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Landscape-level Ecological Tree Species Benchmarks Pilot Project: First Approximation Benchmarks in Five British Columbia Timber Supply Areas

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EXECUTIVE SUMMARY

The landscape-level ecological tree species benchmarks pilot project was initiated in 2012 as the next phase of the landscape-level species strategy project (Mah et al. 2012) in support of the Chief Forester's Future Forest Ecosystems Initiative. This pilot project is an exploration in producing landscape-level ecological tree species benchmarks to aid the development of specific landscape-level tree species targets in five Timber Supply Areas (TSAs) in the Central Interior of British Columbia.

A co-operative inquiry approach was used in three sessions—Williams Lake, Prince George, and Smithers—that engaged individuals from multiple disciplines to produce first approximation landscape-level ecological tree species benchmarks for 35 Biogeoclimatic Ecosystem Classification (BEC) subzones/variants. This process was undertaken with limited data sources and within the context of a changing climate.

The main findings of the report are as follows:

- A methodology was developed for drafting landscape-level ecological tree species benchmarks for a BEC subzone/variant.
- The concept and intended use of the benchmark was articulated. A benchmark represents the desired proportion of tree species for managed stands at the landscape level that would maintain or increase tree species diversity in ecosystems and promote resilient landscapes. The intended use of the benchmark is to provide forest management direction from an ecological perspective within a BEC subzone/variant for the next 10–15 years, with a review approximately every 5 years against actual tree species proportions for managed stands.
- The outcomes of the sessions are dependent on the cross-section of knowledge holders present, the available supporting data, and the geographic and ecological context.
- The benchmarks are presented in two formats—single number and range. The benchmarks from the Williams Lake and Prince George sessions are presented as a range of proportions for a given species (e.g., lodgepole pine, 20–50%). The benchmarks from the Smithers session are presented as a single proportion (e.g., lodgepole pine, 10%).

The report recommends testing the implementation of the landscape-level ecological tree species benchmarks in landscape-level and/or operational planning, including the application and limitations of the two benchmark formats in developing a landscape-level tree species strategy and species targets for a Timber Supply Area.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

Over the past 30 years, forest managers in British Columbia have used various guidelines and policies to inform decisions regarding tree species selection following harvesting. The development of tools, such as establishment to free-growing guidebooks, regional ecosystem field guides, ecologically based site index estimates, and stocking standard policies, has led to generally successful reforestation programs, which have helped maintain the biological diversity of the province's forests. However, the application of these tools has been site specific and has not considered landscape implications. Additionally, the climatic changes forecast for the next seven decades (Spittlehouse 2008; Wang et al. 2012) will significantly challenge forest management activities based on existing tools. High levels of uncertainty surround the nature of climatic changes and the potential maladaptation of tree species to their current sites (Aitken et al. 2008).

Recent compelling events, including the mountain pine beetle infestation in the province's Central Interior and the *Dothistroma* needle cast outbreak in northwestern British Columbia (Woods et al. 2005; Westfall and Ebata 2007), have heightened our awareness of the linkages between species management decisions at the stand level and aggregated results across a landscape (Campbell et al. 2009). Landscape-level tools, such as a species strategy within an adaptive management framework (Mah et al. 2012), will be needed to guide stand-level species selection decisions and help manage forests as complex, changing ecosystems (Messier et al. 2013).

Mah et al. (2012) recognized the need to address ongoing climate change and the risk of major shifts in ecological conditions across the provincial landscape by adapting forest management practices. To foster the creation of landscape-level species strategies, the authors recommended investigating the development of specific targets for tree species composition at the landscape level within a management unit.

This pilot project is an exploration in producing landscape-level ecological tree species benchmarks to aid the development of specific landscape-level tree species targets in five Timber Supply Areas (TSAs) in the Central Interior of British Columbia. In this report, we describe a collaborative exploration of species selection issues undertaken in Williams Lake, Prince George, and Smithers that used an action research[1] approach to engage individuals from multiple disciplines in producing first approximation landscape-level ecological tree species benchmarks. The process was undertaken with limited data sources and within the context of a changing climate.

1.1 Background

Natural resource management requires balancing social, ecological, and economic values. Current management strategies and plans include social and economic stand- to landscape-scale objectives but not an expression of the desired ecological condition or benchmark for the land base to inform the development of landscape-level tree species targets. Without such targets, it is difficult to determine whether management practices are moving towards a

1 "Action research is a participatory, democratic process concerned with developing practical knowing...seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people..." (Reason and Bradbury 2008).

chosen goal. One approach is to develop a baseline for tree species composition and relative abundance in a given landscape or management unit by using ecological benchmarks. When combined with economic and social considerations, such benchmarks will inform the development of tree species targets within a landscape-level species strategy or plan.

Two types of uncertainty are anticipated when exploring methodologies to create benchmarks. The first is associated with the knowledge used—that is, the effects of climate change on limiting resources (e.g., water) and projected future distributions for the ecological zones in British Columbia (DeLong et al. 2011; Wang et al. 2012). The second is associated with ambiguity—that is, the same problem viewed with multiple "frames" by the specialists and practitioners involved in generating the knowledge (Brugnach and Ingram 2012).

When confronted with uncertainty, decision makers can use information from several knowledge domains (e.g., economics, politics, social factors and ethics, along with scientific research), something Boschetti (2011) refers to as "fuzzy" knowledge. Although this information can be considered in the decision-making process, it is not brought directly into policy development. Another of Boschetti's models (Figure 1) illustrates how scientific research can be included in the decision-making process by subjecting it to "de-fuzzifying" filters, in which complex information is synthesized into a hard number or a threshold.

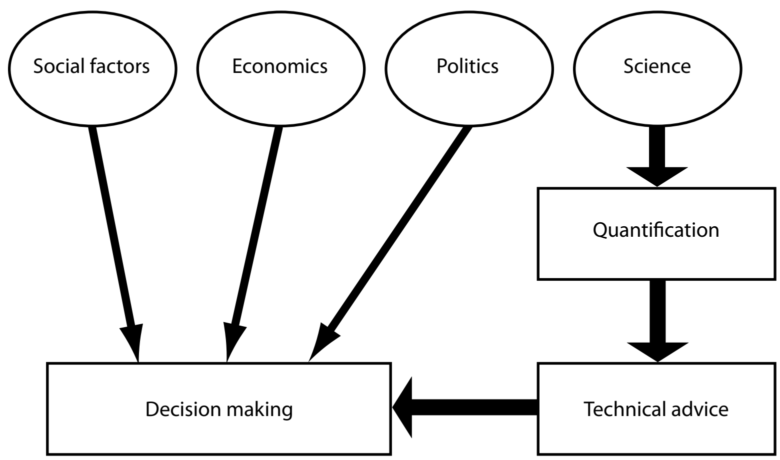

FIGURE 1 *Quantification of scientific knowledge into technical advice (Source: Boschetti 2011, Figure 5A modified).*

The challenge we faced in this study was to render the body of relevant scientific knowledge for a given management unit or the "what we have" in Figure 2 (i.e., species ecology baseline distribution and processes, and the drivers that affect their variability) into a quantified format or technical advice (i.e., ecological tree species benchmarks, for use in defining "what we want," namely adjusted target [baseline] ranges of variability of species distribution and composition).

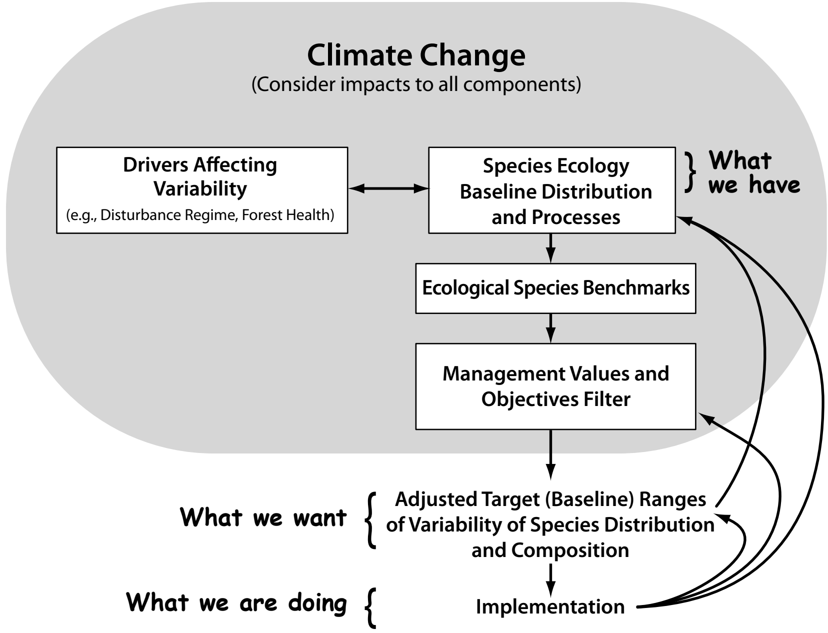

FIGURE 2 *Framework of key elements of landscape-level species strategies (revised from Mah et al. 2012:9).*

1.2 Study Area and Participants

The study area included five TSAs (Figure 3) that have experienced large losses of growing stock due to the mountain pine beetle infestation and which are seeking ways to address serious mid-term timber supply challenges. Developing landscape-level strategies to guide tree species selection decisions in these areas is considered to be important for improving reforestation out-

FIGURE 3 *Study area, which includes the Quesnel, Prince George, Lakes, Morice, and Bulkley Timber Supply Areas.*

comes. The synthesis of existing species information at a landscape scale is a key input to this process.

To allow maximum flexibility and to respond to developments as they occurred, the methodology sessions were organized as workshops and facilitated by the project co-leads. Depending on the availability of expertise in the session location, individuals from multiple disciplines (ecology, silviculture research, forest health, wildlife habitat, soils, operations, forest policy, range, and landscape-level biodiversity) participated in developing the landscape-level ecological tree species benchmarks (Table 1).

TABLE 1 *Session participants and areas of expertise*

Areas of expertise	Williams Lake session[a]	Prince George session[b]	Smithers session[c]
Ecology	Ray Coupé Shirley Mah Bruce Rogers Mike Ryan	Craig DeLong Shirley Mah Bruce Rogers	Allen Banner Will MacKenzie Shirley Mah Bruce Rogers
Silviculture research	Teresa Newsome Michaela Waterhouse	Michael Jull Phil LePage	Dave Coates Phil LePage
Forest health		Bob Hodgkinson	Ken White Alex Woods
Wildlife habitat	Michaela Waterhouse		Doug Steventon
Soils	Bill Chapman		
Operations	Kerri Howse Mike Pelchat Brad Powell Lee-ann Puhallo	Alena Charlston Cathy Middleton John Pousette Andrew Tait	Agathe Bernard Glenn Buhr Jennifer Plummer Carolyn Stevens Shawna Young
Forest policy	Kevin Astridge	Kevin Astridge	Kevin Astridge
Range		Laura Blonski	
Landscape-level biodiversity		Shannon Carson	
Operations (post-session)		Norma Stromberg-Jones Joanne Vinnedge	
Ecology (whitebark pine)	Ray Coupé	Joanne Vinnedge	Sybille Haeussler

a Session held at B.C. Ministry of Forests, Lands and Natural Resource Operations regional office in Williams Lake; two natural resource districts represented.
b Session held at Prince George Natural Resource District office in Prince George; three natural resource districts represented.
c Session held at Skeena-Stikine Natural Resource District office in Smithers; three natural resource districts represented.

1.3 Session Materials

Supporting materials for each session included available information and data on tree species at the landscape level, and information that would assist in assessing risks to managed stands (Table 2). Certain information, such as climate envelope projections, drought risk predictions, and tree species shift projections, was not available for the session in Williams Lake.

TABLE 2 *Summary of resource materials[a] by session*

Session materials	Williams Lake	Prince George	Smithers
BEC subzone/variant maps[b]	X	X	X
Species analysis profiles	X		
Landscape species descriptions[c]	Draft descriptions	Descriptions with tables	Descriptions with tables
VRIMS[d], RESULTS[e] species composition/proportion pivot tables	X	X	X
Climate data summaries[f]	X		
Climate envelope projection maps (Wang et al. 2012)		X	X
Drought risk prediction tool (DeLong et al. 2011)		X	X
Tree species shift projections (Gray and Hamann 2012)			X

a An "X" indicates that resource material was available in the session.
b Version 7 of the Biogeoclimatic Ecosystem Classification (BEC) map (B.C. Ministry of Forests and Range 2008).
c Written by the regional ecologist (www.for.gov.bc.ca/hfp/silviculture/TSS/bec_zones.htm).
d Vegetation Resources Inventory Data Management System (www.for.gov.bc.ca/hts/vridata/).
e Reporting Silviculture Updates and Land status Tracking System (www.for.gov.bc.ca/his/results/).
f Pacific Climate Impacts Consortium regional climate summaries (www.pacificclimate.org/resources/regional-climate-summaries).

2 METHODOLOGY

The three sessions (Williams Lake: January 2012; Prince George: September 2012; Smithers: October 2012) evolved along the lines of the four phases in a co-operative inquiry approach (Heron and Reason 2006):

- Phase 1 – Invitations were sent out to knowledge holders.
- Phases 2 and 3 – In a workshop format, the objectives of the session were agreed upon, and the participants collectively developed the options and outcomes.
- Phase 4 – A synthesis session was held with participants from the three sessions.

In each session, the methodology developed for drafting the benchmarks generally included three steps for the Biogeoclimatic Ecosystem Classification (BEC) subzones/variants in each TSA (Table 3):

1. Review the current status and subsequent trends in the inputs/information for age class–tree species profiles in each BEC subzone/variant in the TSA.
2. Consider risks for tree species establishment by reviewing factors related to forest health, disturbance agents, environment, drought risk, and climate change.
3. Draft ranges of desired species proportions (if possible, density distribution)—a first approximation termed a "2012 ecological benchmark"—building in flexibility for management and monitoring.

TABLE 3 *Summary of Biogeoclimatic Ecosystem Classification subzones/variants[a] considered during each session*

Williams Lake session (14 subzones/variants in Quesnel TSA)	Prince George session (24 subzones/variants in Prince George TSA)	Smithers session (15 subzones/variants in Lakes, Morice, and Bulkley TSAs)
	BWBSdk1	
		CWHws2
	ESSFmc	ESSFmc
		ESSFmk
	ESSFmm1	
	ESSFmv1	ESSFmv1
	ESSFmv3	ESSFmv3
	ESSFwc3	
ESSFwk1	ESSFwk1	
	ESSFwk2	
	ESSFwv	ESSFwv
ESSFxv1		
	ICHmc1	ICHmc1
		ICHmc1[a]
		ICHmc2
	ICHvk2	
	ICHwk3	
ICHwk4		
		MHmm2
MSxv		
SBPSdc		
SBPSmc	SBPSmc	SBPSmc
SBPSmk		
	SBSdk	SBSdk
SBSdw1		
SBSdw2	SBSdw2	
	SBSdw3	SBSdw3
SBSmc1		
SBSmc2	SBSmc2	SBSmc2
	SBSmc3	
SBSmh	SBSmh	
	SBSmk1	
SBSmw		
	SBSvk	
SBSwk1	SBSwk1	
	SBSwk3	SBSwk3
	SBSwk3[a]	

a For information about each subzone/variant, see www.for.gov.bc.ca/hre/becweb/resources/classificationreports/subzones/index.html.
TSA: Timber Supply Area.

Detailed session notes on the methodology developed for drafting the benchmarks are provided in Appendix 1. The session in Williams Lake did not have the benefit of a draft methodology. Thus, this group collaboratively developed the methodology from “scratch” by first reaching a common understanding of the study’s objectives, followed by an exploration of how to develop outputs to achieve them.

3.1 Concept and Intended Use of the Benchmarks

Each of the three sessions contributed to the articulation and refinement of the concept and intended use of a landscape-level ecological tree species benchmark for an ecological unit, as follows:

The benchmark for a given BEC subzone/variant represents the desired proportion of tree species for managed stands at the landscape level that would maintain or increase tree species diversity in ecosystems, correct any imbalances, and promote resilient landscapes.

The benchmarks are not static. Approximately every 5 years they should be evaluated against actual tree species proportions for managed stands in age class 1 (<20 years) at time of regeneration delay, free-growing, and post free-growing (age class 2).

The intended use of the benchmarks is to provide forest management direction from an ecological perspective within a BEC subzone/variant for the next 10–15 years. However, it is understood that licensees will use an economic lens in forest management planning when applying the benchmarks (i.e., a general goal or trend, not what to attempt to specifically achieve) in a BEC subzone/variant.

The resulting outputs from each co-operative inquiry session were a set of draft "first approximation" BEC subzone/variant landscape-level ecological tree species benchmarks (or "technical advice") for use in developing a landscape-level tree species strategy (Tables 4–6). In the Williams Lake and Prince George sessions (Tables 4 and 5), the benchmarks for a given species are presented as a range of proportions (e.g., Pl, 20–50%). In the Smithers session (Table 6), the benchmarks are presented as a single proportion (e.g. Pl, 10%).

TABLE 4 *Quesnel Timber Supply Area (TSA) draft (2012) landscape-level ecological tree species[a] benchmarks (%)*

BGC unit	At/Ac	Ep	Pl	Sx	Bl	Cw	Hw	Fd	Lw	Sb	Pa	Lt	Notes
ESSFwk1	0–5		10–20	40–50	25–30	0–5		0–5					
ESSFxv1	0.1		50–65	20–25	10–15						3–5		Pa is keystone species—increased from 1–5% to 3–5%
ICHwk4	3–5		10–15	30–40	5–10	5–10	10–15	10–15					At/Ac 3–5% includes Ep
ICHwk4[b]	3–5		20–25	30–40	5	5	10	10–15					Quesnel TSA THLB (large portion of entire variant is in protected areas)
MSxv			80–90	10–20	1–5								Bl in southeast Chilcotin area
SBPSdc	5–10		70–90	10–20						1–5		0.1	Fd <1%, would rarely occur and only on warm aspect sites that have low frost hazard
SBPSmc	5–10		65–70	20–30	0.1–1					5			At/Ac includes Ep
SBPSmk	5–10		45–65	30–40				0.5–3					Lt, Bl, Sb for wet sites, maintain on landscape but no targets (Williams Lake session, Jan. 2012); Pl—averaging 70% in the current snapshot, lots of rust in Pl, and other forest health issues (i.e., mountain pine beetle)
SBSdw1	10–20	5–10	20–30	15–20	0.1–1			30–40	1–2				Act—up to 5%; Bl—stays in the understorey, rarely in the canopy; Lw—currently beyond its natural range, check Chief Forester's memo; add initially on sites with good air drainage and on sites near ICH transition; may be used more widely with anticipated climate change
SBSdw2	10–15	2–3	45–50	10–15	0.1–1			20–30	0–5	0–1			Large areas of At more common in southern half, and scattered Lt more common in PG TSA; Act—0.1–1%; Fd and Pl—with climate change, could increase by an additional 5%
SBSmc1[c]	10		50	20–30	5			1–5					
SBSmc1	10		50	20–30	5			0.1–2					Small unit, but do not lump with SBSdw1 because they are quite different
SBSmc2	0–5		35–55	30–40	15–20								Quesnel SBSmc2—upper-elevation knobs, most constrained part of the SBSmc2; small hardwood component in DQU; Bl—high wildlife value
SBSmh	30–40		15	20–25	5			20–25					At/Ac—includes Ep
SBSmw	10–20	5–10	30–40	25–30	0–5	0–5		20–25	up to 5%				Benchmarks fit the whole subzone, including TFL52; Bl—mostly in mixed stands
SBSwk1	5–10	0–5	15–20	45–60	10–15	0–5		0–5					Cariboo variation of SBSwk1; minimal Ep, Cw, Fd; Hw in PG only
SBSwk1[c]	0–5	0–1	15–20	45–60	10–15	0–1		0–5					Benchmarks for Quesnel TSA; minimal Ep, Cw, Fd

a Species codes: At–trembling aspen; Ac–black cottonwood; Ep–paper birch; Pl–lodgepole pine; Sx–hybrid spruce; Bl–subalpine fir; Cw–western redcedar; Hw–western hemlock; Fd–Douglas-fir; Lw–western larch; Sb–black spruce; Pa–whitebark pine; Lt–tamarack.
Full descriptions of each biogeoclimatic (BGC) unit can be found at www.for.gov.bc.ca/hre/becweb/resources/classificationreports/subzones/index.html.
b Benchmark is for the portion of the BGC unit within the Quesnel TSA timber harvesting landbase
c Benchmark is for the portion of the BGC unit within the Quesnel TSA

TABLE 5 *Prince George Timber Supply Area (TSA) draft (2012) landscape-level ecological tree species[a] benchmarks (%)*

BGC unit	At/Ac	Ep	Pl	Sx	Bl	Ba	Cw	Hw	Fd	Lw	Sb	Pa	Pw	Notes
BWBSdk1	15–30	2–5	30–50	15–25	2–5						5–10			Proportions for new classification BWBSdk
ESSFmc	1–2	1–2	15–30	35–65	30–45							2–5		Higher % for Se because management will start in the lower elevations of the subzone
ESSFmm1			10–15	40–60	30–50				5–10		1–2	2–5	1–2	More Se because management will probably manage lower elevations of ESSFmm
ESSFmv1	1–2		40–65	20–30	15–25				1–2			1–2		Mixed species planting, higher densities of Pl to deal with forest health issues
ESSFmv3	2–5		20–40	20–40	25–40							1–2		Balsam bark beetle; 2-cycle budworm
ESSFwc3			5–10	25–40	45–80									ESSFwc3 usually above the ESSFwk1
ESSFwk1	1–5		10–20	35–60	25–45		5–10	1–2	1–5					
ESSFwk2	1–2	1–2	5–10	40–70	30–50		1–2		1–2			1–2		Pl—snowpress, more on the eastern side of the ESSFwk2; Fd—on south-facing slopes with good air drainage
ESSFwv	1–2		5–10	15–40	50–70	1–2		5–10						Higher % for Se because management will start in the lower elevations of the subzone; Hm only in the Prince Rupert region ESSFwv
ICHmc1	5–15	2–5	5–15	10–25	15–30		2–5	25–40	1–2					Pl—lowered range due to Dothistroma consideration; Fd—around large lakes, and well-drained areas
ICHvk2	2–5	5–10	2–5	30–45	5–10		20–30	10–15	5–10					Cw—a portion should be pure stands as a recruitment for the older Cw stands
ICHwk3	10–15	10–20	2–5	25–40	10–15		15–25	10–15	5–10		1–2			At/Ac—important to have a proportion in the landscape in all age classes; best to manage in patches; Pl—dropped % to reduce risk from Dothistroma; Fd—on drier sites
SBPSmc	10–20		60–80	10–25	1–2				1–2		1–2			Sx at high risk of drought; Pl at moderate risk (Craig's drought tool) by 2080 on mesic sites; Fd—around large lakes or on ridges with good air drainage
SBSdk	10–20	1–2	20–45	15–25	1–2				5–10	5–10	1–2			Sx at high risk of drought; Pl at moderate risk (Craig's drought tool) by 2050 on mesic sites; Fd—okay on drier sites, ridges, and those with good air drainage; Lw—area is in the expanded Lw map
SBSdw2	10–15	2–5	35–55	10–15	1–2				25–40	2–5	2–5			Sx at high risk of drought; Pl—range increased from 45–55% to 35–55%; Pl at moderate risk (Craig's drought tool) by 2050 on mesic sites; Fd—okay on drier sites, ridges, and those with good air drainage; Lw—area is in the expanded Lw map

a Species codes: At–trembling aspen; Ac–black cottonwood; Ep–paper birch; Pl–lodgepole pine; Sx–hybrid spruce; Bl–subalpine fir; Ba–amabilis fir; Cw–western redcedar; Hw–western hemlock; Fd–Douglas-fir; Lw–western larch; Sb–black spruce; Pa–whitebark pine; Pw–western white pine

Full descriptions of each biogeoclimatic (BGC) unit can be found at www.for.gov.bc.ca/hre/becweb/resources/classificationreports/subzones/index.html.

Continued on next page

TABLE 5 *Continued*

BGC unit	At/Ac	Ep	Pl	Sx	Bl	Ba	Cw	Hw	Fd	Lw	Sb	Pa	Pw	Notes
SBSdw3	10–25	1–2	30–50	10–15	1–2				15–30	5–10	2–5			Pl—range reduced from 20–50% to 30–50%; Sx—drought tool shows high risk by 2020
SBSmc2	5–10	1–2	40–55	20–30	10–25				1–2		1–2			
SBSmc3	2–5		60–85	15–30	5–10				2–5		2–5			Fd—around larger lakes, hilltops with good air drainage
SBSmh	10–25	5–15	5–15	10–15	1–2				25–45	2–5	1–2			Sx, Ep at high risk of drought; Pl at moderate risk (Craig's drought tool) by 2020 on mesic sites
SBSmk1	5–15	1–2 <3	25–50	25–40	5–10				5–10		2–5			Pl range reduced from 25–50% to 30–50%
SBSvk	5–10	5–10	5–10	50–65	20–30		2–5	1–2	5–10		1–2			Older management, good unit for managing Bl, no moisture deficit; Sx—spruce weevil is low risk in the SBSvk but high concern overall in the PG TSA; Fd—on south-facing slopes with good air drainage
SBSwk1	10–15	5–6	10–20	40–60	10–20		0–5	0–5	5–10					Climate change not expected to change species proportions; At/Ac—manage in patches; Ep—moose browse a consideration; Pl—Dothistroma a consideration; Cw—frost a consideration, okay near large lakes or sites with good air drainage; Hw transition area
SBSwk3	10–15		30–50	30–45	5–10				5–10		2–5			
SBSwk3a	10–15	2–5	25–40	25–35	5–10				10–20	2–5	1–2	1–2		

DeLong, Oct.11/12: In general, the range should not be greater than 20% when below 50% (e.g., 30–50%) and up to 25% over 50% (e.g., 60–85%).

Jull, Oct. 24/12: Caution on the amount of pine in the benchmarks for wet cool or cold subzones of the ESSF (should be lower?)—potentially aspect and slope specific.

TABLE 6 *Lakes, Morice, and Bulkley Timber Supply Areas (TSAs) draft (2012) landscape-level ecological tree species[a] benchmarks (%)*

BGC unit	At/Ac/ Ep 5 yr	At/Ac/ Ep	Pl 5 yr	Pl	Sx 5 yr	Sx	Ss 5 yr	Ss	Bl 5 yr	Bl	Ba 5 yr	Ba	Cw 5 yr	Cw	Hw 5 yr	Hw	Hm 5 yr	Hm	Fd 5 yr	Fd	Lw 5 yr	Lw	Sb 5 yr	Sb	Pa 5 yr	Pa	Notes
CWHws2	1	1	2	2			15	25	5	t	35	30	5	15	37	32											
ESSFmc			10	5	40	40			50	50															t–1	5	
ESSFmk			5	5	40	40			50	45	t	t			5	5									t–1	5	Pa—on suitable sites, ESSFmk/02; Hw—includes Hm
ESSFmv1	t	t	40	30	35	40			25	30																	
ESSFmv3		t	20	20	40	40			40	40																	
ESSFwv			5	5	30	35			55	50							10	10							t	t	
ICHmc1	5	5	10	5	20	20			30	25				5	35	30				5	t	5					
ICHmc1a	5	5	10	5	20	20					35	35		5	30	25				5		5					
ICHmc2	10	10	10	5		15			10	10			15	20	25	25			5	10	5	5					
MHmm2					10	10					50	50					40	40							t	t	
SBPSmc	10	10	75	75	15	10			t	t									t	5			t	t			
SBSdk	10	10	30	30	30	20			t	t									20	25	10	15	t	t			
SBSdw3	10	5	35	20	25	15			t	t									20	40	10	20	t				
SBSmc2	5	5	25	20	40	45			30	20						t			t	10				t			
SBSwk3	5	5	30	25	30	25			25	20									10	20	t	5	t	t			

Pair of benchmarks—5 year and LT—spp. proportions total 100% for a BGC unit
t—trace.

a Species codes: At–trembling aspen; Ac–black cottonwood; Ep–paper birch; Pl–lodgepole pine; Sx–hybrid spruce; Ss–Sitka spruce; Bl–subalpine fir; Ba–amabilis fir; Cw–western redcedar; Hw–western hemlock; Hm–mountain hemlock; Fd–Douglas-fir; Lw–western larch; Sb–black spruce; Pa–whitebark pine.
Full descriptions of each biogeoclimatic (BGC) unit can be found at www.for.gov.bc.ca/hre/becweb/resources/classificationreports/subzones/index.html.

A synthesis session with participants from all three sessions was held in February 2013. The discussion focussed on three fundamental aspects of the landscape-level ecological tree species benchmarks: (1) definition and intended use, (2) format, and (3) implementation.

4.1 Definition and Intended Use of the Benchmarks

The participants provided clarification on the definition and intended use of the first approximation landscape-level ecological species benchmarks, including the following:

- Benchmarks portray a general goal or trend (not what to attempt to specifically achieve) in a BEC subzone/variant.
- Benchmarks form part of a framework to develop a rationale or strategy.
- Benchmarks inform the next steps in the process of working towards the benchmark, such as specific species targets or given management objectives or values.
- Benchmarks are strategic and set at the landscape level.

4.2 Format of the Benchmarks

Single number or range format? There was much discussion about the advantages and disadvantages of both formats, and the participants stressed the importance of attaching to the benchmarks clear documentation of their definition and intended use, including the strengths of each format.

The following summarizes of the strengths of the two benchmark formats:

1. Single number – This format gives the user a high-level target to head towards, and it assumes there is no "right answer." It allows trends to be monitored more easily when evaluating species management practices against the benchmark. When using this format, the following points should be considered:
   - A clear description of the number's purpose avoids the perception that it is prescriptive.
   - A single number benchmark is less confusing when monitoring trends.
2. Range – This format provides more flexibility when developing landscape-level tree species targets, although it is more difficult to evaluate. It is possibly easier to develop a rationale for a range that is related to ecological variation. When using this format, the following points should be considered:
   - A range benchmark may be perceived as less prescriptive, but it still requires a clear description of its purpose.
   - A range benchmark provides a way of describing the natural range of variability. For example, the range can be broad (30–70%) for some tree species in a BEC subzone/variant but narrow (50–60%) for other species in the same subzone/variant or even for the same species in another subzone/variant.

4.3 Implementation of the Benchmarks

Throughout all three sessions, there was discussion about how the benchmarks could be implemented, and recognition that the format of the benchmarks and their implementation are closely linked. Synthesis session participants agreed that implementation pilots are necessary to understand what is required for ecological benchmarks to be effective. Such pilots could:

- gauge the interaction between stand-level free-to-grow standards and reforestation practices;
- determine how landscapes with high variability in forest health and site productivity influence the development of tree species strategies;
- allow licensees to test which benchmark format is attainable at an operational level; and
- test the use of the benchmarks in setting specific tree species targets in forest management planning.

5 CONCLUSIONS

A co-operative inquiry approach was effectively used in three sessions held in British Columbia's Central Interior to develop a methodology for producing first approximation landscape-level ecological tree species benchmarks for five Timber Supply Areas affected by the mountain pine beetle. The documentation of this process is intended to provide any future sessions with a methodology and key issues to consider when drafting such benchmarks. However, as this pilot study indicated, outcomes will depend on the cross-section of knowledge holders present, the available supporting data, and the geographic and ecological context. Transferability of the drafted benchmarks to other areas with similar ecological units is not necessarily desirable nor possible without a situational review.

The success of the sessions described in this report was attributable largely to the willing collaboration of Ministry staff who have long-term regional ecological, silvicultural, forest health, and operational reforestation knowledge and experience. Over the next 3–5 years, the level of Ministry expertise is expected to be greatly reduced due to staff retirements and attrition.

In all sessions, participants identified the need for an implementation pilot to ground-truth the practical application of the benchmarks (single number or range) in developing landscape-level species targets and species strategy. The participants also identified the need for a framework for developing methods to monitor trends and assess new information, which would be used to review the benchmarks and determine whether adjustments were necessary.

6 RECOMMENDED NEXT STEPS

1. Test the implementation of the tree species benchmarks in landscape-level and/or operational planning and the application and limitations of the two benchmark formats (single number and range) in developing a landscape-level tree species strategy and targets for a Timber Supply Area.
2. Develop a framework and methodology to evaluate landscape-level ecological tree species benchmarks.

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1 Co-operative inquiry approach

To develop landscape-level ecological tree species benchmarks or "co-produced knowledge" in the context of the co-operative inquiry approach, we organized and facilitated methodology sessions in British Columbia's Central Interior in 2012. We identified potential knowledge holders and available information and data that were pertinent to the geographical and ecological context of a priority management unit.

These sessions evolved along the lines of the four phases of reflection and action outlined by Heron and Reason (2006):

- Phase 1 – Invitations were sent out to knowledge holders.
- Phases 2 and 3 – In a workshop format, the objectives of the session were agreed upon, and the participants collectively developed the options and outcomes.
- Phase 4 – A synthesis session was held with participants from the three sessions.

After the co-operative inquiry session in Williams Lake was completed (phases 1–3) in January 2012, we received a request from colleagues working on a forest management-level planning project in the Quesnel Timber Supply Area (TSA) (Type IV Silviculture Strategies project; www.for.gov.bc.ca/hfp/silstrat/) to expand our project to include two more priority Timber Supply Areas that have been affected by the mountain pine beetle. We agreed, and with the collaboration of knowledge holders in the two additional sessions held in Prince George and Smithers, we completed phases 1–3 of the co-operative inquiry approach by the end of 2012. In February 2013, phase 4 was conducted as one session that included all participants from the three sessions.

Participants and areas of expertise To allow maximum flexibility and to respond to developments as they occurred, the methodology sessions were organized as workshops and facilitated by the project co-leads. For each session, participants were chosen based on the areas of expertise needed to inform the development of tree species benchmarks. Depending on the availability of expertise in the session location, these areas included ecology, silviculture research, forest health, wildlife habitat, soils, operations, forest policy, range, and landscape planning. In addition, district stewardship staff provided operational silviculture experience. Because our focus was on developing tree species benchmarks before the consideration of any management objectives, the sessions did not include industry participants. We envisaged that licensees would be involved in the next stage of developing tree species targets within a landscape-level tree species strategy.

2 Session notes and draft benchmarks

Session 1 – Williams Lake The Williams Lake session, which focussed on the Quesnel TSA (Figure A1), was the first of the three co-operative inquiry sessions held in the province's Central Interior. The January 2012 meeting started with the facilitator providing the context and reason for the session—

FIGURE A1 *Geographic extent of the Quesnel Timber Supply Area in British Columbia (approx. 2 080 000 ha).*

an overview of the landscape-level tree species strategy scoping report and its recommendations for developing landscape-level tools (Mah et al. 2012). The facilitator described the session as an exploration in which to "develop a proposed set of species targets for each BEC subzone/variant in the TSA."

The need for developing landscape-level guidance was not disputed, but the facilitators and participants spent the morning of the session's first day discussing what was meant by "species targets" as an output, what would be the basis and process for their development, and what would be the potential implementation issues. The facilitators had brought a set of supporting materials, including analyses for the Quesnel TSA's main BEC subzones/variants, based on the ICHmc2 methodology pilot (Mah et al. 2012), which portrayed tree species proportions (%) and their lognormal density distribution curves (stems per hectare). However, the distribution curves were new to the group, which led to considerable discussion about how they were developed and how they could be used to develop "species targets." The group was unable to reach agreement on the use of the distribution curves; they agreed that the curves could be used to examine species trends but that they were too difficult to interpret and use in the session.

Throughout the day, some of the operations knowledge holders asked how the results from the session could be directly applied in their forest-level planning analyses. When some of the researchers in the group were asked to "just tell us what you want," the different expectations within the group regarding the session's goal and desired outputs became apparent. Despite well-intentioned discussion, the first day ended without a common understanding of the session's goal, but the group agreed to continue on the next day.

The next morning, the facilitator and participants shared their thoughts on why the group's discussions had seemed counter-productive. They agreed that management objectives had become mixed in with the discussion on developing the species targets, and that the session needed to focus on the ecological aspect of the species targets separate from their application and implementation issues; these would be addressed in a separate forum. Once this understanding was reached, the group began to review the available data sources, in combination with their collective expertise, in order to draft a current snapshot or landscape-level description of the tree species within an ecological unit (e.g., BEC subzone/variant). In drafting the first species target, participants agreed to give a proportion (%) range for each tree species; these ranges were expected to be feasible both ecologically and silviculturally, and desirable at the landscape level in a changing climate. These species ranges were deemed to represent a baseline or benchmark; thus, the term "benchmark" was adopted because it gave a clearer indication of their intended use than did the word "target."

By the end of the second day, the Williams Lake group had drafted a set of 14 tree species benchmarks for the Quesnel TSA (Table 4).

Session 2 – Prince George The Prince George co-operative inquiry session, which focussed on the Prince George TSA (Figure A2), was held in late September 2012. The areas of expertise represented were similar to those in the Williams Lake session (Table 1).[2] The participants in this session had exten-

FIGURE A2 *Geographic extent of the Prince George Timber Supply Area in British Columbia (approx. 7 970 000 ha).*

2 Several participants were members of the technical working group that was established to improve the implementation of the Order Establishing Landscape Biodiversity Objectives for the Prince George Timber Supply Area (http://archive.ilmb.gov.bc.ca/slrp/srmp/north/prince_george_tsa/pg_tsa_biodiversity_order.pdf).

sive experience in dealing with landscape-level issues in the TSA, which benefitted the discussion and the drafting of the tree species benchmarks.

After a brief overview of the inquiry process and the results from the Williams Lake session, the facilitators opened the floor to the participants. Following a discussion that honed in on the intended use of the benchmarks, what they represented, and the need for accompanying documentation on these points, the group agreed that:

- the intended use of the benchmarks is to provide forest management direction from an ecological perspective within a BEC subzone/variant for the next 10–15 years. However, it is understood that an economic lens would be used in the type 4 silviculture strategies or by licensees when applying the benchmarks;
- the benchmarks represent the desired proportion of tree species for managed stands at the landscape level (i.e., for managed stands and natural disturbance areas, and areas affected by the mountain pine beetle that have been assessed by Forests for Tomorrow and that have an inventory label); and
- the benchmarks are not static. Approximately every 5 years they should be evaluated against actual tree species proportions for managed stands in age class 1 (<20 years) at time of regeneration delay, free-growing, and post free-growing (age class 2).

Over the next day and a half, the Prince George group drafted a set of 24 tree species benchmarks for the Prince George TSA (Table 5) using information that was similar to that assembled for the Williams Lake session. However, this group had additional data on climate envelope projections and drought risk.

Session 3 – Smithers The Smithers co-operative inquiry session, which focussed on the Lakes, Morice, and Bulkley TSAs (Figure A3), was held in October 2012. The facilitators began the session with an overview of the background and purpose of the landscape-level tree species strategy project, its current exploration into the development of landscape-level ecological tree species benchmarks, the draft process to date, and the outputs generated during the sessions in Williams Lake and Prince George.

The group discussed the goal of the landscape-level tree species strategy and the concept of tree species benchmarks, and agreed that their intended purpose and use was to guide reforestation of managed stands at the landscape level. Consequently, tree species benchmarks would be used to develop targets or objectives within a larger landscape-level planning process, and would subsequently be monitored and evaluated. The group then raised implementation issues, such as how the benchmarks would be used in setting landscape-level targets or objectives, and the type of survey that would be needed to assess the targets each year. It was agreed that these details could be worked out during a benchmark implementation phase. The group recognized that many landscapes within the TSA may require a change in practices to move them towards the ecological benchmarks; however, the first step was to define a benchmark that would allow any shifts over time, small or otherwise, to be monitored.

FIGURE A3 *Geographic extent of the Lakes, Morice, and Bulkley Timber Supply Areas in British Columbia (approx. 3 843 000 ha).*

The participants in the Smithers session did not automatically adopt the range format for the benchmarks, that was used in the previous sessions. Instead, it was suggested that a single number format that totals 100% for the species within a BEC subzone/variant could be used. The rationale was discussed, and the group agreed to use the single number format for drafting the set of 15 tree species benchmarks for the Lakes, Morice, and Bulkley TSAs (Table 6). This group benefitted from having data on climate envelope projections and drought risk, as well as additional information on tree species shifts related to climate change projections (L. Gray, Univ. Alberta, pers. comm.; Gray and Hamann 2012).

3 Discussion

At the beginning of each co-operative inquiry session, time was needed to collectively develop the objective of the session and clarify the way each participant viewed the problem and its associated issues. The groups did not proceed until a common understanding of the session's objective was reached. The Williams Lake group first articulated the concept of a landscape-level ecological tree species benchmark as a precursor to informing the development of a landscape-level tree species target. This was a breakthrough in the methodology exploration, and the concept was developed further in the subsequent sessions. Critical to each session was the discussion and agreement reached about the concept and intended use of the ecological tree species benchmarks.

Factors affecting co-generation of knowledge in the co-operative inquiry sessions: knowledge holders and frames of interpretation To contribute to the co-production of the landscape-level ecological tree species benchmarks, each co-operative inquiry session included participants from three knowledge domains: (1) scientific or expert, (2) bureaucratic or administrative, and (3) practical, professional (Edelenbos et al. 2011). Although not all those who were invited were able to attend, we tried to ensure that a nucleus of individuals (expert and practical) with knowledge of the TSA ecosystems and tree response to environmental factors (e.g., forest health agents, fire) was available for each session. For those who were unable to attend the session, phone calls and email were used to gather their input.

The Williams Lake session did not include any forest health specialists because the forest pathologist had just retired and the forest entomologist position was vacant. At the other two sessions, forest health data were used to refine the species proportion within a benchmark.

Boschetti's (2011) graphical representation of types of uncertainty (Figure A4) can be used to describe the uncertainty associated with the available information and the participants at the three initial co-operative inquiry sessions. For example, the associated level of uncertainty and awareness of the available information used to draft the tree species benchmarks was relatively high in all three sessions (i.e., in the "known unknowns" sector in Figure A4). The participants with long-term local knowledge of the ecosystems and their response to disturbance and management balanced the uncertainty associated with the projected climate-based changes to the BEC subzones/variants in the TSAs.

Possibly the most challenging aspect of this exploration of methodology was the different frames or interpretations of the same issue associated with the Z-axis in Figure A4. For example, the significant amount of time required to clarify the Williams Lake session's objectives was probably related to the participants' different interpretations of the objectives, specifically the term "species targets." This "misunderstanding" seemed to be resolved once the fa-

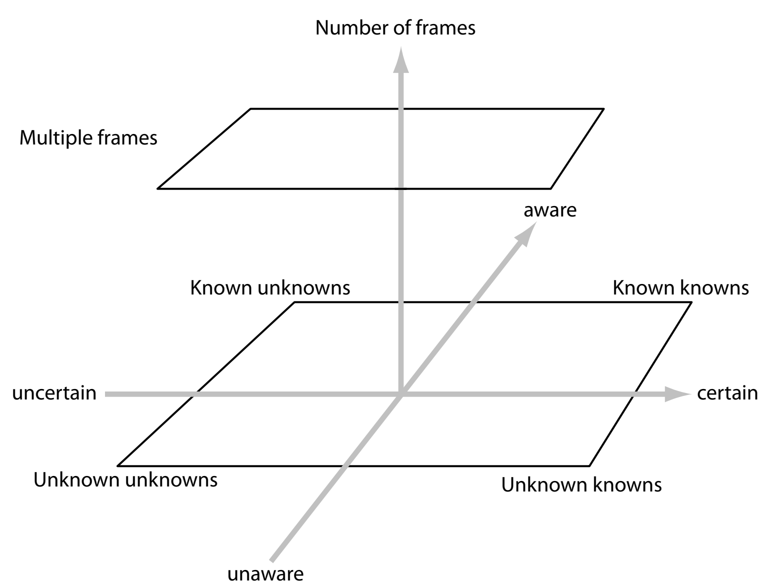

FIGURE A4 *Three-dimensional level–awareness–perception plot, where the X-axis maps the level of uncertainty (from uncertain to certain), the Y-axis maps the awareness of uncertainty (from unaware to aware), and the Z-axis maps the number of different frames or interpretations of the same issue (Source: Boschetti 2011, Figure 1).*

cilitator's and participants' awareness was raised about the need to separate the objectives related to the development of a set of tree species benchmarks from their implementation.

In future sessions, it would be useful to acknowledge that there are probably different frames or interpretations of the session's objective, and that an opportunity for them to be shared and understood should be provided so that a common frame of reference can be achieved. The facilitators should also be open to the need to clarify and refine the objective. In all three sessions, the facilitators were co-explorers in the development process, especially in the Williams Lake session.

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