLNRO to perform the following functions.

a) update RISC population inventory and monitoring standards (also see recommendations in Species Monitoring Statements and the summary table J1 in Appendix J).
b) assist wildlife biologists with project and data management in order to ensure all big game inventories are conducted to RISC standards and inventory results are being entered in SPI.
c) review the RISC inventory submission process to assess whether big game inventory data submission requirements to the SPI data system are being met.
d) review current mechanisms in retrieving species inventory information to assess whether the information meets client needs .

e) maintain a current provincial summary list of inventories for each big game species extending from 1980 to present (e.g. for moose SRB surveys, this list would include the BGMA, PMU, survey area size (km^2), the SCF used, moose/km^2, bulls:100 cows, calves: 100 cows, and contact source for more information).
f) produce annual summary reports of big game inventory and monitoring projects in B.C.
g) provide regional support for developing regional big game species management plans, conducting inventories, and assisting with big game stock assessments.

Recommendation #3: Address gaps in PMUs, BGMAs and regional management plans.

Action #3.1: Develop PMUs for all big game species in B.C.

Action #3.2: Develop BGMAs for high priority PMUs.

Action #3.3: Develop regional management plans or management statements for all big game species (see *Kootenay Elk Management Plan, 2010 to 2014* for an example at http://www.env.gov.bc.ca/kootenay/emp/ Kootenay%20elk%20management%20plan%202010-14%20(final).pdf). A regional species plan or statement should: establish PMUs for the big game species within the region; develop management objectives for all PMUs; and establish BGMAs and big game monitoring schedules within high priority PMUs.

Recommendation #4: Build a data system to integrate harvest and inventory data by PMU.

Action #4.1: Investigate the potential to incorporate PopR into B.C.'s hunting transformation project.

Action #4.2: Improve the functionality of B.C.'s big game harvest data system through the hunting transformation project.

Recommendation #5: Invest in staff training for big game inventory and modelling.

Action #5.1: Train wildlife staff in new inventory techniques as RISC standards are updated.

Action #5.2: Update the big game stock assessment manual to include Bayesian modelling and SPR, and distribute to wildlife staff.

Action #5.3: Hold periodic population modelling training workshops to train/re-train wildlife biologists in new big game stock assessment methods.

Action #5.4: Train wildlife staff on how to incorporate ARM into wildlife management decision-making to reduce key uncertainties.

Recommendation #6: Foster collaborative big game monitoring.

Action #6.1: Develop partnerships with First Nations, other government agencies, traditional stakeholders and citizen-science volunteers to collaborate on inventory and monitoring initiatives.

Action #6.2: Expand the use of smartphone technology to enable hunters to record their observations of big game (e.g. number of moose seen per hour hunting as an index of abundance, number of bulls and cows seen as an index of bull:cow ratios).

Action #6.3: Develop collaborative agreements with First Nations to enable annual reporting of their harvest.

7.3 Summary of Species-specific Recommendations

Several trends emerged from an analysis of the 78 species-specific recommendations gleaned from Section 5. Appendix J (tables J1 and J2) lists the species-specific recommendations and shows the detailed analysis of how these themes relate to key recommendations and actions. The following themes in species-specific recommendations informed development of the key recommendations and corresponding actions in this report.

- Most big game species still require designation of PMUs.
- With planning and training, citizen-science volunteers can collect valuable monitoring data for many of B.C.'s big game species.
- SPR holds promise for determining population size and trends of caribou, mountain goat, thinhorn sheep, grizzly bears and cougars over large areas of the province. To optimize use of this modelling method requires collecting adult survival rate data through radio-telemetry studies.
- Correcting for visibility bias through improved sightability models is important for a number of species including mule deer, Roosevelt elk, moose and bighorn sheep.
- RISC inventory standards need updating for many big game species including moose, mountain goat, wolf and cougar.
- Standardized winter severity indices need to be developed for big game species such as mule deer and white-tailed deer.
- More research is needed to evaluate CPUE as an index of abundance, which is commonly used to monitor population trends of black-tailed deer, mule deer and white-tailed deer.
- The moose survey app that is currently being developed in B.C. should be expanded to other species, and a large carnivore app may be particularly useful for determining relative abundance and trends for grizzly bears, black bears, wolves and cougars.
- As it is generally difficult and not cost effective to survey furbearers, a detailed annual trapper return survey should be developed in collaboration with the BCTA for wolves, lynx, bobcat, and wolverine.

7.4 Implementation Framework and Phasing

Figure 10 outlines an implementation framework for big game inventory and monitoring in B.C. These activities can be substantially enhanced by implementing the six key recommendations and corresponding actions, carrying out the species-specific monitoring recommendations, and following this report's inventory and monitoring principles. Enhanced big game population inventory and monitoring in turn will enable managers to incorporate a structured adaptive approach to decisions that achieves desired wildlife management outcomes.

Implementing the vision described in Section 6 involves three phases of implementation.

Phase One– a Big Game Inventory and Monitoring Unit is established to work collaboratively with headquarters and regional staff on big game inventory and monitoring activities. FLNRO develops an objective and structured approach to determine the funding requirements for a fully operational Big Game Inventory and Monitoring Program that will meet management needs.

Phase Two - a comprehensive annual provincial inventory and monitoring budget is developed and funding sources identified and secured.

Phase Three - on-the-ground implementation is underway for all six of the report's key recommendations and corresponding 12 actions and 78 species-specific recommendations. An integrated management system for automatic compiling, analyzing and reporting of population inventory and harvest data by PMU is implemented. Collaborative big game monitoring projects with First Nations, other government agencies, stakeholders, and citizen-science volunteers are underway.

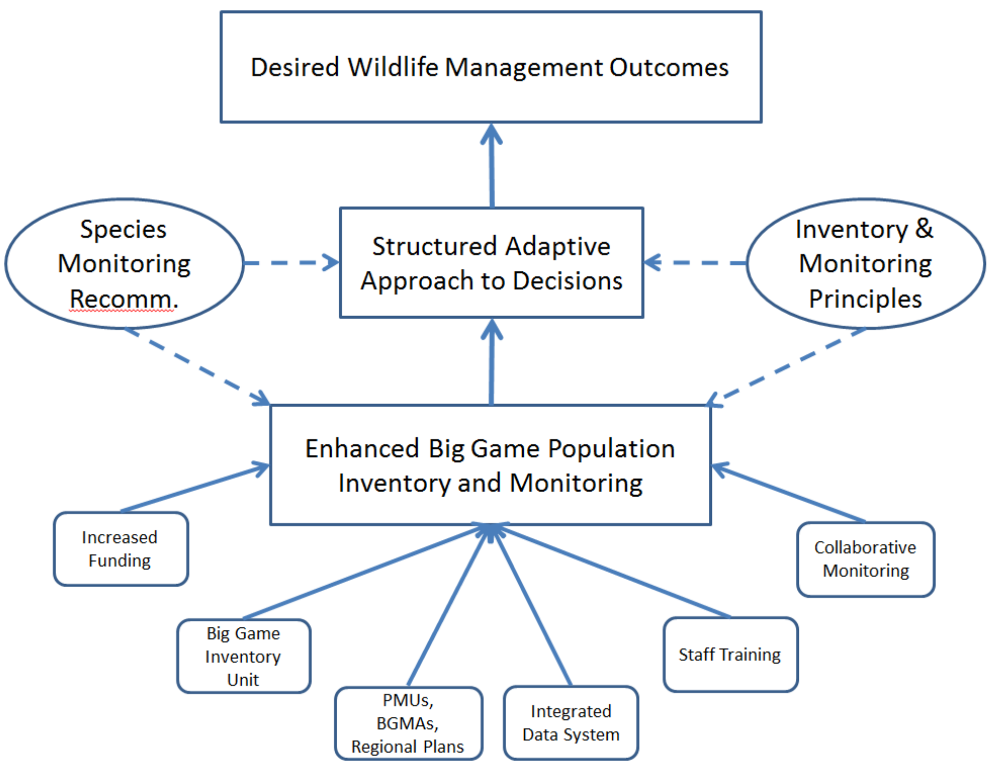


FIGURE 10. Implementation framework for Strategic Big Game Inventory and Monitoring Strategy vision.

8. Glossary of Terms

Terms listed here appear in **boldface** the first time they are used in the main text of this report.

Absolute abundance – the total number of animals in an area, usually reported as absolute density; i.e. the number of animals per unit area.

Accuracy – how closely a sample-based estimate represents the true population.

Additive mortality – where a given mortality factor (e.g. harvest, predation) causes an immediate reduction in total survival of a wildlife population.

Adaptive Harvest Management (AHM) – application of adaptive resource management to the objective of sustainable harvest.

Adult survival rate – the survival rate of yearling and older animals, usually over one year.

Adaptive Resource Management (ARM) – management involving an explicit objective, model-based predictions under two or more alternative models, a method for making an optimal decision considering the objective and model predictions and weights, and a monitoring program to update model weights for inclusion in future decision making.

Annual Allowable Harvest (AAH) – the number of animals that are allowed to be killed by resident hunters and guided hunters each year.

Bayesian Belief Network (BBN) – a probabilistic network model consisting of uncertainty or chance nodes, connected by direct arcs that represent causality.

Bayes' Rule – a technique to propagate structural uncertainty through time, the technique combines measures of uncertainty at each point in time with data from post-decision monitoring to produce new measures for the next time.

Bias – a systematic difference between a sample-based estimate and true value, also termed sample bias.

Big game – includes any mountain sheep, mountain goat, bison, caribou, elk, moose, deer, grizzly bear, American black bear, cougar, wolf, bobcat, Canada lynx, wolverine or other animal designated by regulation under the B.C. *Wildlife Act*.

Big game harvest management policies and procedures – policies and procedures are designed to provide guidance to statutory decision makers when exercising their decision-making authority, and to provide staff with direction on how to proceed when carrying out specific duties related to their position functions (see http://www.env.gov.bc.ca/fw/wildlife/policy_procedures).

Big game inventory – a survey that documents one or more population parameters at one point in time. The population parameters may include (1) absolute or relative population abundance, (2) sex and age composition and recruitment, and (3) spatial distribution. As an inventory is focussed on a “snapshot” in time, it generally is insufficient to determine trends in population parameters or the causation of trends.

Big game management – a sub-set of wildlife management focused on the objective of producing harvestable populations of big game species and managing the harvest of these species.

Big game management plan – a document that reviews the status of a big game species, sets goals and objectives, and recommends approaches appropriate for species conservation and management. Management plans are more detailed documents than management statements and include public review and comment.

Big game management statement – similar to a management plan but with less detail. Management statements may not include public consultation, as they are primarily intended for internal use.

Big game monitoring – an inventory (survey) repeated through time to determine changes or trends in population parameters. There are two types, surveillance monitoring and targeted monitoring.

Big game monitoring area (BGMA) – a survey area within a population management unit that is re-surveyed over time.

Big game status report – a document that reviews the status of a big game species.

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

Category A species – a big game species, population, or class allotted through the *Harvest Allocation Policy*.

Citizen- science volunteers – volunteers who collect and/or process data as part of a scientific inquiry. This may include hunters, trappers, guide-outfitters, naturalists, other organizations and individuals.

Collaborative monitoring – where government biologists work with First Nations, other government agencies, traditional stakeholders and/or citizen-science volunteers to monitor big game populations.

Compensatory mortality – where a given mortality factor (e.g. harvest, predation) does not reduce total survival of a wildlife population until it reaches some threshold value.

Compulsory inspection – a requirement for specific game species under the B.C. hunting regulations in which a hunter who takes or kills a specific game species must be submit the animal, or parts of the animal, in person to a compulsory inspection center for the purposes of taking both hunting and biological information.

Compulsory reporting – a requirement for specific game species under the BC Hunting regulations in which a hunter who takes or kills a specific game species must report specific hunting and biological information either by mail, email, fax or phone.

Conservation – management of wildlife so that it may yield the greatest sustainable benefit to present and future generations while protecting natural biodiversity.

Designatable units – species, subspecies, varieties, or geographically or genetically distinct populations that may be assessed by COSEWIC, where such units are both discrete and evolutionarily significant (see http://www.cosewic.gc.ca/eng/sct2/sct2_5_e.cfm).

Desired wildlife management outcomes – outcomes from wildlife management actions that achieve fundamental objectives, e.g. mule deer populations with healthy buck:doe ratios and hunting opportunities that satisfy the harvest needs of hunters; healthy wolverine populations that satisfy the needs of First Nations, stakeholders and the public..

Detection probability – probability that an animal that is present in a survey area or sampling unit is detected by the observer.

Expected Value of Perfect Information (EVPI) – average value to decision making gained from reducing uncertainty in the absence of other uncertainty, .

Fundamental objectives – objectives that relate to the core (fundamental) values of a decision maker or stakeholder.

Game management zone (GMZ) – the default PMU, where big game species-specific PMUs have not been established.

Healthy – refers to the demographic "health" of a wildlife population as measured by population size, sex/age composition, recruitment rate, and juvenile and adult survival rates.

Hyperdepletion – where CPUE drops much faster as population abundance drops. In this case the population appears to be depleted, yet abundance has not dropped as much as CPUE. This may occur where there is a small but highly vulnerable subset of animals in the population that is depleted by hunting, leaving behind a much less vulnerable, but still abundant population component.

Hyperstability – where CPUE stays high as population abundance drops. It can be expected to occur where searching by hunters is highly efficient so that most effort concentrates on areas where animals are most abundant, and animals remain concentrated as abundance drops.

Hunter opportunity – the ability to hunt as enabled through regulation, often measured as hunter days.

Integrated Population Modelling (IPM) – a modelling approach that provides a unified analysis of population inventory, harvest and demographic data.

Juvenile survival rate – the survival rate of juveniles from birth to 12 months of age. The juvenile survival rate is often subdivided into a summer survival rate (birth to six months of age) and a winter survival rate (six months to 12 months of age).

Management actions – actions designed to affect desired outcomes in order to achieve fundamental objectives.

Management objectives – specific outcomes or performance measures that guide decision-making and are used to evaluate the success of management actions. Two types are identified, fundamental objectives and means objectives.

Maximum Sustained Yield (MSY) – the largest number of animals that may be taken from a population each year over an indefinite period of time.

Means objectives – objectives that are intended to contribute to the fulfillment of one or fundamental objectives, but do not in themselves represent fundamental objectives.

Metapopulation – a biological unit consisting of two or more subpopulations that occasionally share individuals through dispersal (immigration or emigration). See also population.

Non-detriment finding (NDF) – used by CITES in which a scientific review has determined that the international trade in a species does not pose a risk to that species.

Occupancy – condition or probability that a site within a study area is occupied by the species being surveyed. May also be referred to as present-absence or present-not detected.

Performance measure – specific outcomes that guide decision-making and are used to evaluate the success of management actions.

PopR – a server-based software system which merges wildlife management agency databases with state-of-the-art statistical software for real-time wildlife data analysis, population modelling and reporting.

Populations – a biological unit where it is meaningful to speak of a birth rate, a death rate, a sex ratio and an age structure in describing the properties of the unit. A local population or subpopulation is a group of intermixing animals with a discrete boundary, having little contact with other such groups.

Population Management Units (PMUs) – geographic areas that represent the year-round range of a big game population, including all seasonal ranges. A PMU should be delineated to minimize interchange (emigration and immigration) with other populations. A PMU is usually composed of several wildlife management units (WMUs), but in some cases only one WMU may make up a PMU.

Population modelling – the modelling of population using mathematical and/or statistical tools to analyze past, current and future trends in a wildlife population.

Population parameters – Parameters that describe the status of population such as absolute or relative abundance, sex and age composition, recruitment and survival rates, and spatial distribution.

Precautionary approach – a strategy to cope with possible risks where scientific understanding is yet incomplete. The International Union for the Conservation of Nature (IUCN) provides guidelines for the use of the precautionary principle to biodiversity conservation and natural resource management - http://cmsdata.iucn.org/downloads/ln250507_ppguidelines.pdf.

Precision – variability associated with an estimate (i.e., how much estimates deviate from true values). Confidence intervals are a common way of expressing the precision of an estimate.

Recruitment rate – the proportion of juveniles in the population, e.g. juveniles/(juveniles + adults) or female juveniles/(female juveniles + adult females). The recruitment rate is generally measured when juveniles are either six months or 12 months of age.

Relative abundance – the number of animals at one location or time relative to the number of animals at another location or time. Generally reported as an index of abundance.

Resources Information Standards Committee (RISC) – a BC Government multi-agency committee that is responsible for establishing standards for natural and cultural resources inventories, including collection, storage, analysis, interpretation and reporting of inventory data.

Sex/Age Composition – the sex and age composition of a big game population that can be determined through inventory, e.g. the sex/age composition of a moose population includes adult bulls, yearling bulls, cows and calves.

Sightability – the probability that an animal within an observer's field of view will be detected by that observer on a survey.

Sightability Correction Factor (SCF) – a correction factor that is applied to survey results in order to adjust the population size and sex/age composition for animals that were missed due to visibility bias.

Sightability model – probability functions built from empirical data (typically aerial surveys) that provide an estimated probability of detection of an animal within the observer's field of view for any combination of environmental covariates included in a model. Covariates typically include group size, behaviour (activity), snow cover, and vegetation cover. Sightability correction factors are usually developed based on detectability of a radio-marked animal.

Species Inventory data system (SPI) – the provincial data system that stores wildlife species inventory information (see http://www.env.gov.bc.ca/wildlife/wsi/spidatasystem.htm, http://www.env.gov.bc.ca/wildlife/wsi/index.htm)

Statistical population reconstruction (SPR) – a statistical method for estimating the demographics of harvested wildlife populations over large geographic areas using age-at-harvest and hunter effort data, often supplemented with auxiliary data including population size and non-hunting survival rates.

Statistical power – the likelihood that a study will detect an effect when there is an effect there to be detected. Statistical power is high, the probability of making a Type II error, or concluding there is no effect when, in fact, there is one, goes down

Structured decision making (SDM) – a framework for making explicit, transparent and defensible choices by the systematic deconstruction and analysis of decision problems through which objectives, facts, values, uncertainties and decision alternatives are explicitly defined, connected, analyzed and evaluated via a model.

Surveillance monitoring – an approach to monitoring that documents the change in one or more population parameters over time.

Survey – see Big game inventory.

Sustainable harvest – the number of harvested animals that when removed from a population result in the population being maintained at a stable equilibrium. This is also known as a sustainable yield.

Sustainable use – the use of wildlife resources at a rate that will meet the needs of the present without impairing the ability of future generations to meet their needs.

Targeted monitoring – an approach to monitoring that documents how big game populations respond to specific management actions or environmental stressors.

Utilities – a modelling term used in decision analysis that expresses a relative score or value, which in turn is often a measure of stakeholder satisfaction in an outcome. The decision alternative from two or more models that has the highest expected utility is interpreted as the optimal decision.

Value of information – the value, as measured in objective function units, of reducing uncertainty in decision making.

Visibility bias – Failure to observe all animals present (in a sampled area) during a survey. This is also called sightability bias.

Wildlife - The British Columbia *Wildlife Act* defines wildlife as all native and some non-native amphibians, reptiles, birds, mammals that live in B.C. For some provisions of the Act, the definition includes fish, and other B.C. legislation defines some insects and plants as wildlife.

Wildlife management – the management of wildlife populations and their habitats. It includes the conservation of species and subspecies and their habitats, mitigation of human-wildlife conflicts, and management of game species for sustainable use. Wildlife management embraces the human dimensions of wildlife and implies stewardship.

Wildlife Practitioners – includes resident hunters, BC Guide outfitters, BC trappers, BC Wildlife Federation, wildlife viewing industry, and First Nations (Morris 2015).

Wildlife use – includes hunting, trapping, guide outfitting, First Nations uses, aviculture, falconry, and viewing, as well as other human recreational activities that disturb wildlife. Some forms of wildlife use, such as hunting and trapping, can be used to manage wildlife-human conflict (e.g. liberal deer hunting seasons to reduce grazing pressure on agricultural lands). Wildlife use includes consumptive and non-consumptive use of wildlife, including commercial and non-commercial uses.

Winter Severity Index (WSI) – an index of winter severity, generally obtained from weather station data on temperature and/or snowfall that can be used to infer big game population trends and/or causes of population fluctuations.

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APPENDIX A: An AHM approach to determine optimal harvest rates using monitoring data

The optimal sustainable harvest rate for mountain goats has and continues to be debated among biologists and stakeholders in B.C. The *Mountain Goat Harvest Management Procedure* recommends that the harvest rate should not exceed three per cent of the estimated population size (FLNRO 2014b). Hebert and Turnbull (1977) suggested that harvest of coastal herds in B.C. should not exceed four per cent of the total population, while Adams and Bailey (1982) concluded that a yearly seven per cent harvest was sustainable in an introduced herd in Colorado. Côté and Festa Bianchet (2003) cautioned that native mountain goat populations may be unable to sustain a yearly harvest greater than two to three per cent. Central to this debate are different models of understanding regarding the strength of density dependence in mountain goat reproduction and survival, and thus whether or not hunting is largely a source of **additive mortality** or **compensatory mortality**. An adaptive harvest management (AHM) approach that incorporates objectives, decision alternatives, two or models to evaluate decision alternatives, comparison of model predictions to monitoring, and includes feedback via Bayes' Theorem for revising model weights, holds considerable promise for helping to resolve this debate (Conroy and Peterson 2013).

The purpose here is to illustrate how AHM could be applied for determining optimal mountain goat harvest rates of a hypothetical mountain goat population from periodic resurveys using a similar approach to that outlined by Conroy et al. (2008). Interested readers should review their paper for more details. Ideally, AHM should be part of a structured decision making (SDM) process. The process of stakeholder engagement, although important, is not covered here; and the models and analysis presented below are greatly simplified. An actual application of AHM would incorporate SDM to formulate the problem statement and objectives, would utilize more complex (realistic) models of mountain goat population growth, and include stakeholder participation.

Decision alternatives

Four decision alternatives are considered, each representing a different harvest rate, i.e. two, three, four or five per cent of a mountain goat population.

Objective value (utility)

Utilities provide relative scores or values (measure of satisfaction) of different decision outcomes by stakeholders (Conroy and Peterson 2013). Utilities should be identified for each stakeholder group, depending on their fundamental objectives. To the extent possible, a common set of utilities that satisfies the fundamental objectives of all stakeholders should be identified (Conroy et al. 2008).

Modelling decision outcomes

Two or more models are required to evaluate the decision alternatives in AHM. The models described here are used to determine the probability that a single population of mountain goats will decrease, stabilize, or increase over a five year period under different harvest rates. Model 1 assumes delayed density dependent logistic growth, while Model 2 assumes density independence with population growth limited by periodic severe winters. These models are highly simplified abstractions of real mountain goat population dynamics and are presented for illustrative purposes only.

$$\text{Model 1:} \quad N_{t+1} = N_t + r_m N_t \cdot \left(1 - (\tfrac{N_t}{K})^{\theta}\right) - H_t$$

$$\text{Model 2:} \quad N_{t+1} = N_t + rN_t - H_t$$

In Model 1, r_m = 0.050 with the density dependent exponent Θ = 5.04 and K = 200. MSY under this model occurs at 70% of *K* carrying capacity. In both Models 1 and 2 the starting population size was set at 140 (i.e. the initial assumed survey estimate) with r = 0.042, although in Model 1, r varies with changes in density. Each model was made stochastic by assuming that r was a random normal parameter with a coefficient of variation (CV) = 0.25, the population inventories have a survey CV = 0.20, and the error in achieving the desired harvest occurs with CV = 0.25. Both models were simulated over a five year harvest period.

A Monte Carlo analysis was performed for each decision alternative (i.e. harvest rate) by conducting 10,000 replicates of each five year simulation to generate probability distributions of population status, as measured by the finite rate of change (λ). Status was categorized as either high decrease (λ < 0.97), low decrease (0.97 ≥ λ < 0.99), stable (0.99 ≥ λ < 1.01), low increase (1.01 ≥ λ < 1.03) or high increase (λ ≥ 1.03). For each replicate, λ was estimated from the slope (*b*) of a log-linear regression of population size (*N*) over the 5-year time period, i.e. $\lambda = e^b$. For Model 2, a severe winter was randomly generated once every five years, which resulted in negative population growth for that year.

Selecting the optimal decision

The utilities (Table A1) and model-specific probabilities of population status (Table A2) were used to compute expected values for each decision alternative and to select an optimal decision, under a range of prior model weights. The utilities were guess-estimates and may not be representative of stakeholder utilities.

TABLE A1. Decision alternatives, outcomes and utilities for the hypothetical mountain goat harvest decision problem

Harvest Rate alternative	Utility of Outcome				
	High Decrease	Low Decrease	Stable	Low Increase	High Increase
5%	0.025	0.40	0.60	1.00	0.80
4%	0.012	0.20	0.50	0.75	0.60
3%	0.010	0.10	0.40	0.60	0.50
2%	0.00	0.05	0.30	0.50	0.40

TABLE A2. Decision outcome probabilities for the hypothetical mountain goat harvest decision problem from population simulation of each model

Model	Harvest Rate	% Probability of Outcome				
		High Decrease	Low Decrease	Stable	Low Increase	High Increase
Model 1: Density Dependence	5%	5.6	41.6	45.3	7.3	0.2
	4%	0.1	12.9	66.5	20.2	0.3
	3%	0.0	0.4	44.1	54.6	0.9
	2%	0.0	0.0	3.7	90.8	5.5
Model 2: Density Independence & winter severity	5%	35.3	43.3	18.9	2.4	0.1
	4%	10.8	45.2	37.8	6.0	0.2
	3%	1.0	22.7	57.7	18.0	0.6
	2%	0.0	3.6	48.3	45.2	2.9

The calculation of expected utilities and optimal decisions were performed using Netica (https://www.norsys.com/), a graphically orientated program for the analysis of **Bayesian Belief Network**s (BBN). Figure A1 shows the BBN used to illustrate the decision problem. Table A3 shows the expected utilities and optimal decisions that were calculated by the BBN. With each model having equal weight (50:50), the three per cent harvest rate was the optimal decision (highest expected utility = 0.437). The BBN showed there was a 40% chance that the population would be stable, a 28% chance of decrease and a 32% chance of increase.

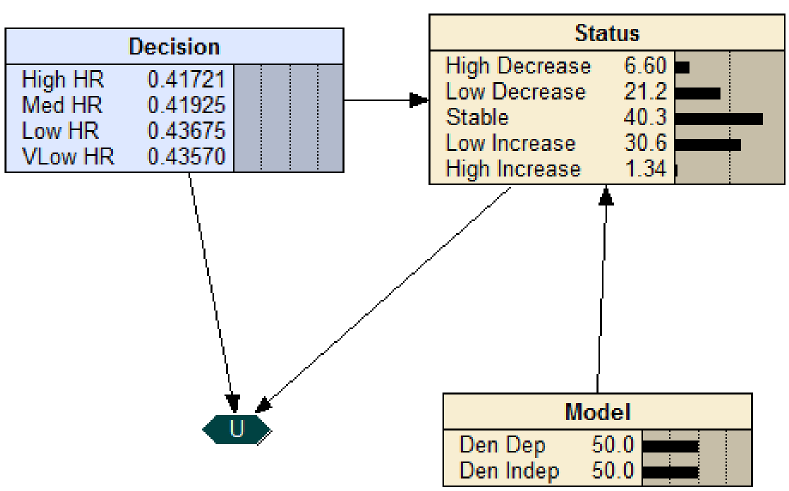


FIGURE A1. Bayesian belief network used to illustrate the hypothetical mountain goat decision problem (High HR refers to 5%, Med HR to 4%, Low HR to 3% and VLow HR to 2%, Den Dep refers to the density dependent model and Den Indep to the density independent model)

TABLE A3. Expected utilities and optimal decisions for the hypothetical mountain goat harvest rate decision problem (bolded utilities represent optimal decisions under model weights)

Model weight		Decision Alternative	Expected Utility
Model 1 (Den Dep)	Model 2 (Den Indep)		
1.00	0.00	5%	0.320
		4%	0.327
		3%	0.365
		2%	**0.384**
0.50	0.50	5%	0.417
		4%	0.419
		3%	**0.437**
		2%	0.436
0.00	1.00	5%	**0.514**
		4%	0.512
		3%	0.509
		2%	0.487

The expected utilities can also be used to calculate the Expected Value of Perfect Information (EVPI). Under Model 1, the highest utility is 0.384, while under Model 2, the highest utility is 0.514. The average of these is 0.449. The optimal decision under uncertainty (50:50 probability weighting to each model) is 0.437, so EVPI = 0.449 - 0.437 = 0.012. This is the amount, in utility units, that would be gained by reducing structural uncertainty to zero. In this case, EVPI suggests there would be a marginal gain by determining which model was correct.

Reducing Uncertainty

By conducting an initial survey and then re-surveying at the end of each five year period one can determine the true population status under a decision alternative, and thus update beliefs about the model weights. Suppose the optimal decision was implemented under the weights of 0.5 for each model (Figure A1). At the end of year five a re-survey is done and finds that the population had a low rate of increase. Based on Bayes' Theorem, the model weights now change to 75% in favour of the density dependent model, and 25% for the density independent model (Figure A2).

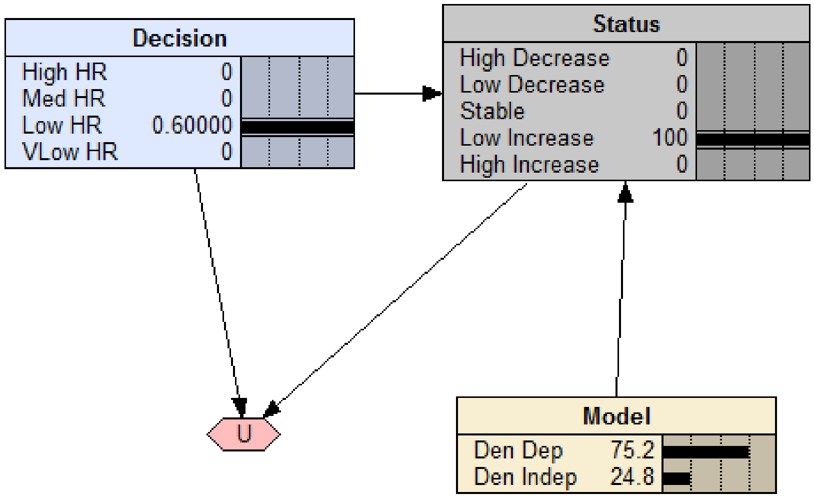


FIGURE A2. Hypothetical scenario with adaptive updating where the selection of the 'low harvest rate' alternative (3%) is assumed to result in a low rate of population increase resulting in new model weights of 75% for density dependence and 25% for density independence

These weights could then re-applied to the next five-year allocation period. The optimal decision is once again selected and implemented, and the population is surveyed again at the end of the period. Suppose this time the resurvey indicates that the population is stable (Figure A3). Bayes' Theorem is again applied to update the model probabilities, which in this case change only slightly (70% and 30%). The optimal decision (3% harvest rate) is once again implemented for the next five year period. At this point there may no longer be a need to continue as two successive resurveys have confirmed that the three per cent harvest rate option is optimal, with stronger evidence for density dependent population growth.

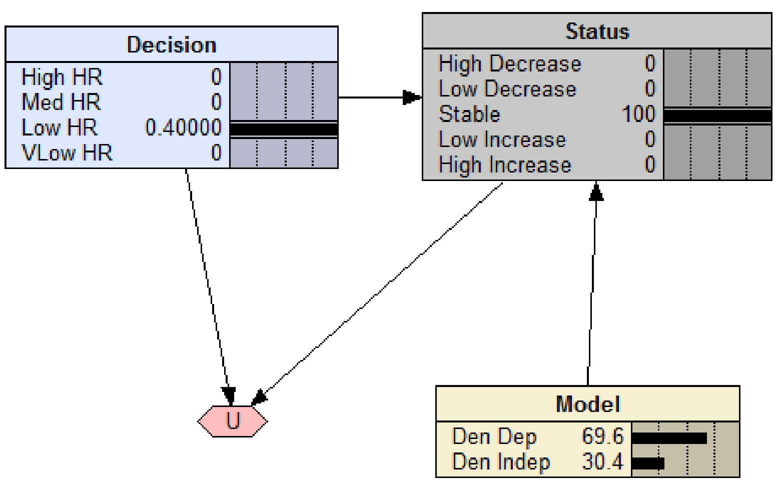


FIGURE A3. Hypothetical scenario with another round of adaptive updating, in which selection of the 'low harvest rate' alternative (3%) is assumed to result in a stable population

APPENDIX B: Template for tracking inventories within big game monitoring areas of B.C.

To ensure the highest priorities for monitoring receive funding, it is important to have a tracking system for documenting completed big game inventories and for identifying future inventory priorities. Table B1 provides a hypothetical example of a monitoring schedule for tracking inventories in a fictitious region where PMUs and BGMAs have been established.

Provincial prioritization of big game inventories for upcoming fiscal funding would be enhanced if each region had a similar tracking schedule of its big game monitoring requirements. The tracking list would highlight immediate big game inventory needs as well as those that are overdue for monitoring. Such a list would also prove very valuable to quickly assist funding decisions for utilizing unspent end-of-fiscal year funds that might become available for big game inventory.

Table B1. An example of a monitoring schedule for tracking moose inventories in Region "99"

Regional Priority[1]	PMU[2]	BGMA[3]	Monitoring Parameter[4]	Last Year Monitored[5]	Re-survey Schedule[6]	Monitoring Due[7]
1	GMZ 99a	BGMA99_1	AS, JS	2013	1/1 yr	2015
2	GMZ 99b	BGMA99_5	SA	2010	1/2 yr	2014
3	GMZ 99c	BGMA99_14	AA	2010	1/10 yr	2018
4	GMZ 99d	BGMA99_9	AA, SA	2011	1/5 yr	2016

[1] Monitoring areas should be identified by regional priority with 1 being the highest regional priority
[2] Population Management Unit – indicate the PMU where the BGMA is located
[3] Big Game Monitoring Area – the BGMA should be cross-referenced to a GIS shapefile of the survey area where the monitoring is being conducted.

[4] Monitoring parameters include AA = absolute abundance, RA = relative abundance, SA = sex/age composition, AS = adult survival, JS = juvenile survival
[5] Indicate last year surveyed
[6] Resurvey schedule may be annual (1/1 yr), bi-annual (1/2 yr), tri-annual (1/3 yr), once every five years (1/5 yr), or once every 10 years (1/10 yr)
[7] Monitoring Due date (re-survey year):
(green) resurvey is due within the current fiscal year
(yellow) resurvey is overdue by one year
(red) survey is overdue by two or more years

APPENDIX C: Assessing and monitoring performance measures of management objectives

The following addendum from the *Interior Mule Deer Management Procedure* (FLNRO 2014a), although specific to mule deer, could be adapted to other big game species.

“Prior to Proposing a Regulation Change:

Population management units for mule deer in the southern interior should have one or more performance measures that are used to determine if management objectives are being met (e.g. maintain buck:doe ratios). It is important to note that these performance measures are meant to be used as general guidance and should not be used as a precise threshold for immediate initiation of a regulation change. This is because of the general problems associated with assessing populations (e.g. unfavourable weather conditions or observer bias when conducting aerial surveys).

It is recommended that multiple lines of evidence be examined that could indicate performance measures are not being met. These include:

a) successive population surveys (i.e. repeat surveys over a year or number of years);
b) a big game stock assessment (analysis of population and hunter harvest information); and
c) reliable field observations from a variety of sources.

The best spatial area to use to assess a management concern is the PMU. There may be circumstances where the performance measure is not being met in a portion of a PMU. In these situations, options should be examined for adjusting harvest regimes in the affected area only so as not to reduce hunting opportunities throughout the entire PMU. Where this occurs, the management focus should be recovery within the affected area, so as to restore consistent regulations throughout the PMU.

Monitoring the Regulation Change:

To evaluate if the regulation change has had the desired population effect (e.g. recovery above management threshold limits), a big game stock assessment should be conducted three to five years after the regulation change has been implemented in order to provide adequate time for the desired change in the population to occur. Normally, the stock assessment would include a minimum of one population survey in addition to the analysis of hunter harvest information.”

APPENDIX D: Extrapolating inventory results from monitoring areas to PMUs

In most cases Big Game Monitoring Areas (BGMAs) will not include an entire Population Management Unit (PMU) and thus it will be necessary to extrapolate the survey results from BGMAs to the PMU. Gasaway et al. (1986:84) discuss using the stratification process from stratified random block surveys of moose to extrapolate survey results from the survey area to adjacent areas. They note that if habitat and snow conditions are similar in both areas, a rough estimate of moose abundance can be made by applying the respective estimated strata densities from the surveyed area to the newly stratified area. While this is the preferred method, there may not always be available adequate survey budgets to do this.

Another approach that is less costly but more subjective comes from the addendum "Game Management Zone 5B Alternative Harvest Strategy Review: Frequently Asked Questions." While applied to moose monitoring areas, the concept also works for other big game species: http://www.env.gov.bc.ca/fw/wildlife/managementissues/docs/FAQ_gmz5b_alternative_harv_strat_review.pdf

"2008 GMZ 5B moose population estimate of 6727

The 2008 GMZ 5B moose population estimated was calculated using the 2006 5-02B Stratified Random Block (SRB) survey and both the 2001 5-02A and 5-02C SRB surveys. The unadjusted moose estimates from all surveys were summed, and a Sightability Correction Factor (SCF) of 1.44 was then applied to account for the estimate of moose missed during the surveys. The applied SCF was calculated as a weighted average of the survey specific SCFs utilized in the three SRB surveys incorporated into the population estimate (see page six of the report for a more detailed explanation of how a SCF is calculated). The total estimate of moose in the surveyed areas was then extrapolated to the total estimated suitable moose habitat area in the GMZ (14,769km^2). Suitable moose habitat was defined as all area excluding: glaciers, rocks, ice, large lakes, grasslands, and major centers (Williams Lake, Quesnel, and 100 Mile House).

In order to conduct the population projections under the various harvest strategies, it was also necessary to develop an estimate of the precision ("coefficient of variation" or CV) for the population estimate. Because of the extrapolation method used to calculate the 2008 GMZ 5B population estimate, there was no statistical method for determining the CV. Rather, we used a series of expansion factors to increase the CV from the original survey results. These included increasing the survey CV by 50% to account for the application of the SCF, then doubling the CV to account for the extrapolation from the surveyed area to the GMZ. This resulted in a 2008 GMZ 5B population estimate of 6727 moose with a CV of ±39%.

The 2008 GMZ 5B estimated bull/cow and calf/cow ratios, 40/100 and 42/100 respectively, were calculated from the estimated bull/cow and calf/cow ratios calculated from the three SRB surveys used in the population estimate, along with two 2007 composition surveys conducted in the MU subzones not covered by the SRB surveys (5-01 and 5-02D). The ratios from the surveys were averaged, giving equal weight to the SRB survey estimates and the more recent composition survey estimates."

APPENDIX E: A primer on applying CPUE and its use as a population index

Catch per unit effort (CPUE), i.e. kills per hunter day, is one source of information that is often readily available for big game species and is often used an index of abundance (Skalski et al. 2005). Although several studies have shown that CPUE provides a useful index of abundance (e.g. Crête et al. 1981, Fryxell et al. 1988, Fryxell et al. 1991, Roseberry and Woolf 1991), this outcome has not always been the case (Crichton 1993, Bowyer et al. 1999). CPUE is typically calculated using the following ratio

$$CPUE_t = 100 \cdot \frac{K_t}{D_t}$$

where C_t is the total harvest in year t and D_t is the total effort in days. The simplest model of the relationship between CPUE and abundance is linear proportionality, i.e.

$$CPUE_t = qN_t \quad \text{(Model 1)}$$

where q is the catchability coefficient and N_t is the population density or abundance. Model 1 is a subset of the form:

$$CPUE_t = \alpha N_t^{\beta} \quad \text{(Model 2)}$$

where α is the standardized coefficient of catchability and β is the catchability exponent (Hilborn and Walters 1992). Model 2 recognizes three possible relationships may exist between CPUE and abundance depending upon the value of β (Figure E1).

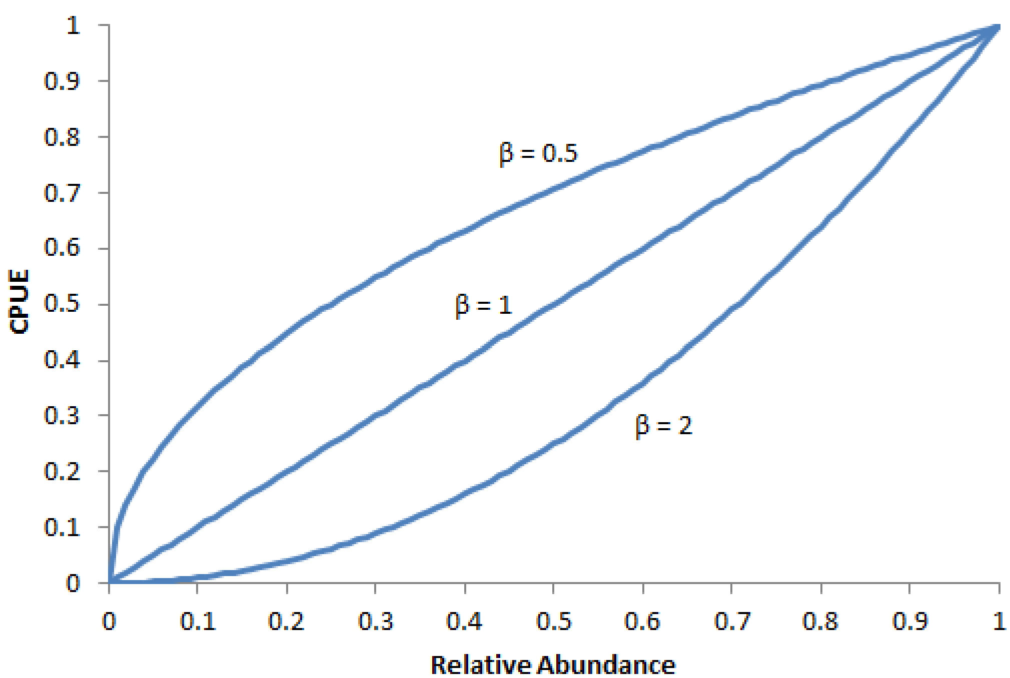


FIGURE E1. Three possible relationships between abundance and CPUE including hyperstability (β = 0.5), proportionality (β = 1.0), and hyperdepletion (β = 2.0) (adapted from Hilborn and Walters 1992)

First CPUE may stay high as abundance drops (β < 1). This situation is referred to as "**hyperstability**." Second, CPUE may be proportional to abundance (β = 1). A third possible relationship, referred to as "**hyperdepletion**", occurs when CPUE drops much faster than abundance (β > 1).

Factors affecting the catchability exponent for big game species include variable weather, snow conditions, seasonal habitat shifts or migration timing during the hunting season (Crichton 1993). Changes in the timing or length of the hunting season, in the classes of animal hunted, in predator avoidance behaviour, and in access are additional factors that could bias CPUE as an index of abundance (Hatter 2001). For example, if β was incorrectly assumed to be 1.0, when it was 0.5, then a measured population decline from CPUE of 29% would correspond to an actual decline of 50%.

Studies of CPUE for black-tailed deer on northern Vancouver Island provided evidence that CPUE and abundance were not proportional (Figure E2). Deer/km declined from 1976-83 (λ = 0.78, population-decline phase) and increased from 1983-90 (λ = 1.17, population-growth phase). Hyperstability in CPUE occurred during a population decline phase (λ = 0.86, β = 0.58), while CPUE was nearly proportional to abundance during the population growth phase (λ = 1.17, β = 0.90).

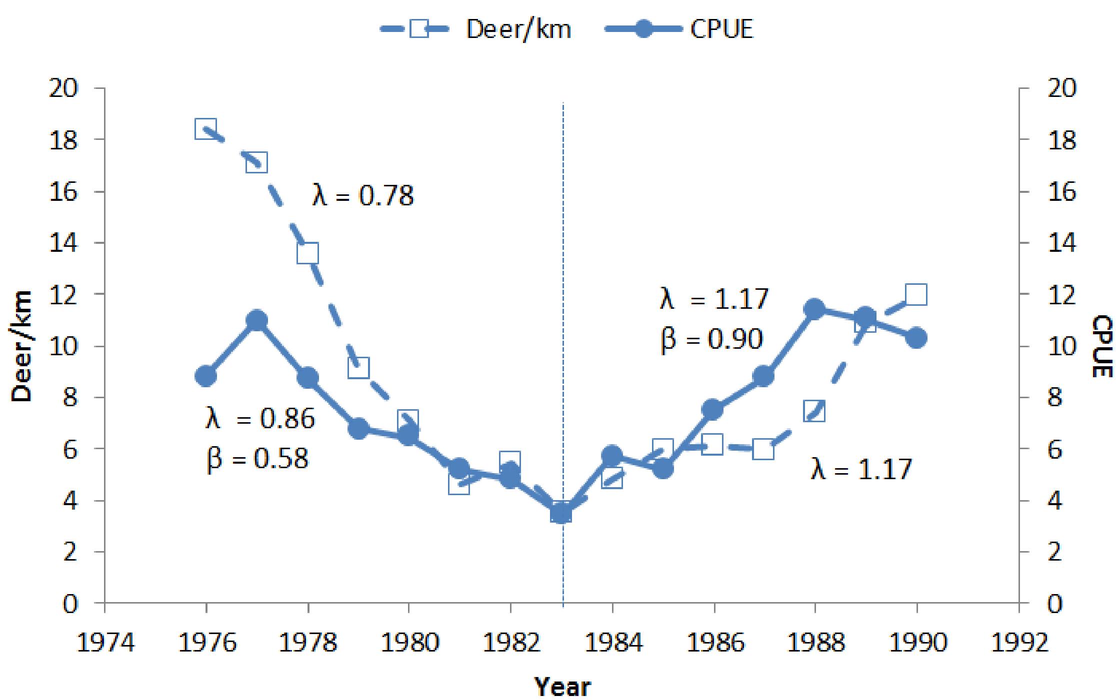


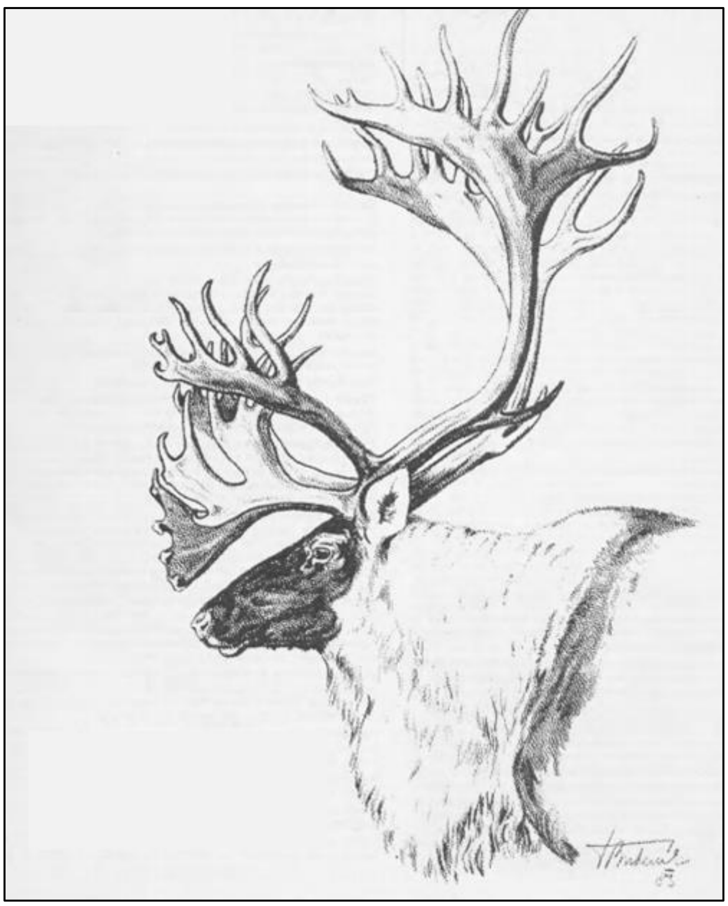
FIGURE E2. Comparison of deer/km (abundance index) with CPUE (buck harvest/100 hunter days) for black-tailed deer in WMU 1-11 on northern Vancouver Island (adapted from Hatter 2001)

Hatter (2001) reported similar results for CPUE for moose in north-eastern B.C. where β averaged 0.46 during periods of population decline and 1.34 during periods of increasing moose numbers. These results for deer and moose suggest that while CPUE may depict broad population trends (i.e. decreasing or increasing populations), it likely underestimates population rates of decline and may overestimate rate of increase. Thus wildlife managers should not use CPUE as an index of abundance in big game stock assessment models, or use it to estimate λ unless the relationship between CPUE and abundance is known.

Before deciding if CPUE is a potentially useful index of abundance wildlife managers should consider the following:

1. Are environmental factors affecting harvest vulnerability likely to be random, e.g. weather patterns, migration timing?
2. Have landscape factors affecting harvest vulnerability remained constant over time, e.g. road access?
3. Have hunting regulations that would affect harvest vulnerability remained constant over time, e.g. change from "4 point buck only" seasons to "any buck" seasons?
4. Have hunter harvest and hunter days been measured with sufficient statistical accuracy to reliably measure CPUE?

If the answer to any of these questions is "no", then wildlife managers should not use CPUE as an index of population abundance, and use other analytical methods if available.



APPENDIX F: Case study: a modelling approach to evaluate mule deer management objectives

Background

Mule deer in PMU 513/514 (WMUs 513 and 514) are an important big game species. In the early 2000s several areas were identified where deer numbers needed to be reduced to mitigate agricultural crop damage. The problem was socially and biologically complex in that hunters preferred abundant deer populations with a high likelihood of harvesting mature bucks, while land owners requested reduced deer numbers on agricultural fields to alleviate crop depredation.

Objectives

Management objectives for mule deer were developed in 2004 by regional Ministry staff in consultation with a multi-stakeholder group. The objectives were to: 1) maintain a spring deer population of 7,000 – 9,000 deer where damage to agricultural crops was considered tolerable; and 2) maintain 20 – 30 bucks:100 does in the post-hunt population in order to provide opportunities to harvest mature bucks. While some adjustments were made to GOS buck seasons, the primary management action to achieve these objectives was adjusting antlerless permits.

Methods

Hunter Harvest Surveys — Harvest statistics from an annual provincial hunter survey were used to estimate total harvest, sex-age composition, hunter numbers and hunter days within the PMU.

Mule Deer Monitoring — Mule deer were surveyed within representative areas of the PMU in the spring (May) using ground counts and in the fall (Nov. – early Dec.) using aerial counts. Annual spring surveys were conducted most years from 1997 to 2012 from 43 km of road transects. The number of deer observed per km of road in year t (I_t) was used as an index to population size (N_t) where $I_t = qN_t$ *and* q is the proportionality constant. Fall aerial surveys (n = 7) were conducted periodically based on the availability of survey funding. These surveys were undertaken during early morning and only under favourable weather conditions. Classification included identification of bucks (1+ year-old males), does (1+ year-old females) and fawns (6 month-old juveniles) in the fall; and fawns (12 month-old juveniles) and adults in spring.

Mule Deer Population Model — The modelling approach is outlined in detail by Hatter et al. (in prep). The model used two time steps per year to coincide with the deer monitoring periods. These were 1) spring (pre-birth) surveys of juveniles:100 adults and relative deer abundance, and 2) post-harvest surveys of mule deer composition (buck:doe and fawn:doe ratios). For modelling purposes, the year began just before juveniles were born in the spring.

A Bayesian population model was used to estimate deer population size and buck:doe ratios from 1995-2018 based on modelled estimates of non-hunting survival rates, fecundity rate, sex ratio of newborn fawns, carrying capacity, and the proportionality constant (q). Fecundity was assumed to be density dependent. The model incorporated process error from random variability in the population parameters, and observation error in the survey data.

Monitoring Data

The harvest and monitoring data used by the model to assess if management objectives were being achieved are summarized in Table F1.

TABLE F1. Estimated harvest of mule deer, fall herd composition (buck/doe ratio, fawn/doe ratio), spring herd composition (fawn/adult) and deer population trend index (NA indicates that data were not available for that year)

Year	Buck Harvest	Doe Harvest	Fawn Harvest	Buck/ Doe	Fawn/ Doe	Fawn/ Adult	Deer Index
1995	619	61	6	0.108	0.438	NA	NA
1996	523	83	0	NA	NA	NA	NA
1997	781	95	11	0.170	0.713	0.422	17.8
1998	642	76	7	NA	NA	0.506	14.2
1999	605	24	0	NA	NA	0.522	22.4
2000	716	52	4	0.306	0.545	0.609	28.1
2001	741	72	8	NA	NA	0.462	26.7
2002	826	56	0	NA	NA	0.426	31.4
2003	933	115	15	0.237	0.744	0.458	NA
2004	974	416	20	0.236	0.573	0.576	36.1
2005	935	600	43	NA	NA	0.466	44.8
2006	759	557	46	NA	NA	0.449	32.9
2007	873	574	28	0.155	0.422	0.416	36.5
2008	711	472	0	NA	NA	0.356	31.8
2009	454	335	39	NA	NA	0.301	25.4
2010	335	334	48	NA	NA	0.299	30.4
2011	491	217	9	NA	NA	0.383	22.1
2012	534	260	8	NA	NA	0.331	23.4
2013	681	231	6	0.208	0.540	0.428	NA

Model Results

Model results are summarized in Table F2 and Figure F1.

TABLE F2. Average spring population size, buck/doe ratio, buck harvest rate and antlerless harvest rate before (1995-2003), during (2004-2010), and after (2011-2013) antlerless LEH permits were increased

Year Period	Spring Deer Numbers	Bucks:100 Does Ratio	% Buck Harvest Rate	% Antlerless Harvest Rate
1995-2003	6539	20.8	43.1	1.0
2004-2010	9262	22.3	32.7	4.8
2011-2013	7756	24.9	29.3	2.5
2014-2018	8576	23.9	31.4	2.5

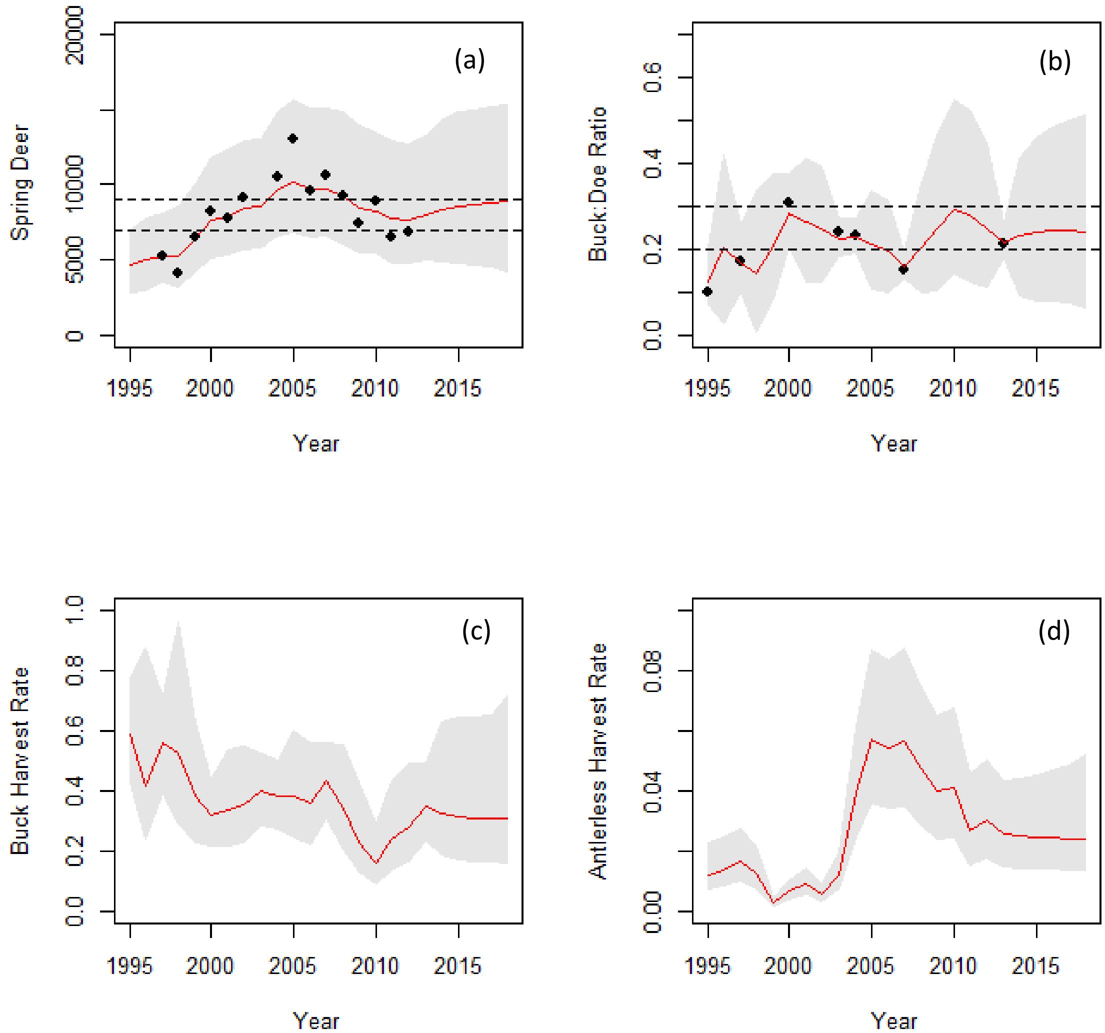


FIGURE F1. Spring deer numbers (a), buck:doe ratio (b), buck harvest rate (c), and antlerless harvest rate (d) from 1995 to 2018. Population means are shown as a red solid line and the 95% credibility interval is shaded. Dashed lines in (a) and (b) refer to the lower and upper range of the management objectives. Solid circles in (a) are the observed deer index/q (proportionality constant), and observed buck:doe ratios in (b).

Summary

The population model, when fitted to deer monitoring and harvest data, was able to assess if the management objectives were being achieved. The model also assessed if deer numbers and buck:doe ratios would continue to be achieved from 2014-2018 if the 2013 harvest levels were maintained. The probability that the 2018 population would be less than 7,000 deer was 26%, while the probability that the population would exceed 9,000 deer was 48%. The probability that the buck:doe ratio would be less than 20 bucks:/100 was 33%, whereas the probability that it would exceed 30 bucks:100 does was 28%. The big game stock assessment, using routinely collected deer monitoring data, enabled managers to evaluate deer objectives, with measures of uncertainty, to inform management decisions.

APPENDIX G: Statistical population reconstruction using age-at-harvest and auxiliary data

Statistical population reconstruction (SPR) is a method for estimating the demographics of harvested wildlife populations over large geographic areas using age-at-harvest and hunter effort data (Gove et al. 2002, Skalski et al. 2005, Clawson 2010, Clawson 2015). SPR has been successfully used for ungulates (Gove et al. 2002, Skalski et al. 2007, Skalski et al. 2012b, Gast et al. 2013), large carnivores (Skalski et al. 2005, Conn et al. 2008, Fieberg et al. 2010, Clawson 2010) and furbearers (Skalski et al. 2011). Hatter (2015) evaluated SPR for grizzly bears in B.C., and noted that it also holds promise for estimating the abundance of caribou, mountain sheep, mountain goat, and cougars where age-at-harvest is routinely collected through compulsory inspection. Hatter (2015) concluded that SPR should be included as another population modelling tool for big game stock assessment in the Strategic Big Game Inventory and Monitoring Strategy. This technique has some serious drawbacks; e.g. it assumes that all human-caused deaths are accounted for and non-harvest mortality rates are available. Nevertheless, it provides the only feasible, cost-effective method for monitoring big game numbers and trends at a regional scale.

The basic population projection equation used in statistical population reconstruction is

$$N_{t+1,a+1} = N_{t,a}\left(1 - P_{t,a}\right)S$$

where $N_{t,a}$ is the number of animals at the start of the spring hunting season, $P_{t,a}$ = probability of harvest in year *t* for age-class *a,* and *S* is the survival probability from natural and non-hunting human caused mortality. The annual harvest probability is modelled as

$$P_{t,a} = 1 - e^{(-(c+\tau_{t,a})f_t)}$$

where $P_{t,a}$ = probability of harvest in year *t* for age-class *a*, f_t = total hunter effort, *c* = vulnerability coefficient and $\tau_{t,a}$ are the random effects grouped by age-class and year.

Recent advances in user friendly software such as Program POPRECON, Version 2 available at http://www.cbr.washington.edu/analysis/apps/PopRecon makes this statistical modelling approach more accessible to wildlife biologists who wish to reconstruct trends in wildlife population numbers, recruitment and harvest rates from age-at-harvest data (Lacy and Skalski 2015). While in theory, SPR can be conducted using only age-at-harvest and hunter effort data, it is advisable to also include additional auxiliary data in order to obtain meaningful estimates (Skalski et al. 2012a, Clawson et al. 2013). The primary auxiliary data are one or more estimates of population size as determined through inventories, and one or more estimates of the adult survival rate as determined through radio-telemetry studies.

Figure G1 shows the results of modelling adult (three years of age or older) male grizzly bears in the Temperate Mountains SPR Region of southeastern B.C. using Program POPRECON. Auxiliary data consisted of a population estimate (2012) and an estimate of the non-hunting survival rate (*S*), i.e. the survival rate from both natural mortality and human-caused mortality excluding legal hunting.

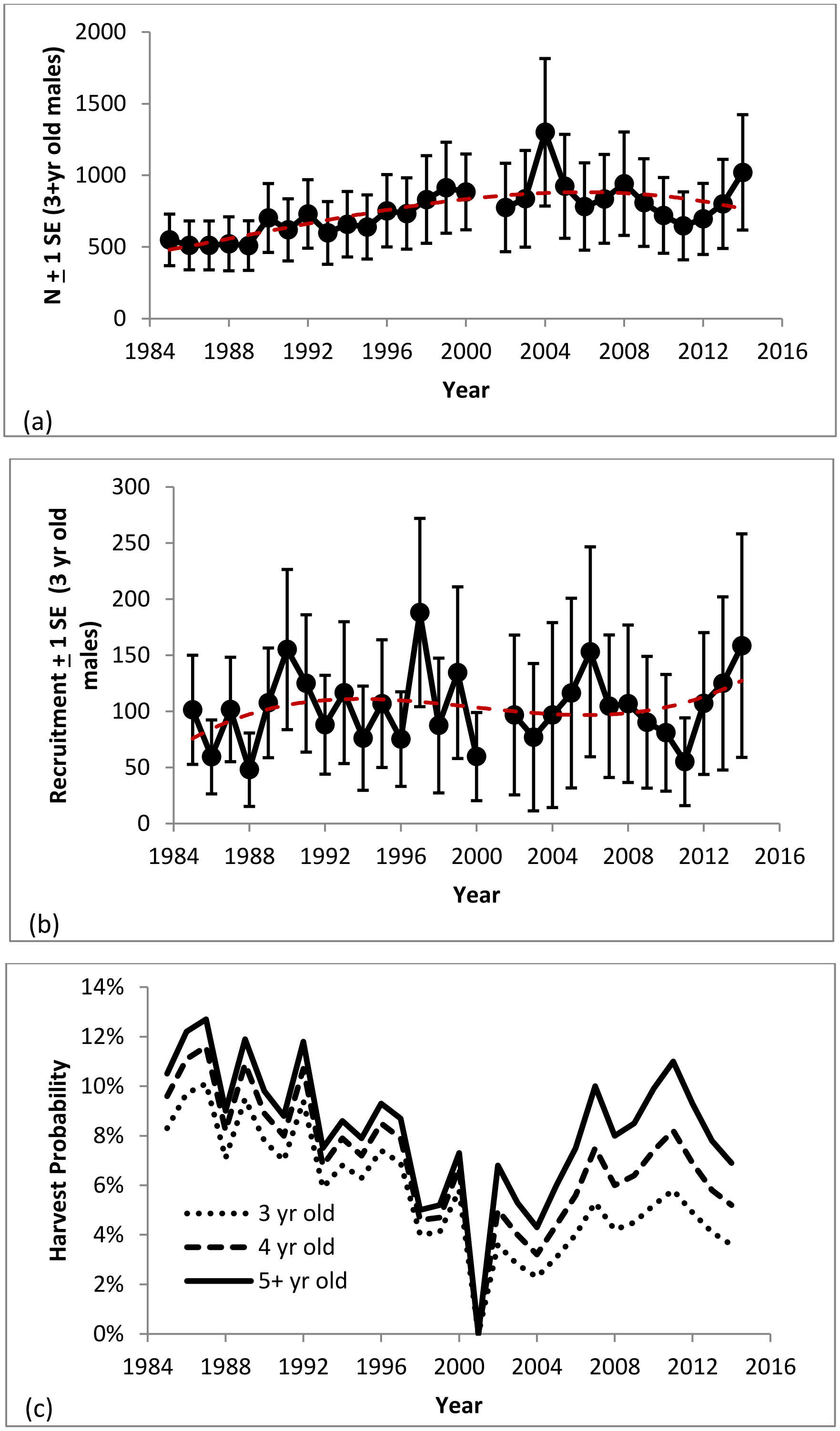


FIGURE G1. Population reconstruction with random effects for the Temperate Mountains SPR Region including (a) population size and trend, (b) recruitment, and (c) harvest probability (from Hatter 2015)

APPENDIX H: Application of the recruitment-mortality equation to estimate ungulate trends

Hatter and Bergerud (1991) developed a model (*RM* equation) that related population rate of change (λ) to adult mortality and juvenile recruitment:

$$\lambda = \frac{(1 - M)}{(1 - R)}$$

where λ is the finite rate of increase, M is the adult mortality rate and R is the juvenile recruitment rate, i.e. juveniles/(juveniles + adults). Because the adult female survival rate (*S*) = 1 - *M*, the equation is often displayed as:

$$\lambda = \frac{S}{(1 - R)}$$

DeCesare et al. (2012) and Hervieux et al. (2013) used the *RM* equation for females only as lambda is primarily determined by reproductive females. In this case, R is estimated as (juveniles/2)/(juveniles/2 + adult females), assuming that 50% of the juveniles are females.

The *RM* equation, when applied to ungulates, generally assumes that recruitment is measured in the spring (i.e. when juveniles become yearlings). If recruitment is measured from fall calf/cow ratios, then the "expected" spring calf/cow can be estimated as (fall juveniles/adult female x winter juvenile survival rate)/adult female survival rate and R is measured as above. Given the data set in Table H1, λ can be estimated for each year.

TABLE H1. Hypothetical data set for a moose or elk population where annual survival rates are estimated from radio-telemetry studies and annual fall calf:cow ratios from aerial surveys

Year	Female survival rate	SE	Fall calf:cow ratio	SE	Winter calf survival rate	SE
2000	0.924	0.092	0.359	0.054	0.648	0.130
2001	0.829	0.083	0.227	0.034	0.768	0.154
2002	0.737	0.074	0.285	0.043	0.693	0.139
2003	0.955	0.095	0.304	0.046	0.752	0.150
2004	0.897	0.090	0.317	0.048	0.685	0.137
2005	0.888	0.089	0.251	0.038	0.792	0.158

DeCesare et al. (2012) and Hervieux et al. (2013) used the *RM* equation to estimate λ for caribou populations in Alberta and outline a methodology for estimating 95% CIs on the estimate of λ derived from the *RM* equation. They also estimated the realized population change as the product of cumulative annual estimates of λ, and used a similar methodology to estimate 95% CI's for this parameter as well.

Figures H1 and H2 show the resulting estimates for both λ and the realized population change, including the 95% CIs derived from using the RM equation, the data in Table H1, and the methodology of DeCesare et al. (2012). In this example, annual estimates of λ decline during the first three years, and then are close to 1.0. The realized population change also declines during the first three years and then remains relatively constant at 0.85. Overall the population showed a slight decline during the six-year period.

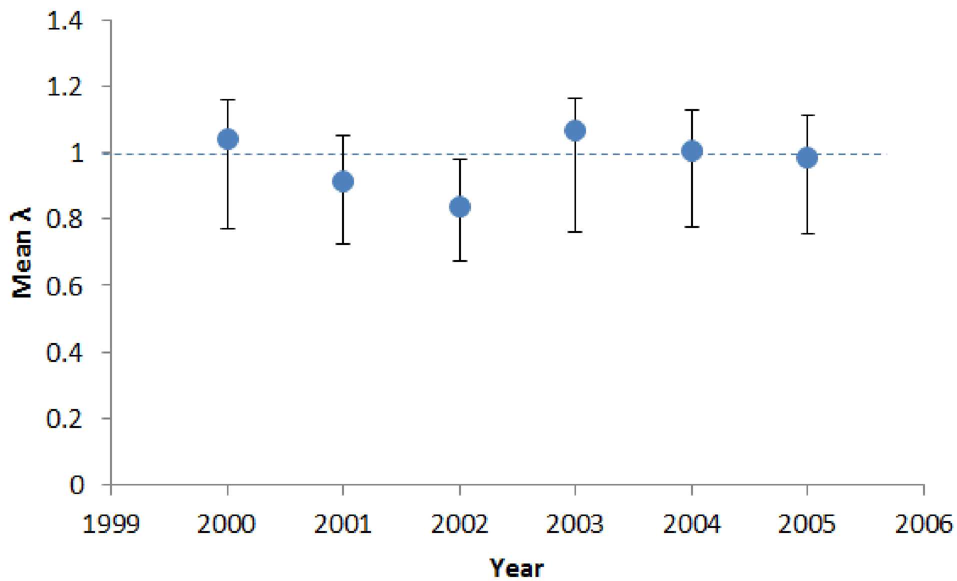


FIGURE H1. Mean estimate of lambda (λ) and associated 95% CIs (data from Table H1)

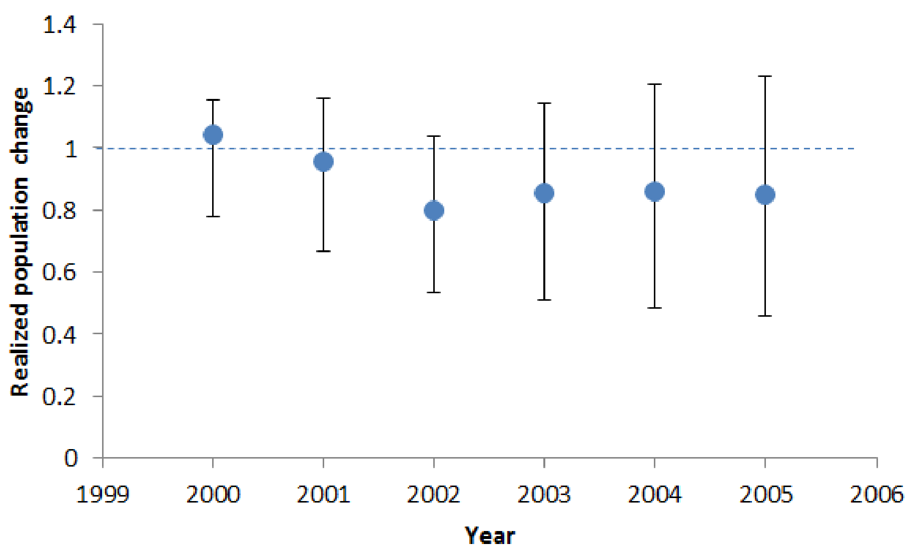
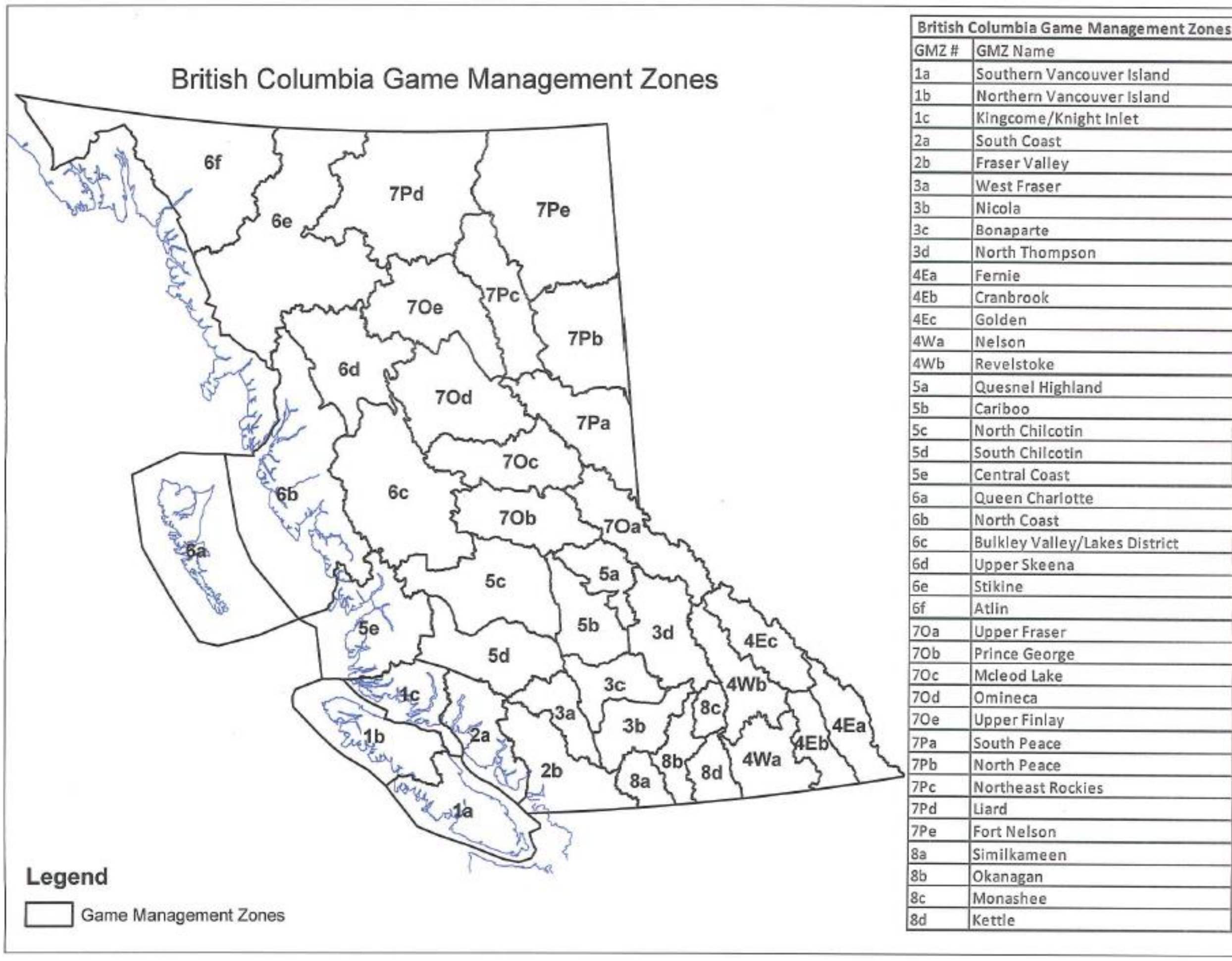


FIGURE H2. Realized population change and associated 95% CIs (data from Table H1)

APPENDIX I: Big game management zones (GMZs) in B.C.



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

Note: This report is for discussion purposes only. It does not represent a position or program of government.

APPENDIX J: Supporting tables for the Implementation Framework

TABLE J1. Species-specific recommendations for all big game species in B.C.

Species	#	Specific Recommendation
Ungulates		
Black-tailed deer	1	Develop black-tailed deer PMUs for all regions in B.C. where they occur
	2	Expand the use of deer spotlight counts to BGMAs within priority PMUs.
	3	Investigate the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
	4	Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of black-tailed deer abundance
Mule deer	1	Develop mule deer PMUs for all regions in B.C. where they occur
	2	Initiate a monitoring scheme similar to that used by Idaho as a trial within one mule deer PMU in the southern interior.
	3	Develop a mule deer sightability model that can be used to more accurately measure deer population size from aerial surveys over forested habitats.
	4	Investigate in training and the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
	5	Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of mule deer abundance
	6	Consider adopting provincial monitoring of winter severity through a standardized WSI
White-tailed deer	1	Develop white-tailed deer PMUs for all regions in B.C. where they occur.
	2	Investigate the use of citizen volunteers to assist in conducting sex/age composition surveys within monitoring areas.
	3	Undertake a detailed analysis of hunter effort to determine if the CPUE index can be further improved as an index of white-tailed deer abundance
	4	Investigate indices for monitoring white-tailed deer populations, such as the number of white-tailed deer observed per hour on mule deer or elk surveys.
	5	Consider adopting provincial monitoring of winter severity through a standardized WSI
Roosevelt elk	1	Ensure current inventory funding is maintained or increased to support intensive management efforts
	2	Consider research to improve aerial survey estimates of sightability on elk winter ranges
	3	Contemplate revisions to proposed PMU targets, objectives and strategies based on First Nations and stakeholder consultation and monitoring results
	1	Develop Rocky Mountain elk PMUs for all regions in B.C. where they occur

Rocky Mountain elk	2	Establish one or more BGMAs within high priority elk PMUs
	3	Ensure current inventory funding is maintained or increased to support intensive management efforts within high priority elk PMUs.
	4	Investigate more suitable methods for surveying elk within agricultural areas.
	5	Promote research on cost-effective methods to estimate elk population trends that do not require intensive helicopter survey sampling and that are less reliant on specific environmental conditions for surveying.
	6	Investigate the use of citizen-science volunteers to assist in conducting sex/age composition surveys within monitoring areas.
Moose	1	Finalize determination of moose PMUs for all regions in the province.
	2	Ensure current inventory funding is maintained to support the provincial moose research program
	3	Update the RISC aerial survey standards to include distance sampling
	4	Promote research on new inventory methods that are less reliant on specific environmental conditions for monitoring moose population trends, including maintaining an adequate sample of radio-collared cows and calves
	5	Repeat and expand previous moose status assessments by PMU, including PMUs in southern B.C., to help assess moose monitoring priorities
	6	Investigate options to determine area-specific, updated demographic parameters to improve population modelling efforts
	7	Explore opportunities to implement a Moose Survey App for hunters to record their sightings via their smart phones
	8	Support First Nation moose harvest surveys so that this information can be included in provincial big game stock assessments
Caribou	1	Develop an inventory schedule outlining survey frequency and recommended survey methodology for all caribou herds in B.C., including hunted herds
	2	Consider undertaking additional adult bull mortality studies using GPS radio-collars to support SPR analyses for the Northern Mountain population.
	3	Conduct a SPR analysis to estimate the number and trends of mature bulls within the Northern Mountain population.
Bison	1	Periodically determine the size, seasonal distribution and demographics of each bison population.
	2	Promote and support the use of First Nations and citizen-science volunteers to assist in conducting road-side sex/age composition surveys in N.E. B.C.
Mountain goat	1	Finalize determination of mountain goat PMUs for all regions in the province

	2	Update the RISC inventory standards for mountain goats to include mark-recapture methods using fecal and hair DNA
	3	Determine optimal sustainable harvest rates using an adaptive management approach within one or more goat PMUs
	4	Consider establishing monitoring areas for mountain goats where there is concern with high levels of human-caused disturbance and/or hunter harvest
	5	Promote monitoring of accessible small, localized mountain goat populations through collaborative monitoring
	6	Consider the application of SPR for estimating mountain goats over larger areas than a PMU where inventory information is lacking
Bighorn sheep	1	Maintain and update the Provincial Wild Sheep Registry as new information becomes available
	2	Prioritize inventory and monitoring needs of wild sheep herds near domestic sheep farms
	3	Consider more extensive radio-collaring and monitoring of sheep to help define bighorn sheep metapopulations and movement corridors
	4	Develop bighorn sheep sightability models for B.C. that can be used to both accurately and precisely measure bighorn population size from aerial surveys
	5	Investigate training citizen-science volunteers to ensure ground-based surveys within road accessible areas are conducted to RISC standards
Thinhorn sheep	1	Develop thinhorn sheep PMUs for Skeena, Omineca and Northeast regions, and establish population monitoring areas within high priority PMUs
	2	Promote ground-based monitoring of accessible small, localized thinhorn sheep populations by First Nations and stakeholders where possible
	3	Undertake additional adult male mortality studies using GPS collars to support SPR analyses
	4	Conduct an updated SPR analysis to estimate the number and trends of mature rams in both the Skeena and Northeast Regions from 1978 to 2015
Omni/Carnivores		
American Black bear	1	Develop American black bear PMUs for all regions in B.C.
	2	Maintain the population monitoring focus on American black bears through the collection of analysis of harvest statistics.
	3	Consider estimating regional American black bear population size through existing information and expert opinion.

	4	Investigate the potential to utilize SPR for estimating adult male American black bear numbers and trends on Vancouver Island.
	5	Explore opportunities for developing and implementing a large carnivore sighting app for hunters to record their sightings of American black bears
Grizzly bear	1	Review the decision support tool developed by Apps (2010) to determine if it requires updating to reflect inventories for sustainable use
	2	Determine key priorities for hair snag DNA mark-recapture inventories that will help to improve the regression model of Mowat et al. (20113b)
	3	Implement the recommendations in Hatter (2016) for improving future SPR models for grizzly bear numbers and trends
	4	Review and consider adopting the recommendations in the recent scientific review of grizzly bear management in B.C. (Boyce et al. 2015)
	5	Explore opportunities for developing and implementing a large carnivore sighting app for hunters to record their sightings of grizzly bears
Wolf	1	Update the RISC inventory standards for wolves based on more recently developed, cost-effective survey methods
	2	Implement three long-term wolf monitoring studies in B.C., including one each in the FLNRO Coast, Southern Interior, and Northern Interior areas
	3	Establish other wolf monitoring areas within the intensive wolf management zones of B.C. using cost-effective survey methods
	4	Explore opportunities for developing and implementing a large carnivore sighting app for hunters to record their sightings of wolves
	5	Work with the BCTA to develop a detailed trapper return survey for wolves
Cougar	1	Develop cougar PMUs for all regions in B.C.
	2	Update the RISC manual on inventory methods for cougar to include protocols for conducting spatial DNA capture-recapture
	3	Maintain support to the pilot studies for determining the cost-effectiveness of estimating cougar densities using spatial DNA capture-recapture inventory
	4	Collaborate with hunters to investigate the utility of other cougar monitoring indices
	5	Improve the collection of harvest age data during compulsory inspection.
	6	Investigate the utility of SPR for cougar abundance within larger SPR regions where auxiliary data on natural mortality rates are available
Canada lynx and bobcat	1	Work with the BCTA to develop a detailed trapper return survey for Canada lynx and bobcat

	2	Review and consider adopting the many other monitoring recommendations by Apps et al. (2011a, 2011b)
Wolverine	1	Work with the BCTA to develop a detailed trapper return survey for wolverine and consider adding the submission of wolverine skulls
	2	Consider updating the wolverine status assessment for each PMU once there is sufficient new information
	3	Consider establishing three long-term trend monitoring areas for wolverines including one each within the Coast, South and North FLNRO areas, using camera traps and collaborative monitoring

TABLE J2. Relating species-specific recommendations to key recommendations and issues

Theme in species-specific recommendations	Issue	Key recommendation
Most big game species still require designation of PMUs	#5 Lack of designated PMUs	#3 Address gaps in PMUs, BGMAs and regional management plans for big game species, Action 3.1
With planning and training, citizen-science volunteers can collect valuable monitoring data for many of B.C.'s big game species	#12 Unrealized opportunities to leverage investment	#6 Foster collaborative big game monitoring, Action 6.1
SPR holds promise for determining population size and trends of caribou, mountain goat, thinhorn sheep, grizzly bears and cougars over large areas of the province. To optimize use of this modelling method will also require collecting adult survival rate data through radio-telemetry studies	#10 Insufficient understanding and/or application of new wildlife techniques	#5 Invest in staff training for big game inventory and monitoring, Action 5.3
Correcting for visibility bias through sightability models is important for a number of species including mule deer, Roosevelt elk and bighorn sheep	#1 Variable funding	#1 Increase funding to support big game inventory and monitoring, Action 1.1
RISC inventory standards need updating for moose, mountain goat, wolf and cougar; and possibly other big game species as well	#3 Outdated inventory guidance	#2 Deploy resources to support RISC inventory and monitoring, Action 2.1
More research is needed to evaluate CPUE as an index of abundance, which is commonly used to monitor population trends of black-tailed deer, mule deer and white-tailed deer	#10 Insufficient understanding and/or application of new wildlife techniques	#5 Invest in staff training for big game inventory and monitoring, Action 5.3
The moose survey app that is currently being developed in B.C. should be expanded to other species, and a large carnivore app may be particularly useful for determining relative abundance and trends for grizzly bears, black bears, and wolves	#12 Unrealized opportunities to leverage investment	#6 Foster collaborative big game monitoring; Action 6.2
As it is generally difficult and not cost effective to survey furbearers, a detailed annual trapper return survey should be developed in collaboration with the BCTA for wolves, lynx, bobcat, and wolverine	#12 Unrealized opportunities to leverage investment	#6 Foster collaborative big game monitoring; Action 6.1

TABLE J3. Key recommendations and actions with the specific issues they address

Recommendation	Action	Specific issues addressed
#1 Increase funding to support big game inventory and monitoring	1.1 Establish and maintain a dedicated long-term budget to fund big game inventory and monitoring	#1, 3, 4, 7, 8, 9, 10 & 11
	1.2 Formally approve the *Big Game Inventory Fund 5-year Plan*	#2, #11
#2 Dedicate resources to support RISC inventory and monitoring	2.1 Create a Big Game Inventory and Monitoring Unit within FLNRO to perform specific functions – function a)	#3
	2.1 functions b) to f)	#4
	2.1 function g)	#5, 6, 7 & 10
#3 Address gaps in PMUs, BGMAs and regional management plans for big game species	3.1 Develop PMUs for all big game species	#5,
	3.2 Develop BGMAs for high priority PMUs	#6
	3.3 Develop regional management plans or management statements for all big game species	#5, 6 & 7
#4 Build a data system to integrate harvest and inventory data by PMU	4.1 Investigate the potential to incorporate PopR into B.C.'s hunting transformation project	#8
	4.2 Improve the functionality of B.C.'s big game harvest data system through the hunting transformation project	#8
#5 Invest in staff training for big game inventory and monitoring	5.1 Train wildlife staff in new inventory techniques as RISC standards are updated	#10
	5.1 Update the big game stock assessment manual to include Bayesian modelling and SPR	#3 & 10
	5.3 Hold periodic population modelling training workshops to train/re-train wildlife biologists in new big game stock assessment methods	#10
	5.4 Train wildlife staff on how to incorporate ARM into wildlife management decision-making to reduce key uncertainties	#11
#6 Foster collaborative big game monitoring	6.1 Develop partnerships with First Nations, other government agencies, traditional stakeholders and citizen-science volunteers to collaborate on inventory and monitoring initiatives	#12 & #9
	6.2 Expand the use of smartphone technology to enable hunters to record their observations of big game	#12 & #9
	6.3 Develop collaborative agreements with First Nations to enable annual reporting of their harvest	#9 & 12

TABLE J4. Issues addressed by report recommendations and corresponding actions

Issue	Recommendation that addresses issue	Specific actions that addresses issue
#1 Variable funding	#1 Increase funding to support big game inventory & monitoring	1.1 Establish and maintain a dedicated long-term budget to fund big game inventory and monitoring
#2 No approved BGIF Plan		1.2 Formally approve the *Big Game Inventory Fund 5-year Plan*
#3 Outdated inventory guidance	#2 Dedicate resources to support RISC inventory and monitoring	2.1 Create a Big Game Inventory and Monitoring Unit within FLNRO to perform specific functions – function a)
	#5 Invest in staff training for big game inventory and monitoring	5.2 Update the big game stock assessment manual to include Bayesian modelling and SPR
#4 Incomplete documentation of inventories	#2 Dedicate resources to support RISC inventory and monitoring	Create a Big Game Inventory and Monitoring Unit within FLNRO to perform specific functions – functions b) & c)
#5 Lack of designated PMUs	#3 Address gaps in PMUs, BGMAs and regional management plans for big game species	3.1 Develop PMUs for all big game species
#6 Lack of designated BGMAs		3.2 Develop BGMAs for high priority PMUs
#7 Lack of regional big game species management plans		3.3 Develop regional management plans or management statements for all big game species
#8 Lack of Integrated data systems	#4 Build a data system to integrate harvest and inventory data by PMU	4.1 Investigate the potential to incorporate PopR into B.C.'s hunting transformation project
#9 Inadequate big game harvest data system	#4 Build a data system to integrate harvest and inventory data by PMU	4.2 Improve the functionality of B.C.'s big game harvest data system through the hunting transformation project
	#6 Foster collaborative big game monitoring	6.3 Develop collaborative agreements with First Nations to enable annual reporting of their harvest
#10 Insufficient understanding and/or application of new wildlife techniques	#5 Invest in staff training for big game inventory and monitoring	5.1 Train wildlife staff in new inventory techniques as RISC standards are updated
		5.2 Update the big game stock assessment manual to include Bayesian modelling and SPR, and distribute to wildlife staff

TABLE J4 (continued). Issues addressed by report recommendations and corresponding actions

Issue	Recommendation that addresses issue	Specific actions that addresses issue
#11 Limited application of ARM	#5 Invest in staff training for big game inventory and monitoring	5.3 Hold periodic population modelling training workshops to train/re-train wildlife biologists in new big game stock assessment methods
	#1 Increase funding to support big game inventory & monitoring	1.1 Establish and maintain a dedicated long-term budget to fund big game inventory and monitoring
		1.2 Formally approve the Big Game Inventory Fund 5-year Plan
#12 Unrealized opportunities to leverage investment	#6 Foster collaborative big game monitoring	6.1 Develop partnerships with First Nations, other government agencies, traditional stakeholders and citizen-science volunteers to collaborate on inventory and monitoring initiatives
		6.2 Expand the use of smartphone technology to enable hunters to record their observations of big game
		6.3 Develop collaborative agreements with First Nations to enable annual reporting of their harvest

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