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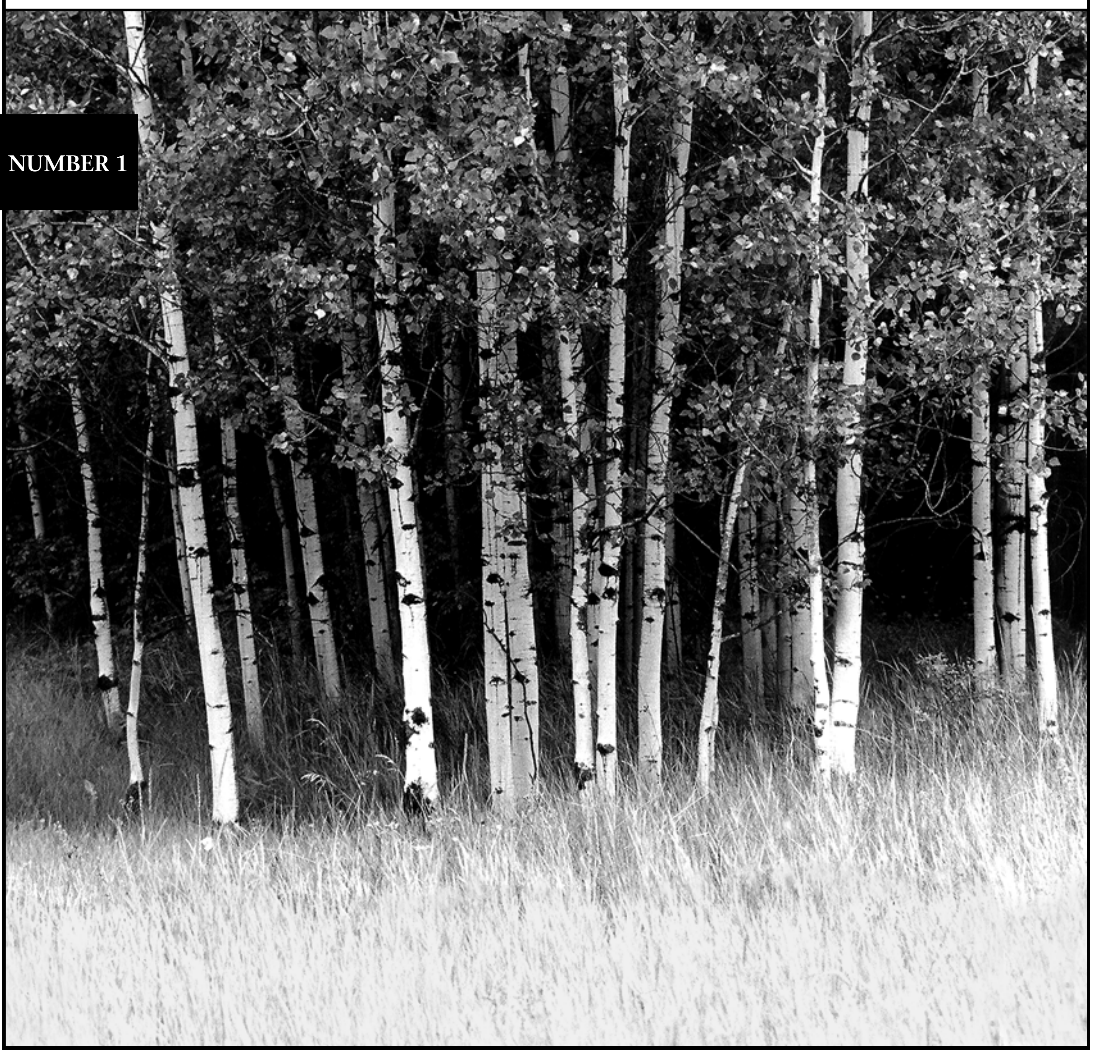

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ABOUT THE COVER PHOTOGRAPH:

"*Contrasts* captures the transition from soft grasslands to strong, vivid aspens at Lac du Bois Provincial Park near Kamloops, B.C."

— *JULIE TAYLOR SCHOOLING*

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About the Publisher

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For more information about the journal, please consult our submission guidelines on page 71.

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We appreciate the hard work of the many people who reviewed papers in this issue of *JEM*. To maintain anonymity where it has been requested, we will acknowledge this year's peer reviewers in the final issue of the fiscal year, Volume 2, Number 2. Our peer reviewers' time and expertise help to ensure accuracy and readability of *JEM* articles—we thank them for their commitment to *JEM*'s high standards of quality.

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Guest Editorial *

It's not just sustainability . . . it's your children's future

Jack Blaney, Chair, Fraser Basin Council

Sustainability was the focus of the Fraser Basin Council's recent "State of the Fraser Basin" conference. More than 350 people from all parts of the Basin attended the conference, which brought together community and environmental organizations, business and industry, and four orders of government to look at the state of the Fraser River Basin and to develop an action plan for its future sustainability.

Achieving a sustainable Fraser River Basin is perhaps the most critical challenge facing the 2.6 million British Columbians who live, work, and play within the Basin. In 30 years, the population of the Basin is expected to reach 4 million people. Managing this growth in ways that enhance the Basin's social, economic, and environmental health is an important responsibility and an urgent priority.

During the conference, attended by Lieutenant-Governor Iona Campagnolo and former premier Mike Harcourt, awards were presented to FORREX–Forest Research Extension Partnership and other sustainability champions. Another highlight was the release of the groundbreaking *State of the Fraser Basin Report: A Snapshot on Sustainability* (***www.fraserbasin.bc.ca/indicatorsRpt_2003.html***). The report is the equivalent of a medical check-up for the Fraser River Basin—it gives us a broad picture of where we stand today, and of how we can create a sustainable future.

The good news is that, in many ways, we are doing fairly well. We're living longer. Water quality has generally improved throughout the Basin. Far more people have a university education than ever before. The service sector, which includes high tech and other clean industries, is now the largest employer in all regions of the Basin. In addition, about half the salmon stocks in the Basin are increasing.

However, the Basin also has some major challenges, including some urgent ones that need to be addressed immediately.

There are far more "boil water" advisories than there were 20 years ago. More people are developing respiratory illnesses, perhaps related to poor air quality. Child obesity has skyrocketed. Fewer of us are volunteering or voting, and we're giving less to charity. For 20% of the population, housing is inadequate or too expensive. The mountain pine beetle is devastating forests throughout the Interior. "Noxious weeds"—or non-native plant species—are invading large tracts of agricultural land. Some communities are not adequately protected from the next great Fraser River flood. Progress on settling First Nations land claims is slow, and half of our salmon stocks are declining.

What became disturbingly evident from coverage of the event and other reactions to the report is that many people—including some senior public officials and many members of the media—still do not have a clear concept of sustainability. For many, sustainability is only an environmental issue.

* Adapted from the State of the Basin address given by Dr. Jack Blaney, Chair of the Fraser Basin Council and former President of Simon Fraser University.

So What *Is* Sustainability?

The Fraser Basin Council believes that sustainability is not just about the environment, nor is it just about the economy. It's about integrating economic, social, and environmental considerations into all of our planning for the future health and prosperity of the Basin.

It's about new ways of thinking. It's about developing new, collaborative models of leadership that can effectively grapple with the big issues—issues like climate change, economic diversification, protecting our ecosystems, and building constructive Aboriginal and non-Aboriginal relationships.

Sustainability is about change that rejects the status quo. It's about the interdependence of people, the economy, and the environment. Sustainability requires that we all work together to find the common ground on which to craft constructive solutions.

Perhaps we should stop trying to define the word and just think of sustainability as working together to build a better future for our children.

To do that, we need leadership that is collaborative, courageous, compelling, and committed.

Overall, the message to decision makers is pretty clear: British Columbians want courageous decisions that will leave a clean environment *and* a healthy economy for future generations, because both are needed for enduring prosperity.

Sustainability Awards: FORREX Honoured

The Fraser Basin Council's "Improving Decision Making" Award for 2002 went to FORREX–Forest Research Extension Partnership. This award celebrates processes that show collaborative decision making, create innovative agreements, and achieve common goals that meet people's different needs in the Fraser River Basin. Working with its 63 government and non-government partners, FORREX fosters improved natural resource decision making and practices in British Columbia, and links the province's forest resource practitioners with the information they need.

The Fraser Basin Council

Formed in 1997, the non-political and independent Fraser Basin Council is a custom-built vehicle that brings people together to find solutions to long-standing issues and conflicts and to take advantage of opportunities. The mandate of the Council is to ensure that decisions we make about the Basin today will protect and advance its economic, environmental, and social sustainability into the future.

The Council's 36-member board includes individuals from all regions of the Fraser Basin, with representatives from federal, provincial, local, and First Nations governments, as well as from the private sector and community and environmental organizations.

For more information, or to receive a copy of the *State of the Fraser Basin Report*, contact:

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Editor's Note

Julie Schooling, *JEM* Managing Editor

Jack Blaney's State of the Basin address outlines the challenge that faces us provincially, nationally, and globally. We must implement sustainable solutions before we fully understand what it takes to achieve sustainability. The remarkable increase in readership of this journal indicates that we are satisfying the urgent demand for cutting-edge information about knowledge-based management of British Columbia's natural resources. We receive new subscriptions to the print version of *JEM* every day, and the growth of on-line access is notable. From the second to third quarters of this fiscal year, the number of unique visitors to the *JEM* Web site increased 166%, while the number of documents downloaded doubled to over 8000! This is wonderful news for past and prospective authors—articles in *JEM* reach a rapidly growing audience. It's also good news for managers and stakeholders who will benefit as the flow of information intensifies and the dialogue in *JEM* expands. Watch for a new Reader Response feature in our next print issue—this section will be your opportunity to contribute to this important dialogue, and to play your part in responding to Jack Blaney's challenge. Let's build a better future now as we wait for the definition of "sustainability" to crystallize.

Perspectives

Water-based ecology: A First Nations' proposal to repair the definition of a forest ecosystem

Michael Blackstock[1]

Abstract

First Nations Elders are very concerned about whether enough clean drinking water will exist for future generations. Three highly respected Elders from the Southern Interior of British Columbia helped the author investigate First Nations water-based ecology: Mary Thomas from the Secwepemc (Shuswap), Millie Michell from the Nlaka'pamux (Thompson), and Mary Louie from the Syilx (Okanagan) Nation. This paper follows on from the author's previous examination of First Nations' spiritual and ecological perspectives on water (*BC Journal of Ecosystems and Management* 1(1):54–66). The Elders' vision of the relationships between water, land, and animals highlights an apparent shortcoming in Western science's definition of an ecosystem. In this paper, the author encourages a shift towards water-based ecosystem management, proposing to repair of the definition of forest ecosystems in a way that interweaves First Nations' philosophy with Western science's ecosystem-based management approach.

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Continuing the First Nations Dialogue on Water

First Nations Elders are very concerned about whether enough clean drinking water will exist for future generations. This paper follows on from my previous discussion of First Nations' spiritual and ecological perspectives on water (Blackstock 2002). Here, I continue to investigate First Nations water-based ecology with the help of three highly respected Elders from the Southern Interior of British Columbia: Mary Thomas from the Secwepemc (Shuswap), Millie Michell from the Nlaka'pamux (Thompson), and Mary Louie from the Syilx (Okanagan) Nation. Their vision of the relationships between water, land, and animals highlights an apparent shortcoming in Western science's definition of an ecosystem. Drawing on their experience and wisdom, I encourage a shift towards water-based ecosystem management by presenting a proposal to repair the definition of forest ecosystems. This new definition interweaves First Nations' philosophy with Western science's ecosystem management approach.

The Elders' vision of the relationships between water, land, and animals highlights an apparent shortcoming in Western science's definition of an ecosystem.

Water: Spiritual and Ecological Perspectives

Water is at the heart of the Elders' vision of an ecosystem. Rain, snow, springs, wetlands, lakes, and rivers are the lifeblood that circulates through the ecosystem, providing sacred and profane sustenance for all beings. Olivia Buck, a Nlaka'pamux youth, believes that we are borrowing clean drinking water from future generations, and thus we are also implicitly accepting the responsibility of returning water in as good or better condition (Olivia Buck, personal communication, 2001).

> **Mary Thomas:** I'm really concerned about the water; that's one of my biggest concerns with the environment. That's why I thought, gee, if you're going to do anything that will make people aware [about the environment], then we need to do something about the water. For example, the poor guy when he came to sell me drinking water, I told him I never thought I'd see the day that I'd spend seventy dollars a month for water! His face just went beet red and he said, "You know I feel really sad having to do this. But it's a must." And I said yes I know. Because I'm right at the end of the city water line, we don't have a thing to flush it. And you can see silt in the water in the house—I don't care how they try to purify it, there's always a certain amount of silt. So it's gathering up, gathering up; you pour a tub full of water and you can see the silt in there. I'm not that dirty!! [laughter] (Mary Thomas, personal communication, 2000).

The Elders emphasized how important it is to understand the spirituality of water—water has a spirit with which they converse and pray. Water is alive—it is biotic. Historically, water seemed to have a significant "life giving" importance in Western thought, but today it exists as an unorganized, non-thinking or unwillful grouping of molecules in the physical world. Western science defines an ecosystem as: *the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space* (Encyclopedia Britannica.com 2002). Water is not explicitly mentioned in this definition, rather it is enveloped in the concept of the physical environment (i.e., as inert matter, such as soil, which interacts with the living world). How would ecosystem-based management theory change if we were to assume that water has the dominant role in the "living community"?

> **Mary Louie:** The water is the biggest part of all our lives; without it, we'd never survive. So when you go to the water and you talk to that water, that water helps you. But you have to come from the heart with it, with your words. If you go to the water early in the morning and get into it before anybody's up or around, that water will strengthen you because your spirit cries for that water, not just your shower or your tub water, it's tired of the hot water; it wants cold water (Mary Louie, personal communication, 2000).

What is water? Clearly, there is a difference between First Nations' and Western science's perspective of water and its role in an ecosystem. This difference, if left unexamined, could lead to cross-cultural misunderstanding and disputes over forest management planning and the perceived effects of the resulting ecosystem intervention.


Ducks Unlimited Canada


Joyce Sam


Michell Family

Top: Secwepemc (Shuswap) Elder, Mary Thomas; Middle: Syilx (Okanagan) Elder, Mary Louie; Bottom: Nlaka'pamux (Thompson) Elder, the late Millie Michell.

Science is a way of knowing, a cornerstone of Western epistemology. Science has served the needs of an evolving society well, but not without its limitations. The taxonomic lens of science has created a chasm between the living and non-living components of our world—and water has unfortunately been placed on the non-living side. Science relies on accurate observation of cause and effect relationships over a measured and appropriate period of time. I define Traditional Ecological Knowledge (TEK) as: "a particular First Nations cumulative and evolving body of knowledge, attained over long periods of time, of their sacred and secular relationships between living beings in a variety of ecosystem types" (Blackstock 2001). First Nations have continually observed and orally recorded the changes in the land for the past 10 000 years. The three Elders involved in this research project have all reflected back on how ecosystems functioned many generations ago, and also on the subsequent changes to these ecosystems. Their way of knowing places water in the living world, and they have observed that water is drying up and that the land is becoming unhealthy. Perhaps Western society's desire to achieve sustainability is hampered by its potentially flawed definition of an ecosystem. First Nations have observed a crack in one of Western society's theoretical cornerstones—the ecological approach to a sustainable environment.

During the interview with Elder Millie Michell, she asked me, "Are you going to fix it?" Millie grew up with knowing and using her traditional teachings about respecting water. Her grandparents and parents taught her to respect everything, and she says we do not teach our children today. In her childhood, they had to pack water for bathing, drinking, cooking, and making tea. *I believe what she meant was, are you [the children, in her eyes] going to fix what is happening to the earth?* And then Millie continued talking about how important it is for children to learn to respect the water (Millie Michell, personal communication, 2000).

Repairing the Definition of "Forest Ecosystem"

If TEK and science are to coexist, then the Western science definition of forest ecosystem should be 're-paired' with a new emphasis on the role of water. For instance, ecologists in British Columbia define a forested ecosystem as: ". . . a segment of landscape that is relatively uniform in climate, soil, plants, animals, and micro-organisms . . . The biotic community of a site is composed of a combination of plants (vegetation), animals, and micro-organisms, each of which forms its own community" (Klinka *et al.* 1989:4). Repairing this definition would clearly symbolize a cross-cultural understanding to the question posed earlier: "What is water?" By incorporating this understanding, a revised definition could read: ". . . a forest ecosystem is a segment of landscape, composed of relatively uniform climate, soil, plants, animals, and micro-organisms, *which is a community complexly interconnected through a network of freshwater hydrological systems.*" Water is always moving, and thus it has the ability to function as the connecting component, or "blood of life." Consequently, ecosystem community relationship diagrams (topological representations of the interrelationships) would change from an unfocused network to a spiderweb network with water as the heart that pumps the blood of life throughout the community.

> **Mary Louie:** That's what I call this term "the blood of life" to Mother Earth's children and without it we'd never survive. So we need that water, and we need to keep it clean. A person would buy a new pair of shoes and would wear it right down to nothing before they'd get to that clean water. That's one of those things that the ancestors talked about [a prophecy]. So that's why I'm saying that we need to learn to preserve water. And that the mining should be cut off all together. They're digging her and hurting her, but yet they're taking the life out of her by doing that. 'Cause all of the ore, silver, the gold, whatever they're drilling for, that's part of hers. That's part of ours as well because we all are connected to everything that's been created. Without that we won't be in balance, because we need that mineral, we need that water, we need that fire, we need that clean air to be in balance. When they start monkeying around with that, that's why everyone is getting sick. We don't have cures for that (Mary Louie, personal communication, 2000).

The Implications of Redefinition

How would this new definition affect theory and practice? First, it would help us define a healthy ecosystem as one in which water, of sufficient quality and quantity, is delivered in a functional rhythm (Blackstock 2001). Water is essential for the existence of life. "Almost every plant process is affected directly or indirectly by the water supply," more than any other single environmental factor (Kramer 1983:1–2). In some cases, the ecological health of a forested watershed can only be maintained by minimizing significant human interventions, such as harvesting. Ecosystem integrity, defined by the Vision for Water and Nature Project, is the ". . . range of interactions between the water cycle, individual species and biophysical, chemical and ecological processes that support the organization of an ecosystem." This suggests that the ecological health or integrity of freshwater ecosystems can be preserved by maintaining "the hydrological characteristics of catchments, including the natural flow regime, the connection between upstream and downstream sections (including coastal and marine zones), the linkages between groundwater and surface waters, and the close coupling between the rivers and floodplains" (World Conservation Union 2000). Ecosystems, such as upper catchment cloud forests, springs, and certain wetlands, directly provide us with clean water and help to regulate flooding and basic ecosystem functions.

> **Mary Louie:** If you take your water and put it in a jar and cover it, then close it, in two days you'll see things in there. That's from the chemicals they put in there. It lines your pipes and . . . coats your showers and your toilets. But the water, it's a gift of life. It bothers me because our water is going down . . . disappearing because it's not being respected [pulled away from human access by Mother Earth in retribution for disrespect]. People won't offer gifts to the water anymore, you know; they don't take food to it, or tobacco. All they're used to is just taking and taking and taking; they don't know how to give back. They've never learned to balance things, huh? (Mary Louie, personal communication, 2000).

Second, researchers would need to acknowledge and respect water's special place in the ecosystem. Researchers have contributed greatly to our understanding of the connections between organisms in the ecosystem; however, this understanding would be more complete if they described these connections in the context of water's ability to make the connections possible in the first place. For instance, Goward and Arsenault (2000) discovered a connection between *Populus* species, conifers, and cyanolichens. Conifer bark is enriched by the rainwater that drips off the leaves of *Populus* species in the canopy above. The bark enrichment process creates a substrate on which cyanolichen can grow; the cyanolichen, which are nitrogen fixers, then indirectly enrich the soil. The role of water (in this case, rainwater) was not emphasized by the researchers, but presumably would be if the work were governed by the new definition of forested ecosystems proposed here. Similarly, Simard *et al.* (1997) discussed the connection between trees of different species through the common mycelium of soil mycorrhizal fungi. Simard found a "tightly linked plant–fungus–soil system." This has prompted forest managers to change their impression of paper birch (*Betula papyrifera*), which was once thought of as a "weed" species. Douglas-fir seedlings grow in a reciprocal relationship with paper birch—a net positive transfer of nutrients exists between each species through a soil mycorrhizal fungi network, which allows water to transport the nutrients across species gradients (Simard *et al.* 1997). However, the researchers did not emphasize the role of water here either. Researchers should be encouraged to design their studies with the assumption that water has an interconnecting role in the ecosystem, and also to inquire into the questions posed by the Elders such as:

- Is groundwater drying up because of harvesting?
- Does the forest act as a groundwater pump bringing water into the rooting zone and tree trunk?
- Does livestock fecal matter significantly contribute to deteriorating water quality?
- Are there fewer wetlands now compared to a couple of generations ago?
- Is water enriched with energy while it travels through photosynthetic hydrological systems (as Mary Thomas believes happens in birch trees).

> **Mary Thomas:** I talk about the birch tree as an example . . . you know my Elders told me that anything that grows has its own aura—it's its spiritual strength. I was reading a book about some monks who were studying some spiritual way in Peru. And it surprised me: we talk about the same thing . . . we talk about our medicine man—when he practised his medicine powers he always went to the water. He swam morning and night, morning and night, morning and night (Mary Thomas, personal communication, 2000).

And lastly, forest management practitioners, working with this revised definition of forest ecosystems, could base their management activities on the assumption that water is the primary component of an ecosystem and that a healthy ecosystem is one in which water, of sufficient quality and quantity, is delivered in a functional rhythm. The first question forest managers need to ask is: "how does this planned intervention affect water?" Throughout their daily practice, they need to acknowledge the special role of riparian and wetland ecosystems, regardless of their size[1]. They also need to "give back," meaning that a high priority should be placed on restoration. A proportion of the profits from resource extraction should be used to restore or improve water quality and quantity. Foresters, ranchers, and other renewable resource managers need to refocus their purpose under this revised definition. The primary product they manage for, under a water-based ecosystem approach, is clean water, and if successful, they can ensure a sustained delivery of secondary products such as timber, livestock, and fish.

A Shift towards a Water-based Ecosystem Approach

David Rothenberg, the co-editor of the enlightening book *Writing on Water*, describes the ability of water to unite: "Water does not divide; it connects. With simplicity it links all aspects of our existence. We feel its many meanings" (2001, xiii)[2]. Elders' TEK is a relationship-based philosophy; water has the primary connecting role which they characterize as the blood of life. Peter Warshall, who writes on ways to harmonize watershed flows with human communities, believes "water is life" and that "a healthy water supply supersedes all other economic and legal dictates" (2001:45). Warshall reflects on the two-thousand-year-old Chinese philosophy of Lao-tzu and writes: "Lao-tzu's great contribution to watershed governance was this: *Always give priority to water over human interests*. No matter how charming human ideals, poetics, political rhetoric, divine revelations, promises, or factoids, hydrophilia is the best consensus builder" (2001:50)[3]. In British Columbia, many cultures reside in, and rely on, the vast diversity of watersheds within its provincial bounds. Thus, these cultures must come to a consensus on the question: *What is water?* The Elders have offered a perspective that, upon interpretation and comparison, highlights a possible shortcoming in Western science's view of water

[1] The Forest Practices Code currently defines a wetland as being greater than one hectare in size, but First Nations are also concerned about those less than a hectare. This is an example of miscommunication. A forester may say, "I have considered wetlands in my plan," not realizing the First Nation is concerned about the ones not fitting the forester's definition of a wetland.

[2] The term "unite" is meant for the ecological context and not for the geo-political one, which is fraught with disputes over rights to water access.

[3] The term "hydrophilia" is defined as the love of or friendship with water.

and its role in the forest ecosystem. As borrowers of water, we should seek a cross-cultural consensus, and thereby ensure a healthy supply of water for future generations.

Acknowledgements

I would like to express my heartfelt thanks to Elders Mary Thomas, Mary Louie, and the family of the late Mildred Michell. Additionally I would like to thank Olivia Buck for her poignant perspectives as an Aboriginal youth.

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Extension Note

Cariboo Forest Region: Part 1 of 3

Forest Health Stand Establishment Decision Aid

Kathie Swift[1], Jennifer Turner[2], and Leo Rankin[3]

Introduction

Over the last four years, the Early Stand Dynamics program of FORREX–Forest Research Extension Partnership has assessed the information needs of the operational silvicultural community. This process has identified a number of issues relating to management of competing vegetation, forest health, silvicultural systems, and best practices. Besides information needs, members of the silvicultural community also expressed concern about the loss of their experiential knowledge.

These operational concerns prompted the initiation of an extension project to fill in the identified information gaps and document local knowledge. Competing vegetation and forest health were selected as the first subject areas on which to focus effort. Information relating to these two subject areas was collected, synthesized, and presented in an easy-to-use format. The resulting product was then presented to both the operational and scientific communities for their review and input.

The extension product generated by this process was called a "Stand Establishment Decision Aid" (SEDA). SEDAs are designed to provide information on the biological features that new and inexperienced practitioners need to consider when making silvicultural decisions about site limiting factors, such as competing vegetation or forest health. These decision aids are not intended to make the decisions for the practitioners. We currently base these decision aids on the Biogeoclimatic Ecosystem Classification (BEC) system. A description of this system is available on-line at: ***www.for.gov.bc.ca/hfd/pubs/Docs/Srs/SRseries.htm***

The SEDAs for the Cariboo Forest Region will be published as a three-part series. The first section of the forest health SEDA provides a hazard rating system that identifies the specific biogeoclimatic zone and subzone where the forest health problem can potentially occur. The second section outlines some possible silvicultural considerations that affect the host species. These considerations could be used to develop a management strategy, if one is required. The SEDA concludes with a resource section outlining where more information can be located. Reference material that is not available on-line can be ordered through the Queen's Printer at: ***www.qp.gov.bc.ca***

Although these decision aids currently identify the problem first, rather than the particular ecosystem in which the problem occurs, we intend to develop a product that focuses on the ecosystem (subzone and site series) and ecosystem-specific problems. This extension product will be presented as part of a compendium of limiting factors in the Cariboo Forest Region, and is currently under development.

The field format of this SEDA is available at: ***www.forrex.org/jem/2002/vol2/no1/art1_rev1.pdf***

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Comandra and Stalactiform Blister Rust – Cariboo Forest Region

www.na.fs.fed.us/spfo/pubs/fidls/comandra/comandrafidl.htm

Comandra blister rust damage to lodgepole pine

B.C. Ministry of Forests, Cariboo Forest Region

Stalactiform blister rust damage to lodgepole pine

Hazard Rating

BEC Zone*	Drier subzones	Wetter subzones
ESSF		wk1 (Low hazard)
ICH		mk3 (High hazard), wk (Mod–high hazard)
IDF	dk3+4 (Low hazard)	
MS	xv (Low hazard)	
SBPS	xc (Low hazard), dc (Mod–high hazard)	mk (Moderate hazard)
SBS	dw1 (High hazard), dw2 (Moderate hazard)	mc2 (High hazard), mw (Mod–high hazard)

Hazard Rating Key

Low hazard · Low–mod hazard · Moderate hazard · Mod–high hazard · High hazard

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

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Silvicultural Considerations

Hosts: Lodgepole Pine

Lodgepole pine are very susceptible to these rusts at an early age. The diseases are most damaging on young trees, and most of the mortality occurs before the age of 20. Mature trees take much longer to kill; thus, infections that have accumulated at a low rate over many years are present, making it appear that older trees have a higher incidence.

Establishment/Regeneration

In high-hazard subzones consider:

- Planting above minimum stocking standard to compensate for disease-induced mortality.
- Planting with non-susceptible tree species.
- Inter-tree planting with non-susceptible host to compensate for rust mortality.

Plantation Maintenance

- Consider spacing cankered trees in areas with a low to moderate hazard rating.
- Calculate expected rust mortality and incorporate into post-spacing tree density.
- If possible, space in late spring during aeciospore dispersal (most visible) to maximize disease removal. However, the existence of infection by basidiospores through wounds in the autumn is very weak, and may not happen at all. The cost of limiting spacing to certain times will likely outweigh any possible benefits.

Lodgepole Pine Dwarf Mistletoe – Cariboo Forest Region

B.C. Ministry of Forests, Cariboo Forest Region

Lodgepole pine dwarf mistletoe

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Hazard Rating

BEC Zone*	Drier subzones	Wetter subzones
ESSF	xc (moderate), xv1+2 (low), dc2 (high)	mv1 (low), wc3 (low), wk1 (low)
ICH	dk (high)	mk3 (high), mw3 (high), wk2 (low–mod), wk4 (high)
IDF	xm (high), xw (high), dk1,3+4 (high), dw (high)	mw2 (high)
MS	xv (low–mod), xk (low–mod), dv (low–mod), dc2 (low–mod)	
SBPS	xc (high), dc (high)	mc (high), mk (high)
SBS	dw1+2 (high)	mc1+2 (high), mh (high), mw (high), wk1 (high)

Hazard Rating Key

Low hazard · Low–mod hazard · Moderate hazard · Mod–high hazard · High hazard

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Silvicultural Considerations

Hosts: Lodgepole Pine

- Do not partially harvest infested stands that are managed primarily for timber, as residual trees will substantially increase disease occurrence in regenerating stands.
- Remove residuals over 50 cm tall.
- Large, rounded clearcuts decrease the likelihood of infection from adjacent stands. Avoid creating cutblocks with convoluted boundaries, as this increases ingress of mistletoe.
- Single tree or group selection systems result in the intensified spread and damage by dwarf mistletoe.
- If possible, avoid leaving islands of infected trees for wildlife patches. However, if wildlife reserves are required, layout islands to minimize spread of dwarf mistletoe into the young stand.
- In stands that have not reached crown closure, *approximately half the infections are invisible* (i.e., no swelling or dwarf mistletoe shoots).
- Leave non-host species as border trees and incorporate natural barriers wherever possible.

Establishment/Regeneration

For moderate–high hazard stands:

- Favour non-host tree species for regeneration or as leave trees.
- Consider mixed species planting.
- Consider planting 20-m strips of resistant species along the border of infested stands, but only if the host species will not invade such strips and take over. Unfortunately, resistant species, such as Douglas-fir and spruce, are commonly overtopped by naturally regenerating pine along stand edges.

Plantation Maintenance

- Avoid thinning if possible. In dwarf mistletoe infected stands, the gains associated with thinning are small compared to the silvicultural costs. However, ensure that yield projections for such stands are properly handled in cut calculations.
- If thinning is required, use wide spacing in moderate–high hazard stands (i.e., crop tree crowns should be 6 m apart).
- Use sanitation thinning for stands younger than half the rotation age. Stands with a dwarf mistletoe ratio (DMR) equal to or greater than 3 should not be thinned.

Lodgepole Pine Terminal Weevil – Cariboo Forest Region

B.C. Ministry of Forests, Cariboo Forest Region

Lodgepole pine terminal weevil larvae

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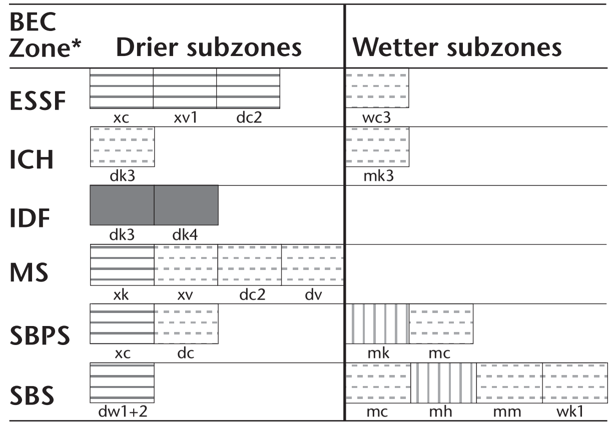
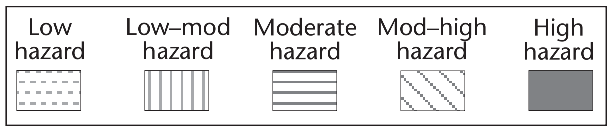
Hazard Rating



Hazard Rating Key



* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

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Silvicultural Considerations

Host: Lodgepole Pine

- Weevil attacks are most common in 10- to 25-year-old stands; therefore, weevil surveys to detect peak attack intensity should be delayed until the stand is at least 15 years old.

Establishment/Regeneration

- Plant a mixture of species (if possible).
- Keep densities high, preferably greater than 2400 stems per hectare in high-hazard stands.
- Note that greater inter-tree distances result in increased stand temperature, which promotes greater brood survival.

Plantation Maintenance

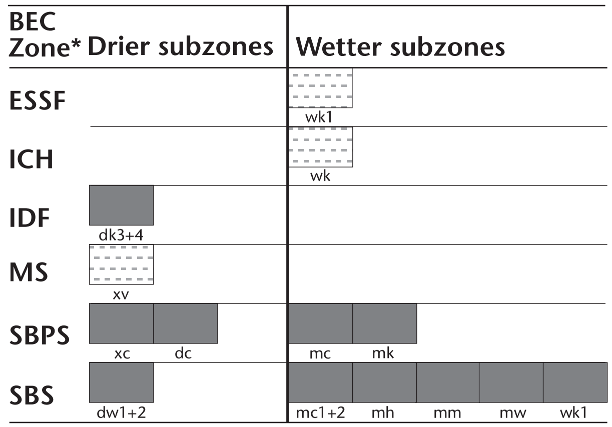
- Avoid spacing to low densities at an early age (8–15 years), as this increases stand susceptibility to weevils and damage severity.
- If early stand densities are very high, use non-mechanical spacing methods.
- Maintain high stand densities and do not brush until trees are more than 5 m high.
- Remove seriously weevil-damaged trees when the stand has reached a sufficient size.
- Note that levels of attack increase after spacing in moderate to high hazard zones (when spacing occurs at 8–15 years).
- Space only when attack rates are less than 10% annual attack.
- If attack rates exceed 10%, modify spacing (leave 2500 stems per hectare) or delay spacing until trees are more than 5 m high or stand is 25 years old.

Pine Needlecast – Cariboo Forest Region

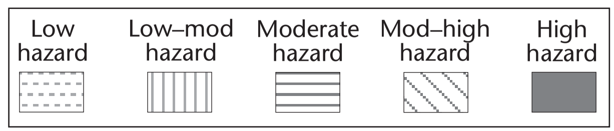
www.pfc.forestry.ca/diseases/CTD/Group/Needle/needle4_e.html

Damage to a young lodgepole due to pine needlecast

Hazard Rating



Hazard Rating Key



* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

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Silvicultural Considerations

Hosts: Lodgepole Pine

- Most widespread and abundant pest of young lodgepole pine in recent years.
- New foliage is infected in early summer.
- Disease is the most damaging on young or suppressed trees.

Establishment/Regeneration

- Planting mixed species may increase stand vigour in areas where disease incidence is high.
- Do not plant lodgepole pine provenances from low-risk areas in high-risk areas, such as sites in the Sub-Boreal Pine–Spruce Very Dry Cold subzone (SBPSxc) or the Interior Douglas-fir Dry Cool subzone, Fraser variant (IDFdk3) and Chilcotin variant (IDFdk4).

Plantation Maintenance

- Thinning may be used to maintain a vigorous stand.
- Select species susceptible to needlecast for spacing.

B.C. Ministry of Forests, Cariboo Forest Region

Stem gall on lodgepole pine infected by western gall rust

Hazard Rating

BEC Zone*	Drier subzones	Wetter subzones
ESSF	xc (Low–mod), xv1+2 (Low–mod), dc2 (Mod–high)	mv1 (Low–mod), wc3 (Low–mod), wk1 (Low–mod)
ICH	dk (Low–mod)	mk3 (Mod–high), mw3 (Low–mod), wk2+4 (Low–mod)
IDF	xm (High), xw (High), dk1,3+4 (High), dw (High)	mw2 (High)
MS	xv (Low), xk (Mod–high), dv (Low–mod), dc2 (Low–mod)	
SBPS	xc (High), dc (High)	mc (High), mk (High)
SBS	dw1+2 (High)	mc1+2 (High), mh (High), mm (High), mw (High), wk1 (High)

Hazard Rating Key

Low hazard · Low–mod hazard · Moderate hazard · Mod–high hazard · High hazard

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Silvicultural Considerations

Hosts: Lodgepole Pine

- Risk of infection and proportion of stem galls is highest on young trees; the highest risk of infection occurs mainly before the age of 15 years.
- Older and taller trees are less likely to be infected since infection sites are found on elongating shoots.
- Certain geographic areas seem more susceptible than others, depending on elevation, prevailing winds, humidity, etc.
- This rust does not generally infect pruning wounds or branch stubs.

Establishment/Regeneration

- Plant at higher densities (or with non-susceptible tree species) in high-hazard subzones to compensate for rust-induced mortality.

Plantation Maintenance

- Refer to Table 3 in the *Pine Stem Rust Management Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment 1996) for a description of disease incidence and treatment levels by activity.
- Perform a prescription survey in late spring or early summer to determine rust thresholds.
- Do not wait to space stands beyond 15 years, as the cost of waiting will likely be too high compared to the small possible gains.
- Consider removing all trees with stem galls to decrease post-spacing growth reduction due to western gall rust. However, since the largest trees tend to be the most susceptible, this management option may result in a loss of forest productivity.
- Consider leaving infected trees if stem galls are less than one-third the circumference of the tree, ***and*** the infected tree is twice the height of the uninfected tree to be spaced. Although leaving stem galls can result in a marked stem deformity called hip canker, (if the tree doesn't die) a larger tree with this deformity may be preferable to a suppressed, small pine that will not reach co-dominance. No systematic research has been conducted on the success of this technique; however, it has proven effective in the Quesnel Forest District.
- Space trees in spring or early summer during spore production (improved visibility) to maximize disease removal. However, even during spore production, it may be difficult for the untrained eye to determine which rust is producing spores.

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Cariboo Forest Region: Part 1 of 3

Vegetation Complex Stand Establishment Decision Aids

Kathie Swift[1] and Jennifer Turner[2]

Introduction

Over the last four years, the Early Stand Dynamics program of FORREX–Forest Research Extension Partnership has assessed the information needs of the operational silvicultural community. This process has identified a number of issues relating to management of competing vegetation, forest health, silvicultural systems, and best practices. Besides information needs, members of the silvicultural community also expressed concern about the loss of their experiential knowledge.

These operational concerns prompted the initiation of an extension project to fill in the identified information gaps and document local knowledge. Competing vegetation and forest health were selected as the first subject areas on which to focus effort. Information relating to these two subject areas was collected, synthesized, and presented in an easy-to-use format. The resulting product was then presented to both the operational and scientific communities for their review and input.

The extension product generated by this process was called a "Stand Establishment Decision Aid" (SEDA). SEDAs are designed to provide information on the biological features that new and inexperienced practitioners need to consider when making silvicultural decisions about site limiting factors, such as competing vegetation or forest health. These decision aids are not intended to make the decisions for the practitioners. We currently base these decision aids on the Biogeoclimatic Ecosystem Classification (BEC) system. A description of this system is available on-line at: ***www.for.gov.bc.ca/hfd/pubs/Docs/Srs/SRseries.htm***

The SEDAs for the Cariboo Forest Region will be published as a three-part series. The first two sections of the vegetation complex SEDAs identify specific species of concern that are found within the particular vegetation complex, and the geographic location of the complex in the forest region. The third section provides a treatment necessity rating system that identifies the specific biogeoclimatic zone, subzone, and site series where the vegetation complex can potentially be considered a problem. The fourth section outlines some possible silvicultural considerations that affect the species growing within this complex. These considerations could be used to develop a vegetation management strategy, if one is required. The fifth section provides information on some of the important autecological characteristics of the species occurring within this complex, followed by information on what roles and functions these species play in the ecosystem. We recognize vegetation community response is a function of many factors (e.g., type and intensity of disturbance); therefore, the vegetation complex SEDAs conclude with a resource section outlining where more information can be located. Reference material that is not available on-line can be ordered through the Queen's Printer at: ***www.qp.gov.bc.ca***

Although these decision aids currently identify the problem first, rather than the particular ecosystem in which the problem occurs, we intend to develop a product that focuses on the ecosystem (subzone and site series) and ecosystem-specific problems. This extension product will be presented as part of a compendium of limiting factors in the Cariboo Forest Region, and is currently under development.

The field format of this SEDA is available at: ***www.forrex.org/jem/2002/vol2/no1/art2_rev1.pdf***

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CITATION —

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B.C. Ministry of Forests, Cariboo Forest Region

Commonly Occurring Species*

Low Shrubs

black huckleberry	**Sitka mountain ash**
oval-leaved blueberry	**falsebox**
velvet-leaved blueberry	**birch-leaved spirea**
white-flowered rhododendron	

Herbs

fireweed	Indian hellabore
bluejoint	Sitka valerian

* **Note:** Species composition will differ between subcomplexes (see General Information for description of ericaceous subcomplexes). Only species that can affect crop tree establishment are listed. For a particular subcomplex, species names appearing in **bold type** have moderate to high ground cover.

Site Series That May Require Vegetation Complex Treatment For Successful Conifer Establishment Following Clearcut Harvesting

BEC Zone*	Subzone	Zonal	Drier Site Series	Wetter Site Series
ESSF	wc3		02	03
	wk1		03	
	xv1		06	
	xv2		06	
ICH	wk2	01	04	
	wk4	01	04, 05	

Treatment Necessity Key

- Low – Treatment may be required
- Moderate – Treatment likely required
- High – Treatment almost always required

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

General Information

The ericaceous shrub complex in the Cariboo Forest Region occurs primarily in the Engelmann Spruce–Subalpine Fir (ESSF) zone. The complex most frequently occurs on mid- to upper slope positions in wetter ESSF subzones. While found on various aspects, it is most common on cool, steep, northern and eastern aspects. The ericaceous shrub and subalpine herb complexes often develop in a mosaic of patches, with the ericaceous complex occupying slightly drier (better drained) and poorer sites. For example, in an area of rolling topography, the ericaceous complex occurs on the drier ridges, while the subalpine herb complex occcupies the swales where soils remain wetter from more persistent seepage. These two complexes share many species in common and their classification is largely determined by the relative abundance of ericaceous shrubs versus tall herbaceous vegetation. Several factors, such as harvesting method, silvicultural treatments, and site characteristics, play roles in determining whether a shrub- or herb-dominated community develops.

The ericaceous complex has been further divided into two subcomplexes. The *ericaceous shrub–rhododendron* subcomplex consists of larger shrubs, such as white-flowered rhododendron, black huckleberry, oval-leaved blueberry, and Sitka mountain ash. This subcomplex commonly occupies mid- to upper slope positions in ESSFwc3 (Wet Cold subzone, Cariboo variant) 01 and 02 site series. However, it also occurs on mid- to upper slope positions with poor to medium nutrient regimes in ESSFxv1 (Very Dry, Very Cold subzone, West Chilcotin variant) 06 site series, where competing vegetation often limits crop tree survival and the growth and establishment of natural regeneration. The principal competing species of the *ericaceous shrub–low shrub* subcomplex are black huckleberry, velvet-leaved blueberry, falsebox, and birch-leaved spirea. This subcomplex occurs more frequently on ridge crests with shallow soil over bedrock in SBSmc1 (Sub-Boreal Spruce Moist Cold subzone, Babine variant) 02 site series.

Silvicultural Considerations

Important vegetation management considerations:

- Determine whether vegetation competition is the most limiting factor on the site.
- Assess competition and control requirements on a site-by-site basis.
- This vegetation complex affects crop tree survival more than growth.

Silvicultural Systems

- Ericaceous shrubs are negatively affected by disturbance to the forest floor; therefore, the complex tends to develop on winter-logged sites where stems have been protected by the snow pack.
- Overstorey removal has relatively little effect on shrub competition, but herbs such as Sitka valerian will greatly increase in vigour. Group selection, or similar silvicultural systems, may improve reforestation success and non-timber values, particularly at higher elevations.

Establishment/Regeneration

SITE PREPARATION

- Mechanical site preparation is the most effective site preparation method to control this complex in the ESSF.
- Late season application of glyphosate may control the shrub component, but can shift species composition to herbs.
- Medium- to high-impact burns have led to successful regeneration in the ESSF zone (wetter subzones), but can shift sites from shrub- to herb-dominated communities.

PLANTING

- Plant sites immediately after site preparation to take advantage of warmer soil temperatures.
- Larger stock sizes may provide a gain in growth, but frost is a concern.
- Correct microsite planning is imperative to successful regeneration.

Plantation Maintenance

BRUSHING

- If sites are prepared and planted promptly following harvest, brushing may not be required.

Ericaceous Shrub Complex – Cariboo Forest Region

Specific Autecological Characteristics

Pre-disturbance

- This complex is typically found in the openings of mature forest stands.
- It is often present under ESSF forest canopy. Although it does not develop or spread quickly in this zone, it may eventually become the dominant plant community following logging. This is particularly true on sites where, before harvest, the complex is well developed under the forest canopy or in openings. These conditions typically occur in very cold, high-elevation ESSF forests where the canopy tends to be open or with gaps.

Post-disturbance

- Undisturbed shrubs increase slowly in height after canopy removal.
- In the ESSF, canopy removal does not cause white-flowered rhododendron cover to change substantially.
- In ESSFwc3 01 site series, a reduction in shrub cover generally results in a substantial increase in the cover of the herb layer.
- In the SBS, shrub and herb cover in the ericaceous shrub–low shrub subcomplex increases little after harvest.
- Vegetation complex shrubs initially become established following seed dispersal by animals (black huckleberry and oval-leaved blueberry) or wind (rhododendron and false azalea), and subsequently spread mainly by vegetative means.
- All *Vaccinium* species reproduce vegetatively via rhizomes; in the case of black huckleberry, rhizomes are 8–30 cm below the soil surface.
- White-flowered rhododendron spreads via rhizomes, by sprouting from the root crown and adventitious buds, and by layering.
- Shrubs infrequently establish by seed; growth is slow on undisturbed sites.
- Sitka valerian increases rapidly in size following overstorey removal; vegetative growth can initiate in the spring when the snow is still 15–25 cm deep.

Other Values of the Species

First Nations' Values

- The scent of the white-flowered rhododendron was valued by the Nlaka'pmx.
- Several Southern Interior natives ate the berries of velvet-leaved blueberry, oval-leaved blueberry, and Sitka mountain ash.
- Sitka mountain ash bark was used to cure coughs, flu, and fever, while the wood was sometimes used by the Carrier to make sidesticks for snowshoes.

Provision of Unique Food/Habitat

- This complex provides valuable habitat for animals using the ESSF year-round or during the snow-free season.
- Although poisonous to most domestic and wild animals, rhododendron has forage value to grouse.
- The fruits of oval-leaved blueberry and black huckleberry are a valued food source for bears, humans, small mammals, and several bird species. Foliage and twigs of these shrubs are also important for winter browsing by deer and mountain goat.
- Wildlife species graze the subalpine herbs of this complex.

Protection

- The susceptibility of falsebox to Armillaria root disease makes it a useful site indicator of the pathogen's incidence.

Bioregulation

- White-flowered rhododendron may impede conifer performance through allelopathy.

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B.C. Ministry of Forests, Cariboo Forest Region

Commonly Occurring Species*

Shrubs

red elderberry	red-osier dogwood
mountain alder	thimbleberry
skunk current	

Herbs

lady fern	**western medowrue**
ostrich fern	spinywood fern
stinging nettle	devil's club

* **Note:** Only species that can affect crop tree establishment are listed. Species names appearing in **bold type** have moderate or high ground cover.

General Information

The fern complex and the mixed shrub complex tend to occupy similar sites and include similar species, although the fern complex is less common in the Cariboo Forest Region. It is found on moist to wet sites in wetter subzones of the Interior Cedar–Hemlock (ICH) and Sub-Boreal Spruce (SBS) biogeoclimatic zones. It most commonly develops on moist, previously burned sites, or where the complex was present before logging. Areas with a high density of devil's club can also develop into the fern or mixed shrub complex after harvesting. The fern complex is of particular concern in the wetter ecosystems and on steeper slopes in the Cariboo Forest Region.

Site Series That May Require Vegetation Complex Treatment For Successful Conifer Establishment Following Clearcut Harvesting

BEC Zone*	Subzone	Zonal	Drier Site Series	Wetter Site Series
ESSF	wk1	01 (Low)		04 (High), 05 (High), 07 (Moderate)
ICH	dk			06 (Low), 07 (Moderate), 08 (High)
	mk3			05 (Moderate), 06 (High), 07 (High)
	wk2			05 (Low), 06 (Moderate), 07 (High), 08 (High)
	wk4			06 (Moderate), 07 (High), 08 (High)
SBS	mh			07 (Moderate), 08 (Moderate)
	mw			08 (Moderate), 13 (High)
	wk1			07 (Moderate), 08 (Moderate)

Treatment Necessity Key

- Low – Treatment may be required
- Moderate – Treatment likely required
- High – Treatment almost always required

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Silvicultural Considerations

Important vegetation management considerations:
- Determine whether vegetation competition is the most limiting factor on the site.
- Assess competition and control requirements for this complex on a site-by-site basis.
- Lady fern competes for light with young seedlings and causes mechanical damage via smothering.

Silvicultural Systems

- This complex should be considered a serious competitor if it is well established (with or without a high density of devil's club) before canopy removal. It will probably diminish in cover on those sites where previously moist soils become prone to drying out following logging.

Establishment/Regeneration

- *Seedlings likely experience minimal competition for moisture and nutrients from this complex. It is possible, however, that excess moisture and high humidity under extremely dense vegetation of this nature can cause seedlings to rot.*
- *High seedling mortality is common immediately following planting in fern-dominated openings; this can sometimes lead to stocking problems.*
- Multiple treatment entries may be necessary to ensure seedling survival, especially in wetter ecosystems and on steeper slopes where snowpress is a concern.

SITE PREPARATION
- Lady fern colonies tend to be favoured by light to moderate burns, but are retarded by mechanical site preparation (MSP).
- This complex usually forms a mat of roots; this can lead to more soil disturbance than desired during MSP. As a result, spot MSP and good operators are essential.

CHEMICAL
- Glyphosate may be applied once, as either a broadcast or spot application.

PLANTING
- Mortality and loss of vigour tends to occur if there are delays between harvesting, planting, and early brushing. Plant seedlings within 1–2 years of harvest or site preparation.
- Plant a large stock type with a large calliper on best microsites for crop establishment on sites with a substantial cover of the fern complex.

Plantation Maintenance

BRUSHING
- Single or repeated manual cutting treatments may be required.

CHEMICAL
- Glyphosate may be applied once, as either a broadcast or spot application.

Fern Complex – Cariboo Forest Region

Specific Autecological Characteristics

Pre-disturbance

- Lady fern (on sites where it is dominant) will commonly persist under a mature overstorey.
- A few sites in the SBSmh can have dense ostrich fern cover.
- Spiny wood fern is a more common complex species than bracken fern in the Cariboo Forest Region.

Post-disturbance

- Lady fern usually becomes a dominant species on logged sites only if it was well established (or is established with a significant cover of Devil's club) in the previous stand.
- Lady fern, if present before logging, reproduces through rhizome division, but it does not form an extensive underground network.
- Ferns reproduce through spores.
- Lady fern often forms large uniform stands.
- Thimbleberry patches are common in this complex. Canopy removal, burning, and mechanical site preparation all stimulate sprouting from rhizomes of thimbleberry plants that were present before logging; burning and MSP creates suitable conditions for germination of new or banked seeds. Once established, thimbleberry plants quickly expand into colonies through vegetative reproduction of the rhizomes.

Other Values of the Species

First Nations' Values

- The Nlaka'pmx used lady fern as a medicine, and ate the fiddleheads in early spring.
- Starch provided by spiny wood fern stems was very important to several First Nations groups.
- All central and southern Interior groups ate fresh thimbleberries. The shoots of this plant could be peeled and eaten raw or in a stew.

Provision of Unique Food/Habitat

- Lady fern is moderately important winter food for deer, elk, moose, bighorn sheep, and caribou.
- Black bear and deer readily eat fiddleheads and mature fronds during spring and summer.
- Many birds and mammals favour thimbleberry fruit. Twigs and leaves have limited value as a food source, but tend to be used more for cover.

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Reedgrass Complex – Cariboo Forest Region

B.C. Ministry of Forests, Cariboo Forest Region

Commonly Occurring Species*

Reedgrass sp.

General Information

The reedgrass complex is found in the Engelmann Spruce–Subalpine Fir (ESSF), the Interior Cedar–Hemlock (ICH), and Sub-Boreal Spruce (SBS) biogeoclimatic zones. The complex is common and often locally abundant at low to high elevations in moist to wet forests, wetlands, and clearings.

Throughout much of southern British Columbia, bluejoint is primarily a wetland species, occurring in swamps, marshes, wet meadows, and floodplains. In the Cariboo Forest Region, it is commonly found north of Likely (on mesic and wetter sites series of the ESSFwk1[Wet Cool subzone, Cariboo variant]), particularly near Wolverine Lake, Kangaroo Creek, and Keithley Creek.

The reedgrass complex grows best on nutrient-medium to rich sites.

Site Series That May Require Vegetation Complex Treatment For Successful Conifer Establishment Following Clearcut Harvesting

BEC Zone*	Subzone	Zonal	Drier Site Series	Wetter Site Series		
ESSF	wk1	01 (Moderate)		04 (High)	05 (High)	07 (High)
ICH	wk2			05 (Low)	06 (Low)	07 (Low)
	wk4			06 (Low)	07 (Low)	08 (Low)
SBS	wk1			09 (Low)		

Treatment Necessity Key

- Low – Treatment may be required
- Moderate – Treatment likely required
- High – Treatment almost always required

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Silvicultural Considerations

Important vegetation management considerations:
- Determine whether vegetation competition is the most limiting factor on the site.
- Assess competition and control requirements for this complex on a site-by-site basis.
- This complex is generally not a major issue in the Southern Interior.
- If considered a problem, apply vegetation control treatments soon after disturbance to control the vegetation before it becomes well established.

Silvicultural Systems
- Use of partial cutting rather than clearcutting could reduce invasion or serious infestation.

Establishment/Regeneration
- *Snow press and smothering of young seedlings can occur.*

SITE PREPARATION
- Any site preparation that mixes the soil will likely encourage rhizome sprouting and germination of buried seed, as will light prescribed burning. Avoid such practices where grass invasion is a possibility.
- Inverted mounds can increase the chance of seedling survival.

CHEMICAL
- Glyphosate provides good to excellent control.

PLANTING
- Plant the site (on the best microsites) immediately following disturbance.
- Use large-caliper stock and higher than minimum stocking levels to increase the chance of seedling survival and reforestation success.
- Check 1- to 3-year survival and determine whether replanting or fill planting is required.

Plantation Maintenance

GRAZING
- Sheep grazing has successfully controlled this complex in the Cariboo Forest Region.

CHEMICAL
- Glyphosate provides good to excellent control.

BIOLOGICAL CONTROL
- The development of an integrated strategy that combines biological control with low impact silvicultural techniques is currently under way.

Reedgrass Complex – Cariboo Forest Region

Specific Autecological Characteristics

Pre-disturbance

- If this complex is already growing in the vicinity, or if grass is well distributed in the forest understorey before harvesting, then the probability of invasion is high (depending on site and location).

Post-disturbance

- Reedgrass can occupy a site quickly because of its ability to produce creeping rhizomes.
- It is an aggressive colonizer after disturbance.

Other Values of the Species

Enhancement of Resource Availability

- It can increase soil organic matter.

Protection

- Light growth of bluejoint on scalped areas of soil may be beneficial in reducing frost heaving of seedling conifers.

Bioregulation

- Provides good control against surface erosion.
- Bluejoint cover can also limit invasion from larger brush species which may have a longer lasting and more serious impact.

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Subalpine Herb Complex – Cariboo Forest Region

B.C. Ministry of Forests, Cariboo Forest Region

Commonly Occurring Species*

Herbs

lady fern	**cow-parsnip**
Sitka valerian	**Indian hellebore**
arrow-leaved groundsel	

Low Shrubs

black gooseberry	black twinberry
white-flowered rhododendron	black huckleberry

* **Note:** Only species that can affect crop tree establishment are listed. Species names appearing in **bold type** have moderate to high ground cover.

Site Series That May Require Vegetation Complex Treatment For Successful Conifer Establishment Following Clearcut Harvesting

BEC Zone*	Subzone	Zonal	Drier Site Series	Wetter Site Series
ESSF	wc3	01 (Low)		
	wk1			04 (High), 05 (High), 07 (Low)

Treatment Necessity Key

- Low – Treatment may be required
- Moderate – Treatment likely required
- High – Treatment almost always required

* See Steen and Coupé (1997) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

General Information

The subalpine herb complex in the Cariboo Forest Region occurs primarily in the Engelmann Spruce–Subalpine Fir (ESSF) zone. It is best developed on lower and toe slopes and small depressions in the wetter subzones of the ESSF, where abundant precipitation and deep snow packs maintain moist to wet soils throughout the growing season. Although occurring on all aspects, it is most common on cool northern and eastern aspects where soils remain wetter from more persistent seepage during the growing season. This complex often develops a mosaic of patches in combination with the ericaceous shrub complex, with the ericaceous complex occupying slightly drier and poorer sites. These two complexes share many species in common and their classification is largely determined by the relative abundance of ericaceous shrubs versus tall herbaceous vegetation.

The subalpine herb complex is dominated by a dense and rich variety of relatively tall forbs. These include Sitka valerian, fireweed, Indian hellebore, lady fern, arrow-leaved groundsel, foamflower, and cow parsnip. Shrubs, if present, occur with low cover. These often include white-flowered rhododendron, black huckleberry, oval-leaved blueberry, and black twinberry.

Silvicultural Considerations

Important vegetation management considerations:

- Determine whether vegetation competition is the most limiting factor on the site.
- Assess competition and control requirements on a site-by-site basis.
- Recognized as a competitor to conifer crop seedlings.
- This complex can create dense shade, which maintains soil temperatures below critical thresholds for water and nutrient uptake and reduces the availability of light for conifer seedlings.

Silvicultural Systems

- This complex usually develops following disturbance to the forest floor (e.g., disturbance as a result of summer logging).

Establishment/Regeneration

SITE PREPARATION

- Mechanical site preparation (MSP) encourages growth of this complex because of the rhizomatous nature of the species. However, in combination with immediate planting of high-quality stock, MSP can be an effective treatment, reducing or eliminating the need for further control measures such as brushing.

CHEMICAL

- Herbicide treatment may not be the best option: some herbs within this complex appear to tolerate glyphosate.

PLANTING

- Plant sites immediately after site preparation to take advantage of warmer soil temperatures.
- Larger stock size may provide a gain in growth, but frost is a concern.
- Correct microsite planting is imperative to crop tree survival.

Plantation Maintenance

BRUSHING

- The need for brushing is unlikely.

LIVESTOCK GRAZING

- Grazing may be the best option for plantation maintenance. Herbs associated with this complex have variable palatability to livestock. Sitka valerian and fireweed are preferred forage species for sheep, and are also grazed to some extent by cattle. However, Indian hellebore is very toxic to these animals.

CHEMICAL

- Herbicide treatment may not be the best option on sites dominated by Sitka valerian, which appears to tolerate glyphosate.

Specific Autecological Characteristics

Pre-disturbance

- This complex is generally poorly developed under a forest canopy, but the presence of the ericaceous shrub complex can indicate its potential occurrence.

Post-disturbance

- All species within this complex have the ability to increase in vigour following canopy removal and disturbance to the forest floor (e.g., that which occurs during summer logging, mechanical site preparation, or medium- to high-impact broadcast burning).
- This complex may be enhanced by the treatment of the ericaceous shrub complex.
- Less is known about individual species in the subalpine herb complex than the ericaceous shrub complex, but most species are rhizomatous and presumably spread rapidly by vegetative means.

Other Values of the Species

First Nations' Values

- Several groups used Sitka valerian as a medicine and disinfectant.
- Racehorses were bathed with Sitka valerian; powder from the dried root was mixed with tobacco to add flavour.
- Rhizomes of Indian hellebore were burned and the fumigant used to drive away evil spirits.
- Indian hellebore was also used as a treatment of skin and scalp conditions.
- Nlaka'pmx used lady fern as a medicine and ate the fiddleheads in early spring.

Provision of Unique Food/Habitat

- Lady fern is moderately important winter food for deer, moose, bighorn sheep, and caribou.
- Black bear and deer readily eat fiddleheads and mature fronds during spring and summer.
- Several herbs associated with this complex are used by wildlife during the summer and fall; moderate use for summer forage by bears, mule deer, caribou, bighorn sheep, mountain goat, marmots, foxes, rabbits, and pikas.
- Herbs associated with this complex have variable palatability to livestock. Sitka valerian is a preferred forage species for sheep, and is also grazed to some extent by cattle; Indian hellebore is toxic to livestock.

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Extension Note

Ectomycorrhizae and forestry in British Columbia: A summary of current research and conservation strategies

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Abstract

Ectomycorrhizae are fungus-root associations that comprise the feeder roots of most commercially important conifers in British Columbia. A large body of research has been conducted on ectomycorrhizae as they relate to forestry in the province; however, much of this information is scattered and is generally of a highly technical nature.

This extension note summarizes the latest research on ectomycorrhizae, including information on the role that ectomycorrhizal fungi play in forest ecosystems. The authors discuss several helpful forest management practices that can maintain a diverse community of ectomycorrhizal fungi across the landscape. These include: retaining refuge plants, mature trees, and old-growth forests; retaining the forest floor during harvest and mechanical site preparation; avoiding high-intensity broadcast burns; minimizing the effects of species shifts, particularly following grass seeding; maintaining the edge-to-area ratio of harvested areas within certain limits; planting a mixture of tree species soon after harvest; retaining coarse woody debris; and managing for the fruiting bodies formed by ectomycorrhizal fungi, including edible mushrooms and truffles, fungi species used by wildlife, and rare and endemic species.

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Introduction

Ectomycorrhizae are fungus-root associations that comprise the feeder roots of most commercially important conifers. Much useful research and management information exists about these tiny "fungus-roots"; however, this information is scattered and is generally of a highly technical nature.

In this extension note, we summarize the latest information on ectomycorrhizae as it applies to forestry in British Columbia[1]. We briefly describe ectomycorrhizal fungi and discuss the reasons why forest managers should be concerned about their conservation. We then discuss the functional role these fungi play in tree growth and several important management techniques that can be used to maintain these beneficial plant/fungal associations across the landscape. These include:

- Retaining refuge plants, mature trees, and old-growth forests;
- Retaining the forest floor during harvest and mechanical site preparation;
- Avoiding high-intensity broadcast burns;
- Minimizing the effects of species shifts, particularly following grass seeding;
- Maintaining the edge-to-area ratio of harvested areas within certain limits;
- Planting a mixture of tree species soon after harvest;
- Retaining coarse woody debris; and
- Managing for the fruiting bodies formed by ectomycorrhizal fungi, including edible mushrooms and truffles, fungi species used by wildlife, and rare and endemic species.

With an increased understanding of ectomycorrhizal fungi, beneficial forest practices can be better developed and more extensively applied, while damaging ones may be avoided.

Why the Interest in Ectomycorrhizae?

Mycorrhizal fungi form close physical associations (or symbiotic relationships) with the roots of most vascular plants (Figure 1). The Greek term "mycorrhiza," which describes the association, literally means "fungus-root."

With an increased understanding of ectomycorrhizal fungi, beneficial forest practices can be better developed and more extensively applied, while damaging ones may be avoided.

Both fungal and plant partners can benefit from this association (Smith and Read 1997). The fungal partner provides the plant with soil nutrients and water and, in turn, receives photosynthetically derived plant carbohydrate.

Several general types of mycorrhizae exist, of which *ectomycorrhizae* predominate on forest trees of western North America (Molina *et al.* 1992). More than 5000 species of fungi are estimated to form ectomycorrhizae (Molina *et al.* 1992) worldwide, although this number may be low. Most of these fungi produce mushrooms and their allies above-ground, and up to one-quarter form truffles below-ground. Some species of mushrooms and truffles formed by ectomycorrhizal fungi are important food sources for small mammals and some species are harvested commercially.

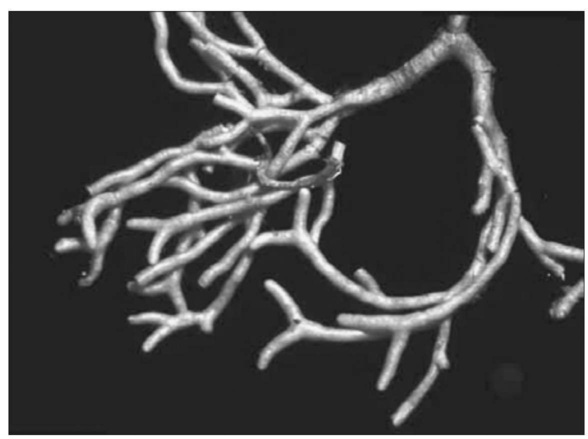

FIGURE 1. *Lactarius* mycorrhizae on fine roots of western hemlock.

[1] This extension note contains information on the ecology and management of non-timber forest products. In promoting implementation of this information, the user should recognize the equitable sharing of benefits derived from the management and use of this product (Article 8[j] of the United Nations Convention on the Conservation of Biological Diversity). Where possible, the user should involve the keepers of this knowledge and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with the conservation and sustainable use requirements (Article 10[c]).

Most of British Columbia's important commercial conifers (e.g., all species of pine, spruce, larch, hemlock, and true fir, as well as both subspecies of Douglas-fir) and some broadleaf trees (aspen and birch species) form ectomycorrhizal associations. Well-known exceptions are cedars and maples, which form other types of mycorrhizal associations, and poplars and alders, which form ectomycorrhizae as well as other types of mycorrhizal associations.

A great deal of research has been conducted on ectomycorrhizae, their functioning in the ecosystem, and the effects of forest management on their abundance and diversity. Forest managers should be concerned about conserving a high diversity of ectomycorrhizal fungi for two main reasons.

1. Different ectomycorrhizal fungi play different roles in tree growth.
2. Different ectomycorrhizal fungal communities associate with differently aged forests across the landscape.

The next section describes some of the basic biology of ectomycorrhizae, their diversity, and the functional role they play in plant growth.

Forest managers should be concerned about conserving a high diversity of ectomycorrhizal fungi.

What Are Ectomycorrhizal Fungi?

Some Biological Basics

Ectomycorrhizal fungi usually form a mantle that encloses the plant rootlet, from which hyphae (i.e., vegetative, non-reproductive, threadlike filaments) radiate outward into the soil, as well as inward between the root cells to form a hyphal network called the "Hartig net." The hyphae of most ectomycorrhizal fungal species proliferate in the duff layer of the forest floor, but some also inhabit mineral soil, and still others prefer decaying wood as a substrate (Goodman and Trofymow 1998). Some ectomycorrhizal fungi require large amounts of carbohydrate, which they acquire from their plant hosts, and so are dependent on mature trees that can meet their carbohydrate demands (Deacon and Fleming 1992). However, these fungi can also colonize seedlings growing in close proximity to roots of mature tree hosts (Simard *et al.* 1997b, Kranabetter and Wylie 1998) via networks of fungal hyphae.

FIGURE 2. *Hydnellum peckii* (Strawberries and cream, or Bleeding hydnellum) found near Adams Lake, B.C.

Ectomycorrhizal fungi colonize new roots from several types of inoculum (i.e., material that is the source of fungal cells):

- hyphae;
- spores, produced by sexual structures called sporocarps or fruiting bodies (e.g., mushrooms and their allies as well as truffles; see Figure 2), or spores produced by simple cell division from hyphae; and
- sclerotia, which are little balls of hyphae.

Ectomycorrhizal fungi generally cannot survive in the soil for long periods without a host, so hyphae are typically attached to living roots. The relative importance of these different kinds of inocula in forests is not well understood. However, the total amount and diversity of fungal inoculum usually decreases rapidly following harvesting or burning of host trees (Kranabetter and Wylie 1998; Baar *et al.* 1999; Hagerman *et al.* 1999a, 2001; Kranabetter 1999; Massicotte *et al.* 1999), with greater declines following more severe disturbances (Bradbury *et al.* 1998). The recovery of ectomycorrhizal fungi following a disturbance takes time, usually decades (Visser 1995).

Several studies highlight hyphae attached to living roots as one of the important sources of inoculum in undisturbed soil. For example, seedlings will form ectomycorrhizae with more species of fungi when they are planted in contact with live roots of mature trees than when a barrier is placed between them (Simard *et al.* 1997b). In addition, seedlings that were originally non-mycorrhizal can become colonized to a greater extent and by more ectomycorrhizal fungi when they are planted near the edges of cutblocks where adjacent forest tree roots extend (Hagerman *et al.* 1999b). In laboratory situations, fungi will form ectomycorrhizae with a wider range of tree species if they colonize from hyphae attached to another seedling rather than from spores (Massicotte *et al.* 1994).

Although all ectomycorrhizal fungi produce spores, only some of these species seem able to colonize from them (Fox 1986a). Nevertheless, spores may be especially important after fire that is severe enough to burn organic soil horizons (Grogan *et al.* 2000). Spores of mushrooms are dispersed by wind and thus can reach the centre of burns and clearcuts (Allen 1987). Spores of truffles are dispersed primarily by small mammals. For instance, mammal species frequenting clearcuts or truffles decomposing underground will leave spores behind (Miller *et al.* 1994), which act as inoculum in the clearcuts.

Once trees are harvested, the ectomycorrhizae remaining in the soil appear to take 1–2 years to die (Harvey *et al.* 1980; Hagerman *et al.* 1999a). Dying ectomycorrhizal roots sometimes support sufficient live hyphae to colonize new roots, depending on the fungal species involved (Bâ *et al.* 1991). Thus, they are a possible source of inoculum following clearcut harvesting.

Sclerotia are produced by relatively few ectomycorrhizal fungal species (e.g., *Cenococcum geophilum*). Sclerotia can persist from a few weeks to months, depending on the fungal species, and can be especially abundant following fire (Fox 1986b; Miller *et al.* 1994). Sclerotia contain sufficient hyphae to act as inoculum (Bâ *et al.* 1991).

Ectomycorrhizal Fungal Diversity

Ectomycorrhizal fungal species differ in several ways, including:

- their ability to take up various forms and types of nutrients,
- their rate of nutrient uptake,
- their tolerance to water stress and temperature extremes,
- the substrates they inhabit, and
- the parts of the root system (distance from the bole) with which they form the associations (Deacon and Fleming 1992; Smith and Read 1997).

> *Ectomycorrhizal fungi play an important role in tree growth.*

Because of the variability in the characteristics of ectomycorrhizal fungi, trees forming a diverse array of ectomycorrhizae are thought to be better suited to survive and grow in variable soil and climatic conditions than trees forming ectomycorrhizae with only one or a few fungal species (Hagerman *et al.* 1999b). However, testing this hypothesis has yielded ambiguous results (Baxter and Dighton 2001; Jonsson *et al.* 2001), and field experiments under various soil conditions have not yet been conducted. We, therefore, do not yet know how ectomycorrhizal fungal diversity affects tree seedling growth.

The Functional Role of Ectomycorrhizal Fungi

Ectomycorrhizal fungi play an important role in tree growth. They provide numerous benefits to their host plant with different fungal species providing different benefits. These include:

- enhancing the uptake of essential nutrients (mainly phosphorus and nitrogen) and water (Boyd *et al.* 1986; Jones *et al.* 1991);
- protecting against pathogens (Marx 1969; Perrin and Garbaye 1983) and heavy metals (Jones and Hutchinson 1986);
- binding soil particles to create favourable soil structure (Borchers and Perry 1992);
- facilitating below-ground nutrient transfer among plants (Simard *et al.* 1997a); and
- altering the competitive relationships among plants of different species (Perry *et al.* 1989a).

One type of ectomycorrhiza, known as a tuberculate ectomycorrhiza, also harbours nitrogen-fixing bacteria (Li *et al.* 1992; Paul *et al.* 1998).

The next section explains some of the techniques that forest managers can use to conserve ectomycorrhizal fungi, thereby maintaining their diversity and their important role in tree growth in the province.

Forest Management Techniques to Conserve Ectomycorrhizal Fungi

Several important techniques to maintain a diverse community of ectomycorrhizal fungi across the landscape are available to forest managers. This section provides a summary of research information related to nine forest management strategies.

Retain Refuge Plants, Mature Trees, and Old-growth Forests

In their decision making, forest managers should consider the benefits that "refuge plants," mature trees, and old-growth forests provide a harvested or naturally disturbed forest, including their role in maintaining a diverse community of ectomycorrhizal fungi.

Several important techniques to maintain a diverse community of ectomycorrhizal fungi across the landscape are available to forest managers.

Refuge Plants

In some situations, ectomycorrhizal plant hosts persist following disturbances such as forest harvesting, and serve as sources of fungal inoculum for regenerating tree species (Perry *et al.* 1989b; Kranabetter 1999). These plants, called "refuge" plants or "reservoir hosts," include bearberry (*Arctostaphylos uva-ursi*), sitka alder (*Alnus viridis* spp. *sinuata*), willow (*Salix* spp.), paper birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*). Research has shown that three years following forest harvesting, bearberry maintained a mycorrhizal fungi community similar to that found on Douglas-fir in the undisturbed forest. Therefore, the bearberry could potentially provide native inoculum for neighbouring Douglas-fir seedlings (Hagerman *et al.* 2001). Some species of refuge plants, particularly trembling aspen and paper birch, are commonly viewed as deleterious because they compete with planted conifer seedlings for light, water, and nutrients (Comeau *et al.* 1999). Because of their competitive abilities, these plants are frequently the targets of vegetation control measures. However, studies show that refuge plants can also facilitate survival or growth of conifer seedlings (e.g., Horton *et al.* 1999).

Mature Trees

The diversity of ectomycorrhizal fungi increases over time up to a certain forest stand age, after which it stabilizes (Visser 1995). As stands age, species are usually added to the fungal community, but they do not necessarily replace the earlier ones (Visser 1995; Bradbury *et al.* 1998). Some fungi, such as *Rhizopogon* spp., may be present throughout the life of a stand (Visser 1995). The change in ectomycorrhizal fungal communities over time is a complex process, which requires further study.

The typically diverse ectomycorrhizal fungal community on mature trees can benefit nearby seedlings. Studies in British Columbia show that significantly greater ectomycorrhizal diversity exists on seedlings planted adjacent to mature trees than on those planted outside of root contact with mature trees (Simard *et al.* 1997b; Hagerman *et al.* 1999b; Kranabetter 1999). This suggests that mature trees can help maintain a diverse ectomycorrhizal fungal community on clearcut sites which include mature tree reserves, and that these trees would be effective sources of inocula. Mature trees may retain these fungal species within the reserves until conditions in the surrounding plantation are favourable for their spread outside the reserves. The importance of green tree retention should increase as the size of the disturbance and distance from the undisturbed forest increases and as the amount of young forest increases across the landscape (Hagerman *et al.* 1999a; Kranabetter 1999).

The typically diverse ectomycorrhizal fungal community on mature trees can benefit nearby seedlings.

Old-growth Forests

Old-growth forests are composed of various tree ages, sizes (including large mature and old trees, and large standing and fallen dead trees), and multiple canopy layers with canopy gaps and understorey patchiness (B.C. Ministry of Forests 1991; Franklin and Spies 1991). Old-growth forests have more diverse macro- and microhabitats than young and mature forests and, therefore, are expected to support a more diverse suite of ectomycorrhizal fungi. Therefore, landscape-level plans should include old-growth forest retention areas and should allow for the recruitment of future old-growth forests.

Some species of ectomycorrhizal fungi fruit exclusively or predominantly in old-growth forests (Ammirati *et al.* 1994; Walker 1995; North and Trappe 1996; Gamiet and Ammirati 1999; O'Dell *et al.* 1999; Smith *et al.* 2000). Studies on the Olympic Peninsula in Washington State reported higher species richness and diversity (see sidebar) of ectomycorrhizal sporocarps in old-growth forests compared with mature forests (Walker *et al.* 1994; North and Trappe 1996). In old-growth forests of the northern spotted owl range in the U.S. Pacific Northwest, approximately 235 species of fungi are being considered and rated for site management because they fruit predominantly within these older forests (Forest Ecosystem Management Assessment Team 1993; Ammirati *et al.* 1994). Old-growth forests may be important for maintaining fungal diversity at the landscape level, but further study is required to determine how these areas function "as refugia for fungal diversity and centres of propagule dispersal" (Massicotte *et al.* 1999). While sporocarps are important as a source of food for animals, their abundance is a poor predictor of the abundance of that fungus on root tips underground (Jonsson *et al.* 1999).

Landscape-level plans should include old-growth forest retention areas and should allow for the recruitment of future old-growth forests.

Ectomycorrhizal fungi sometimes form dense mats of a single species in forest floor litter and mineral soil. A study in the Cascade Range of Oregon (Griffiths *et al.* 1996) showed that these mats covered a greater area in old forests than in younger forests. Several different genera of fungi form mats and each can differ in the role it plays in nutrient cycling. For instance, some species assist in the nutrient cycle by weathering mineral soils, thereby releasing nutrients (Jongmans *et al.* 1997; Arocena and Glowa 2000; Landeweert *et al.* 2001).

Species Richness and Evenness

Diversity is commonly expressed simply as the total number of species present in a community (species richness), or as an index which includes two components—species *richness* and species *evenness*.

Species evenness refers to the proportional abundance of each species within a community. For example, plant communities 1 and 2 each have four tree species with the following number of stems per hectare (sph):

Community 1	Community 2
Species 1: 110 sph	Species 1: 300 sph
Species 2: 105 sph	Species 2: 10 sph
Species 3: 107 sph	Species 3: 500 sph
Species 4: 100 sph	Species 4: 50 sph

Species richness (the number of species) is the same for each community, which both have four tree species. However, Community 1 has a uniform number of each of the four species and therefore would have a higher species *evenness* value than Community 2. Species evenness values range between 0 and 1, where 1 is uniform or even, and 0 is non-uniform or uneven.

Retain Forest Floor during Harvest and Site Preparation

Both the upper mineral soil and the forest floor, with its organic layers and woody debris, are home to various soil micro-organisms, including the majority of the ectomycorrhizal root tips (Vogt *et al*. 1981; Amaranthus *et al.* 1989; Perry *et al*. 1989b). Removal or loss of the forest floor during site preparation may alter the colonization of seedling roots by ectomycorrhizal fungi (Amaranthus *et al.* 1989; Simard *et al.* 2002a), which in turn can affect seedling survival and growth (Jurgensen *et al.* 1997). Other forest activities, such as timber harvesting, natural and prescribed fires, grazing, and recreation, can also change the character of the forest floor (Graham *et al*. 1999). For example, one unreplicated study has shown that soil compaction and forest floor removal resulted in a 60% decrease in ectomycorrhizal fungal abundance and diversity on

Removal or loss of the forest floor during site preparation may alter the colonization of seedling roots by ectomycorrhizal fungi, which in turn can affect seedling survival and growth.

Douglas-fir seedlings (Amaranthus *et al.* 1996). Ectomycorrhizal fungus diversity on western white pine, by contrast, was not affected by the same treatment. In another study, mechanical removal of pinegrass and the forest floor in 150 × 150-cm patches reduced the diversity and richness of ectomycorrhizal fungi on lodgepole pine seedlings when compared with chemical treatments that left the forest floor intact (Jones *et al.* 1996; Simard *et al.* 2002a). The mechanical treatment also resulted in lower seedling survival and growth. Two years after planting the treatment differences in ectomycorrhizal diversity disappeared, probably because the seedling roots had grown outside of the treated patches, but early seedling survival differences continued to persist 9 years after treatment. In northern British Columbia, the diversity of ectomycorrhizal fungi showed no statistically significant change after forest floor removal, but a change in fungal species occurred (Mah *et al.* 2001). Another study (Simard *et al.* 2002a) concluded that removal of forest floor material should be avoided during site preparation because of the short-term negative effects on the ectomycorrhizal community, nutrient availability, and soil physical properties. These results support earlier recommendations (Harvey *et al.* 1987) to minimize massive break-up of the forest floor and to maximize the diversity of microsites following site preparation for regeneration objectives. However, the evidence available at this time does not warrant major changes in forest practices, which already strive to minimize displacement of forest floor materials.

Avoid High-intensity Broadcast Burns

The effects of fire (either natural wildfires or prescribed fires) on ectomycorrhizae are diverse—every fire has unique characteristics as does every plant community and physical environment. Uniformity and depth of burn, heat intensity, and heat penetration into the soil will all vary with the thickness and moisture content of the forest floor as well as with the type and loading of fuel.

Fire can also have a negative, positive, or negligible effect on ectomycorrhizae depending on the species of fungus involved (Baar *et al.* 1999; Stendell *et al.* 1999; Mah *et al.* 2001). It is not surprising, therefore, that variable effects of fire on ectomycorrhizae are reported in different studies. For example, one found no statistically significant effects of fire on ectomycorrhizal fungus diversity in broadcast-burned clearcuts (Mah *et al.* 2001), whereas others found a decrease in diversity with increasing fire intensity (Dahlberg *et al.* 2001). Severe, hot burns may be more destructive to ectomycorrhizal fungi than physical disturbances such as screefing (Visser and Parkinson 1999). Species evenness, but not species richness, appeared lower in burned stands than in unburned stands in another study (Jonsson *et al.* 1999). Following an under-burn in a mature ponderosa pine forest, a highly statistically significant loss of ectomycorrhizal biomass in the forest floor occurred, but no statistically significant change occurred in the upper mineral soil layers (Stendell *et al.* 1999). However, in another mature ponderosa pine forest where the forest floor was moist at the time of under-burning, the microbiological and nutrient properties of the organic layer were preserved (Graham *et al.* 1999).

The use of low-intensity fire as a site preparation treatment may be useful since it facilitates seedling establishment and limits the effects on ectomycorrhizal fungal diversity (Figure 3). At the same time, variability in fire characteristics can help to maintain variability in forest types across the landscape. Where landscape-level

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FIGURE 3. A prescribed burn at the Sicamous Creek Silviculture Systems Trial, Sicamous, B.C.

management plans include higher-intensity fires in localized areas, forest managers should ensure that sources of fungal inocula for regenerating stands are in close proximity.

Minimize Grass Seeding and Avoid Species Shifts

Invasion or dominance by non-mycorrhizal or other types of mycorrhizal plants can suppress the growth of ectomycorrhizal plants, especially if the site has been altered substantially during or after harvest. Survival and growth of ectomycorrhizal tree species can decrease dramatically when domestic grasses seeded to the site out-compete the native shrub-dominated plant community (Amaranthus and Perry 1994; Simard *et al.* 2002b). Such declines in tree performance were attributed to reduced levels of ectomycorrhizal inoculum, and direct competition with grasses for soil water (Simard *et al.* 2002b). However, where native plants still dominate the community, low rates of grass seeding likely have little effect on the ectomycorrhizal community (Simard *et al.* 2002b).

Changes in the mycorrhizal and microbial communities following herbicide treatment and grass invasion were also studied at a high-elevation site in the Pacific Northwest (Perry *et al.* 1989b). These treatments resulted in a shift in the plant community to one dominated by other non-ectomycorrhizal plants. This may be partially responsible for the failure (after four attempts) to regenerate this once-productive white fir (*Abies concolor*) site to native ectomycorrhizal tree species.

Non-mycorrhizal plants can also replace the natural, mycorrhizal species as a result of overgrazing and cultivation (Perry *et al.* 1989b). Dramatic changes in plant community composition, such as can occur with heavy grass seeding, overgrazing, or invasion by exotic weeds, may weaken the ectomycorrhizal linkages between old and new stands (Amaranthus and Perry 1994) and reduce ecosystem productivity.

> *Invasion or dominance by non-mycorrhizal or other types of mycorrhizal plants can suppress the growth of ectomycorrhizal plants.*

> *Harvesting of forest stands reduces one of the major sources of inoculum—the hyphae attached to living roots.*

Plant Soon After Harvest

Harvesting of forest stands reduces one of the major sources of inoculum—the hyphae attached to living roots. Dying ectomycorrhizae may act as an inoculum source, but most ectomycorrhizal roots typically die and disappear within two years following clearcut logging (Harvey *et al.* 1980; Bradbury 1998; Visser *et al.* 1998; Hagerman *et al.* 1999a; Byrd *et al.* 2000). For example, in Douglas-fir, western larch, subalpine fir, and Engelmann spruce stands in western Montana, the numbers of active ectomycorrhizal roots decreased considerably by the first July following October logging (Harvey *et al.* 1980). In a subalpine fir and Engelmann spruce stand in the Southern Interior of British Columbia, numbers and diversity of ectomycorrhizae 16 m and greater from the forest edge remained unchanged for the first summer after winter logging, but declined dramatically by the second summer (Hagerman *et al.* 1999a).

Other sources of ectomycorrhizal fungal inoculum that remain on a site after clearcut logging include sclerotia and spores. These can be highly effective sources of inoculum for germinants that appear immediately after a stand-destroying fire (Baar *et al.* 1999; Grogan *et al.* 2000) and the same is likely true on clearcuts. Unfortunately, we do not know how long spores or sclerotia remain viable in soils; consequently, we do not know how soon to plant after harvest in order to retain high inoculum levels. For instance, when Douglas-fir and ponderosa pine were grown in a greenhouse in soils from clearcuts 1–22 years old, no correlation existed between time since clearcut harvesting and ectomycorrhiza formation (Parke *et al.* 1984). However, these soils were all collected from clearcuts classified as "difficult to regenerate." In contrast, seedlings planted in clearcuts that had no living ectomycorrhizal hosts for 5 years or more showed reduced colonization (Amaranthus *et al.* 1990; Borchers and Perry 1990). To take advantage of ectomycorrhizae inoculum from the previous stand (and therefore the widest range of inoculum), seedlings should be planted within the first growing season after clearcut logging. If planted more than 5 years after harvest, total inoculum levels will more likely be below the threshold for complete colonization.

Plant a Mixture of Tree Species

Regenerating mixed species stands is a valuable ectomycorrhizae management strategy for two reasons.

1. Some evidence suggests that trees are able to associate with a wider range of ectomycorrhizal fungi when they are grown adjacent to trees of other species (Massicotte *et al.* 1999). For example, when Douglas-fir is grown together with paper birch, the number of fungi shared by the two species appears to increase compared to when they are grown separately (Simard *et al.* 1997c). In the field, ectomycorrhiza species evenness increased slightly for Douglas-fir when grown in plots with paper birch (Jones *et al.* 1997).
2. Mixed stands help sustain a higher species diversity of ectomycorrhizal fungi on a site because they contain more hosts for fungi with narrow host ranges as well as for fungi with broad host ranges[2]. A recent study of mixed stands in the Canadian boreal forest (Kernaghan *et al.* 2001) showed a clear, positive relationship between the diversity of overstorey trees and the diversity of ectomycorrhizae present in the soil. Higher fungal diversity is probably important for tree growth because different species exhibit different characteristics and provide different benefits to the host tree. Fungi with narrow host ranges will disappear from a harvested site unless their particular host is retained or included in the regenerated mixture of tree species.

Maintain Edge-to-Area Ratio within Certain Limits

After clearcut harvesting, there are two sources of ectomycorrhizal hyphae on living roots. The first source is living ectomycorrhizal hosts in the cutblock, such as:

- residual conifer stems,
- advance regeneration,
- broad-leaved trees such as aspen or birch, or
- woody shrubs such as bearberry, sitka alder, and willow (see section on *Refuge Plants*).

The second source is the roots of trees in the surrounding forest, which are likely to extend 8–13 m into the harvested area (Stone and Kalisz 1991; Parsons *et al.* 1994). Levels of ectomycorrhizal fungal inoculum are therefore expected to be greatest in the periphery of the cutblock (Harvey *et al.* 1980). For instance, research has shown that young, non-mycorrhizal Engelmann spruce seedlings planted 2 or 3 m from the forest edge were colonized at twice the rate as seedlings planted 16 m or more from the edge (Hagerman *et al.* 1999b). These seedlings were also colonized by 50% more types of ectomycorrhizal fungi (Figure 4). Similar reductions in ectomycorrhizal fungal diversity with increasing distance from the forest edge were observed for naturally regenerating western hemlock seedlings (Kranabetter and Wylie 1998).

Interestingly, reduced colonization or decreased ectomycorrhizal diversity with distance from the edge was less apparent for seedlings grown in nurseries than for naturally regenerated seedlings (Durall *et al.* 1999; Jones *et al.* 2002). This is may mean that high edge-to-area ratios are more important in naturally generated clearcuts than in planted clearcuts. Containerized seedlings frequently become mycorrhizal in the nursery, either from airborne spores of ectomycorrhizal fungi or as a result of inoculation with a commercial product. Edge-effect patterns are probably masked in these cases

Melanie Jones

FIGURE 4. A 1-ha harvested patch in the Sicamous Creek Silviculture Systems Trial, Sicamous, B.C.

[2] Some species of ectomycorrhizal fungi will only colonize the roots of a few specific plant species (Molina *et al.* 1992). These fungi are said to have narrow host ranges. Other species of ectomycorrhizal fungi will colonize the roots of many different plant species and thus are said to have broad host ranges.

as nursery fungi may slow the rate of colonization by indigenous fungi following planting (McAfee and Fortin 1987), although indigenous fungi will eventually replace nursery fungi.

On sites where conifers, broadleaves, or other refuge plants are not retained, ectomycorrhizal inoculum is maximized when harvested areas are designed with a reasonably high edge-to-area ratio or with reserves. Ectomycorrhizal colonization of trees is highest when both light and inoculum levels are adequate, such as along forest edges of clearcuts (Hagerman *et al.* 1999b), or in thinned stands (Zhou and Sharik 1997). Partially cut forests also retain a diversity of ectomycorrhizal fungi (Durall *et al.* 1999; Kranabetter and Kroeger 2001). Some component of partial cutting on a landscape allows timber removal, while maintaining the mature forest and fungal communities. These forests could be an important source of inocula, along with old-growth reserves, thereby facilitating the succession of ectomycorrhizal fungi into clearcuts.

Retain Coarse Woody Debris

Different species of ectomycorrhizal fungi colonize different substrates, including various types of organic substrates. Studies in Idaho and Oregon and on Vancouver Island showed that some fungi preferentially colonize rotten wood, while others colonize mineral or organic soil horizons (Kropp 1982; Harvey *et al.* 1997; Goodman and Trofymow 1998). Maintaining a diverse mix of mineral and organic patches in clearcuts will therefore encourage a varied ectomycorrhizal fungal community.

The highest number of ectomycorrhizal roots are generally found in organic substrates, particularly in decayed wood or soil mixtures containing decayed wood and organic matter, and comparably fewer numbers are found in mineral substrates (Harvey *et al.* 1997; Goodman and Trofymow 1998). On extremely dry, harsh sites, coarse woody debris and decayed wood are particularly important because these substrates hold moisture during summer drought periods (Harvey *et al.* 1986; Amaranthus *et al.* 1994). Logs appear more productive than stumps, containing a greater number of ectomycorrhizae as well as more types of ectomycorrhizal fungi (Goodman and Trofymow 1998).

In lodgepole pine forests of central British Columbia, coarse woody debris is an important substrate for tuberculate mycorrhizae and associated nitrogen-fixing bacteria (Paul *et al.* 1998). It is also exceedingly important as a habitat for the production of both below-ground (truffles) and above-ground (mushrooms) fruiting bodies of ectomycorrhizal fungi.

Maintaining a diverse mix of mineral and organic patches in clearcuts will encourage a varied ectomycorrhizal fungal community.

At Douglas-fir forest sites in Oregon, eight of the 21 truffle species occurred only in coarse woody debris (Amaranthus *et al.* 1994) and the dry weight of truffles was ten times higher in coarse woody debris than in soil in the mature forest. Although this great a difference was not observed in any of the nearby plantations, it suggests that coarse woody debris is required for some ectomycorrhizal fungi to fruit. This study highlights the importance of forest management practices that retain coarse woody debris in helping to conserve the abundance and diversity of truffles, as well as the small mammals that depend on them (Amaranthus *et al.* 1994). Coarse woody debris management recommendations are available for several Montana, Arizona, and Idaho ecosystems (Graham *et al.* 1994), some of which are similar to ecosystems in the Nelson Forest Region.

Manage for Fruiting Bodies Formed by Ectomycorrhizal Fungi

The ectomycorrhizal association is part of the vegetative stage of a fungus. When environmental conditions are appropriate, many ectomycorrhizal fungi also produce reproductive structures, or fruiting bodies, either above- or below-ground (Figure 5). Fruiting bodies come in a variety of shapes, sizes, colours, and odours. Their importance to humans varies—some are poisonous or unpalatable, while others are delectable and are harvested commercially or for personal consumption. They are also important to several species of mammals and invertebrates, such as northern flying squirrels (*Glaucomys sabrinus*), California red-backed voles (*Clethronomys californicus*), kangaroo rats, deer, springtails, and beetles. The fruiting bodies of some ectomycorrhizal fungi are also classified as "rare." Various forest management activities can have either beneficial

Paul Kroeger

FIGURE 5. *Boletus edulis* (King bolete): a deliciously edible ectomycorrhizal fruiting body.

or negative effects on the production of ectomycorrhizal fungal fruiting bodies. Resource managers need to be aware of these effects so that management practices can be designed accordingly. This may be critical for those ectomycorrhizal fungi that rarely fruit.

Edible Mushrooms

British Columbia's wild edible mushroom harvest generates millions of dollars each year and consists largely of ectomycorrhizal fungi, such as pine mushrooms (*Tricholoma magnivelare*), chanterelles (*Cantharellus formosus* and *C. subalbidus*), and boletes (*Boletus edulis*). Pine mushrooms are the most commercially important wild forest mushroom in the province and are exported exclusively to Japan (de Geus 1995), while chanterelles, boletes, and others are primarily exported to parts of North America and Europe (de Geus 1995). Known commercial mushroom sites are located across all regions of the province (de Geus 1995; Freeman 1997; Trowbridge and Macadam 1999; Ehlers and Frederickson 2000; Berch and Wiensczyk 2001; Kranabetter *et al.* 2002) in forests from 20 to more than 200 years old (Hosford and Ohara 1995; Norvell 1995; Redhead 1997a; Pilz *et al.* 1998).

Forest practices, such as logging, site preparation, tree selection, fire, fertilization, pesticide use, brushing and spacing, and grazing, will influence mushroom presence, reproduction, and productivity. Ectomycorrhizal fungi require living roots, and therefore living trees to survive. As a result, timber harvesting, particularly clearcutting, profoundly reduces mushroom production (Durall, Gamiet, and Simard [unpublished]); Smith *et al.* 2002) until the mature forest becomes re-established. Local pickers in the Anaheim Lake area (Chilcotin Region, B.C.) report, however, that pine mushrooms are still produced in any island remnants retained within a cutblock. These island remnants apparently provide appropriate inoculum levels and environmental conditions, and a carbon source for some level of mushroom production (Bill Chapman, B.C. Ministry of Forests, pers. comm., March 2001); however, for how long and at what level is unknown. In the Date Creek area of the Prince Rupert Forest Region, gap area size significantly affected the production of fruiting bodies in forests (Durall *et al.* 1999). In this study area, sporocarp diversity declined significantly in gaps larger than 900 m^2. Soil compaction from machinery and trampling can damage the mycelium (a mat-like mass of fungal hyphal), and reduce mushroom productivity (Colgan *et al.* 1999; Bill Chapman, B.C. Ministry of Forests, pers. comm., March 2001).

Forest management techniques that promote mushroom production have been studied in other countries. To encourage matsutake mushroom (*Tricholoma matsutake*, a close relative of the pine mushroom) production in Japanese forests, for example, various silviculture treatments have been applied. Overstorey trees are thinned, tree species composition is altered, non-host understorey shrubs and herbs are cut, and organic litter is removed from the forest floor (Hosford *et al.* 1997). In North America, such intense management of forests for pine mushroom production does not occur. Studies in Europe show that nitrogen deposits from air pollution (Arnolds 1991) and applications of nitrogen fertilizers (Termorshuizen 1993) reduce the productivity of edible ectomycorrhizal fungi. Information on the effects of pesticide application or grazing on edible mushrooms is currently not available for British Columbia. More research is required to determine how silviculture techniques could be used to promote the fruiting of economically important fungi in North American forests.

Ectomycorrhizal Fruiting Bodies and Wildlife

A highly evolved, beneficial relationship exists between ectomycorrhizal fruiting bodies, host trees, and wildlife. Fruiting bodies of ectomycorrhizal fungi are an important food source for many temperate forest mammals and invertebrates (North and Trappe 1996; Janos and Sahley 1995; Cazares and Trappe 1994; Johnson 1994;

Lawrence 1989; Bruns 1984; Fogel and Trappe 1978; Fogel 1975). In the process of consuming the fruiting body, fungal inoculum is dispersed throughout the animal's range, thereby exposing the ectomycorrhizal host trees to a higher diversity of inocula. Above-ground sporocarps generally disperse their spores through the forest by means of air and water currents. Below-ground fruiting bodies, by contrast, depend on animals for spore dispersal. Animals are attracted to the aromatic compounds produced by truffles and false-truffles (i.e., true truffles belong to the class Ascomycete; false-truffles belong to the class Basidiomycete), which lead them to excavate and consume these fungi. The spores in the fruiting bodies ingested by the animal pass through the gut and are deposited with fecal pellets (Cazares and Trappe 1994; Johnson 1994; Currah *et al.* 2000).

Some small mammals, such as the northern flying squirrel and the California red-backed vole use truffles as their primary food source (Amaranthus *et al.* 1994). These mammals, in turn, are important prey for other species of animals such as the threatened northern spotted owl (Forsman *et al.* 1984). Cavities in downed and standing dead wood are commonly used by small mammals to store food when foraging (Bunnell *et al.* 1999), and are therefore important not only for wildlife survival, but also as sources of ectomycorrhizal fungal inocula for the surrounding forest. Retaining standing and downed coarse woody debris is thus important for the dispersal of spores from both above- and below-ground ectomycorrhizal fruiting bodies.

Managers should practise forestry that encourages long-term, sustainable productivity of ectomycorrhizal fruiting bodies used by small mammals and invertebrates. A study in the U.S. Pacific Northwest showed that thinning Douglas-fir forests resulted in a shift in truffle species dominance. For example, some truffle species occurred only in thinned stands and not in the uncut controls, while other species declined significantly in thinned stands (Colgan *et al.* 1999). Another study showed that truffle density tends to be lower in young stands until the canopy closes, after which diversity increases over time (Amaranthus *et al.* 1994). Similar results were observed in high-elevation Engelmann spruce–subalpine fir forests in British Columbia where no truffles were collected in 0.1-, 1-, and 10-ha cutblocks four years following harvesting (Durall, unpublished).

Fruiting bodies of ectomycorrhizal fungi are an important food source for many temperate forest mammals and invertebrates.

In young (4–27 year old) Douglas-fir plantations, few truffles were produced on coarse woody debris because the trees in this study had not yet developed root systems and mycorrhizae within this substrate (Amaranthus *et al.* 1994). Many above- and below-ground ectomycorrhizal fungi fruit predominantly in coarse woody debris, therefore its retention following silvicultural and logging practices encourages fruiting of these fungi.

Rare and Endemic Ectomycorrhizal Fungi

Some species of ectomycorrhizal fungi fruit infrequently and thus are considered rare. In the Netherlands, approximately 944 fungi are "red-listed," of which 182 are threatened with extirpation and 91 are considered extinct (Arnolds 1991, 1992; Redhead 1997b). In the American Pacific Northwest, the U.S. Department of Agriculture's Forest Ecosystem Management Assessment Team has compiled a list of rare and uncommon mycorrhizal, saprophytic, and pathogenic fungi associated with old-growth forests (Forest Ecosystem Management Assessment Team 1993). In British Columbia, the list of uncommon, rare, and endangered species is limited because many ecosystems are not yet inventoried, or specimens of various species are not adequately documented and preserved in herbariums. Using Conservation Data Centre criteria[3], only two ectomycorrhizal species (*Albatrellus caeruleoporus* and *Suillus pseudobrevipes*) are considered rare for the central and southern interior regions of the province (Redhead 1997b), while approximately 20 are tentatively identified as uncommon or rare (Ginns *et al.* 1998). However, a species that might appear rare because it is reported only once or twice might be found more commonly if the province was extensively inventoried.

[3] The British Columbia Conservation Data Centre (CDC) (***http://srmwww.gov.bc.ca/cdc***) is a provincial government organization that, in conjunction with the Nature Trust of BC, the Nature Conservancy of Canada, and the Nature Conservancy (US), documents and maintains a database of rare and endangered plants, animals, and plant communities in the province. The status of each species is determined using CDC criteria on the nature of occurrence (global or provincial) and the number of still surviving occurrences (from extremely rare to common) (Redhead 1997b).

Another threat to specific mycorrhizal fungi is the reduction in habitat and host ranges. Some native, or endemic, ectomycorrhizal fungi associate exclusively with birch, pine, Douglas-fir, or larch species (Molina *et al.* 1992). While pine, Douglas-fir, and birch species occur extensively in the interior of the province, larch are more restricted in their range. As at least nine ectomycorrhizal fungi are associated exclusively with larch species (Molina *et al.* 1992), threats to larch habitats are also threats to these fungi. Young, pure stands of birch are also decreasing because of fire suppression, silviculture treatments in young stands, and forest type conversions, which could all affect the availability of old birch stands in the future. Other species with limited distribution in interior British Columbia that could be threatened by habitat loss or climate change include: Pacific yew (*Taxus brevifolia*), whitebark pine (*Pinus albicaulus*), tamarack (*Larix lyallii*), grand fir (*Abies grandis*), Alaska yellow-cedar (*Chamaecyparis nootkatensis*), and mountain hemlock (*Tsuga mertensiana*).

Forest management strategies for the conservation of rare and endemic fungi are similar to those suggested for sustainable wild edible mushroom harvests. Recommendations for managing rare, endemic, and endangered fungal species are also available (see Ginns *et al.* 1998). Compiling baseline species lists from existing literature and collecting from specific habitats is a first step. Samples of any suspected rare, endemic, or endangered species should be collected, evaluated by trained taxonomists, and preserved for future reference in herbariums. Then, habitats supporting these species should be inventoried, mapped (Trappe and Castellano 1996), and monitored over the long term for changes.

Recommendations

Several existing forest management practices can help to maintain a diverse community of ectomycorrhizal fungi across the landscape. Table 1 provides a summary of the forest management strategies recommended in this extension note.

TABLE 1. Summary of forest management strategies to maintain ectomycorrhizal fungi diversity

Strategy	Management Practice
PROVIDE SOURCE OF ECTOMYCORRHIZAL FUNGAL INOCULUM	• Retain refuge plants (e.g., bearberry, aspen, birch, willow) in harvested areas • Retain green trees (single trees and patches) • Retain areas of old-growth forest across the landscape • Conduct partial harvesting in some areas • Maintain high edge-to-area ratio by keeping harvested areas small or by including green tree retention areas
PROVIDE VARIOUS HABITATS OR MICROSITES TO ENCOURAGE A DIVERSE ECTOMYCORRHIZAL FUNGAL COMMUNITY	• Avoid high-intensity broadcast burns as much as possible; where broadcast burning is required, use mainly low-intensity burns • Minimize disturbance to forest floor during harvesting and site preparation • Retain standing and downed coarse woody debris
MAINTAIN A DIVERSE ECTOMYCORRHIZAL FUNGAL POPULATION	• Use low seeding rates where grass seeding is required, and ensure native plant species still dominate the community • Plant soon after harvest: within first season after harvest is best; maximum limit is within 5 years • Plant or encourage regeneration of a mixture of tree species
CONSERVE ECTOMYCORRHIZAL FRUITING BODY PRODUCTION FOR: • *HUMAN USE (COMMERCIAL AND PERSONAL CONSUMPTION)* • *WILDLIFE* • *RARE AND ENDEMIC FUNGAL SPECIES*	• Minimize soil compaction from heavy machinery and trampling • Minimize disturbance to forest floor when harvesting mushrooms and truffles • Maintain green tree retention areas • Retain standing and downed coarse woody debris • Keep logged areas small (i.e., $< 900m^2$) • Maintain populations of host species (e.g., birch) • Be aware of cultural and social differences amongst mushroom harvesters • Watch for potential conflicts with mushroom and truffle harvesting and archaeological sites

Our understanding of ectomycorrhizal fungal ecology is improving every year. In the future, we should have more information about many important topics, including:

- the effects of fungal diversity on stand growth and health;
- the significance of hyphal linkages in reducing competition between trees;
- the suspected occurrence of "keystone" fungal species in certain habitats;
- the time needed for ectomycorrhizal fungal species to recover after disturbance in different forest types and tree species; and
- the indicator mushroom species for mature forest habitat.

Further research is also required on the taxonomy, biology, and ecology of specific mushrooms and truffles, on productivity levels of ectomycorrhizal fungal species in different habitats, including mapping these habitats at local and landscape levels, and on the effects of various silviculture systems and techniques on fruiting body production.

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Research Report

Natural resource information needs of Aboriginal communities in the Southern Interior of British Columbia

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Abstract

This paper describes the First Nations Community Needs Analysis Process that FORREX–Forest Research Extension Partnership (formerly SIFERP, the Southern Interior Forest Extension and Research Partnership) undertook in 1999/2000 to identify and analyze the land and natural resource management information needs of the First Nations' communities in the Southern Interior of British Columbia. It also responds to the outcomes of the information needs assessment by presenting a "Framework for Action," part of which includes establishing the Partnership's Aboriginal Forestry Extension Program.

Based on the results of the information needs assessment, First Nations' communities in the Southern Interior of British Columbia clearly have a need and a desire to participate in forestry extension services. The information needs assessment also revealed and expanded on several issues that must be considered in the provision of extension services to First Nations' communities.

With incentive from its Aboriginal partners, FORREX has taken a leadership role in providing extension services and has undertaken the responsibility of working with its Aboriginal partners to identify the information and research needs in their communities. The needs analysis process has also provided direction for including traditional ecological knowledge in natural resources management and policy development.

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Introduction

FORREX–Forest Research Extension Partnership is a non-profit co-operative organization focused on developing, using, and sharing knowledge about forested ecosystems—how these ecosystems function, their sustainability, and how to manage them from a holistic perspective.

The Partnership's primary goal is to facilitate collaborative extension, technology development, and research ventures between partnering organizations. The broad goals of the Partnership are to:

- Ensure the natural resource community information needs and demands are identified,
- Provide extension and research services that are focused on the real needs of partners,
- Ensure scientific and expert support for an adaptive management approach, and
- Guarantee that resources and information are shared.

Membership in the Partnership currently includes government agencies, First Nations' communities, forest companies, learning institutions, and other public and special interest groups.

This paper outlines the First Nations community needs analysis process that the Partnership undertook to identify and analyze the land and natural resources management information needs of the First Nations' communities in the Southern Interior of British Columbia. This paper also presents a "framework for action" that responds to the outcomes of the information needs assessment process.

Initiating the First Nations Community Needs Analysis Process

In the early stages of its development, the Partnership set out to identify the information needs and gaps of its members and of the forest community at large. In 1998, a client survey was undertaken (Gregory and Satterfield 1999) to identify the primary information needs of the Partnership's clients and other members of the forest sector. To help determine its own role in providing information to the forest community, the Partnership sought to identify current sources of information, methods of transferring information, and barriers to accessing information.

Only a small number of the returned surveys came from First Nations' communities. To address this gap, the Partnership initiated the First Nations community needs analysis process to determine the land and natural resource management information needs of First Nations. First, a series of three focus groups with First Nations people was delivered in three regions of the Southern Interior. Second, a comprehensive meeting of the focus group participants was conducted to synthesize what was learned at the three regional workshops. Third, the Partnership analyzed the outcomes of the process, and from this a framework for action emerged to guide the Partnership in addressing the natural resource management information needs of the groups assessed.

The Needs Analysis Process

Step 1: Regional Focus Groups

Organization and Objectives

In June 1999, three workshops were scheduled in the Thompson–Okanagan, the Cariboo–Chilcotin, and the Kootenays regions of British Columbia's Southern Interior. These workshops were designed to have First Nations people identify the land and resource management information needs of their communities, to determine which of these information needs would likely need to be addressed using sources outside their own communities, and to prioritize these needs.

To ensure that meaningful results were obtained, the workshops were carefully planned and organized to accommodate the learning and work styles of the participants. Throughout the process, emphasis was placed on mutual respect and trust, willingness to listen and understand, and acknowledgement of knowledge and contributions. Groups were kept small, consisting of no more than 12 people, and the brainstorming/consensus building approach was used to identify needs and issues. Considerable attention was given to providing the individual participants, and the tribal councils and bands, with adequate preliminary and preparatory information before attending the workshop. In addition, the workshops were scheduled so that ample time was available for networking, rest, meals, and travel. They were held in comfortable locations as much away from distractions as possible. Participants were invited to join a focus group based on their ability to accurately identify the needs of the community they represented, their commitment to the exercise, and their willingness and ability to attend the workshop from beginning to end.

The workshop began with a brainstorming session surrounding the question: "What does your community need in regard to land and natural resources?". All responses were accepted without judgement or criticism. In consensus-building sessions, the group focused on specific needs, and identified the actions required to meet their needs. The group then prioritized their needs; they were also asked to distinguish between which needs they could address themselves, and with which they needed help addressing. Of the latter, they were asked to identify which needs the Partnership could help them with.

The end result of each workshop was a "needs analysis matrix" for each geographical area. After the workshop, participants had an opportunity to confirm that the matrix accurately represented their information needs. They were also asked to identify the top five needs within their communities—particularly needs with which they felt that the Partnership could assist. The outcomes are consolidated in a set of tables, one for each group/region (see Tables 1–3).

Outcomes

Based on the results of the focus groups, the information needs of First Nations' communities in the Southern Interior appear to be similar. The following list of unranked priorities related to natural resource management issues was identified by workshop participants as areas in which they were willing to work with non-Aboriginal agencies.

- Build capacity[1] and develop the community.
- Access technological resources, information, funding, land, and employment.
- Revamp the education system to meet the needs of Aboriginal communities.
- Acquire knowledge of, and apply, both traditional ecological knowledge[2] and science.
- Protect the land, its resources and wildlife.
- Request involvement in developing natural resources management plans and in decision making with non-Aboriginals.
- Educate non-Aboriginals about Aboriginal communities and Aboriginal rights and title as it affects natural resources management.

Participant feedback suggests that the needs analysis focus groups were very informative and worthwhile to attend.

Step 2: Follow-Up Meeting

Organization and Objectives

On March 6–7, 2000, the Partnership hosted a two-day follow-up meeting with the First Nations community needs analysis focus groups. All participants who had attended the initial focus groups in June 1999, as well as members of the FORREX Aboriginal Forestry Extension Working Group[3], were invited; 17 people participated in this workshop.

The objectives of this meeting were to:

1. Give people from different regions an opportunity to exchange information and experiences about natural resource management issues common to Aboriginal communities.
2. Synthesize the information in the matrices produced at the three previous workshops into a program of principles to guide the Partnership's Aboriginal Forestry Extension Specialist Program.
3. Obtain a mandate for the Partnership to provide extension services to Aboriginal groups.

At this meeting, participants further discussed the prioritized topics of the previous focus groups. An overview of the overall outcomes follows (see Tables 1–3 for regional summaries).

Land and resources: All three regional groups placed strong emphasis on the importance of protecting land, resources, and wildlife. They would like to acquire the knowledge and resources to conduct wildlife assessments and resource inventories, practise sustainable development, identify and protect endangered species, and identify and monitor tree diseases and other forest health indicators.

Technical expertise and research: Two of the groups identified a need to continue using expertise that already exists within First Nations' communities, and develop expertise from a scientific perspective. They would like

[1] Capacity refers to the infrastructure and resources of First Nations' communities, in terms of technology, human resources, and knowledge.
[2] "Traditional ecological knowledge" (TEK) has become the standard term for referring to the knowledge and scientific systems of Indigenous Peoples. This term is well understood by the scientific and government communities; however, it is not the term that Indigenous Peoples prefer to use for their knowledge systems. The current term accepted by Indigenous Peoples at the United Nations level is "indigenous peoples' knowledge" (IPK).
[3] The Aboriginal Forestry Extension Working Group guides the FORREX Aboriginal Forestry Extension Program.

TABLE 1. Outcomes of the information needs analysis workshop held in the Thompson–Okanagan Region. Priority information needs that the Aboriginal participants felt they could best address by working with the Partnership appear in ***BOLD ITALIC*** type; other non-priority information needs that the Aboriginal participants felt they could best address working with the Partnership appear in *italic* type. Information needs that the Aboriginal participants felt they could best address by working alone appear in **bold** type.

GENERAL AREA OF NEED — A. BUILD CAPACITY

SPECIFIC NEEDS:

- **A-1 Establish community involvement**
- *A-2 Identify our resources*
- *A-3 Identify needs*
- *A-4 Build infrastructure*
- *A-5 Identify opportunities*
- *A-6 Participate fully in all areas of natural resources that affect us*
- *A-7 Require active involvement in the community*
- **A-8 Demonstrate political unity at all levels (internal)**
- ***A-9 DEMAND LONG-TERM COMMITMENT***
- *A-10 Develop land bases*
- *A-11 Develop own research; acquire more research resources*
- ***A-12 ACCESS TECHNICAL RESOURCES; SHARE ABORIGINAL TECHNICAL RESOURCES***
- *A-13 Identify and create partnerships*
- *A-14 Support Aboriginal networking*
- *A-15 Develop and incorporate entrepreneurial and small business development*
- *A-16 Demand and provide meaningful employment*
- *A-17 Provide employment and enjoy economic independence*
- *A-18 Demand our share of funding; money from government*
- *A-19 Access funding*
- **A-20 Have self-respect**

GENERAL AREA OF NEED — B. EDUCATE

SPECIFIC NEEDS:

- **B-1 Encourage self-discipline**
- **B-2 Encourage self-respect**
- *B-3 Share traditional education*
- *B-4 Incorporate Aboriginal language, history, and culture in the local school system*
- *B-5 Provide more educational alternatives to Aboriginal people—technical, trades, apprenticeships, etc.*
- *B-6 Incorporate Traditional Ecological Knowledge in contemporary education*
- *B-7 Develop Aboriginal professionals*
- *B-8 Provide support for continuing education*
- **B-9 Educate at the band level; encourage community involvement**
- *B-10 Merge and balance traditional ecological and technical knowledge*
- *B-11 Demand recognition of Aboriginal rights and title*
- *B-12 Educate general public about Aboriginal people*
- *B-13 Educate media about Aboriginal people*
- *B-14 Educate industry and government about Aboriginal people*
- **B-15 Apply ethics**
- **B-16 Provide role models**
- *B-17 Develop professional Aboriginal associations*

GENERAL AREA OF NEED — C. COMMUNICATE EFFECTIVELY INTERNALLY

SPECIFIC NEEDS:

- **C-1 Network with other Aboriginal communities**
- **C-2 Re-establish trust**
- **C-3 Provide Aboriginal representation**
- *C-4 Communicate with policy makers and community*
- *C-5 Co-operate with international Aboriginal organizations*
- **C-6 Communicate between nations regarding wildlife management**

GENERAL AREA OF NEED — D. ESTABLISH EXTERNAL COMMUNICATION AND CO-OPERATION

SPECIFIC NEEDS:

- *D-1 Implement the "new relationship" from the Royal Commission*
- *D-2 Demand respect from government*
- *D-3 Provide Aboriginal liaison and representation*
- *D-4 Demand full and meaningful consultation in all other fields*
- *D-5 Have unencumbered access to information*
- *D-6 Have direct involvement in development processes*
- *D-7 Require communication between ministries*
- *D-8 Demand government and industry accountability*
- *D-9 Require companies to pay for referrals*
- *D-10 Participate in international Aboriginal affairs*
- *D-11 Re-establish trust*

GENERAL AREA OF NEED — E. EXERCISE ABORIGINAL RIGHTS AND TITLE

SPECIFIC NEEDS:

- *E-1 Demand external recognition of ownership*
- *E-2 Demand external recognition of inherent Aboriginal rights*
- *E-3 Share Traditional Ecological Knowledge and wisdom*
- *E-4 Access all resources*
- **E-5 Clarify native rights**
- *E-6 Demand recognition of ownership of cultural heritage resources*
- *E-7 Assert authority and jurisdiction*
- *E-8 Demand recognition of Delgamuukw*
- *E-9 Protect Indigenous intellectual knowledge and property rights*
- **E-10 Exercise Aboriginal rights and title**
- **E-11 Exercise sovereignty**

TABLE 1. *Continued*

GENERAL AREA OF NEED — F. DEVELOP OWN LEGAL EXPERTISE

SPECIFIC NEEDS:

- *F-1 Implement principles of Delgamuukw*
- *F-2 Use Traditional Ecological Knowledge and wisdom effectively*
- *F-3 Clarify native rights*
- *F-4 Protect natural resources; protect fish and wildlife*
- *F-5 Demand government and industry accountability*
- *F-6 Protect Indigenous intellectual knowledge and property rights (international/national)*
- *F-7 Develop international expertise*
- *F-8 Develop national expertise*

GENERAL AREA OF NEED — G. MANAGE RESOURCES

SPECIFIC NEEDS:

- *G-1 Incorporate Traditional Ecological Knowledge and wisdom*
- *G-2 Implement Delgamuukw*
- *G-3 Recognize endangered species*
- *G-4 Recognize the needs of the ecosystem, economy, and community*
- *G-5 Identify gaps in resource needs*
- *G-6 Plan and develop projects*
- *G-7 Access and provide training*
- *G-8 Establish resource inventory*
- *G-9 Protect fish and wildlife*
- *G-10 Protect natural resources*
- *G-11 Protect endangered species*
- *G-12 Expand land base*
- *G-13 Establish Aboriginal game reserves*
- *G-14 Build capacity for referrals*
- *G-15 Access resources*
- *G-16 Share resource revenues*
- *G-17 Control resources*

TABLE 2. Outcomes of the information needs analysis workshop held in the Cariboo–Chilcotin Region. Priority information needs that the Aboriginal participants felt they could best address by working with the Partnership appear in ***BOLD ITALIC*** type; other non-priority information needs that the Aboriginal participants felt they could best address working with the Partnership appear in *italic* type.

GENERAL AREA OF NEED — A. DEVELOP AND OBTAIN CAPACITY

SPECIFIC NEEDS:

- *A-1 Obtain capacity for expert research*
- *A-2 Obtain capacity for footwork research*
- *A-3 Obtain time and resources to do more research within Aboriginal communities*
- ***A-4 MATCH RESOURCES TO NEEDS***
- *A-5 Obtain capacity to maintain resources*
- *A-6 Build capacity for the development of Tribal Council technological centres (i.e., GIS, GPS, computers, archives)*
- ***A-7 OBTAIN TECHNOLOGY***
- *A-8 Obtain capacity to access information on how other cultures have dealt with similar situations*
- *A-9 Recruit financial partners*
- *A-10 Obtain funding to manage regeneration of areas that have been grossly mismanaged (i.e., mines sites, large clearcuts)*
- *A-11 Work with non-Aboriginal interest groups (i.e., coalition)*

GENERAL AREA OF NEED — B. ACQUIRE AND DEVELOP EDUCATION AND TRAINING

SPECIFIC NEEDS:

- *B-1 Revamp high school education to meet the needs of aboriginal communities (i.e., fast-tracking)*
- *B-2 Develop educational opportunities/programs that reinforce Aboriginal view of the land*
- *B-3 Provide exposure to educational opportunities outside communities*
- *B-4 Acquire knowledge of ecosystems*
- *B-5 Learn how to use technology*
- *B-6 Develop specialized knowledge through education, training, and experience*
- *B-7 Acquire knowledge of Traditional Ecological Knowledge and Western science regarding natural regeneration*
- *B-8 Learn and practise the traditional role of fire in the forest*
- *B-9 Develop and implement training in land use studies*
- *B-10 Develop expertise in proposal writing*
- *B-11 Develop capacity through education, training, and experience*
- *B-12 Learn about impacts of land management and industrial activities on Aboriginal peoples' sustenance resources*
- *B-13 Provide training in entrepreneurship*
- *B-14 Obtain employment-related education and training*
- *B-15 Gain knowledge, expertise, and experience in construction trades*
- *B-16 Gain knowledge of pesticides and herbicides*
- *B-17 Acquire education from the Partnership*

TABLE 3. Outcomes of the information needs analysis workshop held in the Kootenay Region. Information needs that the Aboriginal participants felt they could best address by working with outside agencies appear in *italic* type. Information needs that the Aboriginal participants felt they could best address by working alone appear in **bold** type.

GENERAL AREA OF NEED —
A. DEFINE OURSELVES

SPECIFIC NEEDS:

- **A-1 Define the Ktunaxa nation**
- **A-2 Define our nation's boundaries (cross-border)**
- **A-3 Utilize our Elders' skills and knowledge (i.e., trapping, language)**
- **A-4 Use the Ktunaxa language every day**
- **A-5 Tell our story**
- **A-6 Learn the cycle of life**
- **A-7 Respect the cycle of life**
- *A-8 Share our knowledge of the cycle of life*
- *A-9 Demand recognition of our nation*
- **A-10 Practice Aboriginal rights**
- **A-11 Identify and use traditional names within our traditional territories**
- **A-12 Exercise traditional use (i.e., hunting, fishing, berry picking)**
- *A-13 Reclaim and utilize traditional trap lines*
- *A-14 Share knowledge (i.e., stories, legends, ecology)*
- *A-15 Conduct archaeology studies in traditional territories (including public and private land)*
- *A-16 Explore the opportunities to protect intellectual property rights*
- *A-17 Revise the Indian Act*

GENERAL AREA OF NEED —
B. MANAGE COMMUNITY DEVELOPMENT

SPECIFIC NEEDS:

- *B-1 Encourage and support wellness initiatives*
- **B-2 Develop and encourage communication within Tribal Council (between departments)**
- **B-3 Encourage interaction with other First Nations**
- **B-4 Define capacity building**
- *B-5 Apply capacity building*
- **B-6 Develop recognition and respect in all matters**
- *B-7 Develop working relationships with different agencies*
- *B-8 Require more First Nations involvement in industry expansion*
- *B-9 Require involvement in industry development plans*
- *B-10 Require involvement in municipal development plans*
- *B-11 Require involvement in federal development plans*
- *B-12 Require involvement in provincial development plans*
- *B-13 Establish a process of sharing revenues and royalties*
- *B-14 Access industry information (i.e., mining, forestry)*
- *B-15 Establish and enforce policing and law making within traditional territories*
- *B-16 Make informed decisions based on traditional knowledge and western science*

GENERAL AREA OF NEED —
C. MANAGE EDUCATION INTERNALLY

SPECIFIC NEEDS:

- **C-1 Accept responsibility for our own learning (from infancy on)**
- **C-2 Develop and implement our own education (from infancy on)**
- *C-3 Provide basic educational needs*
- *C-4 Ensure our students acquire an adequate education*
- *C-5 Enlighten the next generation on the importance of ecology*
- *C-6 Provide alternative education to encourage youth to stay in school*
- *C-7 Conduct ongoing needs analysis regarding education*
- *C-8 Provide life skills training*
- *C-9 Provide life-long career counselling*
- *C-10 Provide recognized upgrading opportunities for adults (not GED)*
- *C-11 Identify post-secondary opportunities that will meet our needs (i.e., archaeology, GIS)*
- *C-12 Acquire an understanding of the impact of noxious weeds on native plants, animals, insects, and fish*
- *C-13 Ensure that post-secondary programs are recognized and certified*
- *C-14 Access more education dollars*

GENERAL AREA OF NEED—
D. PROMOTE ECONOMIC DEVELOPMENT

SPECIFIC NEEDS:

- *D-1 Identify economic options and opportunities*
- *D-2 Recruit and promote employment opportunities*
- *D-3 Access community-based entrepreneurial training and other forms of business training*
- *D-4 Encourage and support self-employment*
- *D-5 Communicate with industry and government*
- *D-6 Acquire expert advice*
- *D-7 Obtain more forestry contracts within traditional territories (i.e., silviculture, forest health, prescribed burning)*
- *D-8 Identify and secure funding*

to conduct their own research, and be respected and recognized for their contributions. Emphasis was placed on preventing the exploitation of traditional ecological knowledge, as well as protecting intellectual property rights[4].

Technology: Each of the three groups expressed a need to have access to technological resources.

Access to information: Two groups noted a desire for access to government information, while the third expressed a need for access to industry information.

Funding: Each of the three groups expressed a need for more government funding, but they also suggested alternative funding sources.

Capacity: Each group identified a need to develop the infrastructure to manage their resources and interests. In particular, one group suggested that long-term commitments from business and government agencies would assist them in developing their much-needed capacity.

Employment: Training in entrepreneurial business practices is required, as well as long-term employment.

Education (community level): The groups expressed a common desire for the incorporation of more First Nations language, history, and culture into the school system. The groups were also concerned about students graduating from secondary school without the ability to continue their education and without access to relevant post-secondary education programs. There is also a need to encourage and support community-level wellness initiatives.

Education (land- and resource-related): Each group expressed a need to learn more about traditional ecological knowledge and the application of science to land and natural resources management. One group expressed a need to learn more about industry concepts and the forest tenure system.

Education (non-Aboriginal parties): Two groups expressed a strong need to share their traditional ecological knowledge and wisdom with other groups (e.g., government, industry, media, and the general public). One group suggested that they wanted to educate non-Aboriginals about the differences between the various nations.

Interest groups: First Nations groups want more involvement in the development of plans and decisions made by industry, and municipal, provincial, and federal governments. They would like full and meaningful consultation, recognition of their shared knowledge and input, and current reports on the plans and decisions resulting from these meetings.

Aboriginal rights and title: Each group would like recognition of their Aboriginal rights and title, access to more land, and the right to continue traditional practices (e.g., hunting, fishing, and gathering) in their traditional territories.

Although many of these needs fall outside of the Partnership's mandate, they form the basis from which Aboriginal communities view their needs as related to the natural resources sector of the economy.

Additional Points

The participants re-emphasized some of the following points or noted other issues/challenges that the Partnership would need to consider in providing forestry extension service to First Nations groups.

Capacity: The dire lack of capacity within the Aboriginal communities is well known, by the communities themselves, the resource-user groups with whom they interact, and by governments. For example, plans for land development activities that might infringe on traditional territory must be referred to the appropriate First Nation for review. However, the worker who deals with referrals has other responsibilities as well, and therefore the community is unable to handle all of these referrals in a timely manner. Many of documents are highly technical, and are prepared by organizations that have readier access to technology and human resources.

Many examples and models of sound resource management practice occur, and some First Nations do have adequate technological, human, and financial resources. However, even where these resources are available, most First Nations have yet to apply them to the day-to-day needs of natural resources management.

For those First Nations lacking the technological, human, and financial resources, an extensive capacity-building requirement will be attached to the provision of extension services. In most other communities, capacity-building initiatives will likely tap into existing technical and human resources to address natural resources management issues.

[4] "Intellectual property rights" are defined in Article 8(j) of the United Nations *Convention on Biological Diversity* (United Nations Environment Programme 1992).

Financial benefits versus costs: All communities expressed concerns about the amount of natural resources being extracted from their traditional territories, with few of the financial benefits returning to the local area. Aboriginal people feel left out of the business and employment opportunities in the resource industries.

At the same time, the responsibility of asserting Aboriginal rights continues to drain the Aboriginal community. For example, the financial cost of addressing referrals has become onerous. The financial resources required to handle referrals effectively do not exist; the unresolved questions of Aboriginal rights and title upon which these difficult questions rest remain unanswered, yet the resource-extraction industries continue to place referrals on the desks of Aboriginal resource managers. These resource managers feel that the resource-extraction industries need to recognize the seriousness of this situation, and that they must offer some level of assistance to resolve this difficult problem.

Avenues and protocols for communication: The leadership and governance structure in the First Nations community requires recognition before any other contact is made. In most areas, the tribal council would be the Partnership's first point of contact.

Seven separate tribal councils exist in the Southern Interior: the Ktunaxa Kinbasket Tribal Council, the Shuswap Nation Tribal Council, the Nicola Valley Tribal Association, the Okanagan Nation Alliance, the Lillooet Tribal Council, the Tsilqot'in National Government, the Carrier–Chilcotin Tribal Council, and the Cariboo Tribal Council.

However, tribal councils do not represent all Aboriginal communities. A number of independent communities (i.e., the various Metis organizations and United Native Nations organizations) address the concerns of urban Aboriginals, as well Aboriginal people who are not registered under the Indian Act.

Determining which communities are independent and which are represented by tribal council members will be important when providing services. Therefore, any initiatives aimed at tribal councils must also be directed towards bands and other Aboriginal communities that are outside of the tribal council system.

The Partnership will also need to communicate with natural resource managers within, or associated with, Aboriginal communities. In some cases, managers from various communities are members of informal associations. These groups desire more organization and the formation of a formal association outside of the existing tribal council system, perhaps at a regional or provincial level.

The question of how the Partnership should connect with Aboriginal communities in the most effective manner is further complicated by the Partnership's nonpolitical mandate. Tribal councils may be viewed as too political by other members of the Partnership. The issue is further complicated because tribal councils do not represent a significant portion of the entire Aboriginal community. While the Partnership must continue to provide extension services to tribal councils, a clear delineation is required between a tribal council's political agenda and the extension services and products the Partnership provides.

The Partnership also needs to consider the role of the cultural education centres and similar organizations. Several of these organizations exist within the Southern Interior, acting as repositories of valuable cultural, historical, linguistic, and socio-economic information. They provide leadership in developing applications of Indigenous knowledge and traditional ecological knowledge. They also develop the information storage and retrieval systems required to access these valuable resources. Cultural centres will play an important role in the development of traditional ecological knowledge practices in resource management. Aboriginal education institutes (e.g., the En'owkin Centre, Nicola Valley Institute of Technology, and the Secwepemc Cultural Education Centre) were suggested as potential institutions from which the Partnership could operate. However, not all tribal areas have such educational institutes.

Another possibility is to establish Aboriginal extension specialists or workers to deliver various extension products to the Aboriginal communities.

Overall Consensus

A general consensus was reached that the Partnership's role in providing forestry extension services would be critical in assisting First Nations' communities to manage their land and natural resources.

Step 3: Developing a Framework for Action

Through the First Nations community needs analysis process, the Partnership identified a range of forestry-related information and research needs in Southern Interior Aboriginal communities. The First Nations groups have also indicated that they want to participate in exchanging information. Therefore, the Partnership has taken a leadership role in addressing these needs through the creation of its Aboriginal Forestry Extension Program. This program will function as an extension and information link between Aboriginal communities and the scientific community, resource users, and government regulatory agencies.

Objectives and Goals

To facilitate understanding between the Aboriginal communities and the larger community, the Aboriginal Forestry Extension Program will provide forums where the knowledge and understanding of Aboriginal Elders, traditional ecological knowledge keepers, and other non-Aboriginal resource practitioners can be shared. This will be accomplished through meetings, conferences, workshops, and written materials. The program's goals follow.

1. Develop strategies for improving Aboriginal participation in Forest Management Plans and other related forest-policy development processes.
2. Facilitate dialogue between Aboriginal resource management agencies and government, forest companies, municipalities, regional districts, and other resource user groups to improve future socio-economic opportunities that result from the natural resource economy.
3. Work with Aboriginal people to provide training opportunities and to facilitate entrepreneurship capacity in resource management, and to improve core skills within the Aboriginal community.
4. Help define the role of traditional ecological knowledge in the development of community, economic, and social planning in the Aboriginal community and in the community-at-large.
5. Work with Aboriginal people to provide knowledge of Aboriginal rights and title as it relates to the Partnership's mandate in order to provide forest extension and research services to all its partners.

Guidelines

1. Through the Aboriginal Forestry Extension Program, the Partnership will provide extension that will enable the involvement of its Aboriginal partners[5] in forest management and decision making which is consistent with sound ecological management principles, provincial forest practices, and Aboriginal rights and title affirmed in the Section (35) of the Canadian Charter of Rights and Freedoms, by:
   - Developing and delivering extension activities that will improve the ability of Aboriginal people to be involved in forest policy development at all levels, taking into account initiatives already started and areas where co-ordination of new efforts is needed.
   - Assisting Aboriginal people to develop a vision of the forest that reflects their shared beliefs, values, and economic aspirations regarding the forest, while respecting regional and ecological diversity.
   - Assisting Aboriginal people to build their knowledge capacity, and to co-ordinate data gathering and reporting activities already carried out by various agencies relevant to Aboriginal participation in forest management.
   - Identifying means by which traditional ecological knowledge can contribute to sustainable forest management, and by which guidelines for defining this knowledge are developed which incorporate TEK into forest research, management practices, and planning and training, in a manner that respects Article 8(j) of the United Nations *Convention on Biological Diversity* (United Nations Environment Programme 1992).
2. The Partnership will assist its Aboriginal partners to develop and facilitate a public dialogue that educates about Aboriginal and treaty rights in sustainable forest management, by:
   - Providing the relevant and necessary extension services to initiate or continue, and where necessary reform, processes for the discussion of existing legislation and policies governing the management of forest lands in light of Aboriginal and treaty rights.
   - Providing the relevant and necessary extension services to: (a) implement policy frameworks that will help guide all resource managers in understanding Aboriginal and treaty rights, (b) ensure that forest operations and tenure arrangements do not infringe, without appropriate justification, on Aboriginal and treaty rights, and (c) ensure that the exercising of these rights does not infringe on sustainable forest practices.
   - Working together to improve understanding between Aboriginal peoples and the rest of the natural resource community in matters of the history behind Aboriginal and treaty rights, traditional forest values, and modern Aboriginal aspirations and needs.

[5] FORREX's Aboriginal Partners are: Ditidaht Nation, En'owkin Centre, Ktunaka Kinbasket Tribal Council, Lillooet Tribal Council, Nicola Tribal Association, Okanagan Nation Alliance, Secwepemc Cultural Education Society, Shuswap Nation Tribal Council.

3. The Partnership will support its Aboriginal partners in developing employment and business development strategies in the forest sector by:
   - Assisting to conduct reviews of proven forest-based business opportunities and business models.
   - Providing extension services that will encourage Aboriginal employment in forestry operations and other forest-based businesses.
   - Assisting in developing business capacity.
4. The Partnership will assist its Aboriginal partners to increase the capacity of their communities and to participate in sustainable forest management by:
   - Assisting in the development of a human resources strategy that addresses the forest-sector education, training, and employment needs of Aboriginal partners.
   - Assisting in developing an agenda to address research capacity and issues specific to sustainable forests.
5. The Partnership will assist its Aboriginal partners to achieve sustainable forest management practices by:
   - Assisting in creating an awareness among Aboriginal leaders and decision makers of the importance of sustainable management of forest land in achieving the broader range of social, ecological, and economic objectives.
   - Assisting in designing and implementing strategies of sufficient scope and duration such that Aboriginal people can undertake sustainable forest management in all of their natural resources management activities.

Conclusion

In 1999/2000, FORREX–Forest Research and Extension Partnership (formerly SIFERP, the Southern Interior Forest Extension and Research Partnership) undertook a First Nations community needs analysis process to determine the information needs of First Nations' communities as related to land and natural resources management, in particular forested ecosystems.

Based on the results of this process, the First Nations' communities in the Southern Interior of British Columbia clearly have a need and a desire to participate in forestry extension services provided by the Partnership.

This needs assessment also revealed and expanded on several issues that the Partnership must consider in providing extension services to Aboriginal communities. The process illustrated that the overall Aboriginal community consists of a diverse set of groups, each with unique characteristics and needs. Various legal, cultural, and political organizations already provide services to Aboriginal people. However, the infrastructure and resources needed to manage natural resources are not equally available, either among the Aboriginal groups themselves or between non-Aboriginal and Aboriginal groups.

Forestry extension between Aboriginal partners and non-Aboriginal partners will also require a considerable sensitivity as the tensions resulting from unresolved issues of Aboriginal rights and title further strain the relationships between the resource industry and the Aboriginal community. In addition, the need to link traditional ecological knowledge to policy making and to industry adds to the complexity of providing extension services to the Aboriginal community. To facilitate these and other matters, the Aboriginal community clearly has a need for forestry extension services.

The Partnership has therefore taken a leadership role in providing these extension services to its Aboriginal partners. With the First Nations needs analysis process, the Partnership began working with its Aboriginal partners to identify the information and research needs of the Aboriginal community, and to create the solutions required to develop linkages and partnerships with the resource industry. This process has also provided direction for including traditional ecological knowledge in natural resources management and policy development. The Partnership's Aboriginal Forestry Extension Program will be a vehicle for serving Aboriginal communities and the various resource-user groups with which they interact in the Southern Interior of British Columbia.

The Aboriginal Forestry Extension Program will provide forums to share the knowledge and understanding of Aboriginal Elders and the keepers of traditional ecological knowledge, and other non-Aboriginal resource practitioners. This will broaden the environmental, economic, social, and cultural understanding of the Aboriginal communities and the larger community with each other, and facilitate the common goal of enhancing the long-term health of the Southern Interior's forest and range ecosystems.

Editor's Note

The intent of the First Nations needs assessment process was to develop extension strategies that will assist First Nations in resolving the human, technical, and other resource gaps that now hinder their meaningful participation in natural resources management. Through the needs assessment process and the development of the Partnership's Aboriginal Forestry Extension Program, opportunities for enhanced collaboration and improved information management will result in new sources of human, technical, and funding capacity.

The reviewers of this paper unanimously agreed that the contents of this paper accurately conveyed the situation of First Nations' communities in their efforts to participate meaningfully in natural resource management. They stated that the Partnership's initiative to advance an Aboriginal extension program would result in an expanded Aboriginal extension infrastructure—a development they had no problem with. They also stated that this new extension capacity would best benefit Aboriginal communities if it was delivered by First Nations' organizations rather than by the Partnership. This approach is consistent with the Partnership model of building extension capacity within the community that will most benefit from these services. It is not the intent of the Partnership to compete with First Nations' communities in the development of extension capacity. Our objective is to fully employ the combined capacity of all our Partners, including First Nations, to collaboratively develop innovative, sustainable ecosystem management practices.

Chris Hollstedt,
FORREX Executive Director
and *JEM* Editor-in-Chief

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Research Report

Field performance of pine stock types: Two-year results of a trial on interior lodgepole pine seedlings grown in Styroblocks™, Copperblocks™, or AirBlocks™

Melanie D. Jones[1], Steven Kiiskila[2], and Anne Flanagan[3]

Abstract

Copper-treated Styrofoam containers and containers with side slits have been designed to modify the root systems of seedlings grown in hardwall containers. By chemical- or air-pruning major lateral roots, they encourage a more fibrous, branched root system, which is more evenly distributed throughout the root plug.

In the study presented here, lodgepole pine (*Pinus contorta* var. *latifolia*) seedlings were grown in Copperblocks™, AirBlocks™, or conventional Styroblocks™ and planted into different rooting environments. Various laboratory tests were performed on the seedlings before planting, but these failed to predict responses to the treatments in the field. Container type influenced root development and potential root viability in the nursery; however, these differences had disappeared in the field after two growing seasons. Only in summer-planted seedlings was root egress near the top of the plug greater for copper-treated than for conventional seedlings in the field. Seedlings grown in Copperblocks with exclusively secondary needles were evaluated separately from those with only primary needles. The secondary-needle seedlings had greater height increments in both growing seasons, although no differences in root collar diameter were apparent. However, both types of seedlings were selected from a population grown under cultural conditions to induce secondary needles, and thus some of the differences may have a genetic basis. Spring-planted seedlings, grown on burnt slopes, grew 5–18% taller than those on screefed plots and 43–67% taller than seedlings on ripped landings. Our major conclusion is that, provided the seedlings are healthy, planting location is more important than stock type.

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Introduction

Several choices must be made when ordering coniferous seedlings for reforestation, such as among container type, container size, seedling age, and needle form. This article reports on a recent study that examined container type and its effect on shoot growth and root egress of interior lodgepole pine (*Pinus contorta* var. *latifolia*) two seasons after outplanting. We also briefly compare field performance of primary and secondary needle lodgepole pine.

Concern over perceived root system instability leading to toppling of planted container-grown pine seedlings in British Columbia has prompted the development of new containers that modify seedling root systems.

Container Type

Concern over perceived root system instability leading to toppling of planted container-grown pine seedlings in British Columbia has led to the development of methods to modify the root systems of container-grown seedlings (Burdett *et al.* 1986). At present, root systems are modified by a system of ribs and by chemical- or air-pruning. Copper (i.e., copper oxychloride) applied to the inside container walls of the commonly used hardwall Styroblock™ container (Beaver Plastics Ltd.) results in a product called the Copperblock™. When new seedling roots come in contact with the copper on the container walls they cease growing. This prompts the generation of more lateral roots (Arnold and Struve 1993), which results in a more evenly distributed, fibrous root system (Wenny 1988). Recently, hard plastic side-slit containers (i.e., AirBlock™), which air-prune seedling roots (Figure 1), have been developed by BBC Sylviculture Systems Inc. as an alternative to Copperblocks.

Copper-treated stock is more expensive to produce because of the greater initial cost of containers, increased mortality during initial nursery culture, and container disposal issues (Peter Richter, Pacific Regeneration Technologies Inc., Vernon, B.C., pers. comm., 1998). AirBlocks also have a greater initial container cost, and seedlings grown in them require more frequent irrigation than seedlings grown in the two other types of containers. Some advantages of AirBlocks over Copperblocks are that these containers may have a longer useful lifespan and carry no concerns about the environmental impacts of copper runoff (although more fertilizer runoff does occur because of the additional irrigation required during seedling production).

Although Copperblocks are used widely in western Canada to produce lodgepole pine seedlings (MacDonald 1991), more information is needed on whether Copperblocks and the newly introduced AirBlocks provide any real advantage in the field over the conventional Styroblock. Differences in root form have been observed for the first few years (2–5 years) after outplanting in seedlings grown in Copperblocks. For example, compared to conventional seedlings, lateral root egress in copper-pruned pine seedlings is more evenly distributed up and down the original plug (Burdett 1981; Winter 1990; Winter and Low 1990; Watt and Smith 1998), or occurs more from the upper portions (Clarke and Winter 1986; Clarke and Winter 1987; Wenny 1988; Priest 1991). This difference did not occur in a study by Winter and Low (1990). While increased root production from the upper portion of the plug is considered a desirable trait in cold soils (Balisky *et al.* 1995), earlier studies show no difference in survival (Burdett 1981; Clarke and Winter 1987; Wenny 1988; Winter 1990; Priest 1991), or only slightly increased survival (Clarke and Winter 1986; Winter and Low 1990) by copper-treated lodgepole pine stock. With a few exceptions (Burdett 1981; Priest 1991), no significant differences have been observed in height or root collar diameter between regular and copper-treated lodgepole pine trees 2–5 years after planting (Clarke and Winter

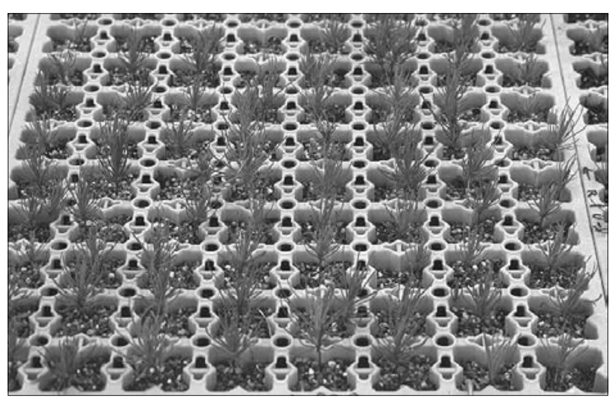

FIGURE 1. Lodgepole pine seedlings in an AirBlock.

1986; Clarke and Winter 1987; Winter 1990; Winter and Low 1990; Kooistra 1991). Thus, though commonly inferred or suggested, little evidence exists that trees originating as Copperblock seedlings perform any better in the first few years following outplanting, or are less susceptible to toppling (Krasowski *et al.* 1996), than conventional Styroblock seedlings. Field performance of lodgepole pine seedlings produced in AirBlocks has not been evaluated. The first objective of this study was, therefore, to compare root system development and shoot growth of interior lodgepole pine seedlings produced in Styroblocks, Copperblocks, and AirBlocks after two growing seasons in the field.

Primary versus Secondary Needles

The first needles formed on pine are called primary needles. On lodgepole pine these may be produced until the end of the first growing season. They are not found after the second growing season under normal conditions in northern temperate (e.g., British Columbia) nurseries (Thompson 1981, 1982). Normally, starting in the second year, mature or secondary needles are formed (i.e., fascicle needles). In the nursery, secondary needles can be induced in the first growing season through the use of long photoperiods (Wareing 1950).

Foresters often order pine seedlings with secondary needles because, with their mature foliage, they are thought to be more robust than comparable primary-needle pine seedlings. However, very few studies have compared field performance of primary- and secondary-needle pine. Work on Scots pine showed that primary-needle seedlings had greater shoot growth potential after planting because of increased stem units in the bud (Thompson 1976, 1981). Two-year results from a recent trial established on lodgepole pine in north-central British Columbia (Mustard *et al.* 1998) suggest little growth advantage of secondary- over primary-needle pine. Thus, no significant evidence to date has shown greater survival and field growth potential of secondary-needle over primary-needle pine seedlings, even though this topic has been debated for some time (Omi *et al.* 1993; van Steenis 1993). Because supplemental lighting is required, production of secondary-needle seedlings is more expensive than comparable primary-needle seedlings. The second objective of our study was to compare shoot and root growth in primary- and secondary-needle Copperblock seedlings after two growing seasons in the field.

Laboratory Predictors

To cull seedlings that have no chance of survival in the field, many morphological and physiological criteria are used to rate nursery stock quality. However, the laboratory tests currently in use are not sophisticated enough to correlate with field performance (Mohammed 1997). In this project, we used several tests (e.g., drought stress resistance, root growth capacity, and root viability) to measure performance attributes (Mattsson 1997). These variables were measured in the laboratory before outplanting of both spring and summer stock. Earlier work on lodgepole pine had shown that root viability, measured by triphenyl tetrazolium chloride (TTC) analysis before outplanting, was a better predictor than root growth capacity of seedling performance in the field (Lukic 1997). A similar result was found for Scots pine by Lassheikki *et al.* (1991). Carbohydrate levels were measured because of their correlation with drought and freezing stress (Niederer *et al.* 1992). These variables were measured to determine whether any would be useful in testing stock quality and predicting field performance before outplanting.

Methods

Production of Seedlings

From 1997 to 2000, we ran two field trials comparing the growth performance of one-year-old (1+0) interior lodgepole pine grown in Styroblocks (PSB 410, 80 ml), Copperblocks (PCT 410, 80 ml), or AirBlocks (PAB 410, 80 ml). The first experiment (spring-planted seedlings) used seedlings from seedlot 32810 sown into an outdoor compound in mid-April of 1997, lifted in November, stored frozen at –2°C, and planted the next May. Seedlings were grown following cultural practices currently used for commercial seedling production and appropriate to each container type. Fertilizer with a 2-1-2 nitrogen-phosphorus-potassium ratio was applied at 100 ppm N for the first 60% of the growing season and at 50 ppm N for the latter 40%. During production of the spring-planted seedlings, the Copperblock seedlings received an extended photoperiod (21 hours) to encourage the development of secondary or mature fascicle needles. Thus, both primary-needle and secondary-needle seedlings were produced in Copperblocks; these were separated during lifting and then compared. Seedlings grown in other block types had no photoperiod extension. Any secondary-needle seedlings were excluded from these groups at lifting. Seedlings from different blocks within a treatment were randomly combined into bundles of 15 for cold storage.

The seedlings (seedlot 39033) for the second experiment (summer-planted seedlings) were greenhouse-sown in early February 1998, then hot-lifted and planted in early June. As one-year-old stock for summer planting is sown in mid-winter when the days are short, supplemental photoperiod was used during the initial production of this stock. However, the length and timing of the photoperiod extension were such that it did not promote secondary needle production in any of the summer stock. For the first nine weeks of growth, greenhouse temperatures were set at 22°C during the day and 20°C at night. For weeks 10 and 11, temperatures were gradually lowered to ambient; at week 12, seedlings were moved outside the greenhouse and exposed to ambient (Vernon, B.C.) temperatures. Fertilizer with a 2-1-2 nitrogen-phosphorus-potassium ratio was applied at 100 ppm N throughout the growing period.

Laboratory Analyses

Laboratory analyses were performed on spring-planted seedlings after three and one-half months of frozen storage, and on summer-planted seedlings immediately after lifting. Root viability testing followed the triphenyl tetrazolium chloride method of Steponkus and Lanphear (1967). Root growth capacity was tested according to Johnson-Flanagan and Owens (1985).

Drought stress was applied by planting nine seedlings per treatment into dry substrate in a growth cabinet. Control seedlings were watered to the point of runoff on days 0, 1, 4, and 8. After 10 days, conductivity was measured on samples of roots and needles (McKay 1992). Stress was expressed as percent root injury, as calculated by Blum and Ebercon (1981).

Soluble carbohydrates in flash-frozen, ground roots were quantified according to the methods of Dubois *et al.* (1956). For starch analysis, the enzymatic method of Rose *et al.* (1991) was employed.

Planting and Field Assessments

Spring-planted seedlings were planted on two cutblocks at approximately 1450 m in elevation near Princeton: 667-2, a 46-ha cutblock with a northeast aspect in the Montane Spruce, dry mild biogeoclimatic subzone (MSdm2); and 619-7, a 18.5-ha bowl-shaped cutblock in the MSdm2. On 667-2, the four treatments (primary-needle seedlings grown in each of the three container types and secondary-needle seedlings grown in Copperblocks) were planted in three regions of the cutblock in a split-plot design. In each region, seedlings were planted onto a landing, an adjacent mechanically spot-screefed area, and an adjacent non-screefed burned area. Thus, nine plots were located on 667-2—three replicates each of landings, screefed, or burned planting sites. On 619-7, the four treatments were planted in two plots only. Both plots were in mechanically spot-screefed locations. Each plot on both cutblocks was planted with 50 randomly arranged seedlings of each nursery treatment.

Later that summer, 50 hot-lifted seedlings from each of the three container types were planted in an interspersed pattern in a split-plot design on three replicate cutblocks (summer-planted seedlings). On each cutblock, plots were established on one landing and an adjacent area of the cutblock. The landings had been mounded, but the adjacent cutblocks had not been site-prepared. Seedlings were planted on the tops of mounds on the landings and on raised microsites on the cutblocks.

Twenty randomly selected seedlings were assessed per treatment per plot in late September 1998 and 1999 for both spring- and summer-planted stock. No attempt was made to measure the same seedlings in both years. In September 1999, three randomly selected seedlings per treatment per plot were excavated and returned to the laboratory. The number and weight of roots produced in the upper, middle, and lower third of the root plug were quantified.

Results and Discussion

Effects of Container Types: Spring-planted Seedlings

Measurements in the laboratory on spring-planted seedlings before outplanting indicated that AirBlock seedlings significantly outperformed ($P < 0.05$; one-factor ANOVA) seedlings produced in conventional Styroblocks with respect to most of the growth and physiological variables measured. AirBlock seedlings also performed as well as, or better than, primary-needle Copperblock seedlings for all variables except drought tolerance. Specifically, the seedlings grown in the AirBlocks produced a higher proportion of new roots in the upper two-thirds of the plug (Figure 2)

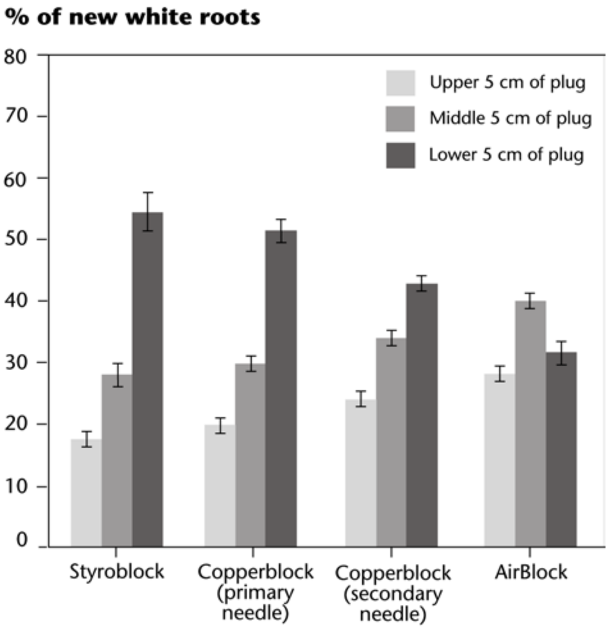

FIGURE 2. Location of new root growth from frozen-stored, spring-planted lodgepole pine seedlings after 10 days under optimal conditions (root growth capacity test). A one-factor ANOVA detected differences among

and had higher root viability following frozen storage compared to primary-needle seedlings from Copperblock or conventional Styroblock containers. The total number of new roots produced during the root growth capacity test, and the carbohydrate concentrations did not differ significantly among treatments. Root injury after 10 days of drought in pots was lower in primary-needle Copperblock seedlings than for any other seedlings. Needle injury differed less among treatments ($P = 0.03$), but primary-needle Copperblock seedlings had significantly less damage than AirBlock seedlings, with Styroblock seedlings intermediate in drought-stress resistance. The unique traits of the primary-needle Copperblock seedlings could be due to several factors: the container treatment, genetic differences, or the photoperiod treatment in the nursery.

At the end of the first growing season (September 1998), total shoot heights of the AirBlock and primary-needle Copperblock seedlings in the field were greater than those of the conventional Styroblock seedlings (Figure 3), although no difference was observed in root collar diameter. By the end of the second growing season (1999), however, seedlings from the three container types no longer differed significantly in shoot size (Figure 3), location of root egress along the plug, or weight of egressed roots.

On cutblock 667-2, the seedlings were planted in three different types of plots: ripped landings, mechanically screefed planting spots, and burned slopes. Although the effect of container type on growth was the same regardless of planting environment (no significant planting site × container type interaction), the planting environment had a major effect on seedling growth. Seedlings planted in the burned plots had greater second-year height increments, larger root collar diameters, and greater root weights than seedlings planted in the two other environments (Table 1). Seedlings in burned plots produced fewer roots than seedlings in screefed plots. Seedlings grown on burnt slopes were 5–18% (3 cm) taller than those on screefed plots and 43–67% (6 cm) taller than seedlings on ripped landings.

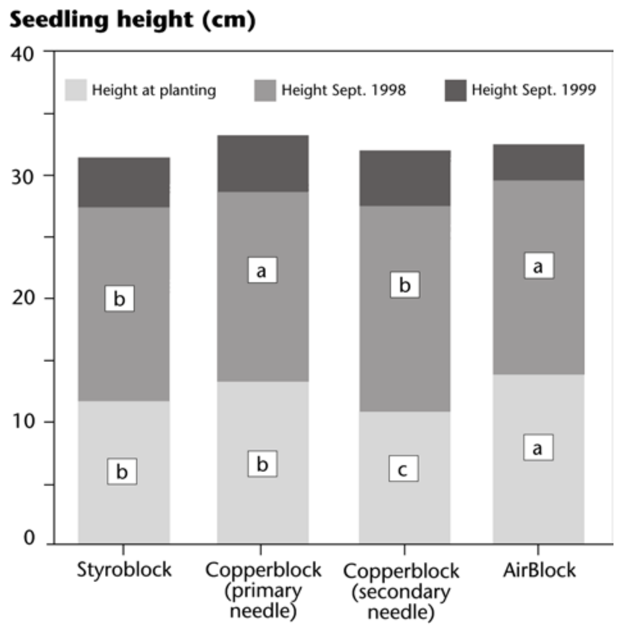

FIGURE 3. Total height (from soil surface to top of needles) for spring-planted lodgepole pine (all planting sites combined). Different letters within the same stippling pattern indicate significant differences according to a Fisher's PLSD test at $P = 0.05$. At planting, heights differed at $P = 0.001$ according to a one-factor ANOVA. At the end of the first growing season, heights differed at $P = 0.002$ according to a two-factor ANOVA. At the end of the second growing season, no differences in total height were evident among container treatments.

TABLE 1. Second-year field assessment of *Pinus contorta* seedlings planted in late May 1998 (spring-planted seedlings) on mechanically spot-screefed sites, burned sites, or ripped landings on cutblock 667-2. Assessments were performed in early September 1999. Data have been combined for primary- or secondary-needle seedlings from all container types. *P*-values are from two-way analyses of variance, with container type and planting location as factors. Within a column, numbers followed by different letters differ at ⁄ = 0.05 in a Tukey's *a posteriori* test.

	Height at planting in 1998 (cm)	1999 height increment (cm)	Total height (cm)	Root collar diameter (mm)	Wt. roots produced since planting (g)	No. roots produced since planting
Screefed	12.3 ± 0.5	16.4 ± 0.6 b	35.8 ± 0.6 a	8.3 ± 0.2 b	1.7 ± 0.2 b	97.4 ± 3.8 a
Burned	12.7 ± 0.6	19.1 ± 0.6 a	37.9 ± 0.7 a	10.0 ± 0.2 a	2.6 ± 0.0 a	68.1 ± 5.5 b
Landings	12.4 ± 0.6	9.8 ± 0.7 c	26.8 ± 0.7 b	6.0 ± 0.3 c	1.26 ± 0.1 b	82.1 ± 8.1 ab
P-value	0.85	0.0001	0.0001	0.0001	0.0002	0.003

Effects of Container Types: Results for Summer-planted Seedlings

Due to the side slits in the container walls, AirBlock stock required additional water during production compared to stock produced in the two types of Styrofoam containers. Because of the difficulty of applying extra water to a small number of AirBlock seedlings grown operationally among a large amount of Styroblock and Copperblock stock, the AirBlock seedlings attained only 58% of the height of the other seedlings when they were lifted (Figure 4). In spite of the major difference in shoot size, most of the physiological and growth tests did not detect any differences among seedlings grown in the three container types. The only difference was in the total number of new roots produced in the root growth capacity (RGC) test, where they were significantly higher ($P = 0.0001$) for Copperblock seedlings than the other two treatments. In contrast to the spring-planted seedlings, no difference was evident in the location of root egress among treatments in the RGC test.

The difference in shoot size observed in the nursery remained throughout the two seasons of the field trial (Figure 4). The dry weight of roots produced after planting was also significantly lower in AirBlock seedlings planted on the cutblock compared to the other seedlings (Figure 5). Interestingly, a significant interaction was evident between container type and planting location with respect to height increment in 1999 (Table 2). This is because the Copperblock seedlings, which had (on average) the largest shoot systems, showed the greatest reduction in growth on the landings. Copperblock seedlings planted on landings had a mean height increment 62% that of Copperblock seedlings planted in the cutblock; the corresponding value was 73% for Styroblock seedlings and 80% for AirBlock seedlings. An interaction between planting location and container type for root growth was also observed (Figure 5). The dry weight of egressed roots differed significantly among the three container types on the cutblock, but not on the landings; this was attributed to the relatively better root growth of AirBlock seedlings on landings.

Following two field growing seasons, Styroblock summer-planted seedlings produced a significantly higher proportion of roots from the bottom third of the plug than the Copperblock or AirBlock seedlings (Figure 6). Over the short length of the study, these differences in the location of root egress were not correlated with shoot or total root biomass. Generally, we feel that it is inappropriate to speculate on how the AirBlock summer-plant seedlings would have performed had they not been so much smaller than the other seedlings initially. Nevertheless, the difference in the distribution of new roots between the Copperblock and Styroblock seedlings should be a robust observation because these two groups of seedlings did not differ in size at planting.

Differences among Primary- and Second-Needle Spring-planted Pine Grown in Copperblocks

The secondary-needle Copperblock seedlings had higher root viability and a lower percentage of roots produced near the bottom of the plug in the root growth capacity test than the primary-needle Copperblock seedlings (Figure 2), but had lower drought stress resistance and produced a shorter shoot in the nursery (Figure 3). Root collar diameter and needle length did not differ.

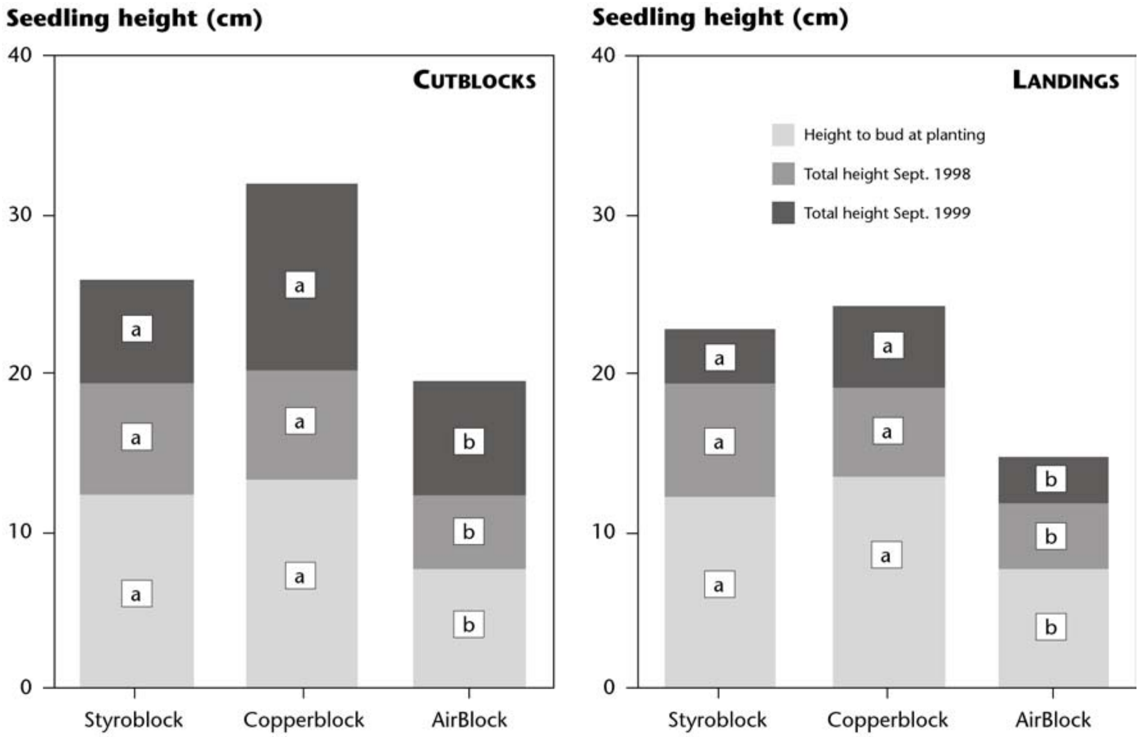

FIGURE 4. Height to bud at planting, as measured on a subset of seedlings in the lab, and total height (soil surface to end of needles) at the end of the first and second growing seasons for lodgepole pine planted in July 1998 (summer-planted seedlings) on cutblocks or adjacent site-prepared landings. For each planting location, different letters within the same stippling pattern indicate significant differences according to a Fisher's PLSD test at $P = 0.05$. P-values for one-factor ANOVAs between container types were as follows: cutblock and landing at planting, $P = 0.0001$; cutblock in September 1998, $P = 0.0005$; cutblock in September 1999, $P = 0.001$; landings in September 1998, $P = 0.0002$; landings in 1999, $P = 0.004$.

TABLE 2. Second-year field assessment of primary-needle *Pinus contorta* seedlings planted in June 1998 (summer-planted seedlings) on site-prepared (mounded) landings or adjacent cutblocks. Assessments were performed in September 1999. P-values are from two-way ANOVAs, with container type and planting location as factors. Within a column, numbers followed by different letters differ at ⁄ = 0.05 according to a Tukey's *a posteriori* test.

	1999 height increment (cm)	**Root collar diameter (mm)**
Styroblock	12.7 ± 1.0 ab	5.6 ± 0.2 a
Copperblock	15.1 ± 1.7 a	5.7 ± 0.3 a
AirBlock	10.2 ± 0.8 b	4.7 ± 0.3 b
Container type *P*-value	0.0006	0.007
Cutblock	14.9 ± 0.9	5.6 ± 0.2
Landing	10.4 ± 0.5	5.0 ± 0.2
Planting location *P*-value	0.0001	0.02
Container × Location *P*-value	0.05	0.4

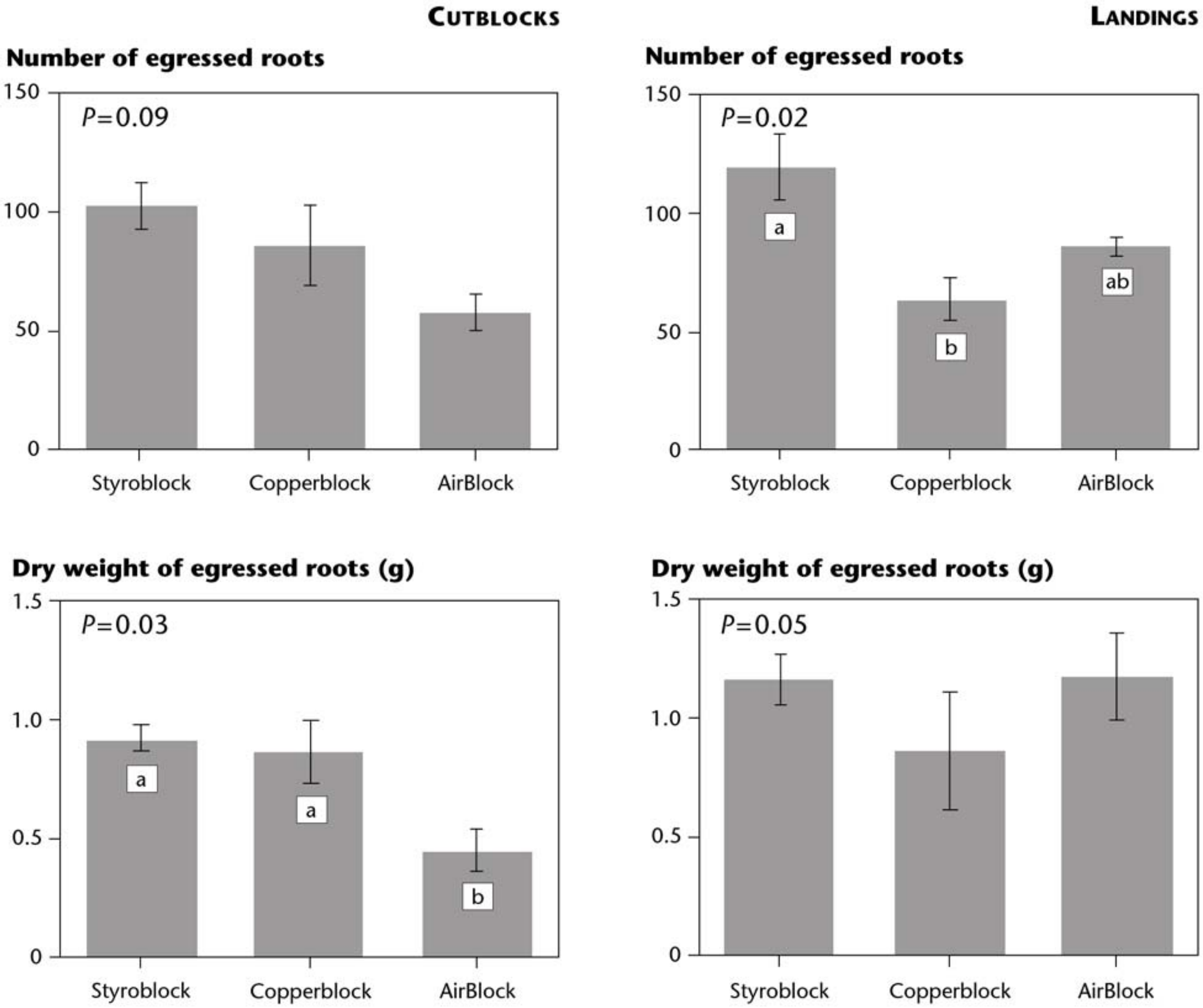

FIGURE 5. Root egress of summer-planted lodgepole pine during 1998 and 1999. *P*-values are those of one-factor ANOVAs and letters within the bars indicate differences detected by a Fisher's PLSD test at $P = 0.05$. A two-factor ANOVA on root number gave $P = 0.006$ for container, $P = 0.3$ for site and $P = 0.09$ for container × site interaction; a two-factor ANOVA on root weight data gave $P = 0.3$ for container, $P = 0.02$ for site, and $P = 0.09$ for container × site interaction.

By the end of the second growing season (1999), however, the primary- and secondary-needle seedlings no longer differed in shoot height or diameter, location of root egress along the plug, or weight of egressed roots. The change in relative shoot height was because the secondary-needle Copperblock seedlings, which were shorter initially, had higher mean height increments in both growing seasons. If this pattern continues, they will be larger than the primary-needle pine in subsequent growing seasons.

Comparisons between the primary- and secondary-needle seedlings should be interpreted with caution, as genetic differences among the seedlings may be confounding the results. The primary-needle seedlings were selected from a population of pine grown under cultural conditions to produce secondary needles (which the majority of seedlings did), not under separate cultural conditions to induce primary needles.

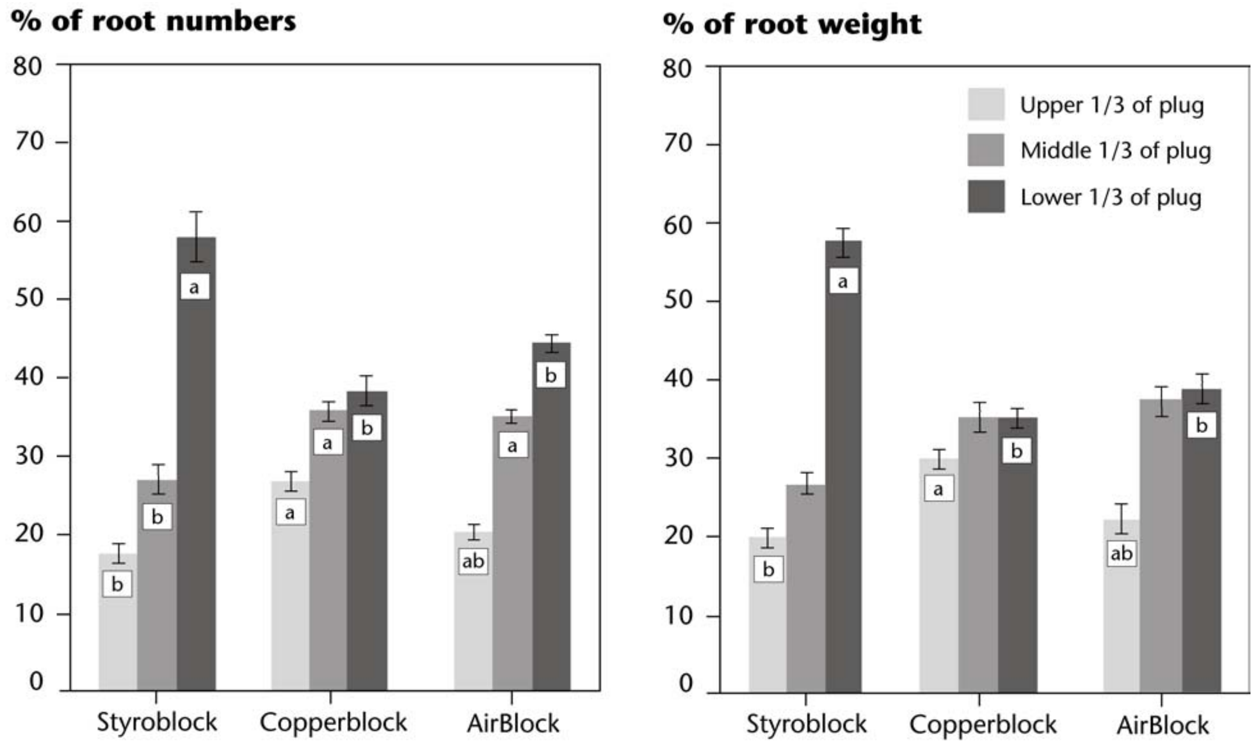

FIGURE 6. Distribution of egressed roots on summer-planted lodgepole pine at the end of the second growing season in the field for both types of planting sites combined. One factor ANOVAs were performed separately for each portion of the root plug. If bars of the same tone have different letters, they differ at $P = 0.05$ according to a Fisher's PLSD test.

Comparison of Laboratory and Field Results

None of the physiological measurements or growth tests performed in the laboratory predicted the relative performance of the different stock types in the field. For spring-planted seedlings, root growth capacity tests predicted differences in root egress patterns, whereas no differences in root production or distribution were observed in the field. Before planting, laboratory tests predicted that field performance would be best in spring-planted AirBlock or Copperblock seedlings because root viability was highest in AirBlock seedlings and damage due to drought stress was lowest in Copperblock seedlings with primary needles. In spite of these predictions, no differences in shoot size were present at the end of two field growing seasons. It is especially interesting that drought stress injury was not a useful variable given that the summer of 1998 was extremely dry.

For summer-planted stock, the distribution of roots produced in the field differed between Styroblock and Copperblock seedlings, whereas this had not been predicted by the root growth capacity test done before planting. The laboratory tests predicted that Copperblock seedlings would produce the largest number of roots in the field, but this did not occur. No other tests detected differences among the treatments.

Management Implications

1. The major conclusion of this study is that, provided seedlings are healthy, planting site is more important than nursery treatments in affecting growth. Spring-planted seedlings in burned plots had the fastest growth rates, regardless of container type, whereas those planted on landings grew the slowest. Moreover, seedlings planted in one cutblock (619-7) grew significantly faster than seedlings planted at the same time on similar microsites in a second, nearby cutblock (667-2) at the same elevation. This suggests that even subtle site differences can be important. Other studies have shown that root morphology (McMinn 1978) and stand stability (Krasowski *et al.*

1996) are more heavily influenced by site conditions such as soil characteristics and stocking density than stock type. This justifies the increased attention currently placed on planting spot selection and planting depth, which can positively influence the amount and location of root egress from planted seedlings by placing seedling roots into the most favourable growing environment (Anonymous 2001).

2. The studies cited in the introduction found that root systems of copper root-pruned seedlings generally differed from the root systems of seedlings grown in conventional, untreated containers (e.g., Styroblock) for at least the first few years after planting. In our study, after two years of field growth, summer stock grown in Copperblocks had a more even distribution of roots along the height of the root plug, but this did not result in differences in shoot growth when compared to Styroblock seedlings. Spring-planted lodgepole pine seedlings grown in conventional Styroblock and Copperblock (with primary or secondary needles), or hard plastic AirBlock containers did not differ significantly in shoot height, root collar diameter, or weight or location of egressed roots after two years growth in the field. Our results are consistent with earlier studies, which generally failed to show any significant benefit of copper-treated blocks to shoot growth. Furthermore, they suggest that any of the three types of container produced stock of equal growth potential.

   We conclude that the root system produced by the conventional Styroblock container does not limit seedling growth and establishment relative to the other container types tested. This may be because, since the development of the Copperblock, the culture and root form of seedlings grown in Styroblock containers in western Canada have improved, which reflects subsequent modifications to the original design. For example, vertical ribs have been added to the original Styroblocks to reduce root spiralling, average seedling container size has steadily increased, and the bulk density of the growing media has been decreased substantially, allowing more vigorous root growth without plug compaction. Moreover, present production methods are such that seedlings are sown at the optimal date to produce the required shoot and root growth, and not left in their containers for unnecessarily long periods of time, thus reducing the possibility of seedlings becoming root-bound (Peter Richter, Pacific Regeneration Technologies Inc., Vernon, B.C., pers. comm., 1998). After only two years growth, it is too early to know whether any of the differences in initial root form of the summer-planted seedlings will have any influence on future tree stability and growth. However, as no significant differences in rooting among the spring-planted container types were evident after two seasons growth, future differences in rooting are unlikely.

> *The major conclusion of this study is that, provided seedlings are healthy, planting site is more important than nursery treatments in affecting growth.*

3. Laboratory tests performed on seedlings before planting did not predict seedling growth in the field for either spring- or summer-planted stock. Even though some of these same tests predicted field performance in lodgepole pine in a trial on lifting date conducted previously in our laboratory (e.g., Lukic 1997), the results described here again suggest that site factors are more important than container types in determining both shoot and root growth in the field.
4. The secondary-needle Copperblock seedlings were significantly (> 3 cm) shorter than primary-needle seedlings at planting, but had reached the same height as primary-needle seedlings by the end of the trial. This is attributed to higher mean height increments. Comparisons between the primary and secondary needle classes should be interpreted with caution, however, as genetic differences among the seedlings may be confounding the results. The primary-needle seedlings were selected from a population of pine grown under cultural conditions to produce secondary needles. Therefore, results from this study should not be used for general growth comparisons between primary- and secondary-needle pine seedlings.

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British Columbia
Journal of Ecosystems and Management

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