Forest Science Program Full Proposal 2006/07 *New Research Projects*

Full Proposal: Y07-1254

Effect of site type on competitive interactions among trees in complex-structured mixed species sub-boreal forests

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Section 1: Proponent Information

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Section 2: Project Information

Project Title: **Effect of site type on competitive interactions among trees in complex-structured mixed species sub-boreal forests.**

Keywords

Crowding, shading, competition, resource gradients, moisture, nutrients, tree growth.

Project Description

In many parts of the world forest management is evolving rapidly, moving from an agricultural model that emphasized simple stand structures toward more complex stand structures based on natural disturbance or ecosystem models. Variable structure is desirable within stands after silvicultural manipulation in order to meet a host of forest management objectives.

Traditional even-aged forest management has relied on the concept of site index to characterize productivity for single-species stands. Site index trees are dominant or codominant individuals that are considered free growing and hence represent site conditions. Site index is a critical component of growth and yield models used to project stand growth, however, it merely represents a retrospective estimate of site productivity for a single species grown in open conditions. Consequently, site index can fail to predict productivity in mixed-species and structurally complex stands. Site index provides little insight into how the competitive interactions among tree species may be affected across resource gradients (or site types) found in forested landscapes.

Understanding the nature of competitive interactions among forest trees is central to our understanding of forest community organization and dynamics. This knowledge is also critical to the development of sustainable management of forest ecosystems, particularly in complex structured mixed-species stands. An open and unresolved question is how interspecific competitive interactions (and hence expected growth rates) of different tree species vary across site types in complex stands. The competitive effects and the interactions of different species are likely non-additive. It is important to understand how the relative strength of competitive interactions among tree species varies across resource gradients. For example, it is well known that trembling aspen (*Populus tremuloides*) can out-compete lodgepole pine (*Pinus contorta* var. *latifolia*) on moister ecosystems in the interior of British Columbia, however, on drier site types pine may be an equal or superior competitor (Haeussler et al. 1990). How do these competitive interactions affect growth rates in mixed-species stands? If we are going to manage complex stands, then we must understand how differing environmental conditions affect competitive interactions among tree species, and how this in turn affects growth rates of individual trees.

There have been two substantial impediments to understanding competitive interactions in complex stands. First, competition among trees is a spatially-explicit neighbourhood dynamic and its quantification requires establishment of expensive stem-mapped plots. Existing plots are usually small (e.g., permanent sample plots) and/or on uniform site conditions (e.g., Canham et al. 2004 only mapped mesic sites). Additionally, in mixed-species complex stands, the number of possible combinations (species, tree sizes, and spatial distribution) of individual tree neighbourhoods is substantial requiring large sample sizes to tease apart competitive interactions (Coates et al. (in prep). Once you include site variability the number of combinations increases rapidly. Consequently, a study of individual tree growth and competition in heterogeneous environments requires a large sample size from large stem-mapped areas. Second, studies of forest ecosystem processes have traditionally used plot data that averages across variation in local neighbourhood composition and structure. With such an approach, it is very difficult to predict changes in ecosystem processes as stand composition changes. We need novel approaches that account for changing conditions and heterogeneous environments.

We propose to resolve these two problems by: (1) applying new remote sensing technology that allows economic creation of large stem-map areas across natural resource gradients, and (2) applying statistical techniques that allow for spatially-explicit analysis of individual-tree based competitive interactions among tree species across resource gradients. These statistical techniques allow tight linkage between field data and the parameterization of stand-level forest dynamics models (e.g., SORTIE-ND). Models can then be used to predict natural stand development, residual tree responses after natural disturbances such as the Mountain Pine Beetle in central BC, or responses after silvicultural interventions.

Target Audience/End Users:

We will be developing new remote sensing and statistical approaches that will be of considerable interest to the research community. Initially, through publication of our research, the primary beneficiary from this project will be the research community. The growth functions we develop will be incorporated into decision support tools and communicated through workshops to forest professionals with an interest in the northern interior. This will help managers make better decisions in the management of complex structured stands. This project will provide (1) a new remote sensing technology that allows economic creation of large stem-mapped areas across natural resource gradients, (2) insight into how individual-tree competitive interactions among trees species change across resource gradients, and (3) robust growth functions that can be incorporated into individual tree models.

The outcomes of this project can be utilized in at least four ways:

(1) Given their large size, the stem-mapped areas resulting from this project will be unique in British Columbia. The stem-mapped areas will be available for other research that is concerned with spatially-explicit processes.

(2) The developed methodology for economic stem-mapping can be utilized by other researches for further creation of large stem-mapped plots.
(3) This project will provide insight into how individual-tree competitive interactions among trees species change across resource gradients. This type of basic scientific knowledge is fundamental to furthering both forest science and forest management in British Columbia and globally.
(4) The results from this project will be utilized to further develop spatially-explicit growth models for mixed-species stands. More specifically, the results will be incorporated into SORTIE-ND. Additionally, the results can be utilized to guide the development of other spatially-explicit individual tree models that are utilized to model complex mixed-species stands.

Project Objectives

Long Term Objectives:

(1) To further our ecological understanding of competitive interactions among trees species in complex stands, and how these interactions vary across resource gradients or site types.
(2) To develop robust cost effective methods to parameterize individual-tree growth models for use in British Columbia and elsewhere
(3) To make SORTIE-ND available for a larger range of site types in British Columbia.

Current Year Objectives:

(1) To select suitable sites in the sub-boreal spruce zone that will provide a range of competitive neighbourhoods and variability in site quality. To acquire a number of high spatial resolution remote sensing imagery on which individual tree crowns and gaps are clearly visible.
(2) To test the effectiveness of image processing routines to extract crown size, and location from the imagery to be used in the production of stem-maps in large sample plots.
(3) To develop alternate empirical mathematical functions that may best explain competitive interactions among trees species across resource gradients.
(4) To start compiling the sample tree and competitive neighbourhood data in remote sensed plots.

Experimental Design and Methods

Introduction

The challenges of managing and maintaining structurally complex stands require a shift in emphasis away from non-spatial models that emphasize plot-level prediction, to more mechanistic, spatially-explicit models that can incorporate the consequences of changing physical and competitive environments, and dynamic spatial structure within stands.

We propose to: (1) apply new remote sensing technology that allows economic creation of large stem-mapped areas across natural resource gradients, and (2) applying statistical techniques that allow for spatially-explicit analysis of individual-tree based competitive interactions among trees species across resource gradients.

Research sites

The research will be conducted within mixed species stands of the Sub-Boreal Spruce (SBS) zone around Smithers, BC. The major trees species of this area are lodgepole pine (*Pinus contorta* var. *latifolia*), interior spruce (hybrid of *Picea glauca* and *P. engelmannii*), subalpine fir (*Abies lasiocarpa*) and trembling aspen (*Populus tremuloides*). Minor species include paper birch (*Betula papyrifera*) and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). We will sample across a range of stand ages and disturbance histories to obtain a dataset that allows analysis of all the dominant tree species in our study area. To perform the proposed analysis, it is essential to obtain a large sample of trees that exhibits both variability in tree neighbourhoods and site quality. Thus, the ideal research sites (stands) will exhibit variability in both site quality and tree neighbourhoods. If an insufficient number of such stands are available, a larger number of smaller stands with variability in tree neighbourhoods but uniform site conditions will be utilized. The critical issue is to get sufficient variability in site quality and tree neighbourhoods to test for alternate competitive effects across resource gradients. Dependent on the actual site-types and site-sizes available, stem-mapping will be performed on 15 - 25 stands ranging between 5 and 15 ha in size. Each of the selected sample stands will be further mapped to site series using the BC biogeoclimatic classification system (Banner et al. 1993). This will provide a qualitative description of moisture and nutrient availability throughout each sample stand.

Stem-mapping with a remote sensing technique

We will use a new generation, airborne, digital camera to acquire the high spatial resolution digital imagery at each sample stand. Individual image frames covering 400 x 400 m can be acquired with a pixel size less than 20 cm, in four spectral wavelengths (usually wavelengths corresponding to Landsat, such as blue, green, red and the near infrared region of the electromagnetic spectrum). Using a number of established ground control locations (specially positioned markers, road intersections and other features) and an existing camera model, the imagery will be corrected to minimize the major geometric and radiometric distortions and a composite ortho-photo derived for each sample stand. To facilitate faster navigation within the stem-mapped areas, a grid of white 1 by 1 meter plastic markers will be positioned in each stand at the time of image acquisition. These makers will be visible on the digital imagery and be mapped on the resulting stem-maps. The location of these markers will be established by a professional survey crew.

Each ortho-photo will then be digitally analyzed with image processing software, including software specifically designed to extract individual tree crown locations, to derive a map of individual tree locations. This software assumes tops of trees appear brightest, being directly illuminated by the sun, while the gaps between trees are darker due primarily to directional reflectance and shading from adjacent crowns. The spectral maxima (peaks) and minima (valleys) are the primary image features used for the identification of crowns, being indicative of crown centroids and boundaries respectively. Using statistics derived from the imagery itself for the associated scene elements (such as exposed soil and understorey vegetation) the algorithms distinguish between vegetation and non-vegetation pixels using interactive thresholds, based on the near infrared region of the spectrum. Once the spectral maxima and the crown boundaries have been identified each crown is then delineated individually. Output statistics are generated for each of the tree crowns identified, including mean reflectance and variance within each defined crown, and spatial characteristics such as area, boundary irregularity and distance to neighbouring crowns (Coops *et al.* 1998; Culvenor 2002).

At least one photographed area will include a site where a previous 0.5 to 1.0 ha professional surveyed stem-mapped plot has been established. This will allow a test of the software that extracts individual tree crown locations. This test will be conducted first to ensure confidence in the remote sensing stem-mapping procedure.

Sampling of individual trees within the stem-mapped areas

We will aim for a sample of approximately 600 trees/species across a broad range of stand conditions and resource availability. To obtain a balanced sample across competitive neighbourhoods and site quality, the sampling will be performed as stratified random sampling. For each sampled tree, we will measure diameter at 1.3 m (DBH) and take an increment core at DBH to determine past radial growth rates. Additionally, the DBH and species of all trees within a specified radius of the sample tree will be recorded.

Analysis

The analysis of our neighbourhood data will closely follow the spatially-explicit analyses outlined in Canham et al. (2004). We will use functional forms that can be implemented efficiently in simulation models like SORTIE-ND (Coates et al. 2003). Some of the previous empirical studies of tree competition have used much more elaborate and elegant functions than described in Canham et al. (2004) to characterize the potential effects of the spatial configuration of neighbours (e.g. Foli et al. 2003), but those functions would incur unacceptable computational overhead in a long-term simulation model like SORTIE-ND. The observed radial growth (mm/yr) of a sample tree is analyzed as a function of (1) the potential growth of a hypothetical "free growing" tree, (2) the size of the tree, and the degree of (3) shading and (4) crowding of trees by neighbours. The crowding effect is represented with the Neighbourhood Crowding Index (NCI). This index includes size and species related parameters that are estimated directly from the data. Thus, the negative effect of crowding on growth of an individual tree will depend on the size and species of its immediate neighbourhood. The degree of shading is the fraction of full light available for an individual tree and is calculated with a spatially explicit analysis developed by Canham et al. 2004. In the analysis of Canham et al. (2004) the effects of crowding and shading was represented by an additive model [1]. Recent research (Canham et al. *in press*; Astrup and Coates *in review*; Coates et al. *in prep*) have shown that these effects likely are better represented by a multiplicative model [2].

[1] Radial increment = Potential increment – Crowding effect – Shading effect
[2] Radial increment = Potential increment × Crowding effect × Shading effect

In this study, we will investigate both the additive and multiplicative version of this analysis. Additionally, we will develop and test a set of different functional forms to describe the Potential increment, the Crowding effect, and the Shading effect. The analysis will be based on likelihood methods and information theory (Edwards 1992, Burnham and Anderson 2002). At the heart of the method is the explicit interplay between data and models, with “model” used in the sense of a mathematical statement of the quantitative relationships that are assumed to have generated the observed data (Canham and Uriate, *in press*). Formal model comparison methods will be used to assess the alternate models. Akaike Information Criterion (AIC) will be used to incorporate both parsimony and likelihood in comparing the alternate models.

We will select the model that best approximates the data pooled across site qualities, then we will test hypothesis regarding how competitive interactions among trees species changes across the resource gradient. A set of competing hypothesis will be developed relating competitive interactions and site quality. For illustration 3 obvious examples are included here: (1) it is only the Potential increment that is affected by site type while the Crowding effect and Shading effect are unaffected by site quality, (2) The Potential increment and Crowding effect are affected by site type while the Shading effect is unaffected by site quality, (3) All of the Potential increment, the Crowding effect, and the Shading effect are affected by site quality. Practically, these hypotheses will be tested by introduction of 0-1 indicator variables into the model that was found to best approximate the data pooled across site type (e.g. an indicator variable will allow the Potential increment to change with site quality while the Crowding and Shading effects remain constant).

Linkages

This project is a natural extension of previous Forest Science Program projects lead by Drs. Coates and Larson. The project is linked to the constantly ongoing improvement and development of the growth model SORTIE-ND. In terms of future Forest Science Program projects, a companion FSP Full Proposal titled “Complex Stand Management; Extension of Recent Research to Forest Managers” has been submitted by the BV Centre to fund a 2 day FORREX workshop that introduces the research and management communities to advances in knowledge about complex stands and use of SORTIE-ND.

Section 3: Extension and Deliverables

Extension Plan

The results will be published in peer-reviewed journals and will be presented at a scientific conference. This will effectively communicate our findings to the research community. By incorporating our findings into SORTIE-ND, which is freely available on the web, results become easily usable in a decision support tool. This will make the results easily available to forest companies, forest consultants, and forest researchers with an interest in the northern interior. A companion Full Proposal titled “Complex Stand Management; Extension of Recent Research to Forest Managers” has been submitted by the BV Centre to fund a 2 day FORREX workshop that introduces the research and management communities to advances in knowledge about complex stands and use of SORTIE-ND.

Table 1. Extension products and activities

Extension products, Activities, and Deliverables	Completion Date (month/year)	Year End Status (e.g., submitted, final)	Peer Review? (y/n)	Target Journal or Publication Media
FORREX workshop	03/07	Final	N	Not Applicable
Conference Presentation	03/08	Presentation to be given summer 07	Y	Unidentified conference
2 Journal papers	03/08	Submitted by 03/08	Y	Canadian Journal of Forest Research
Incorporating results into SORTIE-ND	Not Applicable	Ongoing	N	Development is updated on the SORTIE-ND web page

Section 4: Project Team

Project Leader: Dr. David Coates, RPF, Research Silviculturist, BC Forest Service, Smithers has extensive knowledge of silvicultural research in northern B.C. He has studied unmanaged and managed forests in northern BC for 25 years. For the past 10 years his research has focused on tree growth in complex mixed-species stands. He has been a key player in the development of SORTIE-ND. Type 'kd coates' at http://scholar.google.com/ for a list of publications.

Rasmus Astrup, PhD-candidate, UBC will undertake the majority of work on the project. He has worked for the last three years on issues related to modeling stand dynamics in mixed-species stands in western boreal and sub-boreal Canada. He will contribute to the research team with extensive knowledge of stand dynamics in mixed-species stands. Additionally, Rasmus has extensive knowledge of SORTIE-ND. This project will provide a post-doc position for Astrup. (FSP funded: 8 months/year).

Dr. Charlie Canham, Senior Scientist, Institute of Ecosystem Studies, Millbrook, New York, is a forest ecologist who specializes in likelihood methods and the analysis of spatial data. He has been an associate editor at Ecology and Canadian Journal of Forest Research and has an extensive list of publications in leading ecological journals. (IES salary: 1 week/yr)

Dr. Nicholas Coops, Associate Professor, UBC and Canadian Research Chair in Remote Sensing, has worked on a large number of successful projects and grants and has administered grants totaling over $1 million in the past 4 years. He has authored over 60 referred publications, as well as reports, proceedings and technical transfer articles.

Dr. Bruce Larson, Professor, FRBC Chair of Silviculture, UBC is contributing to the research team with knowledge of stand dynamics and silviculture. This knowledge is clearly demonstrated through his textbooks (Oliver and Larson 1996; Smith *et al.* 1997).

Summer students, Two summer students will be hired. This allows us the opportunity to continue providing training for students in northern forest ecology. (FSP funded: MoFR rates, 2 students/yr)

In previous Forest Science Program projects, Drs. Coates and Larson together with Rasmus Astrup have demonstrated successful collaboration and communication. Drs. Coates and Canham have a long working relationship and multiple publications together. With the addition of Dr. Coops and his extensive knowledge of remote sensing, the research team is fully equipped to undertake all phases of this project.

Section 5: Project Costs and Funding

Cost/benefit Description:
This project will carry out basic research on competitive interactions among trees species, how these interactions affect growth, and how these interactions may vary across resource gradients in structurally complex mixed-species stands. This type of research is the foundation for practicing scientifically sound forest management. One of the major impediments to improving out knowledge of complex stands is the cost of acquiring basic stand data. If this project is successful, the use of remote sensing techniques will allow that data to be gathered at a much lower cost, and as a result the current gaps in knowledge could be filled more rapidly.

The current forest management paradigm calls for increased use of complex mixed-species stands; for example, to mitigate future risks associated with projected climate change. Additionally, the Mountain Pine Beetle (MPB) epidemic will result in structurally complex unsalvaged stands and salvaged stands with variable levels of retention. Currently, we have limited understanding of the interactions among competitive effects, tree species, site types, and stand structure. Our current ecological and growth models are not fully suited to deal with structurally complex conditions. We are in a situation where lack of knowledge could seriously impede our ability to make informed policy and management decisions. This is especially critical for decisions around MPB management and mid-term timber supply. Lack of knowledge could lead to unfortunate effects on future AAC and wildlife habitat strategies. The type of knowledge that will be generated through this project is absolutely essential for changing this situation for the better.

The funding requirement from FSP for this project is relatively small compared to the outcomes. The small cost is due to the innovative research design and the research team's extensive knowledge of the topic. Without this innovative research approach, this project would have required a longer and much more expensive project. The outcomes of the project have a potentially large value for many different stakeholders in the northern interior. Consequently, we believe that the value of the outcomes of this project greatly exceed the cost of this project to FSP. The overwhelming majority of the project cost is related to a post-doctoral position (36000/year) and the employment of two summer students (27000/year).

Section 6: Literature Cited

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Section 7: Appendices

Dr. K. David Coates
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Education:

Degree	*College, University or Institution:*	*Subject:*	*Year:*
PhD	University of British Columbia	Silviculture	1998
MS	Oregon State University	Silviculture	1988
BSF	University of British Columbia	Forest Management	1979

Related Work Experience (last 10 years):

Position Held:	*Date:*	*Department:*	*Organization:*
Research Silviculturist	1989-present	Research, B.C. Ministry of Forests, Smithers, BC	
Temporary Secondment	1999-2001	Université du Québec à Montréal	

Research Interests:
Dr. Coates is the leader of the Date Creek silvicultural systems experiment; an internationally recognized forest dynamics experiment that has integrated silviculture with forest ecology and provided silvicultural solutions for biodiversity problems. His research interests include linking tree population dynamics to ecosystem processes, canopy understory interactions, spatially-explicit stand dynamics, gap dynamics and simulation modeling. He has been instrumental in the development and promotion of the Bulkley Valley Centre for Natural Research and Management, a registered not-for-profit society based in Smithers, that conducts high quality interdisciplinary research on temperate, montane, and boreal ecosystems, including their human dimensions.

Much of the research undertaken by Dr. Coates in the past few years has been focused on linking empirical studies with model development. He is a lead developer of the complex stand dynamics simulator SORTIE-ND. He is currently using the SORTIE-ND model to explore silvicultural issues in stands damaged by the Mountain Pine Beetle.

Recent Contributions to Scientific Community:

a) Deputy Coordinator of IUFRO Research Group 1.05.12: Northern Forest Silviculture and Management.
b) Scientific Program Coordinator for the 4th International Disturbance Dynamics in Boreal Forests Conference, August, 2002, Prince George, BC

Recent and Selected Publications:

Raymond, Patricia, Alison D. Munson, Jean-Claude Ruel and **K. David Coates**. 2006. Spatial patterns of soil microclimate, light, regeneration and growth within silvicultural gaps of mixed tolerant hardwood – white pine stands. Can. J. For. Res., *in press.*

Walters, Michael B., Cleo C. Lajzerowicz and **K. David Coates**. 2006. Soil resources and the growth and nutrition of tree seedlings over gap-forest transects in interior cedar-hemlock forests, British Columbia. Can. J. For. Res., *in press.*

Kneeshaw, Daniel D., Richard K. Kobe, **K David Coates** and Christian Messier. 2005. Sapling size influences shade tolerance ranking among southern boreal tree species. J. Ecology, *in press*.

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PROFESSIONAL PREPARATION

Montana State University	Botany	B.S. 1975
University of Wisconsin (Madison)	Botany	M.S. 1978
Cornell University	Ecology and Evolutionary Biology	Ph.D. 1984

APPOINTMENTS

2004-	Senior Scientist, Institute of Ecosystem Studies
1997–2004	Scientist, Institute of Ecosystem Studies
1991–1997	Associate Scientist, Institute of Ecosystem Studies
1985–1991	Assistant Scientist, Institute of Ecosystem Studies, NY Botanical Garden
1990–	Adjunct Associate Professor, Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT
1984–1985	Postdoctoral Research Associate, Institute of Ecosystem Studies, New York Botanical Garden, Millbrook, NY

5 PUBLICATIONS MOST CLOSELY RELATED TO THE PROPOSED PROJECT

Canham, C. D., P. T. LePage, and K. D. Coates. 2004. A neighborhood analysis of canopy tree competition: effects of shading versus crowding. Canadian Journal of Forest Research 34:778-787.

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Uriarte, M., R. Condit, C. D. Canham, and S. P. Hubbell. 2004. A spatially explicit model of sapling growth in a tropical forest: does the identity of neighbours matter? Journal of Ecology 92:348-360.

Uriarte, M., C. D. Canham, J. Thompson, J. K. Zimmerman, and N. Brokaw. 2005. Seedling recruitment in a hurricane-driven tropical forest: light limitation, density-dependence and the spatial distribution of parent trees. Journal of Ecology 93:291-304.

Canham, C. D. and M. Uriarte. Analysis of neighborhood dynamics of forest ecosystems using likelihood methods and modeling. Ecological Applications, *in press*

5 OTHER SIGNIFICANT PUBLICATIONS

Canham, C.D., M.J. Papaik, and E.F. Latty. 2001. Interspecific variation in susceptibility to windthrow as a function of tree size and storm severity for northern temperate tree species. Canadian Journal of Forest Research 31:1-10.

Canham, C.D., J.J. Cole, and W.K. Lauenroth (eds.). 2003. Models in Ecosystem Science. Princeton University Press.

Coates, K. D., C. D. Canham, M. Beaudet, D. L. Sachs, and C. Messier. 2003. Use of a spatially explicit individual-tree model (SORTIE/BC) to explore the implications of patchiness in structurally complex forests. Forest Ecology and Management 186:297-310.

Canham, C. D., M. L. Pace, M. J. Papaik, A. G. B. Primack, K. M. Roy, R. J. Maranger, R. P. Curran, and D. M. Spada. 2004. A spatially-explicit watershed-scale analysis of dissolved organic carbon in Adirondack lakes. Ecological Applications 14: 839-854.

Schnurr, J. L., C. D. Canham, R. S. Ostfeld, and R. S. Inouye. 2004. Neighborhood analyses of small-mammal dynamics: Impacts on seed predation and seedling establishment. Ecology 85:741-755.

SYNERGISTIC ACTIVITIES

- Development of maximum likelihood methods and software for data analysis; development and teaching of an intensive short course on likelihood methods for ecologists (taught annually since 2003)
- Development and use of SORTIE-ND as an open-source software platform for spatially-explicit modeling of forest dynamics
- Development and use of SORTIE/BC (a variant of SORTIE-ND) to design sustainable silviculture for temperate forests
- Board of Trustees, Adirondack Chapter of The Nature Conservancy (1996 – present); Board of Directors, Adirondack Land Trust (1996 – present); Board of Directors, Great Mountain Forest Corporation (nonprofit) (2004 – present); Board of Directors, The Adirondack Council (2005 –present)
- Board of Editors, Ecology and Ecological Monographs (1996 – 1999); Associate Editor, Canadian Journal of Forest Research (1999 – 2003); Board of Editors, Frontiers in Ecology and the Environment (2002 – present); Associate Editor, Ecoscience (2004 – present).

COLLABORATORS WITHIN PAST 48 MONTHS

John Aber (UNH), Paula Bartemucci (U. Quebec), Paul Barten (UMass), Seth Bigelow (USFS), Bertrand Boeken (Ben Gurion U.), Andre Bouchard (U. of Montreal), Nick Brokaw (UPR), David Coates (B.C. Forest Service), Jon Cole (IES), Richard Condit (STRI), David Coomes (Cambridge U.), Ray Curran (Adirondack Park Agency), Ulf Dieckmann (IIASA, Vienna), Parick Dube (U. of Montreal), Adrien Finzi (Boston U.), Anton Fischer (Technische Universitat Munchen), Marie-Josee Fortin (U. of Toronto), Gerhard Gratzer (Inst. of Forest Ecology – Vienna), David Greene (Concordia University), Steven Hubbell (UGA), Richard Inouye (Idaho State U.); Yoh Iwasa (Kyushu University), Jennifer Jenkins (U. of Vermont), Clive Jones (IES), Felicia Keesing (Bard College), Liza Knapp (UMass), Erika Latty (Hollins College), Bill Lauenroth (Colorado State U.), Richard Law (U. of York), Philip LePage (B.C. Forest Service), Manfred Lexer (Inst. of Silviculture – Vienna), Gene Likens (IES), Orie Loucks (Miami U.), Gary Lovett (IES), Robert Manson (Autonomous University of Mexico), Roxane Maranger (U. of Montreal), D. Marceau (U. of Montreal), Peter Marks (Cornell), Will McWilliams (U.S. Forest Service), Andre Menard (U. of Montreal), Christian Messier (U. of Quebec), Richard Ostfeld (IES), Michael Pace (IES), Michael Papaik (U. of Quebec), Avram Primack (Miami U.), Richard Root (Cornell), Karen Roy (New York Dept. of Env. Cons.), Don Sachs (Canadian Forest Service), Holger Sandmann (Simon Fraser U.), Eric Schauber (U. of Illinois – Carbondale), Jaclyn Schnurr (Wells College), Dan Spada (Adirondack Park Agency), Tom Spies (U.S. Forest Service), Bernhard Splechtna (Inst. of Forest Ecology – Vienna), Jerzy Szwagrzyk (Agricultural University – Krakow), Jill Thompson (UPR), Christopher Tripler (IES), Maria Uriarte (IES), Jerry Wolff (NSF), David Wood (U. of California – Chico), Elaine Wright (New Zealand Dept. of Cons.), Jess Zimmerman (NSF)

GRADUATE AND POST-GRADUATE ADVISORS: O.L. Loucks, P.L. Marks, and G.E. Likens.

THESIS ADVISOR AND POSTGRADUATE-SCHOLAR SPONSOR: Graduate students: Adrien Finzi (PhD, UConn, 1996), Erika Latty, (PhD, Cornell, 2000), Mike Papaik, (MS, Bard College, 1998; PhD, UMass 2005), Liza Knapp, (MS, Bard College, 1999). Postdoctoral Associates (current affiliations): David Wood (U. of California – Chico), Bertrand Boeken (Ben Gurion Univ.), Seth Bigelow (USDA Forest Service), Cheryl McCutchan, Jaclyn Schnurr (Wells College), Chris Tripler (U. of Louisville), and Maria Uriarte (IES).

CV: Rasmus Astrup

Contact information:

Rasmus Astrup
701-2121 Alma Street
Vancouver, BC
V6R 3R1
(604) 999-7410
Astrup@interchange.ubc.ca

Education:

PhD candidate, University of British Columbia, Vancouver, BC, Canada
(2002 – Expected defense early spring 2006). Supervisor: Dr. Bruce Larson.

Exchange student, University of British Columbia, Vancouver, BC, Canada (2000 – 2001)

BSc Forestry, Royal Agricultural and Veterinarian University (KVL), Copenhagen, Denmark. (1997 – 2000)

Current Research:

The main topic of my current research is stand dynamics and growth modeling in mixed stands of aspen and spruce in western boreal Canada. More specifically my thesis and my related research project have 5 main topics: (1) Modeling light transmission, (2) Modeling understory tree growth, (3) Modeling juvenile and mature tree mortality, (4) Further development of SORTIE-ND as a growth model, and (5) Evaluation and validation of SORTIE-ND as a growth and yield model.

Teaching experience:

2003, 2004: Teaching Assistant: Silviculture I (FRST 305), UBC
2003: Teaching Assistant: Silviculture II (FRST 306), UBC

Forestry related work experience:

2005: (Current) SAS data analysis of datasets relating to tree allometry. Contract for Dr. David Coates (BC Ministry of Forests and Range, Smithers)
2005: Review of the relationship between light and spruce and pine growth to provide a basis for further development of TASS. Contract for George Harper (BC Ministry of Forests and Range, Research Branch)
2005: Supervised field work for the project “Modeling Individual Tree Mortality for Northern Mixed-Species Stands”
2002: Fieldwork for PhD thesis in western boreal Canada
1999: Field assistant on the project “Modelling the Effects of Competition Between Individual Trees in Forest Stands” supervised by Dr. Lars Wichmann, KVL, Denmark.
1996-1997: Internship at Tjele Gods Forest Estate, Denmark.

Publications:

Journal papers:
Astrup, R. and Larson, B.C. (submitted). Variability of species-specific crown openness for aspen and spruce in western boreal Canada. For. Ecol. Manage.
Astrup, R. and Larson, B.C. (2005). A Bayesian framework for model parameterization: an approach for inclusion of different sources of knowledge in model parameterization. International Forestry Review. 7: 256-257.

Invited seminars:
2005: Stand dynamics of boreal mixedwoods. Lecture at the stand dynamics seminars arranged by Dr. Bruce Larson, UBC.
2004: Individual tree growth models with special focus on SORTIE. Lecture at the Ecosystems modeling seminars arranged by Dr. Hamish Kimmins, UBC.

Conference presentations:
2005: A Bayesian approach to model parameterization. XXII IUFRO World Congress, 8-13 August, Brisbane, Australia.

Academic Awards:

Canada:
Donald S. McPhee Fellowship (2005), UBC
Donald S. McPhee Fellowship (2004), UBC

Denmark:
Awards directed at studies at UBC:
Skovbrugernes rejeselegat (2001), KVL
Uni-puljen (2000), KVL
Studiefonden for studerende ved KVL (2000), KVL
PLAN-Danmark (2000), KVL

Team Member on related FSP projects

Forest Investment Account, Forest Science Program, March 2005. Project: Modeling Individual Tree Mortality for Northern Mixed-Species Stands.

Forest Investment Account, Forest Science Program, March 2004. Project: Evaluation of the Simulation Model SORTIE for Prediction of Growth and Yield in Mixed Aspen-Spruce Stands.

Forestry Innovation Investment, Forest Science Program, March 2003. Project: Modeling Growth of Juvenile Aspen and White Spruce in Western Boreal Canada.

NICHOLAS CHARLES COOPS

Date and place of birth: 14 March 1968, Victoria. Australia.

Current Employment:

Canadian Research Chair in Remote Sensing
Department of Forest Resource Management
2424 Main Mall, University of British Columbia, Vancouver, BC. V6T 1Z4.
(W) 604 822 6452, Fax (604) 822-9106, Nicholas.coops@ubc.ca

Education:

1991 B. App. Sc. (Cartography) (with Distinction)
Royal Melbourne Institute of Technology
1996 Ph.D. Royal Melbourne Institute of Technology

Employment:

1992 - 1993 Lecturer,
Department of Land Information,
Royal Melbourne Institute of Technology, Melbourne Australia.

1994 - 1996 Research Scientist in Conservation Biology,
CSIRO Wildlife and Ecology, CSIRO, Canberra, A.C.T.

1996- 2004 Research Scientist in Forest Information Management Systems
CSIRO Forestry and Forest Products, Canberra and Melbourne.

Selected Current Grants:

Coops, N. Multi-scale assessment of forest carbon dynamics using near-field, airborne and satellite remote sensing. NSERC Discovery. CAD$125,000

Coops, N.C. Sustainable forestry indicators derived from high spatial resolution satellite imagery and airborne LIDAR data. BC Ministry of Forests. April 2005 – April 2007 CAD$90,000

Gergal, S., Coops, N.C Quantification of Small Stream Riparian Zones and Biodiversity using High Spatial Resolution Remote Sensing and LIDAR. BC Ministry of Forests. April 2005 – April 2006 CAD$90,000

Waring, R.H. Coops, N.C. Fan, W. Predicting Tree Diversity across the Contiguous U.S.A. from Growing Season Patterns in Photosynthesis derived with Satellite-driven Models. For $US 589,000.

Refereed Journal Papers Most Relevant to Project (*from a total of 60*):

Catling, P. C. and Coops, N. C. (1999). Prediction of the distribution and abundance of small mammals on the eucalypt forests of south-eastern Australian from airborne videography. *Wildlife Research*. **26**: 641-650.

Coops, N.C. (1999) Linking multi-resolution satellite-derived estimates of canopy photosynthetic capacity and meteorological data to assess forest productivity in a *Pinus radiata* (D. Don) stand. *Photogrammetric Engineering and Remote Sensing.* 65, 10: 1149-1156.

Coops, N.C. (2002) Eucalypt Forest Structure and Synthetic Aperture Radar Backscatter: A Theoretical Analysis. *Tree Structure and Function*. 16 (1): 28 - 46

Coops, N.C., Catling, P.C. (1997) Predicting the Complexity of Habitat in Forests from Airborne Videography for Wildlife Management. *Int. J. Remote Sensing.* 18:12 pp. 2677-2686.

Coops, N.C., Catling, P.C. (2000) Estimating Forest Habitat Complexity in relation to Time since Fire using Binomial Distributions. *Austral Ecology* 25, 344-351.

Coops, N.C. Catling, P.C. (2001) Prediction of Historical Forest Habitat Pattern using Gamma Distributions and Simple Boolean Logic from High Spatial Resolution Remote Sensing. *Computers and Geoscience* 27: 795-805.

Coops, N.C., Culvenor, D., Preston, R and Catling. P.C. (1998) Procedures for predicting habitat and structural attributes in eucalypt forests using high spatial resolution remotely sensed imagery. *Australian Forestry*. 61:4 pp. 244-252.

Coops, N.C., Culvenor, D (2000) Utilizing local variance of simulated high-spatial resolution imagery to predict spatial pattern of forest stands. *Remote Sensing of Environment*. 71(3): 248-260.

Coops, N.C., Goodwin, N., Stone, C. (2005) Predicting *Spherophsis sapinea* Damage on *Pinus radiata* stands using CASI-2 Derived Spectral Indices and Spectral Mixture Analysis. *Photogrammetric Engineering and Remote Sensing*. (in press)

Coops, N.C., Goodwin, N., Stone, C and Sims, N. (2005) Assessment of Forest Plantation Canopy Condition from High Spatial Resolution Digital Imagery. *Canadian Journal of Remote Sensing (in press*).

Coops, N.C., Waring, R.H. and Law, B. (2005) Predicting the Influence of Climate Variability on the Productivity and Distribution of Ponderosa Pine Ecosystems in the Pacific Northwest. *Ecological Modelling 183:107–124.*

Coops, N.C., Wulder, M., Culvenor, D.C., St-Onge, B. (2004) Comparison of forest attributes extracted from fine spatial resolution multi-spectral and lidar data. *Canadian Journal of Remote Sensing*. 30: 855-866.

Goodwin, N., Coops, N.C. Stone, C. (2005) Quantifying Forest Canopy Condition from Airborne Imagery using Spectral Mixture Analysis and Fractional Abundances. *International Journal of Applied Earth Observation and Geoinformation*. 7: 11-28

Bruce C. Larson

Education -

Ph. D., College of Forest Resources, University of Washington, Seattle, Washington. 1982. Dissertation title, "Development and growth of even-aged and multi-aged mixed stands of Douglas-fir and grand fir on the east slope of the Washington Cascades."

M. F. S., School of Forestry and Environmental Studies, Yale University. 1978. Major emphasis in silviculture and forest genetics.

A. B., Harvard University. 1976. Major in biology. magna cum laude.

Professional Career -

2002 – present
Professor
FRBC Chair of Silviculture
Forest Sciences Department
Faculty of Forestry
University of British Columbia

Previously have served on the faculties of Yale University (17 years) and University of Washington (2 years)

Teaching:

Have regularly taught graduate and undergraduate courses in silviculture, forest stand dynamics, and forest management over the last twenty years at Duke University, Yale University, University of Washington and, now, University of British Columbia. Many other more specific courses have been taught on a non-continuing basis.

Currently chair (or co-chair) supervisory committee of 6 Ph.D. students and 1 MSc. student

Books:

1992 - M. Kelty, B. C. Larson, and C. D. Oliver, editors, **The Ecology and Silviculture of Mixed-Species Forests**. Kluwer Publishers. 287 p.

1996 - C. D. Oliver and B. C. Larson, **Forest Stand Dynamics (Updated Edition)**. Wiley, Inc. 488p.

1997 - D. Smith, B. C. Larson, M. Kelty, and P. M. S. Ashton, **The Practice of Silviculture: Applied Forest Ecology**, (9th edition), Wiley, Inc. 550p.

1999 – K.A. Vogt, B.C. Larson, D.J. Vogt, J.C. Gordon and Anna Fanzeres, **Forest Certification: Roots, Issues, Challenges and Benefit**, CRC Press.

Recent Published Papers:

(under revision) - Astrup, Ramus and B.C. Larson, Variability of species-specific crown openness for mature boreal aspen and spruce, submitted to **Forest Ecology and Management**.

(under revision) - Larson, B.C. , A. Tikina, and M.J. Ducey. Basic cluster sampling approach for forest certification field. Submitted to **Journal of Environmental Management.**

(submitted) – Ducey, M.J., J.H. Gove and B.C. Larson. Some properties of size-biased distributions with application to subsampling for additive density measures, submitted to **Forest Science**

2003 - Ducey, M.J.; , B.C Larson. Is there a correct stand density index? an alternative interpretation . **Western Journal of Applied Forestry**, 18:179-184

2003 - Larson, B.C. Managing using a multi-objective paradigm:carbon credits make it possible -XII World Forestry Congress,Qubec City, Canada FAO-0740-B1.

2002 - Vogt K.A., Asbjornsen H., Grove M., Maxwell K., Vogt D.J., Sigurdardottir R., Larson B.C., Schibli L. and Dove M. Linking social and natural science spatial scales. In: *Integrating Landscape Ecology into Natural Resource Management*. Jianguo Liu and W.M. Taylor eds. Published by Cambridge University Press.

2000 – M. Ricker, C. Siebe, S. Sanchez, K. Shimada, B. C. Larson, M. Martinez-Ramos, and F. Florencia Montagnini, Optimizing seedling management: *Pouteria sapota*, *Diospyros digna*, and *Celdrela odeorata* in a Mexican rainforest. **Forest Ecology and Management** 139:63-77.

1999 – M.J. Ducey, M.S. Ashton and B.C. Larson, Site classification and the management of landscape pattern in agroforestry systems. In: *The Silvicultural Basis for Agroforestry Systems*. M.S. Ashton and F. Montagnini eds. Published by CRC Press.

1999 - M. J. Ducey and B. C. Larson, Accounting for bias and uncertainty in nonlinear stand density indices. **Forest Science** 45:452-457.

1999 - M. J. Ducey and B. C. Larson, A fuzzy set approach to the problem of sustainability. **Forest Ecology and Management** 115: 29-40.

1999 – K. A. Vogt, D. J. Vogt, P. Boon, A. Franzeres, P. Wargo, P. A. Palmiotto, B. C. Larson, J. L. O'Hara, T. Patel-Weynand, E. Cuadrado, and J. Berry, A non-value based framework for assessing ecosystem integrity. In: Proceedings of Symposium on Pacific Northwest Forest and Rangeland Soil Organisms. Published by USDA in PNW-GTR-461, pp. 3-20.

1999 – M. J. Ducey and B. C. Larson, Rapid assessment of risk using stand density indices. **Western Journal of Applied Forestry** 14:149-152.

1998 - Bruce C. Larson, W. K. Moser, and V. K. Mishra, Some relationships between silvicultural treatments and symmetry of stem growth in a red pine stand. **Northern Journal of Applied Forestry** 15:90-93.

Forest Science Program
2006/07 Full Proposal Submission

Partner Confirmation Form

Project Information

Project No: Y071254
Title of Project: Effect of site type on competitive interactions among trees in complex-structured mixed species sub-boreal forests.
Proponent: Bulkley Valley Centre for Natural Resources Research and Management

Partner Information

Partner Organization: Ministry of Forests and Range
Partner Contact Name and Title: Dave Coates, Research Silviculturist
Partner Phone: 250 847 6386
Partner Email: Dave.Coates@gov.bc.ca
Partner Address: 3333 Tatlow Road, Smithers BC V0J 2N0

In-kind support

Estimated Amount	Details
$8,000	Salary: Dave Coates. 2 weeks for advice and selection of sample stands

Cash Contributions

Amount	Details (please indicate if funds are from another source i.e., NSERC)
nil	

Partner Signature:

Dave Wilford, Ph.D. RPF, PGeo
Head, Forests Sciences

Date: December 12, 2005

Forest Science Program
2006/07 Full Proposal Submission

Partner Confirmation Form

Project Information

Project No: Y071254
Title of Project: Effect of site type on competitive interactions among trees in complex-structured mixed species sub-boreal forests.
Proponent: Bulkley Valley Centre for Natural Resources Research and Management

Partner Information

Partner Organization: Institute of Ecosystem Studies
Partner Contact Name and Title: Charles D. Canham
Partner Phone: 845 677-5343
Partner Email: ccanham@ecostudies.org
Partner Address: Box AB, Millbrook, NY. 12545

In-kind support

Estimated Amount	Details
$5,000	Salary: Charles Canham. 1 week for statistical advice

Cash Contributions

Amount	Details (please indicate if funds are from another source i.e., NSERC)
nil	

Partner Signature:

Dr. Charles Canham
Senior Scientist

Date: December 13, 2005

Forest Science Program
2006/07 Full Proposal Submission

Partner Confirmation Form

Project Information

Project No: Y071254
Title of Project: Effect of Site Type on Competitive Interactions among Trees in Complex-Structured Mixed Species Sub-Boreal Forests

Proponent:
Dr. K. David Coates, Bulkley Valley Centre for Natural Resources Research and Management

Partner Information

Partner Organisation: UBC
Partner Contact Name and Title:
Professor Bruce Larson
Associate Professor Nicholas Coops

Partner Phone:
Bruce Larson: 604 822 1284
Nicholas Coops: 604 822 6452

Partner Email:
Nicholas.coops@ubc.ca
blarson@interchange.ubc.ca

Partner Address:
2424 Main Mall, Vancouver, BC, V6T1Z4

In-kind support

Estimated Amount	**Details**
$4000	2 weeks of work from Dr. Nicholas Coops (Faculty of Forestry)
$4000	2 weeks of work from Dr. Bruce Larson (Faculty of Forestry)

Partner Signature:

Date: