Mixedwood Management Association

Historic Report: 2000-2015

March 2016

Stacy Bergheim, Gitte Grover, and Sharon Meredith

Contents

A Message from the MWMA Chair, Gitte Grover

The MWMA as we know it has come to an end. However, we are now part of a bigger association, the Forest Growth Organization of Western Canada (FGrOW). FGrOW has more members working co-operatively on growth and yield, and I believe we will not only continue our innovative work on mixedwood management but we will expand on it!

We had a successful 15-year period in which we worked towards our goals. Many projects funded by the MWMA focused on improving the Mixedwood Growth Model (MGM) and it is anticipated that MGM will be approved by the Alberta government in 2016.

A number of projects involved white spruce understory protection, including development and implementation of a monitoring protocol, as well as providing MGM with white spruce release data. This allowed the University of Alberta to build a multi-strata model in MGM that can forecast development of post-harvest understory protection stands while taking into account competitive effects of the various strata.

Some of our work with the University of Alberta aided the development of the new regeneration survey standard (Reforestation Standard of Alberta, Alberta Sustainable Resource Development, 2010). Multiple projects investigated the interactions between aspen and white spruce, and silviculture practices to manage mixedwoods for maximum yield.

And lastly, the Alberta Forest Growth Organization (AFGO) was initiated through co-operation of the MWMA and West Fraser. It successfully negotiated co-operation between all Forest Management Agreement holders in the province and created a provincial growth and yield database that will reduce the Permanent Sample Plot (PSP) effort by individual companies and provide an extensive dataset for modellers.

This report highlights the projects funded by the MWMA over the last 15 years as a summary of the MWMA work from inception to integration into FGrOW.

Let the great work continue!

Gitte

Mixedwood Management Association Membership and Hosting Background

The Mixedwood Management Association (MWMA) was created in 2000 by a group of eight Alberta forest companies with the goal to co-operatively advance the science and management of boreal white spruce/aspen mixedwood forests.

The MWMA was committed to providing funds in support of new knowledge and its implementation in the management of mixedwood forests.

Membership History

The Mixedwood Management Association was officially founded in the summer of 2001 with the signing of the Memorandum of Understanding (MOU) between eight forest companies and the Alberta Sustainable Resource Development (SRD), Land and Forest Division (now Alberta Agriculture and Forestry). The signatories of the MOU included Ainsworth Lumber Co. Ltd. (Ainsworth), Alberta-Pacific Forest Industries Inc. (Al-Pac), Daishowa-Marubeni International Ltd. (DMI), Millar Western Forest Products Ltd. (Millar Western), Tolko Industries Ltd. (Tolko), Vanderwell Contractors (1971) Ltd. (Vanderwell), Slave Lake Pulp/Alberta Plywood Ltd. (Alberta Plywood), and Weyerhaeuser Company Ltd. (Weyerhaeuser). In May of 2002, Footner Forest Products (FFP) was formally admitted to the MWMA. Canadian Forest Products Ltd., Hines Creek Division, (Canfor) joined the MWMA in January of 2003.

Due to economic pressures and shrinking Forest Resource Improvement Program (FRIP) funds, Canfor, Ainsworth and Vanderwell resigned from the MWMA in 2008, 2011 and 2012, respectively. The FFP mill closed in 2008 and the company thus ceased to be a member. The 6 remaining companies, Al-Pac, DMI, Millar Western, Tolko, Alberta Plywood, Weyerhaeuser, and Alberta Agriculture and Forestry, remained members of the MWMA until March 2015, at which time they transitioned to the Mixedwood Management Project Team under the new umbrella organization, the Forest Growth Organization of Western Canada (FGrOW).

Hosting Body and Administration History

Alberta Research Council's (ARC) Forest Resources Business Unit was the first coordinating body for the MWMA starting in 2001. ARC provided administrative, accounting, and project management support as well as facilities to the MWMA, with Dr. Ken Greenway as Science Director and Administrator. Due to reorganization of the ARC, the MWMA moved to the University of Alberta (UA) in 2003. Dr. Rongzhou Man became the new Science Director and Administrator in June 2003 until this position was taken over by Sarah Gooding in January 2005. A new hosting agreement between the UA and the MWMA was signed in October of 2005 and

was effective for 5 years to March 31, 2010. In February 2006, Willi Fast from The Forestry Corp., was hired as Science Director and Stacy Bergheim as Administrator. The 2005 hosting agreement was renewed for another 5-year term and remained in effect until March 31, 2015. Willi Fast was replaced by Sharon Meredith in April 2012.

Hosting Body
2001 to 2002 – Alberta Research Council (ARC) – Forest Resources Business Unit
2003 to March 2015 – University of Alberta (UA) – Department of Renewable Resources

Chair of Steering Committee
2001 to March 2003 – Dr. Gitte Grover
April 2003 to March 2005 – Mr. Noel Roberts
April 2005 to March 2015 – Dr. Gitte Grover

Research Coordinator/Science Director Position
Inception to June 2003 – Dr. Ken Greenway
June 2003 to December 2004 – Dr. Rongzhou Man
January 2005 to February 2006 – Mrs. Sarah Gooding
February 2006 to March 2012 – Mr. Willi Fast
April 2012 to March 2015 – Ms. Sharon Meredith

Program Administrator
February 2006 to March 2015 – Mrs. Stacy Bergheim

MWMA Mandate

The MWMA acted as a forum to collectively address practical and scientific issues concerning the management of mixedwood stands to sustain their mixed species characteristics. The MWMA sought to increase knowledge through financial and in-kind support of basic and applied research; to enhance the forest community's understanding of mixedwood forests through support for workshops and conferences; and to increase information collection, sharing, dissemination, and its application to forest management activities.

Mixedwood Management Association Principles and Goals

The MWMA founding members collectively agreed to the following 6 guiding principles:

1. to forecast and validate managed and natural stand growth and yield of the boreal mixedwood forest consisting of white spruce and *Populus* species mixes;
2. to establish research needs and priorities, facilitate the completion of research projects, and ensure that the results of the research are disseminated;

3. to coordinate with other research groups and, where priorities cannot be addressed by existing research groups, initiate research;
4. to facilitate discussions to increase understanding within the forestry community of mixedwood management issues;
5. to develop and use standardized data collection protocols with the purpose of creating data sets that are reputable and can be amalgamated; and
6. to develop a data sharing agreement.

The MWMA developed the following five goals as its priority issues in mixedwood management with the expectation to fill key knowledge gaps constraining the wide scale implementation of mixedwood management in the boreal mixedwood forests.

1. Support the development of defensible, ecologically-based (e.g. that accounts for the effects of succession), site-specific yield curves for:
   a. Naturally-regenerated stands with or without treatments; and
   b. Post-harvest regenerated stands across a range of potential management interventions (treatments)
2. Development of defensible site-specific crop plans that lead to mixedwood stands in:
   a. Post-harvest regenerated stands across the range of potential management interventions (treatments)
   b. Naturally regenerated stands
3. Development and use of standardized monitoring protocols to:
   a. Validate yield predictions
   b. Address knowledge gaps for goals 1 and 2
4. Identify opportunities and techniques for management of understory spruce:
   a. Select hardwood stands that will allow for the successful establishment and growth of understory spruce
   b. Facilitate assignment of understory spruce to appropriate yield trajectories.
   c. Develop stand selection criteria for understory spruce protection treatments and predict stand development
5. Development of decision-support tools and models for crop plan development.
   a. Regeneration models
   b. Growth models

MWMA Information Dissemination and Extension Activities

The MWMA hosted an open house in Edmonton on June 20, 2001 to present its goals and objectives to the research community. One purpose of this session was to allow the MWMA and research community to explore options for collaboration. On June 25th, 2001 a press release was published announcing the establishment of the MWMA, a list of members, and the strategic direction for this new association.

The MWMA was approached by the publishers of the Western Woodlot Conservationist magazine to contribute to the September 2001 issue which was dedicated to Mixedwood Management. The MWMA was provided with a half-page free of charge in order to describe the association and its activities. Several member companies published articles of their individual mixedwood operations in this issue as well, providing good coverage of what mixedwood management is and how the industry is implementing it in their operations.

A two-day workshop titled "Boreal Mixedwood Crop Planning" was hosted by the MWMA on March 5-6, 2002 to discuss and formulate crop plans. The workshop was well attended by more than 40 people who represented all sections of forestry in Alberta. Dr. Ken Greenway provided a workshop summary in May 2002:

- Greenway, K. 2002. Boreal Mixedwood Crop Planning Workshop Summary. MWMA internal report.

On December 18-19, 2002, the MWMA hosted another two-day workshop titled "Model II Workshop", to discuss the policy, framework and monitoring protocols for the implementation of Model II, share details of monitoring systems under development, and explore possibilities for synergies. Approximately 44 people were in attendance representing government, industry and academia.

The construction of the MWMA website was completed in 2003. The MWMA website contained both public and 'member-only' internal pages. The public portion of the website included information about the MWMA, partnerships, research projects, publications, contacts, and links to other relevant sites. The 'member-only' area was password protected and held information such as meeting minutes, MWMA documents, budget, as well as reports for completed and on-going project. The MWMA website was hosted by the UA until September 2015 and all historic MWMA documents referenced in this document are being transitioned to a website hosted by fRI Research - https://fgrow.friresearch.ca/ .

On October 21, 2004 another workshop was hosted by the MWMA, this time dealing with white spruce understory protection, with nearly 40 invited guests from Alberta industry, government, and academia. The focus was on strip cut understory protection and included discussions around stand selection, harvest design, and yield trajectories of treated stands.

On April 14-15, 2005, the MWMA hosted a two-day workshop in Edson, Alberta on the subject of underplanting aspen with white spruce. There were 42 participants at the workshop representing industry, government and academia. The discussions focused on stand selection, site preparation, planting, mortality, growth potential, and the policies regarding white spruce underplanting. A summary was written by Sarah Gooding:

- **Gooding, S.** 2005. Underplanting Aspen with White Spruce Workshop. MWMA internal report.

In June 2006, the MWMA participated in the Sustainable Forest Management Network Conference, with a showcase session titled "Ecology and Sustainable Management of Western Boreal Mixedwood Forests". Ten researchers presented their mixedwood research and a synthesis was provided by Willi Fast, director of the MWMA.

In March, May and September 2006, three articles were published in the "The Edge Forest Business Magazine" that highlighted some of the key MWMA projects and other issues facing mixedwood managers:

- **Holehouse, D.** 2006. *Mixedwood Management Association celebrates five years*. The Edge Forest Business. March Issue: page 13.
- **Seinen, S.** 2006. *Session will showcase science solutions to operational issues*. The Edge Forest Business. May Issue: page 18.
- **Seinen, S.** 2006. *Workshop looks at data gaps in management*. The Edge Forest Business. September Issue: page 19.

Mr. Willi Fast was also featured on the "Innovation Alberta" radio discussing mixedwood management on behalf of the MWMA. In April 2007, the MWMA published another article in "The Edge Forest Business Magazine" featuring the Dynamic Aspen Density Experiment (DADE), which had just successfully secured $ 950,000 from FRIAA open funds for a 5-year project.

- **Seinen, S.** 2007. *Research project aims to improve mixed species regeneration*. The Edge Forest Business. April Issue: page 15.

In October 2007, Dr. Gitte Grover and Willi Fast published an article in The Forestry Chronicle highlighting the Association and its research projects.

- **Grover, G., and Fast, W.** 2007. *Alberta making strides in mixedwood management*. For. Chron. 83: 714-718.

Alberta Forest Growth Organization

The Alberta Forest Growth Organization (AFGO) was established in 2009 as a partnership between the Mixedwood Management Association, and three West Fraser divisions (Hinton Wood Products, Blue Ridge Lumber, and Sundre Forest Products). In 2013, the Alberta government and Canfor became AFGO members. AFGO was funded for an initial three-year period through FRIAA Open Funds, and was subsequently sustained through membership dues.

AFGO's main objectives were:

1. Fostering collaboration among existing Alberta growth and yield associations.
2. Engaging Alberta's energy sector to investigate joint opportunities in the emerging carbon economy.

Early AFGO initiatives included:

- Organizing and hosting two workshops and a conference in 2010 to address forestry-based opportunities in the carbon economy.
- Joining Canfor, Alberta Newsprint (ANC) and Manning Diversified Forest Products (MDFP), in securing an Alberta Innovations Fund grant from FP Innovations (FPI) to develop a strategic analysis of how Alberta's forest companies might integrate carbon management into their forest management business model. The project, led by Milo Mihajlovich from Incremental Forest Technologies (IFT), was initiated in 2009 and completed in March, 2011.

In 2011, AFGO initiated a project to seek government collaboration and approval for creating regional-based data collection programs (permanent sample plots) and a centralized database. This initiative, the Provincial Growth and Yield Initiative (PGYI), strives to eliminate redundancy, maximize the utility of collected data, and reduce the cost to individual companies. All FMA holders in Alberta have joined PGYI, which is continuing under FGrOW.

Another AFGO subcommittee was created in 2012 to investigate strata assignment to cutblocks at Performance Survey and to link strata at year 14 to rotation age. A proposal on how to deal with strata assignment and reconciliation has been submitted to the Alberta Government on August 25, 2015.

Association Restructuring

Beginning in November 2012, the MWMA engaged in discussions with the Western Growth and Yield Association (WESBOGY), Alberta Forest Growth Organization (AFGO), and the Foothills Growth and Yield Association (FGYA) about facilitating information exchange, combining resources and potentially amalgamating the associations. Members of the four associations voted to form a new organization to be hosted at fRI Research (formerly the Foothills Research Institute). This new association, the Forest Growth Organization of Western Canada (FGrOW), commenced operations on April 1, 2015. AFGO, FGYA and MWMA were replaced by three Project Teams under FGrOW, each with existing projects and continued funding. WESBOGY became an FGrOW Project Team on January 1, 2016.

All information from the historic MWMA website will be transferred to the FGrOW section on the fRI Research website. The website can be reached with the following link: https://fgrow.friresearch.ca/ . If you require assistance or would like to request any of the documents listed in this report, please contact Stacy Bergheim (stacybergheim.fgrow@gmail.com).

Mature Aspen Overstory with a White Spruce Understory

MWMA Research Support

During the past 15 years, the MWMA contributed $2,191,190 towards research that improved the understanding of mixedwood dynamics, and developed tools for the management of mixedwood forests. The MWMA was able to leverage $2,887,460 in additional funding resulting in a total value of MWMA projects of more than $5 million. Table 1 provides a summary of projects, MWMA funding and leveraged funds.

Table 1: Summary of MWMA Projects and Funding

Project	Year of Initiation	Year of Completion	Total MWMA Funding	Total Leveraged funding	Origin of leveraged funding
Meta-analysis of release and underplanting treatments (Man)	2001	2003	$58,000.00	$0.00	
Developing Mixedwood Regeneration Modeling Capabilities (Fast)	2002	2003	$118,000.00	$0.00	
Development of MW Silviculture guide: Phase I (Beckingham)	2002	2003	$35,000.00	$0.00	
Silviculture guide – Phase II (MWMA)	2004	2007	$150,393.25	$290,000.00	FRIAA Open Funds Project
Strip Shelterwood Understory Protection Monitoring Protocol (Fast)	2002	2003	$31,500.00	$0.00	
Strip Cut Understory Protection PSP's (MWMA)	2005	Continuing	$376,145.48	$0.00	
Hotchkiss river mixedwood management demonstration area 10th year re-measurement and third pass harvest (MacIsaac)	2003	2004	$20,000.00	$40,000.00	DMI, Manning Diversified and the MWMA funded the re-measurements
Modeling growth of juvenile aspen and white spruce (Astrup/Larson/Coates)	2002	2006	$5,000.00	$75,000.00	Forest Investment Account; FRBC Chair of Silviculture; BC Ministry of Forests, Prince George Region
Analyses for revision of mixedwood regeneration standards (Lieffers)	2004	2005	$83,000.00	$0.00	
Influence of stand development on interactions between aspen and white spruce (Comeau)	2002	2006	$82,146.42	$0.00	
Effects of aspen density and duration of vegetation control on competition and MW stand development (Pitt/Comeau)	2002	2008	$30,000.00	$490,000.00	$170,000 Industry Support $320,000 NSERC Support Other In-kind Support
Development of improved indicators of seedling growth and mortality of important boreal tree species: a long term study (Kenkel/MacDonald)	2004	2007	$10,000.00	$20,000.00	$10,000 - NSERC match $10,000 - funds from Dr. Macdonald's research program
Adapting the Mixedwood Growth Model (MGM) for post-harvest and managed stands (Comeau)	2004	2007	$68,317.11	$283,500.00	FRIAA Open Funds Project
Adaptive management of mixedwoods to maximize fibre recovery and retained stem volume growth and ecosystem sustainability (Lieffers/Sidders)	2006	2009	$67,000.00	$67,000.00	$67,000 NSERC match

Project	Year of Initiation	Year of Completion	Total MWMA Funding	Total Leveraged funding	Origin of leveraged funding
Modeling Mid-rotation growth and mortality in Boreal Mixedwoods (Stadt)	2006	2012	$275,000.00	$557,400.00	$325,000 FRIAA $232,400 NSERC
Boreal Forest Mortality Modeling (Dawson)	2006	2010	$22,500.00	$67,500.00	$22,500 MITACS $45,000 NSERC
Natural Regeneration of Spruce in Mixedwoods Following Harvest (NSERC IPS)	2006	2009	$12,000.00	$30,000.00	NSERC Industrial Post-Grad Scholarship
Evaluation of banding as an alternative for establishing mixedwood stands (Comeau)	2006	Continuing	$101,000.00	In-kind	Each company is paying for their own re-measurements as the project continues
Benchmarking Natural Origin Stand Development (Bokalo/Stadt)	2007	2009	$43,000.00	$77,062.00	FRIAA Open Funds Project
Dynamic Aspen Density Experiment (MWMA)	2006	Continuing	$407,873.38	$590,000.00	FRIAA Open Funds Project
G & Y implications of understory protection and other mixedwood silviculture systems (MacIsaac)	2007	2009	$110,000.00	$0.00	NRCAN in-kind
Alberta Forest Growth Organization (MWMA)	2009	Continuing	$85,314.03	$300,000.00	FRIAA Open Funds Project
Total Project Expenses			**$2,191,189.67**	**$2,887,462.00**	**$5,078,651.67**

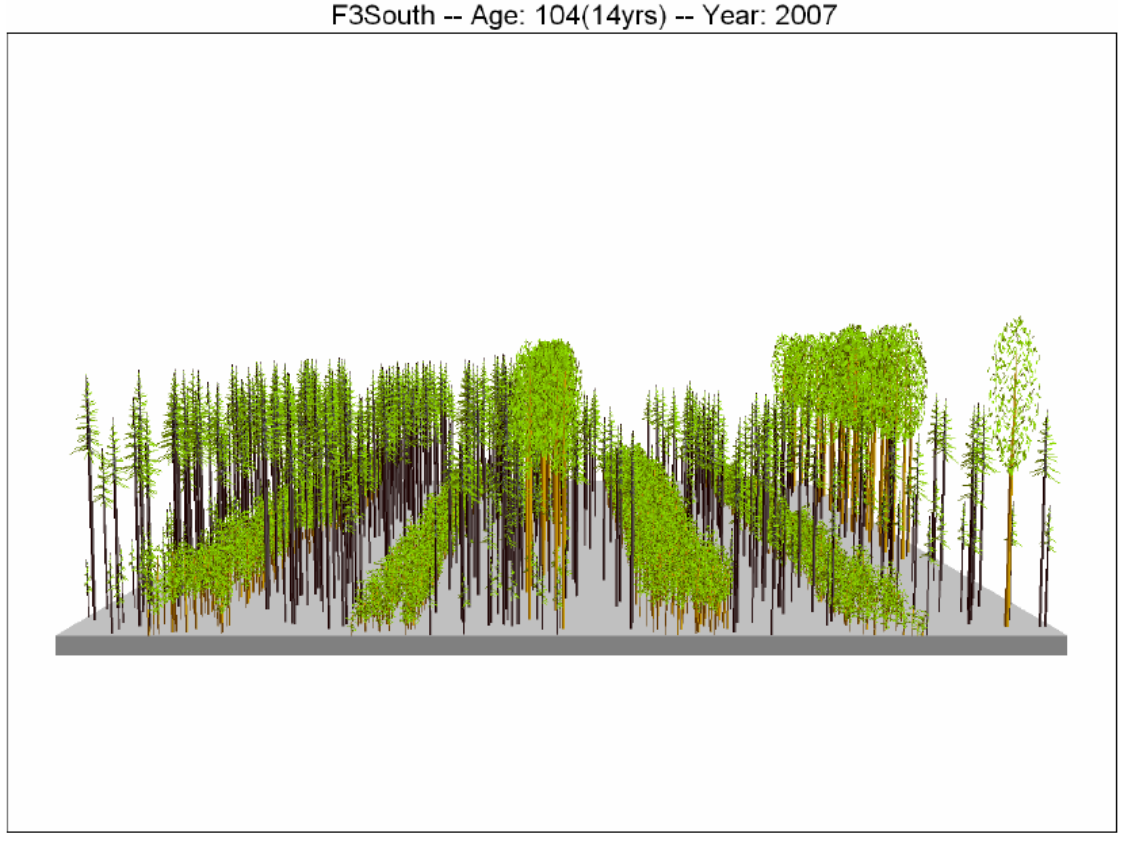
The Projects

Developing Mixedwood Regeneration Modeling Capabilities

In 2002, the MWMA engaged The Forestry Corp to undertake a project to review and evaluate growth models like the Mixedwood Growth Model (MGM) and SORTIE, and if suitable, recommend one of the models for future research support.

The objectives for the project were as follows:

1. Document the specific growth modeling requirements of MWMA members;
2. Consult with growth model developers and third party growth and yield experts to assess model capabilities for addressing the MWMA growth modeling requirements identified above;
3. Collect existing growth and/or yield data for juvenile stand development in Alberta;
4. Compile existing data to produce observed juvenile stand development trajectories;
5. Test model predictions against observed trends from existing Alberta data;
6. Communicate test results to model developers, and solicit feedback to identify data needs and analytical strategies for model improvement;
7. Recommend model(s) of choice for further MWMA support and development/improvement;
8. Develop a MWMA Five-year Growth and Yield Plan to support improvement of the MWMA model(s) of choice.



Example of MGM Model Projection Schematics

The principle investigator for this project was Willi Fast. The total funding for this project was $118,000.00. The project was completed and the final report was received June 2003.

- **Fast, W.** 2003. *Developing Mixedwood Regeneration Modeling Capabilities.* MWMA internal report, June, 2003.

Fast suggested continued development and support of MGM and SORTIE as follows:

- MGM
  - Recalibrate juvenile growth model with new SDS and Growth Monitor Plot data
  - Initiate a cooperative juvenile stand PSP program
  - Consider support of Bokalo Stand Reconstruction research at U of A
- SORTIE
  - Incorporate volume calculation and reporting
  - Incorporate Alberta height-diameter equations
  - Develop non-linear aspen self-thinning function
  - Support field sampling and analysis to improve adult tree growth function

The MWMA decided to focus on MGM since it was based on Alberta data with researchers at the University of Alberta, rather than trying to calibrate a model that was developed in British Columbia. The following projects (details are provided later in this report) were funded with the purpose of improving MGM:

- Adapting the Mixedwood Growth Model (MGM) for Post-harvest and Managed Stands (Comeau, 2004-2007 $60,000);
- Modeling Mid-Rotation Growth and Mortality in Boreal Mixedwoods (Stadt, 2006-2011, $275,000);
- Boreal Forest Mortality Modeling (Dawson, 2006-2010, $22,500);
- Benchmarking Natural Origin Stand Development (Bokalo, 2007-2009, $43,000); and
- Growth and Yield Implications of Understory Protection and Other Mixedwood Silviculture Systems (MacIsaac, 2007-2009, $110,000).

The MWMA also supported SORTIE-BOREAL by providing partial funding to the following projects:

- Modeling Growth of Juvenile Aspen and White Spruce in Western Boreal Mixedwoods (Astrup/Larson/Coates, 2003-2006, $5,000); and
- Development of Improved Indicators of Seedling Growth and Mortality of Important Boreal Tree Species: A Long Term Study (Kenkel/Macdonald, 2004-2007, $10,000).

Meta-Analysis of Release and Under-Planting Treatments

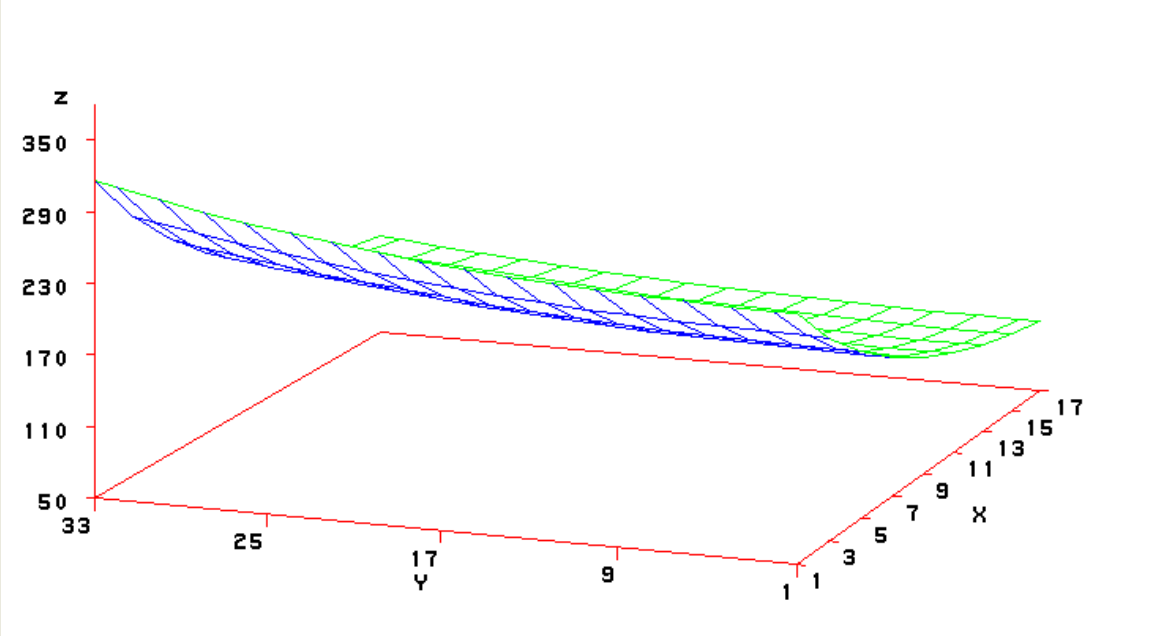
This project concentrated on quantifying the growth response of white spruce to release and underplanting treatments, and to model response patterns with summaries of individual studies extracted from literature or calculated from original raw data. The results of this study provided information for growth and yield modeling of mixed-species stands where release and underplanting treatments are applied.

Dr. Rongzhou Man was the lead investigator on this project. The total funding for this project was $58,000.00. The project was completed and the final report was delivered March 2003. This report was also published in The Forestry Chronicle:

- **Man, R., and Greenway, K.J.** 2004. *Meta-analysis of understory white spruce response to release from overstory aspen.* For. Chron. 80: 694-704

Over 300 publications were assessed for suitability for meta-analysis. The focus was on experiments in the boreal mixedwood area, but data from mixed aspen and spruce stands with release and underplanting treatments outside the boreal mixedwood area were also included for a larger sample size and possibly more robust conclusions. The analysis of all the data revealed that the mean cumulative growth of released trees is 61% greater in height, 73% greater in diameter, and 132% greater in volume. Survival is 4% greater compared to unreleased control trees. For underplanting, mean height is 6% shorter, and diameter is 24% smaller. Survival is 7% greater in seedlings planted under forest canopy than seedlings grown in open conditions.

Three models with reasonable predictive power were developed for height, diameter, and volume response of white spruce to release treatment, depending on variables including initial tree height, the number of years after release, and residual basal area at the time of release. Among the residual trees of different heights, the best growth response is at 7-9 m for height and volume, and 9-11 m for diameter. Higher amount of residual trees generally results in smaller diameter and volume response, but greater height growth at basal area below 13-15 m^2.



Example of the Interactions of Volume Growth with Basal Area at Release, where Y is years after response, X is residual basal area at release in m^2, and Z is volume growth response in percentage.

The models developed in this study can be used to predict the height, diameter, and volume growth of individual released white spruce trees, given the growth of unreleased control trees, initial tree height, residual basal area, and time since release. The individual tree volume prediction can be easily scaled up to stand level if residual tree density and distribution is known. Since the models were developed to predict the growth of released trees relative to the growth of unreleased control trees, they are not only applicable to the site and stand conditions where release study has been conducted, but can also provide reasonable estimations in situations where no release data are available yet.

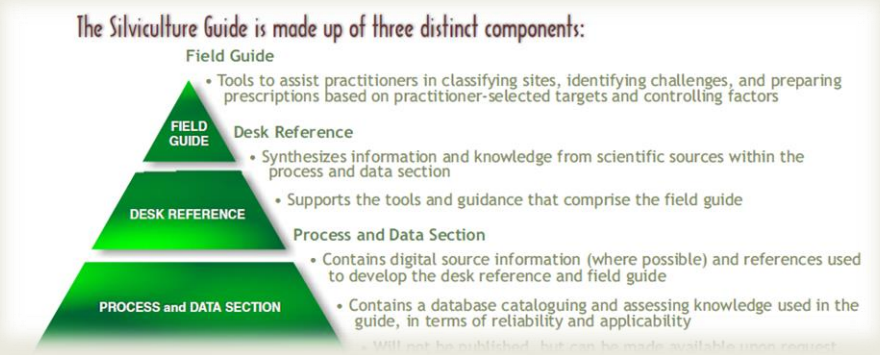
Dr. Man suggested that more research is required to determine the course of growth response beyond the time range covered by the data used in this meta-analysis. The majority of the data was from trees less than 40 years old and he cautioned against using the information to estimate growth response beyond that (e.g. to rotation age). He also suggested that future research should pay attention to the early growth response of released trees and identify the causes of delayed/negative responses, particularly of small understory trees.

In response to Dr. Man's recommendations, the MWMA embarked on a strip cut understory protection monitoring program (SCUP) described later in this report. Dr. Phil Comeau *et al.* are currently investigating white spruce release response, especially in small trees, in a project sponsored by FGrOW.

Development of Mixedwood Silviculture Guide, Phase I: Assessment of Existing Silvicultural Systems

The objective of this project was to review existing Silviculture Guides and make recommendations for the development of an Alberta Silviculture Guide that combined ecologically-based silvicultural decisions and maximum return on investment.

The principle investigator on this project was Mr. John Beckingham. The total funding for this project was $35,000.00. The final report was submitted September 2003.

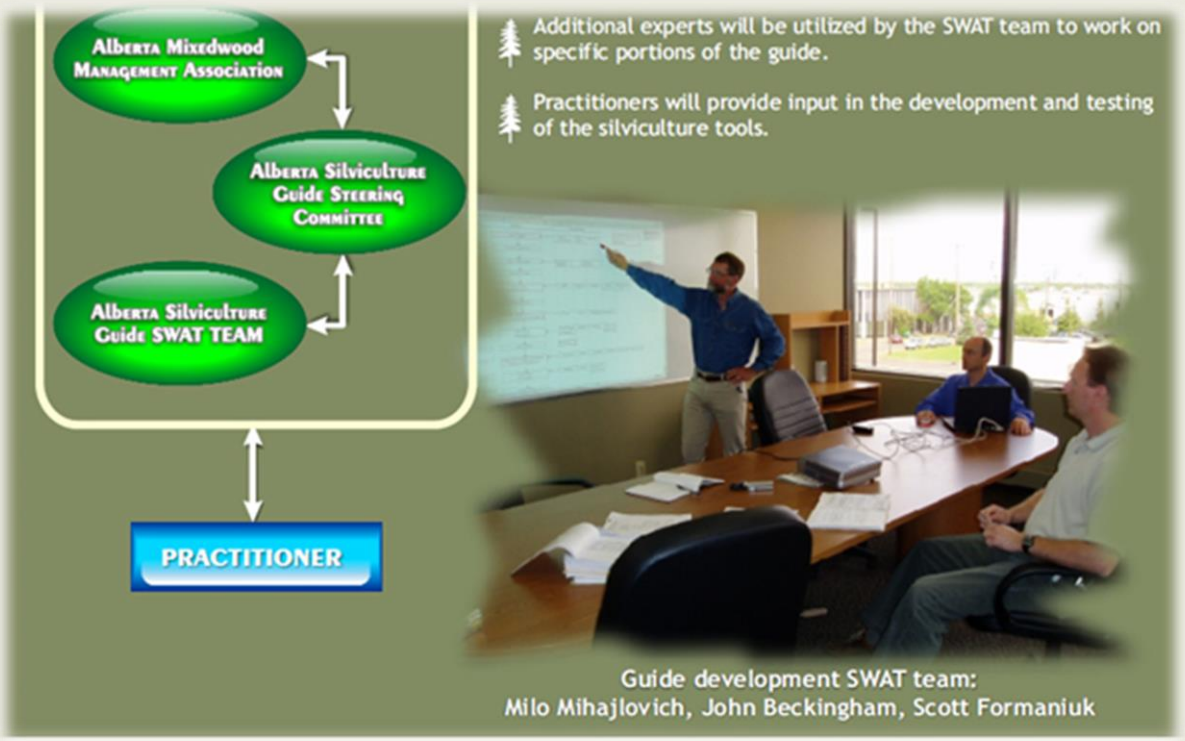


Proposed Structure of the Silviculture Guide

John Beckingham provided a summary of recommendations for development and structure of an Alberta Silviculture Guide. The MWMA submitted a successful FRIAA Open Funds proposal to complete this work. The Silviculture Guide, Phase II project began in 2003.

Development of a Mixedwood Silvicultural Guide, Phase II - Guide Development

The Alberta Silviculture Guide was intended for use by field and management foresters allowing them to interpret field data and identify risks and opportunities. It was expected to deliver knowledge to professional foresters to enable them to select the appropriate silviculture regime to meet the stand-level targets consistent with their DFMP goals and objectives. The Guide interpreted carefully considered information from the published literature (and where adequate published knowledge was unavailable, from other sources) and integrated this knowledge to directly predict future stand characteristic such as volume, species composition, gross stand structural attributes, fibre quality and economic return as a function of initial species composition, ecosite types and management interventions. In addition, non-fibre stand attributes (i.e. habitat quality, thermal cover etc.) may be inferred from the predicted stand characteristics although they were not the focus of the Guide. The Guide was intended to outline a range of silvicultural opportunities/strategies with their associated risks and the likely resultant stand trajectories of these management activities.



Schematic of Guide Development Interactions and Development Team

The Development Team included Scott Formaniuk from Coast to Coast Reforestation, John Beckingham from GDC Consulting and Milo Mihajlovich from Incremental Forest Technologies.

The FRIAA Open Funds awarded $290,000.00 to the project, while the MWMA provided $150,393.25 in funding. The Guide was completed during the fall of 2007. The MWMA held two practitioner workshops in November 2007. The workshops were designed to “test-drive” the guide and reveal potential problems. Any issues revealed during the workshops were resolved if possible and the improved Guide was released in the fall of 2008 with another set of practitioner workshops held in December 2008.

The guide was developed for use with MS Excel 2000/2003 and MS Windows XP. The Guide is currently not compatible with the newer versions of MS Windows or MS Excel and can no longer be accessed. The cost of upgrading the Guide to newer operating systems and applications is being investigated.

Strip Shelterwood Understory Protection Monitoring Protocol

The objectives of this project were:

1. Provide a measurement protocol that is sufficiently general to be used to monitor the range of understory protection systems in use by the MWMA membership. The protocol will develop a data collection system of common response variables, quality assurance/control measures, and data management;
2. Provide a measurement protocol which provides statistically valid stand development information which can be used to either develop or calibrate growth models;
3. Provide a protocol that is acceptable to the Alberta government; and
4. Provide re-measured data to quantitatively describe the development of crop trees after understory protection harvest treatments.

Understory Protection Extraction Trail and White Spruce Retention

Willi Fast and The Forestry Corp were engaged to complete this work. Total funding for the project was $31,500.00. As a result of this project, The Forestry Corp developed two field manuals: “Protocol for Estimation of Block-Level Strata Proportions” and “Strip Shelterwood Understory Protection Monitoring Protocol and Field Manual” in 2003.

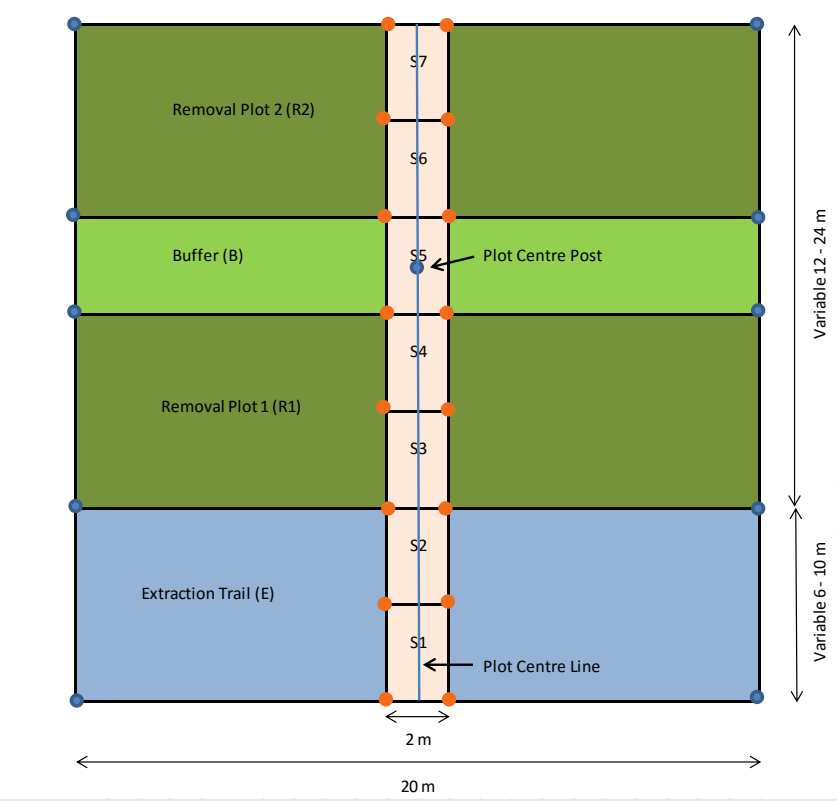
The MWMA began the Strip Cut Understory Protection (SCUP) project in 2005. This project continues today and utilizes the protocols developed during this project to collect the data.

Strip Cut Understory Protection Permanent Sample Program

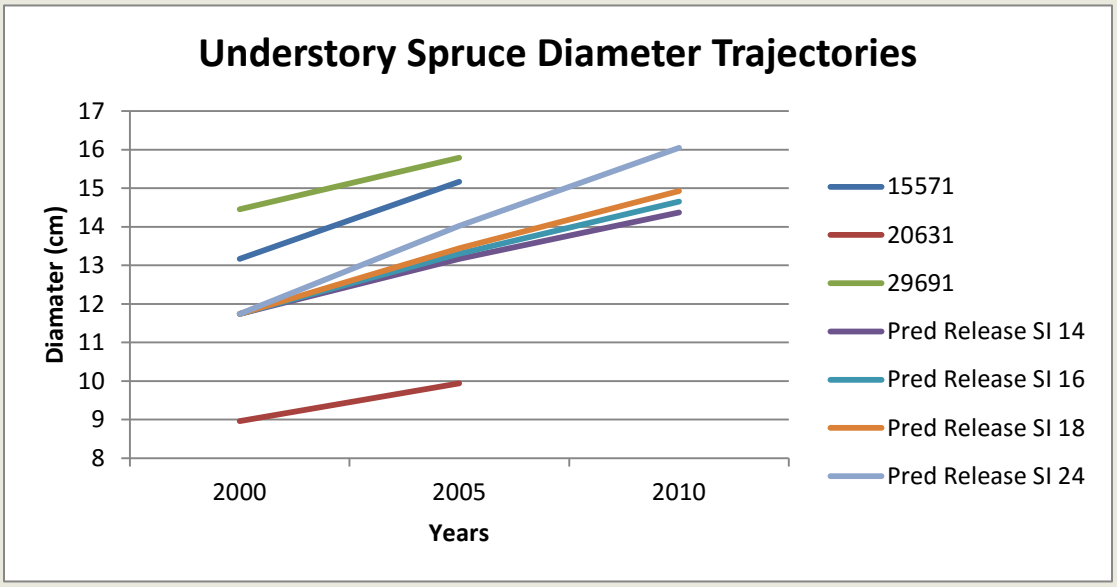
The objective of this project is to collect data on the trajectory of understory white spruce tree growth after overstory removal through strip cut harvesting, and on aspen regeneration and growth in machine corridors. The project was initiated in 2005 and up to 2015, $376,145.48 were spent on installation, measurements and management.

The goal is to create a dataset that will enable the development of valid growth and yield curves for mixedwood stands following strip understory protection harvest in different ecological subregions and stand conditions (understory spruce density) in Alberta. Cutblocks were selected in several ecological subregions with different understory spruce densities (300 – 600 sph, 601- 1000 sph and >1000 sph) to populate a matrix. Due to availability and budget constraints, a total of 18 understory protection PSPs were established, 17 in the Central Mixedwood and 1 in the Boreal Highlands Ecological Subregions, sampling all 3 understory densities. Since strip cut understory protection is currently being practiced by more companies, the matrix could be completed in future years when funding becomes available.

The field manual produced by The Forestry Corp in 2004 was revised in 2013 by Sharon Meredith and Dr. Gitte Grover with input from Katrina Froese, Froese Forestry Consulting and Dr. Mike Bokalo, University of Alberta.



Layout of Understory Protection PSP



Preliminary analysis of the SCUP data in 2013 compared observed growth to project growth in MGM.

Table 2 below shows completed and anticipated measurements.

Table 2: SCUP re-measurement schedule

Location	PSP Installation #	Plot #s	Established	Re-measure	Site Index Measurement	Re-measure
Van	7012	6	2005	2010	2012	2015
Al-Pac	27131	6	2005	2010	2012	2015
Al-Pac	19191	6	2005	2010	2012	2015
Al-Pac	29691	6	2005	2010	2012	2015
Al-Pac	16751	6	2005	2010	2012	2015
Al-Pac	11911	6	2007	2012	2012	2016
Al-Pac	22361	6	2007	2012	2012	2016
Al-Pac	36551	6	2007	2012	2012	2016
Al-Pac	36271	6	2007	2014	2014	2018
Al-Pac	36381	6	2007	2014	2014	2018
Al-Pac	34591	6	2007	2013	2013	2018
Al-Pac	27631	6	2007	2013	2013	2018
Al-Pac	15571	6	2007	2013	2013	2018
Ains	572	2	2007	2014	2014	2018
Tolko	330	2	2007	2014	2014	2018
Tolko	2212	2	2007	2014	2014	2018
Al-Pac	17781	6	2007	2013	2013	2018
Al-Pac	20631	2	2007	2013	2013	2018

This project will provide the data needed to calibrate growth models for yield curve development. Drs. Phil Comeau and Mike Bokalo used the data from several of the SCUP plots to refine white spruce release response in MGM and provided the MWMA with a report titled "Release response of white spruce regeneration following understory protection harvesting" in April 2014.

This project will continue under the Mixedwood Project Team with FGrOW.

Hotchkiss River Mixedwood Management Demonstration Area: 10th Year Re-Measurement and 3rd Pass Harvest

The original objectives of this white spruce understory protection project were to:

1. Test the effectiveness of designated silvicultural and harvesting prescriptions for reducing wind damage to immature residual white spruce and to determine their effect on aspen regeneration;
2. Assess post-harvest white spruce composition, density and stocking, and subsequent periodic growth in order to develop and refine mixedwood regeneration and stocking standards and growth and yield methodologies;
3. Assess harvesting productivity and costs for each prescribed treatment;
4. Provide an operational-scale demonstration of alternative harvesting systems in a boreal mixedwood landscape that will facilitate integrated use and contribute to maintaining biodiversity and long-term boreal ecosystem sustainability.

Aerial photo of the F3S alternate strip treatment with two entries each 20 m wide and a 5 m aspen residual every 40 m in the second-entry. Photo taken June 4, 2008 by D. MacIsaac.

The principle investigator was Dan MacIsaac, Canadian Forest Service. Total funding provided by the MWMA for this project was $20,000.00. This project was also funded by DMI, MDFP and FRIP. The project was completed and the final report was received December 2004.

This project represented the tenth year re-measurement and third pass harvest assessment of the white spruce understory protection research at the Hotchkiss River Mixedwood

Management Demonstration area and resulted in the addition of those measurements and stand characteristics to the database.

Conclusions from 10-year monitoring of post-harvest understory protection strip cut are as follows:

- Key variables to use in the stratification process (by forest planners) are white spruce height and density, rooting depth and topography;
- Medium and low spruce densities run the greatest risk of having a low total stand volume increment following understory protection;
- Avoidance of immature residual white spruce using the clearcut system is not recommended due to wind throw;
- To maximize deciduous regeneration in the machine corridors, a single entry, single pass harvest is recommended;
- Harvesting on unfrozen ground decreased deciduous regeneration density by 29%; therefore, winter harvest on frozen ground is preferable;
- The recommended prescription for understory protection is a one-pass harvest with 10% - 15% aspen retention. This retention level provides enough white spruce protection from wind throw, yet removes most of the overstory to allow for significant release of white spruce growth.

Modeling Growth of Juvenile Aspen and White Spruce in Western Boreal Mixedwoods

The objective of this project was to enhance knowledge of boreal mixedwood dynamics which are applicable to forest management through a modeling framework. Of special interest were the regional variation in species-specific crown openness for mature trees, and light-growth relationships for juvenile trees.

The lead investigators on this PhD project were: Rasmus Astrup, Dr. Bruce Larson and Dr. Dave Coates. Total funding for this project was $5,000.00. Dr. Astrup's Ph.D. thesis was accepted as the final report in November 2006. Dr. Astrup published the following paper from this research:

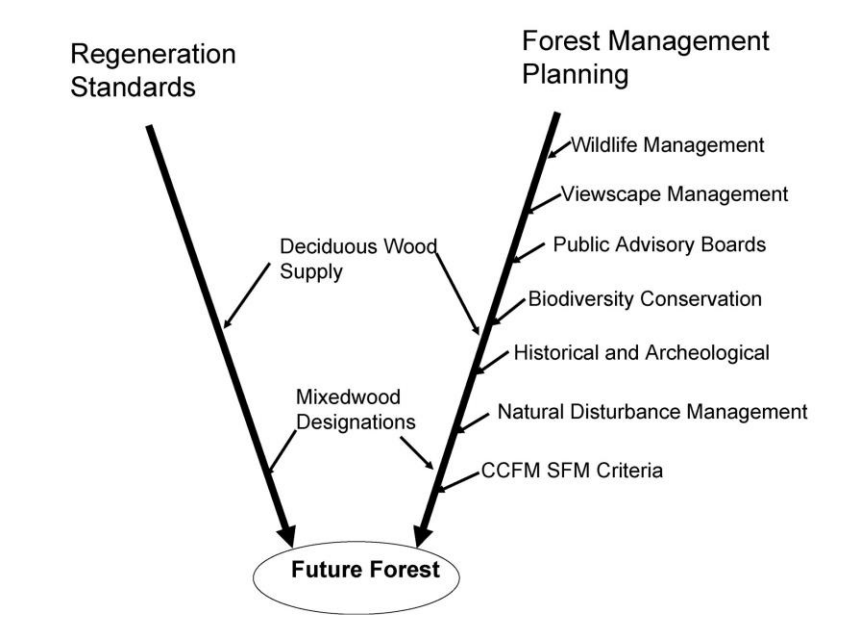
- **Astrup, R., and Larson, B. C.** 2006. *Regional variability of species-specific crown openness for aspen and spruce in western boreal Canada*. For. Ecol. Manage. 228: 241-250.

The main objective of this study was to investigate whether regional differences in mean species-specific crown openness exist for aspen and white spruce in western boreal Canada. To ensure a robust comparison of regional mean species-specific crown openness, initial investigations looked at the underlying assumption that crown openness is unaffected by dbh and angle of view. In the data, both aspen and spruce crown openness was found to be independent of angle of view. Crown openness was also independent of dbh in aspen, while

weak indications of a correlation between crown openness and dbh was found for white spruce. However, this relationship has little actual effect on crown openness and its effect on predicted understory light level is judged to be small. Significant regional differences were found in mean crown openness for both aspen and spruce. Again, these regional differences are small and are likely to have relatively little effect on understory light levels predicted with SORTIE. The results from this study indicate that, although previous estimates of aspen and spruce crown openness in western boreal Canada varied greatly, this is more likely the result of different methodologies than actual differences in crown openness.

Analyses for Revision of Mixedwood Regeneration Standards

The objective of this project was to evaluate the potential of utilizing tree height and height growth rates as the basis for free-to-grow assessments, and to examine stocking levels which are necessary to achieve different management goals in aspen-white spruce mixedwood strata. Data were collected from 25 tended and 25 non-tended cut blocks to examine growth and future yield of spruce trees grown with various aspen densities.

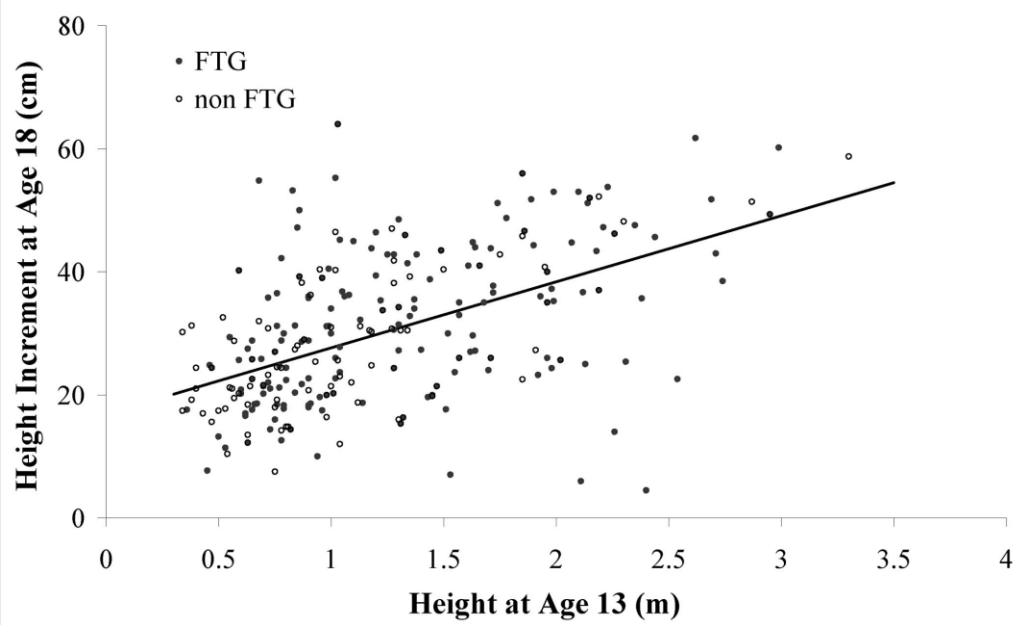


Factors influencing the development of regeneration standards and forest management planning over the last decades. Note that the regeneration standards have remained focused on wood supply and have had little influence from other values.

The lead investigator for this project was Dr. Victor Lieffers, University of Alberta. Total funding for this project was $83,000.00. The final report was received in 2005. Four papers were published from this work:

- **Feng, Z., Stadt, K.J., Lieffers, V.J., and Huang, S.** 2006. *Estimation of site index of juvenile white spruce stands.* For. Chron. 82: 819-824.
- **Feng, Z., Stadt, K.J., and Lieffers, V.J**. 2006. *Linking juvenile white spruce density, dispersion, stocking and mortality to future yield*. Can. J. For. Res. 36: 3173-3182.
- **Lieffers, V.J., Stadt, K.J., and Feng, Z.** 2007. *Free-to-grow regeneration standards are poorly linked to future growth of spruce in boreal mixedwoods.* For. Chron. 83: 818-824.
- **Lieffers, V.J., Armstrong, G.W., Stadt, K.J., and Marenholtz, E.H.** 2008. *Forest regeneration standards: are they limiting management options for Alberta's boreal mixedwoods?* For. Chron. 84: 76-82.

The results from this project revealed that site index based upon growth characteristics of juvenile stands might overestimate the true site index at age 50 by approximately 16%. The investigators demonstrated the protocol for estimating the site index of regenerating stands using data collected at the time of the Performance Survey. This is done using either height – age or growth intercept techniques, coupled with the correction for bias. This approach can be applied only to uniform landform types within cutovers.



Height increment after year 18 in relation to FTG assessment at year 13 and height attained at year 13. A tree was classed as FTG if it was not overtopped by deciduous trees within 1.78-m radius. ANCOVA demonstrated that height increment was related to height at year 13 ($p < 0.001$), but was marginally related to FTG status ($p = 0.057$) and their interaction ($p = 0.077$). Regression of all data points is: Htinc18 = 16.9 +10.7 _ Ht13, R2 = 0.28.

Trees that were designated as free-to-grow were taller and had higher rates of height growth than leading trees designated not free-to-grow. However, direct measures of the presence of hardwood trees in the mil-hectare plots were only weakly related to the height increment of the leading tree in the plot. Regardless of whether a tree's growth is affected by recruitment

age, genetics, microsite, disease and herbivore damage, or competition, the most important parameter for yield predictions is how fast it is growing. The investigators proposed to abolish the complexity of FTG standards, substituting it with current height growth as the best indicator of future growth.
Since the 1.78m radius cylinder is too small to characterize the current or future competition for individual trees at the performance survey, competition would be better considered at the block level as overall densities or stocking of deciduous and coniferous components. The mortality rates of the deciduous versus the coniferous components should also be considered in estimating the future stand composition.

Results from this research project contributed to the development of the Reforestation Standard of Alberta.

Influence of Stand Development on Interactions Between Aspen and White Spruce

The objective of this study was to determine whether relationships between the growth of target spruce crop trees and measures of the amount of neighbourhood competition (light, overtopping basal area, Lorimers index or other measures of competition) change with stand age or stand development. A second objective was to develop and test regression models for estimating growth of white spruce as a function of competition, tree size, amount of light absorbed during the growing season, and other independent variables.

The lead investigator of this project was Dr. Phil Comeau from the University of Alberta. Total project costs were $82,146.42. A final report was submitted in 2006 and one paper was published from this work:

- **Filipescu, C.N., and Comeau, P.** 2007. *Competitive interactions between aspen and white spruce vary with stand age in boreal mixedwoods.* For. Ecol. Manage. 247: 175-184.

Results from this study indicate that simple competition indices based on density are limited in their ability to predict growth of understory spruce trees. Distance-dependent indices provide little or no improvement over simpler distance independent indices in these stands. Better results were provided by indices or models which include a measure of initial size of target spruce trees. The researchers suggest that it may be desirable to represent the effect of initial subject tree size separately from the effects of competition through the use of multiple regression models.

Example of a boreal mixedwood stand with a mature aspen overstory and an immature white spruce understory

Relationships between aspen competition and spruce growth seem to vary with age, making age and/or size specific calibration of these relationships necessary. Modellers may choose to include initial size of spruce in their growth models as well as calibrating for age and/or size relationships.

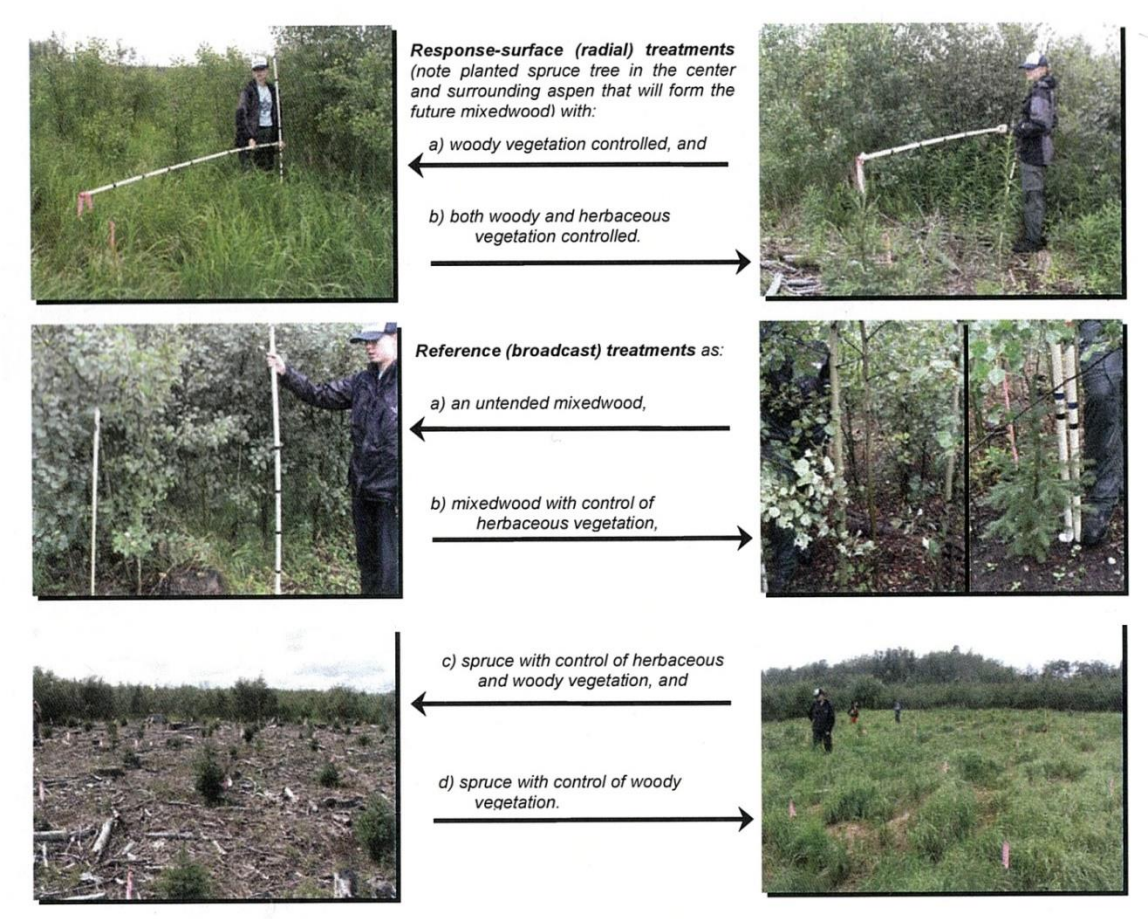
Effects of Aspen Density and Duration of Vegetation Control on Resource Competition and Mixedwood Stand Development

This was a CFS-NSERC funded project with MWMA providing a portion of the industry support. The study aimed to improve our understanding of the effects of herbaceous competition and aspen stem density on the establishment and development of white spruce and aspen mixed stands on clearcut sites. The objectives of this study included identification of the optimum stand tending and stem density regimes necessary for producing an aspen fibre crop by age 30-45 and a high quality spruce saw log crop by age 80+.

The lead investigators were Drs. Phil Comeau and Doug Pitt. The total funding provided by the MWMA was $ 30,000.00. The total cost of the project was $520,000 resulting in $490,000 of leveraged funds. The CFS/NSERC project was completed at the end of 2007. A final partner report was received January 2008. One paper was published:

- **Man, C.D., Comeau, P.G., and Pitt, D.G.** 2008. *Competitive effects of woody and herbaceous vegetation in a young boreal mixedwood stand.* Can. J. For. Res. 38: 1817-1828.

Following five growing seasons at the Alberta site, planted white spruce receiving early woody and herbaceous competition control, either as a broadcast or radial treatment, exhibited nearly 3-fold gains in stem diameter over untended trees, resulting in over 12-fold gains in stem volume index. In contrast, spruce receiving control of only woody or herbaceous competition exhibited close to 3 and 4.5-fold gains in stem volume index, respectively. Spruce receiving 4 years of radial complete vegetation control had a 43% growth advantage over their counterparts receiving only 2 years of control. Aspen crop trees on the site also exhibited a response to herbaceous weed control. The broadcast herbaceous treatment provided a small 6% gain in stem volume index over untended aspen; radial treatment provided a 49 to 55% gain, possibly due to the combined thinning effect of the radial treatments, and the adjacent herbaceous weed control. Across all treatments, mean spruce mortality rose only slightly from 11% in 2006 to 12% in 2007.



Key response-surface (radial) and reference (broadcast) treatments illustrated during the 5th gowning season at the Alberta site.

This project demonstrated that effective control of both woody and herbaceous competition is beneficial to the early growth of white spruce. Treatments that control only woody competition generally result in increased herbaceous vegetation and reduced seedling survival. Two-meter radius, individual-tree treatments that control both woody and herbaceous competition appear

to have potential for the establishment of spruce and aspen as intimate mixtures. Through 5 growing seasons, adjacent aspen has not significantly hindered the growth of planted spruce and may offer some benefit in mitigating climatic extremes and reducing exposure injuries. Long-term monitoring is needed to document the dynamic interactions between these two species, as established, and formulate practical regeneration strategies and crop plans for spruce-aspen mixedwoods.

Development of Improved Indicators of Seedling Growth and Mortality of Important Boreal Tree Species: A Long Term Study

This was a NSERC funded project with contributions from MWMA, Tembec Inc. and the CFS. The MWMA funding supported the work of Dr. Ellen MacDonald in Alberta while Tembec Inc. And CFS supported the research in Manitoba.

The overall objective was to increase understanding of the critical processes of growth and mortality of boreal forest advance regeneration (i.e. seedlings that have survived the initial years of extremely high post-germination mortality), and to develop robust estimates of growth and mortality rates.

The specific objectives of the study were:

1. To examine large-scale patterns in growth and mortality among regions and species, and processes determining these patterns, using pooled regional data.
2. To examine smaller-scale variation in growth and mortality rates (e.g. between high and low light environments), and to determine the factors contributing to this variation.
3. To provide comprehensive empirical data on long-term growth and mortality of advance regeneration for boreal stand dynamics models (e.g. SORTIE-BOREAL).
4. To develop practical and operationally meaningful indicators of advance regeneration vigour for commercially important boreal tree species.

Dr. Norm Kenkel of the University of Manitoba was the principle investigator for this collaborative project with researchers from Alberta, Manitoba, Ontario, and Quebec. Dr. Ellen MacDonald, University of Alberta, was the lead researcher for the Alberta portion. The MWMA provided $10,000 in funding for this project. An additional $ 20,000 were contributed to the Alberta portion from NSERC and from Dr. MacDonald's grants. The final CRD report was received July 2007.

To achieve the above objectives, 122 permanent study plots were established in the spring of 2000. The plots were located at 8 study locations in four provinces: Québec, Ontario, Manitoba and Alberta. Study locations were chosen to ensure western, central, and eastern representations of four economically important tree species. Between 60 and 100 seedlings were tagged in each permanent study plot, for a total of 9334 monitored individuals (2197 white spruce, 1066 black spruce, 3419 balsam fir, and 2652 trembling aspen). Half the study plots were located in low light (closed canopy) environments and the other half in high light environments (clear-cuts, openings, or large canopy gaps). Seedling survival, as well as various

morphological and growth variables, were recorded each spring and fall over seven years (2000 through 2006). In addition, relative measures of light availability were taken at each seedling location. Biotic and abiotic disturbances to seedlings (herbivory, frost damage, etc.) were also recorded. The following tables (3-5) summarize the mortality observed in the study.

Table 3: White spruce growth and mortality

White spruce					
Site	Light condition	% of full light - at leader	Mortality rate per year	Height increment/yr (cm)	Leader increment/yr (cm)
			%	mean (95 % C.I.)	mean (95 % C.I.)
LLB	High light	41.95	0.11	12.52	12.54
				5.42	1.05
LLB	Low light	18.04	0.80	6.26	6.65
				3.86	0.58
EMEND	High light	49.56	0.06	8.04	7.93
				4.07	0.66
EMEND	Low light	18.04	0.17	4.83	5.09
				3.46	0.51
Annual height increment may be less than annual leader growth because of top die-back on some trees					

Table 4: Balsam fir growth and mortality

Balsam Fir					
Site	Light condition	% of full light - at leader	Mortality rate per year	Height increment/yr (cm)	Leader increment/yr (cm)
			%	mean (95 % C.I.)	mean (95 % C.I.)
LLB	High light	24.16	0.23	7.51	7.90
				4.16	0.74
LLB	Low light	10.38	1.49	5.94	6.35
				3.76	0.70
EMEND	High light	14.32	1.66	5.68	6.22
				4.14	0.78
EMEND	Low light	8.86	1.43	3.36	3.98
				3.81	0.54
Annual height increment may be less than annual leader growth because of top die-back on some trees					

Table 5: Trembling aspen growth and mortality

Trembling Aspen				
Site	Light condition	% of full light - at leader	Mortality rate per year	Height increment/yr (cm)
			%	mean (95 % C.I.)
LLB	High light	68.62	5.16	21.56
				13.51
LLB	Low light	31.20	9.00	11.82
				12.21
EMEND	High light	68.91	5.12	38.86
				9.59
EMEND	Low light	26.27	10.64	15.06
				8.67

The results show that the seedling bank of a mature boreal forest is critical to stand renewal following natural small-scale disturbance or commercial harvesting. However, prior to our study few data were available on trends in the growth and mortality (survivorship) rates of regenerative forest seedling banks. Our study has also provided critical data on the response of the seedling bank to environmental changes associated with canopy gap formation (i.e. increased availability of light). Such data are critical to the development and validation of long-term stand dynamic models, and to refining silvicultural practices aimed at preserving the seedling bank as an immediate growing stock for the renewal of commercially harvested forest stands.

These findings will help improve sustainable boreal forest silvicultural policies and practices in Canada. They provide strong empirical evidence for the importance of preserving and maintaining the seedling bank as a growing stock for the renewal of harvested forest stands. The results will also be used to refine boreal forest stand growth models which are used to predict forest yields, stand dynamics, and timber supplies.

Adapting the Mixedwood Growth Model (MGM) for Post-Harvest and Managed Stands

The objectives of this FRIAA open funds project were to add new functionality and capabilities to MGM through:

- Improving the representation of early tree and stand growth using newly available juvenile stand data that will
    a) Improve existing growth and mortality functions for trees in natural stands; and
    b) Add the capacity to model post-harvest and treated natural stands;
- Modifying the architecture of MGM to permit incorporation of process-oriented functions and to provide flexibility for modeling a range of current and future silvicultural practices;

- Developing and enhancing the capability of MGM for predicting the response of mixedwood stands to silvicultural practices (such as: under-planting, understory scarification and seeding, juvenile spacing, harvesting with understory protection, partial cutting, herbicide treatment, and brushing) using a combination of empirical and process-oriented modeling approaches;
- Develop volume loss factors (VLF) to adjust model predictions when they are applied to a stand rather than plot level.

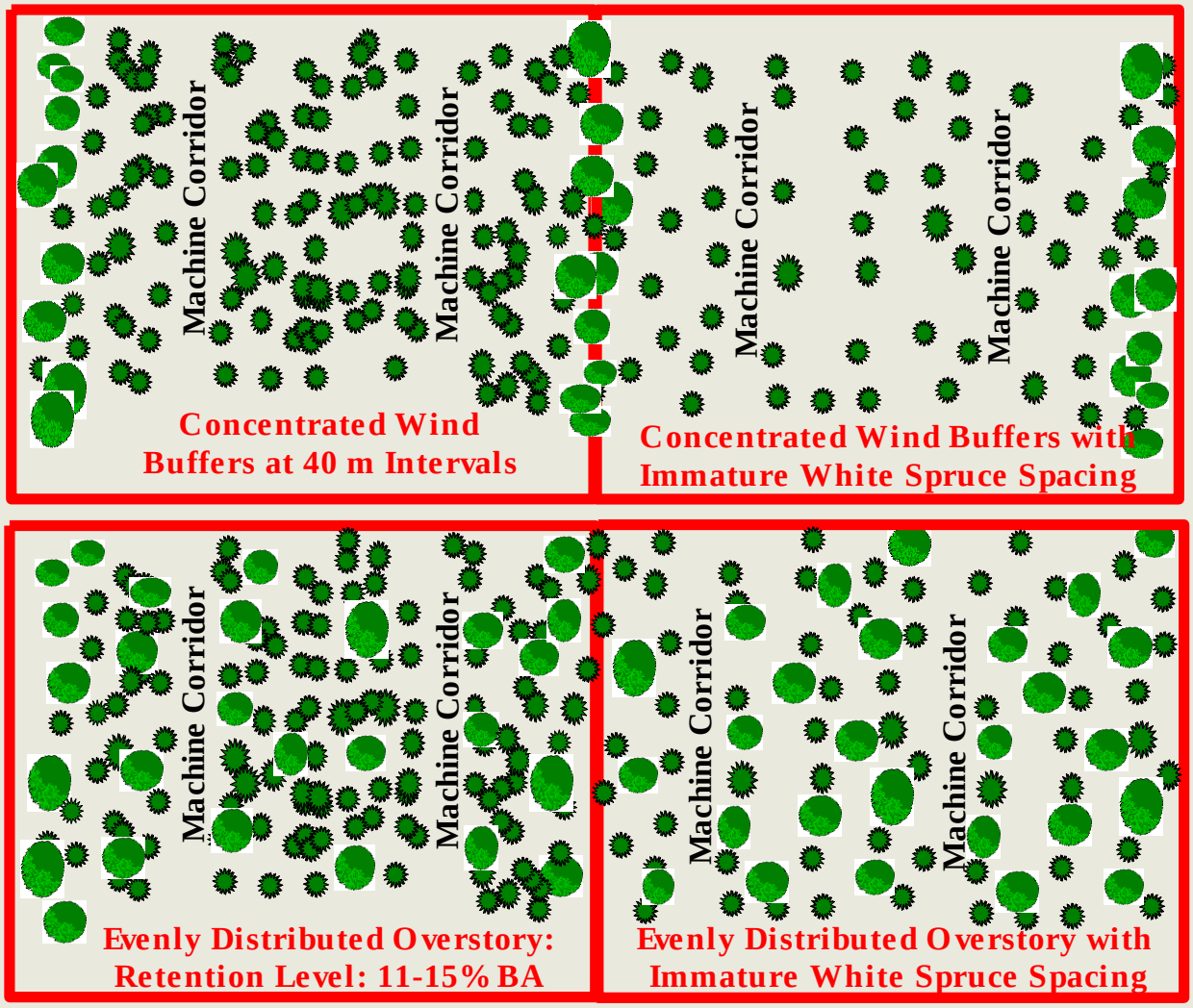
The lead investigator for this project was Dr. Phil Comeau from the University of Alberta. The project cost to the MWMA was $68,317.11. FRIAA Open Funds provided $283,500.00.

The main product of this work was a new version of the Mixedwood Growth Model (MGM) with enhanced capability for forest growth projections following harvesting and management interventions. As MGM is the only mixedwood growth and yield model currently calibrated for Alberta, this project will facilitate forest planning under enhanced forest management, allowing the development of strategies for increased productivity (e.g. overlapping aspen and spruce rotations) and more ecologically sensitive management (e.g. mixed-species forestry).
The new model was introduced to users in a workshop in 2007 at the University of Alberta. A compiled, user-friendly version of the model and manual are freely available to the public, forest managers, regulators, and researchers as downloadable files from the MGM website (http://www.rr.ualberta.ca/research/mgm/mgm.htm).

Adaptive Management of Mixedwoods to Maximize Fibre Recovery and Retained Stem Volume Growth and Ecosystem Sustainability: 'Understory Protection and Release and Overstory Fibre Recovery'

This was a large scale research experiment that demonstrated and tested the most advanced practices for boreal mixedwood management of aspen and white spruce in fully stocked stands. Specifically, the objectives were:

- To test promising practices for management of mature aspen stands with understory spruce in boreal mixedwood forests;
- To establish a network of sites with various forest companies that tests, demonstrates, and validates new practices associated with objective one;
- To develop a field guide of mixedwood harvesting and silviculture options for understory protection systems;
- To establish permanent sample plots in these various silvicultural treatments to determine the effects of treatments on growth and yield and other biological responses;
- To evaluate the cost effectiveness of the operational aspect of the new practices associated with objective one.



Layout of the 4 Harvesting and Thinning Designs

The lead investigators of this project were Dr. Victor Lieffers (U of A) and Derek Sidders (CFS). The MWMA committed $67,000 to Dr. Lieffers for this project. Mr. Sidders also obtained FRIAA open funds for this project. There was a significant amount of in-kind contributions from the participating companies and from Natural Resources Canada, Wood Fibre Centre. This project was completed and a final report submitted in 2009.

Completed Extraction Trail Prior to Retention Strip Felling

The approach was to maximize recoverable aspen and white spruce volume and quality while employing economically feasible systems that will be viewed as desirable by both ecologists and society in general. Treatment prescriptions maximized initial aspen/white spruce harvest volume recovery; while at the same time developed operational systems that protect the understory spruce from damage, thereby increasing the future value of the stand. A broad range of sites from Alberta's boreal mixedwood forest were included in this experiment and demonstration. This project was developed with participation from numerous forest companies actively managing mixedwoods. Replicates of the experiment were consistently applied by each forest company on their own forest tenure areas. The feasibility of thinning the understory spruce at the time of logging and if this thinning would result in an increase in yield/value of the future stand was also tested.

This experiment demonstrated that understory protection can be achieved through maintaining a protective overstory of mature aspen in either concentrated wind buffers or by systematically distributing residual trees evenly in the cut area. Productivity assessments conducted by Canadian Forest Service during harvesting operations identified the following: Skidding productivity ranged from 76.0 m^3/PMH for the even distribution treatment to 82.2 m^3/PMH for the Concentrated Wind Buffers treatment with the skidders forwarding an average of 78.9 m^3/PMH for the understory protection treatments as a whole. Processing productivity ranged from 27.1 m^3/PMH for the dangle head processors to 43.7 m^3/PMH for the stroke delimbers.

To compare the operational feasibility of the three understory treatments: even distribution, concentrated wind buffers and understory protection as a whole, the treatments were compared to regular harvesting operations. The information identified that if the contractors had been paid by the cubic metre for their operations, hourly incomes would have decrease by 4.3% per GMH and 12.9% per PMH. To compensate the contractors for the lost productivity the cubic metre harvest remuneration rate for regular tree-length processing operations would need to be increased by 11.8% for understory protection treatments. For cut-to-length processing operations, the cubic metre rate would require an increase of 12.9%. Assessments conducted one growing season post harvest identified that the newly developed even-distribution harvesting treatment suffered 40% less wind damage per hectare than the proven concentrated wind buffers harvesting treatment. As a result of the first year wind damage, understory retention levels dropped to 65% for the even-distribution treatment and to 56% for the concentrated wind buffers treatment. The early results conclude that the newly developed even-distribution harvesting system is effective for providing wind protection in understory protection treatments.

After the first and second year since harvest, aspen sucker density and growth was similar between the two partial harvests, but was much lower than in the clear-cuts. However, in the partial cuts the regeneration density was very much dependent on the position in relation to residual trees. The density of regeneration was controlled by residual aspen, whereas sucker height was suppressed by the residual spruce. Although there were adequate numbers of suckers after partial harvest, their viability and contribution to the long-term productivity of these mixedwood stands is not clear.

The following papers were published from this study:

- **Lennie, A.D., Landhausser, S.M., Lieffers, V.J., and Sidders, D.** 2009. *Regeneration of aspen following partial and strip understory protection harvest in boreal mixedwood forests.* For. Chron. 85: 631-638.
- **Marenholtz, E.H., Lieffers, V.J., Silins, U**. 2010. *Evaporative demand across a range of microsites in partial cut boreal forests*. Scandinavian Journal For Res 25: 2, 118-126.

Modeling Mid-Rotation Growth and Mortality in Boreal Mixedwoods

This project was initiated in 2006 and completed in 2012. It was funded by multiple agencies. Contributions were from the MWMA ($297,500), FRIAA ($325,000), NSERC ($277,400) and MITACS ($22,500). The principle investigator was Dr. Phil Comeau, University of Alberta.

There were 5 individual projects encompassed within this Collaborative Research and Development (CRD) grant, investigating the following questions:

1. What is the average mortality rate for white spruce in the boreal mixedwood, and how is it linked to tree size, growth rate and competition?

2. What are the effects of competition on retrospective height and stem diameter growth of white spruce and trembling aspen at mid-rotation age?
3. What is the sustained response of white spruce to release from aspen competition throughout the mid-rotation period?
4. What is the effect of aspen competition on white spruce growth in mid-rotation spruce-centered PSPs?
5. Can we improve white spruce and aspen behavior in models combining data from several sources?

Example of tree disc used for retrospective diameter growth assessment

All five studies were carried out successfully. Aspen – white spruce interactions in the age 27-70 data gap were quantified, and growth and mortality models covering the mid-range of stand development were improved. The team refined dendrochronological techniques for sampling mortality and growth in relation to competition dynamics, and developed new modeling techniques for estimating the release of spruce from aspen. These new models qualitatively supported earlier (2007) calibration of MGM using only the PSP data; however, they impose larger growth and mortality penalties on white spruce grown under aspen, reducing the maximum total yield of fibre (deciduous plus coniferous), and prolonging the aspen dominance of these stands. On the other hand, it was shown that white spruce productivity, as measured by site index (the height of dominant trees at a reference age of 50 years) was considerably higher than previously assumed. These results confirm that mixed stands exhibit more total yield than monocultures which supports emerging literature demonstrating the yield benefits of mixtures (e.g. Pretzsch 2005, Man and Lieffers 1999).

A final report on all projects was accepted from Dr. Stadt in June 2012. The following publications have been produced from these projects:

- **Dawson, A., K. J. Stadt, J.-G. Huang, and P. G. Comeau.** *Predicting white spruce mortality from retrospective data: competition versus recent growth.* Submitted to Ecological Applications in December, 2013

- **Huang, J. G., K.J. Stadt, A. Dawson, and P.G. Comeau.** 2013. *Modelling Growth-Competition Relationships in Trembling Aspen and White Spruce Mixed Boreal Forests of Western Canada.* PloS one, 8(10), e77607.
- **Osika, D., K.J. Stadt, P. Comeau and D. MacIsaac.** 2012. *Sixty-year Effects of Deciduous Removal on White Spruce Height Growth and Site Index in the Western Boreal.* Can. Journal of Forest Research, Accepted 13 November 2012.

Natural Regeneration of Spruce in Mixedwoods Following Harvest

The objective of this project was to explore the conditions influencing the successful natural regeneration of white spruce following harvest. The study examined spruce regeneration in cutblocks in the boreal mixedwood forests of Northern and Central Alberta. Specifically, what the effects of competing vegetation communities in post-harvest stands have on the recruitment and establishment of white spruce seedlings, as well as the impact on their longer-term survival and growth. Regeneration of boreal mixedwood stands to fully stocked white spruce stands through intensive planting and tending is one of the most costly and controversial silvicultural goals in Canada. Mixedwood stands have regenerated naturally in the past, and it is likely that there are specific scenarios where natural regeneration could be used in modern forest management as a viable alternative to planting, especially where natural mixed-species forests are the goal.

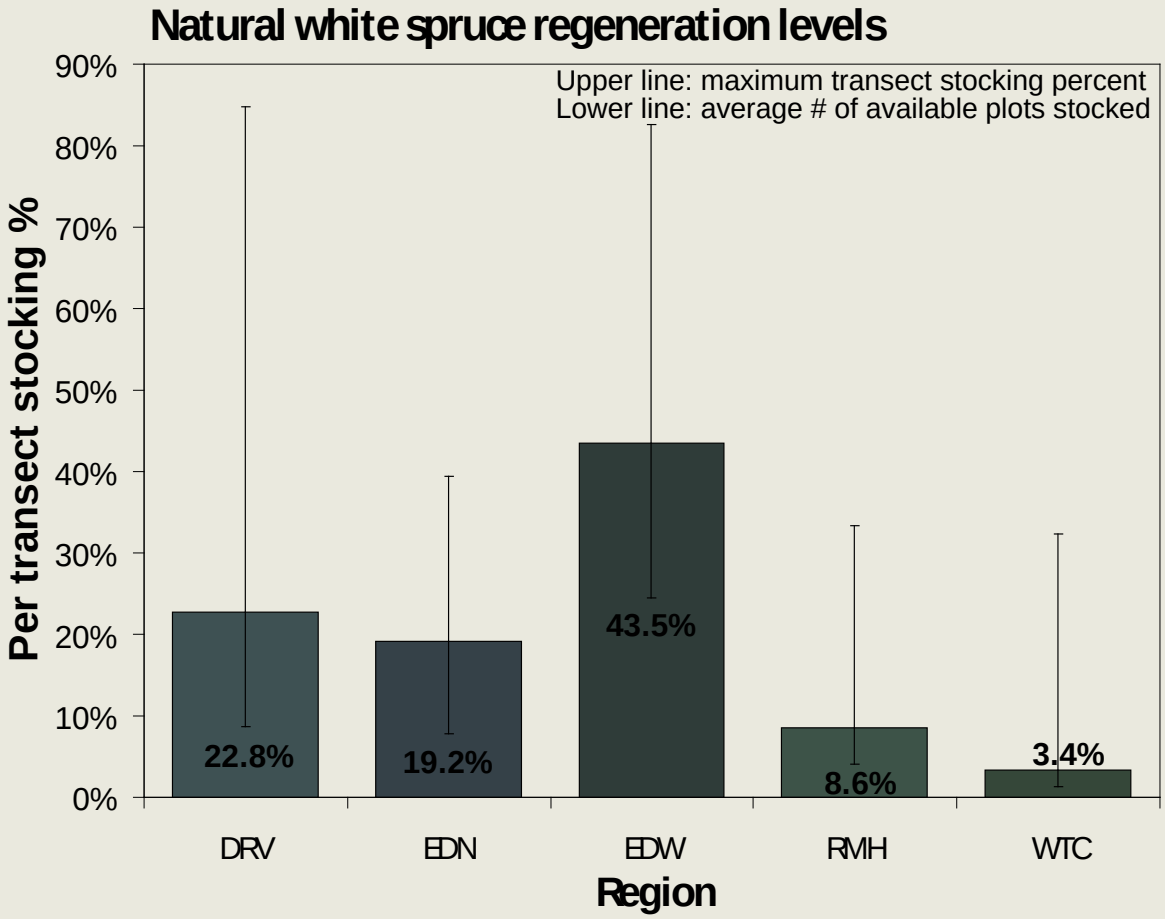
Natural White Spruce Ingress in Deciduous Cutblocks

The lead investigators of this project were Dr. Vic Lieffers, and Dr. Ellen Macdonald from the University of Alberta with Jonathan Martin-DeMoor as MSc candidate. The MWMA contributed a total of $12,000 to this project and Jonathan Martin-DeMoor received a NSERC scholarship in

the amount of $30,000. Jonathan Martin-DeMoor's thesis was accepted as the final report in 2009. One paper was published based on this study:

- **Martin-DeMoor, J., Lieffers, V.J., and Macdonald, S.E.** 2010. *Natural regeneration of white spruce in aspen dominated boreal mixedwoods following harvesting.* Can. J. For. Res. 40: 585-594.

Substantial amounts of naturally regenerated white spruce were found in the 162 transects across 81 cutovers. Sites with no seed trees had virtually no spruce regeneration. Average stocking was 7% (percentage of 9 m^2 plots along a transect across a cutover that had at least one seedling), ranging from 0% to 62%. Stocking levels were higher in cutblocks that had been harvested in the summer, prior to seedfall of a mast year, and where there was a seed source within 60 m. Stocking was lower when conditions were cool and wet the year before and 2 years after harvest and when the site contained extensive cover of grass or woody vegetation.



Average Percent of White Spruce Stocking in Deciduous Cutblocks

Evaluation of Banding as an Alternative for Establishing Mixedwood Stands

The objectives of this project are to demonstrate and test the potential use of patch/banding herbicide treatments and mechanical site preparation for regenerating mixedwood stands. Detailed measurement of tree growth and microclimate will provide useful information on effectiveness of these treatments and can be applied through the development of cost-effective silvicultural prescriptions.

The lead investigator of this project is Phil Comeau. The MWMA contributed a total of $101,000.00 to this project. This project continues with support from the companies involved.

Aerial view of a banding treatment

This study compared herbicide (ARSENAL) application in bands, spots and broadcast. The band herbicide applications are showing effective control of aspen and other vegetation within the treated bands, and a sharp boundary between treated and untreated. Spot treatments with

ARSENAL achieved moderate to good control of aspen, poplar and birch, moderate control of woody shrubs, and variable control of *Calamagrostis* at the end of 2 years.

Broadcast treatments show good control of aspen, poplar and birch and woody shrubs and variable to good control of *Calamagrostis.* Lack of protection in the broadcast treated ARSENAL strips appears to be increasing winter injury and frost injury problems for white spruce in one of the two sites.

6 year measurements were completed at 3 sites in 2014 and analysis of these data remains to be completed. Year 10 measurements were completed for the oldest 2 installations in the fall of 2015 and are planned for fall of 2017 for the other 3 installations. Thinning and radial motor-manual brushing treatments have only been completed in 2014 for one installation, and in 2015 for two additional installations. The remaining two installations are scheduled for treatment in 2016.

ARSENAL Spot Treatment at Sulphur Lake

Benchmarking Natural Origin Stand Development

The objective of this project was to obtain benchmark data from natural (fire) origin pure and mixedwood stands and compare to post-harvest stand data. A secondary objective was to provide a range of juvenile natural origin stand conditions (density, stocking, size distribution) to assist in initializing growth and yield models such as the Mixedwood Growth Model (MGM) and the Growth and Yield Projection System (GYPSY). The total MWMA budget for this project was $43,000. An additional $77,062 was provided by FRIAA. The final report was received in 2009.

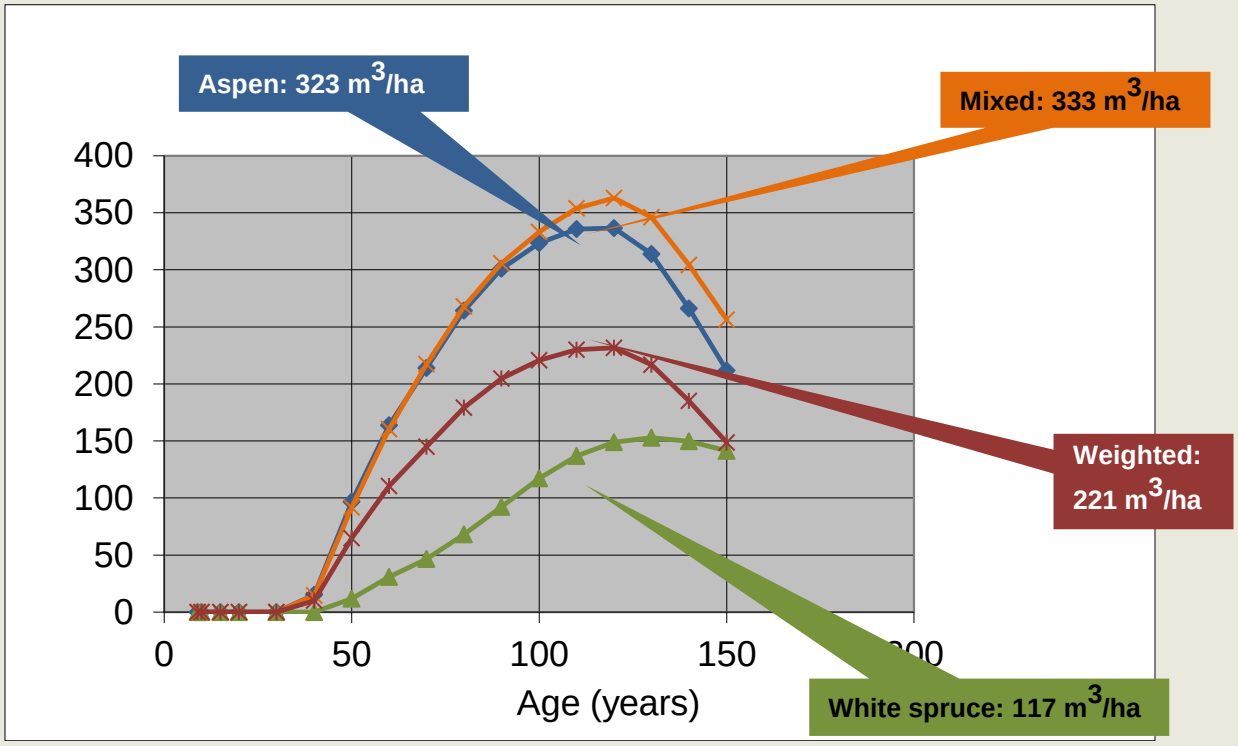
Natural regeneration 14 years after wildfire.

Key findings and recommendations for forest management were extracted from the following publication that has been produced from this project:

- **Gärtner, S. M., M. Bokalo, S.E. Macdonald, and K. Stadt.** 2014. *Variation in post-wildfire regeneration of boreal mixedwood forests: underlying factors and implications for natural disturbance-based management.* New Forests 45:215-234.

The key findings of the study were:

- There was high variability in the regeneration attributes between and within burns;
- Pre-fire pure conifer (white spruce) stands have the highest proportion of un-stocked area compared to pre-fire mixedwood or pure deciduous stands;
- In both post-fire regeneration and cutblocks:
    - The dominant species in terms of frequency and height was aspen;
    - When conifer regeneration occurred it was mostly pine;
    - White spruce regenerated in low densities and the seedlings were small;
- At performance age:
    - the plantations had much higher overall stocking;
    - the planted white spruce was much taller;
    - aspen densities and heights were similar in post-fire and post-harvest;



MGM predicted volumes in white spruce, aspen and mixed polygons and the area weighted total volume.

Recommendations for forest management by the study's authors include:

- In order to learn about natural post-fire dynamics in boreal mixedwood forests a representative set of stands should be left un-salvaged within each fire;
- To provide a seed source for natural white spruce regeneration after fire, individuals or patches of white spruce should be retained (not salvaged);
- The 30 cm height limit for white spruce at performance age represents the natural situation better than the greater heights and/or free-to-grow requirements of previous regeneration survey protocols;
- Under the natural dynamics of boreal mixedwoods, to get a similar conifer proportion as the pre-disturbance state, a longer rotation would be necessary;
- Under extensive management, allowing lower percentages of white spruce in stands and on the landscape should be considered acceptable in return for higher proportions of mixedwood stands on the landscape.

The researchers also noted that:

- In the areas studied, managed post-harvest plantation yields (conifer and total) on upland mixedwood sites can be expected to be higher than yields from natural fire-origin stands because of higher conifer densities and the lower proportions of un-stocked areas;
- Using these data as input variables for MGM results in average stand volume forecast of 220 m^3, which similar to empirical yield curve forecasts based on post-fire PSPs.

Growth and Yield Implications of Understory Protection

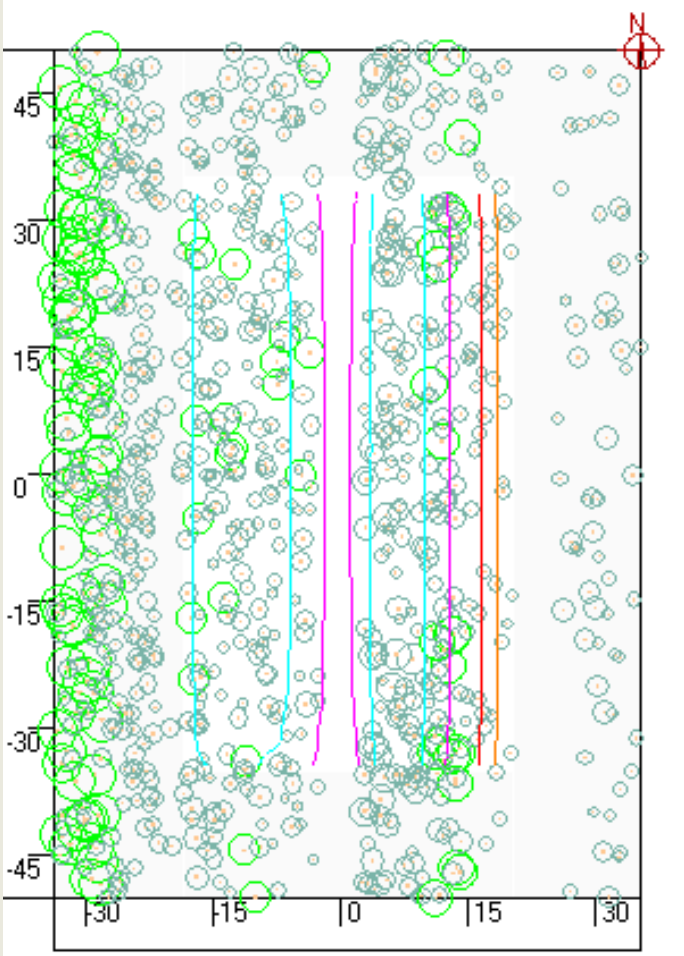
This project aimed to evaluate and refine the multi-strata version of the Mixedwood Growth Model using semi-spatial understory protection data.

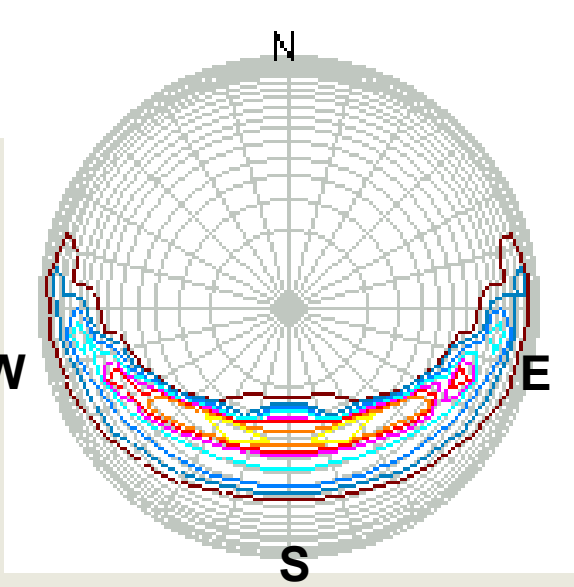
The lead investigator for this project was Dan MacIsaac from the Canadian Wood Fibre Centre, Canadian Forest Service in collaboration with the MGM modellers Dr. Mike Bokalo and Dr. Ken Stadt, University of Alberta. The total MWMA budget for this project was $110,000. The final report was received in 2009.

Multi-strata MGM was enhanced by creating a light availability model that would reflect the influence of one stratum on another, i.e. aspen residual shading effect on the spruce understory and the spruce understory shading effect on the regenerating aspen on the machine corridor. The light model was tested with 44 hemispherical photos taken in machine corridors with varying densities of surrounding white spruce. The fit was unbiased, with an R^2 of 0.48. The light level in each stratum was then used as a modifier for tree growth rates.

To test these modifications to MGM, data from the Hotchkiss River Understory Protection Demonstration site (1993-2008) was compiled from all treatment units. The light modification approach in MGM validates well for the growth of individual white spruce.

Schematic illustrating the shading effect





Shading effect as influenced by the sun's pass (cardinal direction)

A user workshop was held on May 20th, 2010 at the University of Alberta and the multi-strata version of MGM was made publicly available.

Dynamic Aspen Density Experiment

The Dynamic Aspen Density Experiment (DADE) was initiated in 2007 and the re-measurements of the PSPs will be long-term. To the end of 2013, the MWMA had spent $526,286 and FRIAA $475,000 on this project. This project will continue with the Forest Growth Organization of Western Canada.

The objective of DADE is to quantify the competitive interactions between aspen and spruce in 17 year- and 22 year-old stands. An understanding of the stand dynamics at this stage of stand development is seen as crucial for being able to fine-tune recently established Reforestation Standards of Alberta (RSA). Another key outcome will be the ability to refine silviculture prescriptions in young mixedwood stands so as to achieve intended objectives. For example, how many aspen trees are needed need to produce a 'CD' or 'DC' stand at 60 years of age?

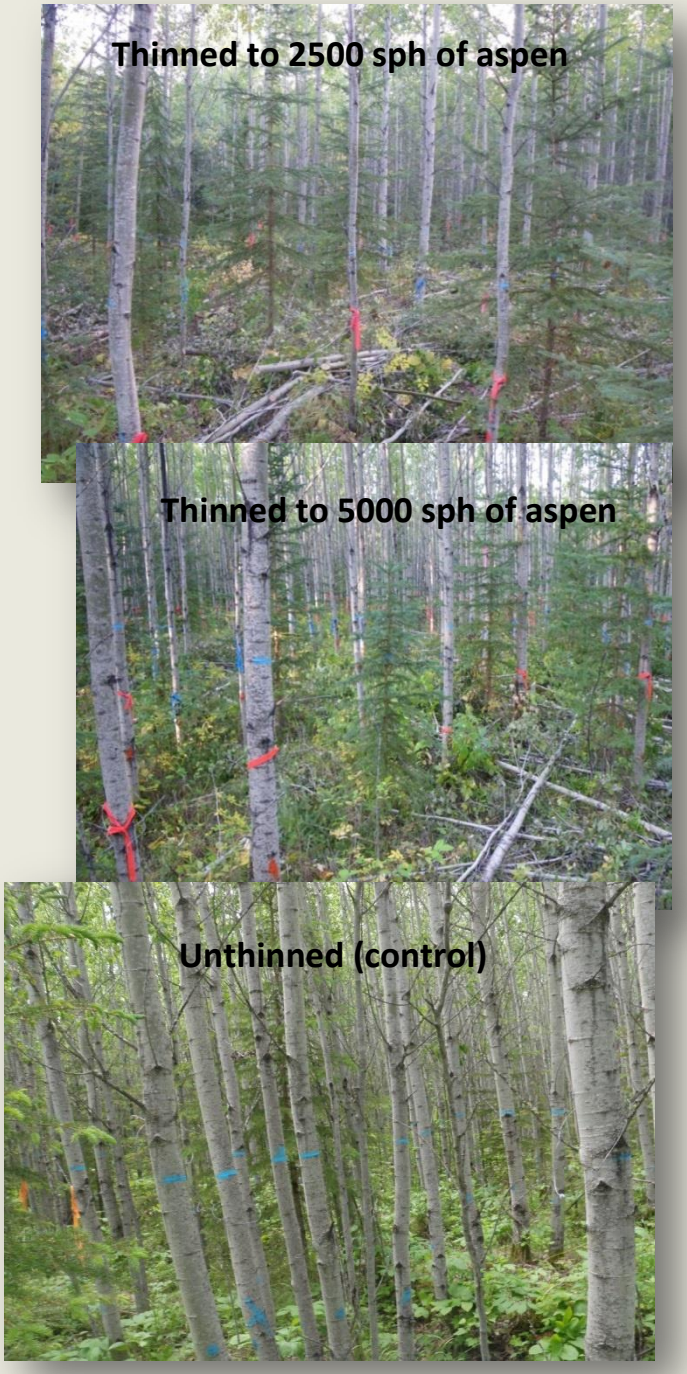
The original intent of DADE was to sample mixedwood regenerating stands of two ages (17 and 22 years) in the Lower Foothills and Central Mixedwood ecoregions and to replicate each combination 5 times for a total of 20 installations. The goal was to establish two installations in each MWMA member's operating area. Due to the difficulty of finding suitable stands in the Lower Foothills ecoregion, the ecoregion dimension of the sampling design was discontinued, and installations were located only in the Central Mixedwood ecoregion. The revised sampling design resulted in seven installations being established in 17- and in 22-year old stands each.

Over the first three years of the project (2007, 2008, 2009), 14 installations were completed across Alberta, Lac La Biche and Calling Lake (Alberta Pacific's Forest Management Agreement (FMA) area) Peace River (Daishowa Marubeni FMA area), and Drayton Valley (Weyerhaeuser Pembina FMA area). Each installation consists of five treatment units where aspen has been thinned to one of five prescribed densities (0, 1000, 2500, 5000 stems/ha, and

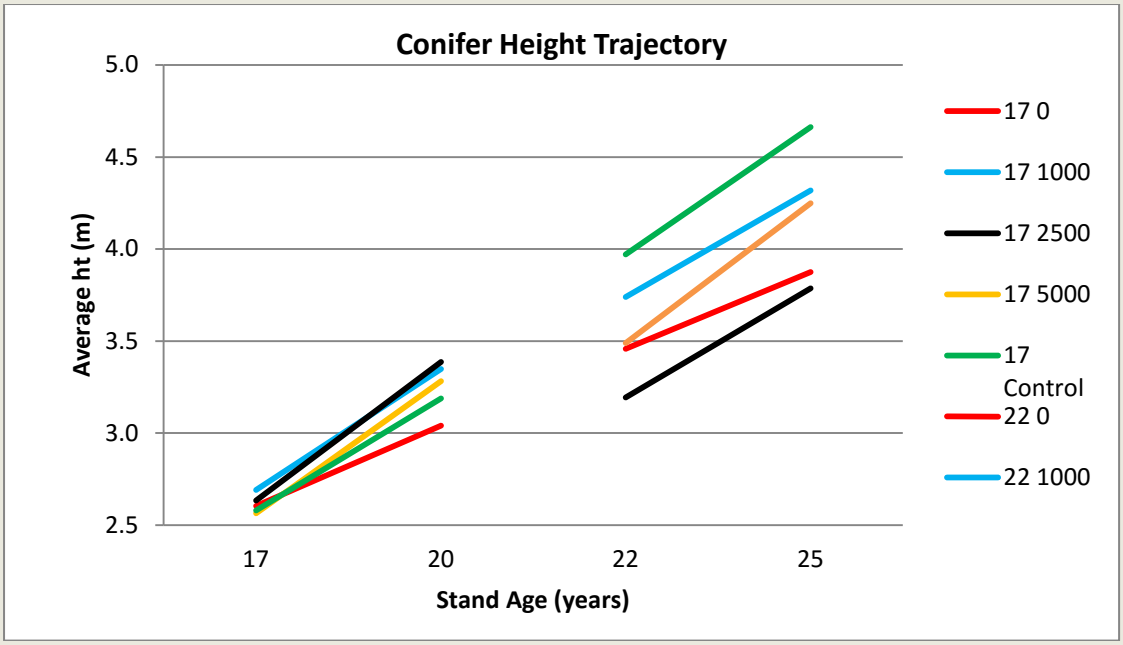
control (no thinning)). Within each treatment unit, a permanent sample plot was established to monitor the growth of remaining aspen and spruce trees, and to quantify mortality and ingress. Initial project plans called for PSP re-measurements three- and five-years after establishment.

One of the 2007 installations, and two of the 2008 installations were destroyed by triclopyr basal-bark herbicide applications, which were completed under a FRIAA administered Forest Worker Employment Program. FRIAA agreed to provide funding in the amount of $ 115,000 to re-establish lost installations. This was planned to occur in 2011, but difficulty in finding suitable replacement sites delayed re-establishment of the new sites until the spring of 2015. Two replacement sites were installed on the Millar Western FMA and a third on the Tolko High Level FMA.

To date, three-year response data have been collected for 11 installations (established from 2007 – 2009).



Preliminary analysis indicates that conifer height, diameter and volume respond to the release treatments in the magnitude of thinning. As illustrated below, one exception is height response in the installation that was thinned to 0 stems per hectare aspen, which is lower than expected. This was due to snow press and blowdown that occurred in this treatment.



5-Year Conifer Height Trajectories for all Treatments and two Populations

Table 6 lists establishment and re-measurement information for each installation. Due to budget constraints, the 5-year re-measurement was changed to an 8-year interval (5 years from last measurement).

Table 6: DADE Establishment Dates and Re-Measurement Schedule

MWMA DADE re-measurement schedule				
Code	**Company**	**Establishment**	**3 Year re-measurement**	**8 year re-measurement**
CM 17-1	AlPac	2007	2010	2015
CM 17-2	AlPac	2007	2010	2015
CM 17-3	Weyco	2009	2013	2017
CM 17-4	Weyco	2009	2013	2017
CM 17-5	Weyco	2009	2013	2017
CM 17-6	Weyco	2009	2013	2017
CM 17-7	Weyco	2009	2013	2017
CM 22-2	AlPac	2007	2010	2015
CM 22-5	DMI	2008	2011	2016
CM 22-6	DMI	2008	2011	2016
CM 22-7	DMI	2008	2011	2016
CM 22-8	MWFP	2013	2016	2021
CM 22-9	MWFP	2013	2016	2021
CM 22-10	Tolko	2015	2018	2023

Project Summary

Table 7 provides a quick reference to all of the reports and publications mentioned for each project. Should you require a copy of an unpublished report, please contact Stacy Bergheim (stacybergheim.fgrow@gmail.com).

Table 7: Publications and reports

Project	Reports
MWMA General	**Press Release**
	Greenway, K. 2002. Boreal Mixedwood Crop Planning Workshop Summary. MWMA internal report.
	Gooding, S. 2005. Underplanting Aspen with White Spruce Workshop. MWMA internal report.
	Holehouse, D. 2006. *Mixedwood Management Association celebrates five years*. The Edge Forest Business. March Issue: page 13.
	Seinen, S. 2006. *Session will showcase science solutions to operational issues*. The Edge Forest Business. May Issue: page 18.
	Seinen, S. 2006. *Workshop looks at data gaps in management*. The Edge Forest Business. September Issue: page 19.
	Seinen, S. 2007. *Research project aims to improve mixed species regeneration*. The Edge Forest Business. April Issue: page 15.
	Grover, G., and Fast, W. 2007. *Alberta making strides in mixedwood management*. For. Chron. 83: 714-718.
Meta-analysis of release and underplanting treatments (Man)	**Man, R., and Greenway, K.J.** 2004. *Meta-analysis of understory white spruce response to release from overstory aspen.* For. Chron. 80: 694-704
	Man, R. 2003. *Meta-analysis of release and underplanting treatments: Research synthesis for growth and yield predictions in boreal mixedwood.* MWMA internal report, March 2003.
Developing Mixedwood Regeneration Modeling Capabilities (Fast)	**Fast, W.** 2003. *Developing Mixedwood Regeneration Modeling Capabilities.* MWMA internal report, June 2003.
Development of MW Silviculture guide: Phase I (Beckingham)	**Geographic Dynamics Corp.** 2003. *Assessment of Existing Silvicultural Systems*. MWMA internal report, September 2003.
Silviculture guide – Phase II (MWMA)	No Report – CD provided
Strip Shelterwood Understory Protection Monitoring Protocol (Fast)	**The Forestry Corp.** 2004. Strip Shelterwood Understory Protection: Protocol for Estimation of Block-Level Strata Proportions. MWMA internal report, January 2004.
	The Forestry Corp. 2003. Strip Shelterwood Understory Protection: Monitoring Protocol and Field Manual. MWMA internal report, October 2003.
Hotchkiss river mixedwood management demonstration area 10th year re-measurement and third pass harvest (MacIsaac)	**MacIsaac, D., and Krygier, R.** 2004. *White Spruce Understory Protection Research at Hotchkiss River Alberta. Tenth Year Re-Measurement and Third-pass Assessment.* MWMA internal report, December 2004.
Modeling growth of juvenile aspen and white spruce (Astrup/Larson/Coates)	**Astrup, R.** 2006. *Modeling growth of understory aspen and spruce in western boreal Canada*. Thesis submitted to UBC September 2006.
	Astrup, R., and Larson, B. C. 2006. *Regional variability of species-specific crown openness for aspen and spruce in western boreal Canada*. For. Ecol. Manage. 228: 241-250.

Project	Reports
Analyses for revision of mixedwood regeneration standards (Lieffers)	**Feng, Z., Stadt, K.J., Lieffers, V.J., and Comeau, P**. 2005. *Linking early performance of white spruce to future yield in boreal mixedwood forests.* MWMA internal report, October 2005.
	Feng, Z., Stadt, K.J., Lieffers, V.J., and Huang, S. 2006. *Estimation of site index of juvenile white spruce stands.* For. Chron. 82: 819-824.
	Feng, Z., Stadt, K.J., and Lieffers, V.J. 2006. *Linking juvenile white spruce density, dispersion, stocking and mortality to future yield*. Can. J. For. Res. 36: 3173-3182
	Lieffers, V.J., Stadt, K.J., and Feng, Z. 2007. *Free-to-grow regeneration standards are poorly linked to future growth of spruce in boreal mixedwoods.* For. Chron. 83: 818-824
	Lieffers, V.J., Armstrong, G.W., Stadt, K.J., and Marenholtz, E.H. 2008. *Forest regeneration standards: are they limiting management options for Alberta's boreal mixedwoods?* For. Chron. 84: 76-82
Influence of stand development on interactions between aspen and white spruce (Comeau)	**Filipescu, C.N., and Comeau, P.** 2006. *Influence of stand development on interactions between aspen and white spruce.* MWMA internal report, June 2006.
	Filipescu, C.N., and Comeau, P. 2007. *Competitive interactions between aspen and white spruce vary with stand age in boreal mixedwoods.* For. Ecol. Manage. 247: 175-184.
Effects of aspen density and duration of vegetation control on competition and MW stand development (Pitt/Comeau)	**Man, C.D., Comeau, P.G., and Pitt, D.G.** 2008. *Competitive effects of woody and herbaceous vegetation in a young boreal mixedwood stand.* Can. J. For. Res. 38: 1817-1828.
Adaptive management of mixedwoods to maximize fibre recovery (Lieffers/Sidders)	**Lennie, A.D., Landhausser, S.M., Lieffers, V.J., and Sidders, D.** 2009. *Regeneration of aspen following partial and strip understory protection harvest in boreal mixedwood forests.* For. Chron. 85: 631-638.
	Marenholtz, E.H., Lieffers, V.J., Silins, U. 2010. *Evaporative demand across a range of microsites in partial cut boreal forests*. Scandinavian Journal For. Res. 25: 2, 118-126.
Modeling Mid-rotation growth and mortality in Boreal Mixedwoods (Stadt)	**Dawson, A., K. J. Stadt, J.-G. Huang, and P. G. Comeau.** *Predicting white spruce mortality from retrospective data: competition versus recent growth.* To be submitted to For. Ecol. Manage. in 2016
	Huang, J. G., K.J. Stadt, A. Dawson, and P.G. Comeau. 2013. *Modeling Growth-Competition Relationships in Trembling Aspen and White Spruce Mixed Boreal Forests of Western Canada.* PloS one, 8(10), e77607.
	Osika, D., K.J. Stadt, P. Comeau and D. MacIsaac. 2013*. Sixty-year Effects of Deciduous Removal on White Spruce Height Growth and Site Index in the Western Boreal.* Can. J. For. Res. 43(2): 139-148, 10.1139/cjfr-2012-0169. Published on the web 13 November 2012.
Boreal Forest Mortality Modeling (Dawson)	**Dawson, A., K. J. Stadt, J.-G. Huang, and P. G. Comeau.** *Predicting white spruce mortality from retrospective data: competition versus recent growth.* To be submitted to For. Ecol. Manage. in 2016
Natural Regeneration of Spruce in Mixedwoods Following Harvest (NSERC IPS)	**Martin-DeMoor, J., Lieffers, V.J., and Macdonald, S.E.** 2010. *Natural regeneration of white spruce in aspen dominated boreal mixedwoods following harvesting.* Can. J. For. Res. 40: 585-594
Benchmarking Natural Origin Stand Development (Bokalo/Stadt)	**Gärtner, S. M., M. Bokalo, S.E. Macdonald, and K. Stadt.** 2014.*Variation in post-wildfire regeneration of boreal mixedwood forests: underlying factors and implications for natural disturbance-based management.* New Forests 45:215-234