2010

Cooperative Forestry Research Unit Annual Report 2010

University of Maine

COOPERATIVE FORESTRY RESEARCH UNIT

2010
Annual Report

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2010 Annual Report

Wilfred J. Mercier and Andrew S. Nelson
Editors

About the CFRU

Founded in 1975, the CFRU is one of the oldest industry/university forest research cooperatives in the United States. We are composed of 28 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests.

Cooperative Forestry Research Unit
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Credits

This annual report is compiled and edited by Wilfred Mercier and Andrew Nelson, Interim Research and Communications Coordinators. Designed by Carol Nichols, University Relations Department at the University of Maine. Individual sections are written by authors as indicated, otherwise by Wilfred Mercier and Andrew Nelson. Photography compliments of CFRU archives, Mike Mardosa, University Relations, and Toby Hollis or as indicated.

A Note About Units

The CFRU is an applied scientific research organization. As scientists, we favor metric units (e.g., cubic meters, hectares, etc.) in our research, however, the nature of our natural resources business frequently dictates the use of traditional North American forest mensuration English units (e.g, cubic feet, cords, acres, etc.). We use both metric and English units in this report. Please consult any of the easily available conversion tables on the internet if you need assistance.

CFRU

1865 THE UNIVERSITY OF MAINE

A member of the University of Maine System

Center for Research on Sustainable Forests

Green Meadow and Door Mountain, Acadia National Park *Photo by Spencer R. Meyer*

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SILVICULTURE AND MODELING

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RESEARCH HIGHLIGHTS

Silviculture and Modeling

- Now at age ten, the Commercial Thinning Research Network (CTRN) expanded to include three new medium quality precommercial thinning (PCT) sites and increased the total number of trees in the database to 113,106. All three sites were harvested and measurements are on track with the schedule of activities.
  Commercial Thinning Research Network

- The hardwood regeneration improvement project is nearing completion after four years of studying the dynamics of post-treated hardwood stands. Also, a new investigation of hybrid poplar performance in the region was presented. Results suggest that clone NM6 had the greatest performance, but the yields were all less than those found in other regions.
  Hybrid Poplar Productivity

- During the second year of the project refining the Forest Vegetation Simulator (FVS) Northeast Variant, researchers continued to fix errors in the data set, develop equations for height-to-crown base and develop a regional index of site productivity. A beta version of the model should be available by summer 2011. Refinement of FVS

- Stem taper and volume equations were developed for most softwood species in the Acadian Region. These equations have been found to outperform the current Honer equations and will be incorporated into the larger CFRU modeling efforts.
  Taper equations

Wildlife Habitat and Biodiversity

- A study is near completion documenting changes in deer wintering areas (DWAs) in northern Maine from 1975 to 2007. Researchers found that current DWA zoning in northern and western Maine are not achieving their objectives, and suggest that additional zoning will not meet desired objectives of the state in the future without a new landscape approach. Deer Wintering Areas

- Cycles of snowshoe hare populations greatly affect the persistence and reproduction of lynx on the landscape. During the 2009-2010 season, researchers found the lowest hare densities in post-clearcut stands since monitoring began in 2001, but they also found that 2nd-stage overstory removal shelterwood harvests create stand conditions that may support high hare densities. Long-term Snowshoe Hare Monitoring

Mark Doty
Chair, Advisory Committee

CHAIR'S REPORT

My first year as chair proved to be both challenging and rewarding. Special thanks go to John Bryant for the invaluable guidance he provided as past chair, as well as to Kip Nichols and Bill Patterson for their insightful counsel in working through the issues faced by the Executive Committee. The economy remained sour for our members and created a dues issue, which the Advisory Committee worked its way through in a professional manner that resulted in full funding and all members still in place.

From the dues issue came the Dues Committee, which examined the dues structure, long-term viability, and sustainability of the CFRU. The Dues Committee recommended that there be no change to the current dues structure, but that dues be indexed for inflation beginning in several years, and that member retention and recruitment be the focus of a committee that is to be put into place. Thank you to John Bryant, Gordon Gamble, Steve Coleman, Bill Paterson, Kevin McCarthy, Bob Wagner, and Wil Mercier for their work on this committee.

The CFRU has said goodbye to our very capable Associate Director Spencer Meyer as he takes on new responsibilities as the Associate Scientist of Forest Stewardship at the Center for Research on Sustainable Forests (CRSF) and pursues his Ph.D. In the interim, Wil Mercier has stepped in to bridge the gap until a full time Assistant / Associate Director can be found. The search is on far and wide, with interviews scheduled.

Thanks to Bob Wagner, Director of the CFRU, Director of the School of Forest Resources, and Director of the CRSF, who remains the constant that continues to keep the past in focus so that we do not need to learn old lessons again, while ably leading the CFRU on to fulfill our mission.
The Spring CFRU Forester's Workshop, "Lessons from the Past, Research for the Future", was a success, helping the participating foresters and member companies learn about recent CFRU research. A wide variety of topics, presented in half-hour bites, served to keep the interest-level up. Topics included silviculture, biomass, spruce budworm, wildlife and biodiversity, along with carbon and climate change.

The Fall Field Tour "Maine's Bioenergy Marketplace: What You Need to Know" proved to be a big draw. Presentations covered Players and Future Markets, Key Industry Issues, and Hot Topics, closing with a tour of the Old Town Fuel and Fiber biofuels plant. If you could not make the meeting and tour, it is worth checking out the presentations on the CFRU website.
I would like to thank the CFRU Advisory Committee members for their insight and cooperative spirit as we work together toward our shared goal of research and technology transfer. I look forward to another productive year building a stronger CFRU.

Robert Wagner
Director, CFRU

DIRECTOR'S REPORT

Despite the continuing financial difficulties with Maine's forest products industry due to low housing starts and other pressures, our member organizations continued to provide full support for CFRU research to improve their forest management efforts. Our membership remained stable this year. As always, we greatly appreciate the confidence that our members have in the University of Maine and the program that we deliver together.

This year ended the term of John Bryant (American Forest Management) as Chair of our Advisory Committee. I thank John for his steadfast leadership through the dues challenges last year, and his efforts to get CFRU on more sustainable footing over the long-term. Mark Doty (Plum Creek) did a wonderful job picking up the reins from John this year and has provided us with consistent and strong leadership. The other members of the Executive Committee, Bill Patterson (The Nature Conservancy) and Kip Nichols (Seven Islands) have provided strong support as well.
Our Cooperating Scientists (Drs. Jeff Benjamin, Dan Harrison, Bob Seymour, and Aaron Weiskittel) continued to provide us with strong research leadership in forest operations, wildlife ecology, silviculture, and forest modeling. I greatly appreciate their efforts in keeping the CFRU doing cutting edge research that is relevant to our members. Rosanna Libby also continued to do a great job in providing administrative support for the CFRU.

A major staff change in CFRU occurred this year when Spencer Meyer left the CFRU as Associate Director to return to school to pursue a Ph.D. at UMaine. However, Spencer will not be far way from CFRU as he also took on a half-time position as Associate Scientist for the Center for Research on Sustainable Forests (CRSF). We wish Spencer the best of luck in his new pursuits. Spencer was associated with CFRU for eight years, first as a M.S. student on the Commercial Thinning Research Network, then as Research & Communications Coordinator, and finally as Associate Director. During that time, Spencer's passion for the CFRU consistently came out in his outstanding communication and leadership efforts. He set the highest standard for every annual report, research note, workshop, field tour, conference, meeting, web page, or poster display that he delivered for the unit. He will be sorely missed in this regard and has created a tough act to follow for his successor. A national search is being conducted for his replacement and the position should be filled early in 2011.

Robert G. Wagner
CFRU Director

MEMBERSHIP

Major Cooperators

Appalachian Mountain Club
Baskahegan Company
Baxter State Park, Scientific Forest Management Area
Black Bear Forest, Inc.
Canopy Timberlands Maine, LLC
Clayton Lake Woodlands Holdings, LLC
EMC Holdings, LLC
Frontier Forest, LLC
Huber Engineered Woods, LLC
Huber Resources Corporation
Irving Woodlands, LLC
Katahdin Forest Management, LLC
Maine Bureau of Parks and Lands
Mosquito, LLC
The Nature Conservancy
Plum Creek Timber Company, Inc.
Prentiss & Carlisle Company, Inc.
Robbins Lumber Company
Sappi Fine Paper
Seven Islands Land Company
Timbervest, LLC
Wagner Forest Management

Other Cooperators

Field Timberlands
The Forest Society of Maine
Finestkind Tree Farms
LandVest
Peavey Manufacturing Company

CFRU members and scientists at the 2009 Fall Field Tour: "Spruce Budworm: What's Past is Prologue"

Advisory Committee

Mark Doty, Chair, Plum Creek Timber Company, Inc.
William Patterson, Vice Chair, The Nature Conservancy
John Bryant, Financial Officer, American Forest Management
Kip Nichols, Member-at-Large, Seven Islands Land Company
Greg Adams, JD Irving, Ltd.
John Brissette, USFS Northern Research Station
Tom Charles, Maine Bureau of Parks and Lands
Steve Coleman, LandVest
Brian Condon, The Forestland Group, LLC
David Dow, Prentiss & Carlisle Company, Inc.
Claude Dufour, LandVest
Kenny Fergusson, Huber Resources Corporation
Gordon Gamble, Wagner Forest Management
Laurie McElwain, Baskahegan Company
Kevin McCarthy, Sappi Fine Paper
Marcia McKeague, Katahdin Forest Management, LLC
Jake Metzler, Forest Society of Maine
David Publicover, Appalachian Mountain Club
Carol Redelsheimer, Baxter State Park, SFMA
Jim Robbins, Robbins Lumber Company
Dan Russell, Huber Engineered Woods, LLC
Hugh Violette, Canopy Timberlands Maine, LLC
G. Bruce Wiersma, University of Maine, CRSF

RESEARCH TEAM

Staff

Robert G. Wagner, Ph.D., CFRU Director

Spencer R. Meyer, M.S., Associate Director

Wilfred Mercier, M.S., Interim Research and Communications Coordinator

Matthew Olson, Ph.D., Research Scientist

Matthew Russell, M.S., Forest Data Manager

Rosanna Libby, Administrative Assistant

Cooperating Scientists

Jeffrey Benjamin, Ph.D., Assistant Professor of Forest Operations

Daniel J. Harrison, Ph.D., Professor of Wildlife Ecology

Robert S. Seymour, Ph.D., Curtis Hutchins Professor of Forest Resources

Aaron Weiskittel, Ph.D., Assistant Professor of Forest Biometrics and Modeling

Project Scientists

Angela Fuller, Ph.D., Post-Doctoral Research Associate
The University of Maine

John Kershaw, Ph.D., Faculty of the University of New Brunswick

William B. Krohn, Ph.D., Maine Cooperative Fish and Wildlife Research Unit

Erin Simons, Ph.D., Assistant Scientist
Center for Research on Sustainable Forests

Jennifer Vashon, M.S., Maine Department of Inland Fisheries and Wildlife

FINANCIAL REPORT

Twenty-eight members representing 8.36 million acres of Maine's forestland contributed $490,001 in dues to support CFRU this year (Table 1). After providing a 25% discount to CFRU members last year, the Advisory Committee voted at the spring meeting to maintain its dues structure at 100% for this year (see 2009 Annual Report). In addition, CFRU membership remained unchanged from last year. We thank all of our members for their continued support during these tough economic times.

In addition to member dues, CFRU Cooperating and Project Scientists were successful at leveraging an additional $503,023 in grants from extramural sources to support approved CFRU projects. Of these funds, $70,000 came from the National Science Foundation as part of CFRU's membership in the national Center for Advanced Forestry Systems (CAFS), which supports our growth & yield modeling efforts. Thus, 47% of total CFRU funding came from outside sources to support our research program (Figure 1). UMaine in-kind contributions from reduced overhead was $75,384 or 7% of total CFRU funding. Total CFRU funding including these leveraged sources was $1,068,407.

Total leveraging of external funds this year meant that for every $1 in dues contributed by our three largest members (JD Irving, Wagner Forest Management, and Black Bear Forest), $6.99 was received from other CFRU member dues, $8.21 in external grants through CFRU scientists, and $1.23 in in-kind contributions from UMaine; for a total of $17.43.

As always, sound fiscal management by CFRU project scientists and staff resulted in spending $9,388 (2.4%) less than $392,824 that was approved by the Advisory Committee (Table 2). All projects came in under or on budget. No funds were spent on the spruce grouse habitat project this year as Dr. Harrison requested and received approval from the Advisory Committee to delay the start of this project by one year. CFRU research expenses by category included 46% on wildlife habitat and biodiversity, and 54% on improving growth & yield models and silviculture (Figure 2).

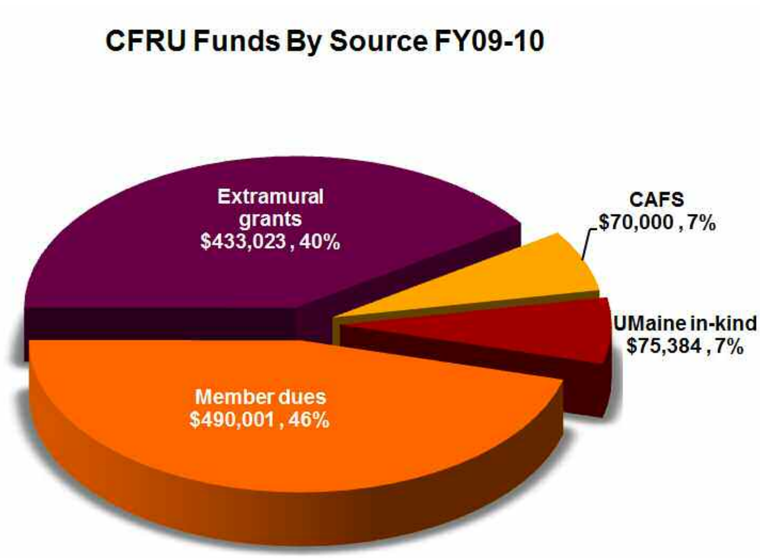


Figure 1. CFRU funds by source during FY09-10 (October 1, 2009 to September 30, 2010).

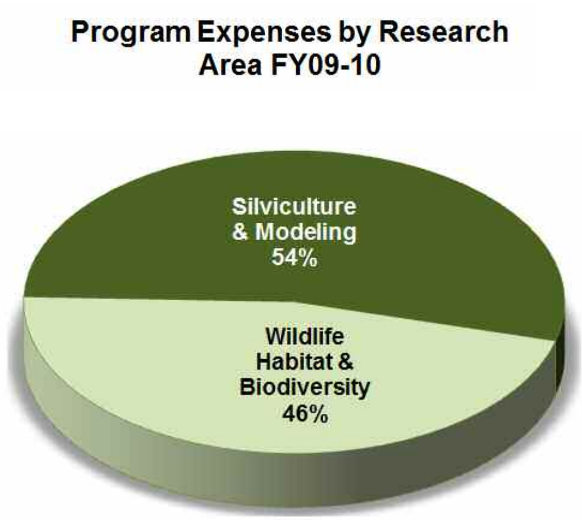


Figure 2. CFRU research expenditures by category during FY09-10 (October 1, 2009 to September 30, 2010).

Table 1. CFRU dues received during FY09-10 (October 1, 2009 to September 30, 2010).

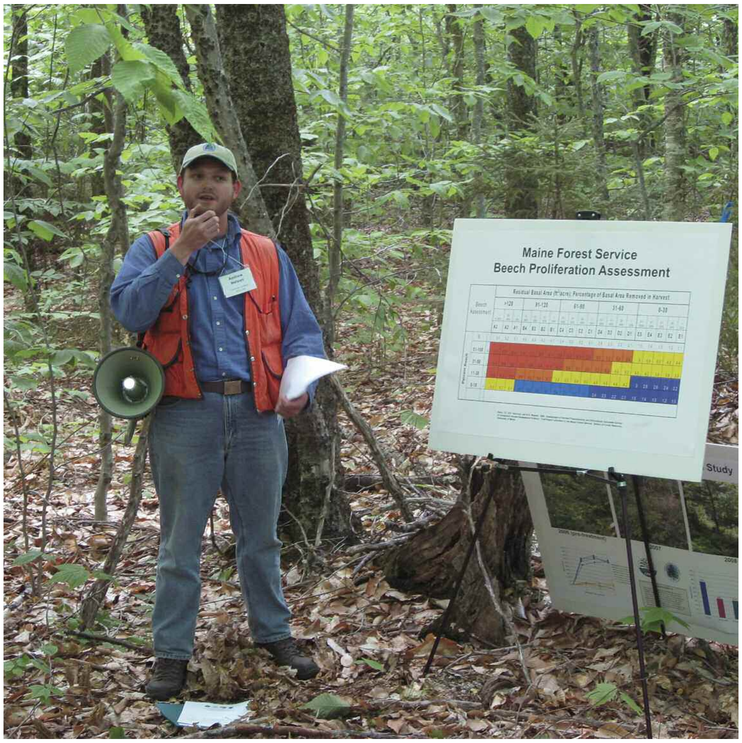
LANDOWNERS / MANAGERS	2010 Acres	Amount Invoiced	Amount Paid
Irving, J. D. Ltd.	1,255,000	$67,750.00	$67,750.00
Wagner Forest Management, Ltd.	1,155,856	$62,792.80	$62,792.80
Black Bear Forest, Inc.	968,656	$53,354.44	$53,354.44
Plum Creek Timberlands	880,000	$48,700.00	$48,700.00
Prentiss and Carlisle	815,641	$45,321.15	$45,321.15
Seven Islands Land Company	721,261	$40,366.20	$40,366.20
Maine Bureau of Parks and Lands	395,000	$22,712.50	$22,712.50
Clayton Lake Woodland Holdings	356,000	$20,470.00	$20,470.00
Huber Resources Corporation	352,437	$20,265.14	$20,265.14
Canopy Timberlands Maine	317,000	$18,227.50	$18,227.50
Katahdin Forest Management, LLC	299,000	$17,192.50	$17,192.50
The Forestland Group, LLC	249,153	$14,326.30	$14,326.30
The Nature Conservancy	177,464	$10,204.18	$10,204.18
Timbervest, LLC	121,129	$6,964.92	$6,964.92
Baskahegan Lands	101,709	$5,848.27	$5,848.27
Appalachian Mountain Club	65,224	$3,750.38	$3,750.38
Frontier Forest, LLC	53,338	$3,066.94	$3,066.94
Baxter State Park, SFMA	29,537	$1,698.38	$1,698.38
Robbins Lumber Company	27,224	$1,565.38	$1,565.38
EMC Holdings, LLC	23,526	$1,352.75	$1,352.75
Mosquito, LLC	16,222	$932.77	$932.77
LANDOWNERS / MANAGERS TOTAL	**8,364,155**	**$466,862.50**	**$466,862.50**
WOOD PROCESSORS	**2010 Tons**		
Sappi Fine Paper	1,619,074	$20,238.42	$20,238.42
WOOD PROCESSORS TOTAL	**1,619,074**	**$20,238.42**	**$20,238.42**
OTHER COOPERATORS			
Huber Engineered Woods, LLC		$1,500.00	$1,500.00
Forest Society of Maine		$1,000.00	$1,000.00
LandVest		$200.00	$200.00
Peavey Corporation[1]		$137.00	$0.00
Field Timberlands		$100.00	$100.00
Finestkind Tree Farms		$100.00	$100.00
OTHER COOPERATORS TOTAL		**$3,037.00**	**$2,900.00**
	GRAND TOTAL	**$490,137.92**	**$490,000.92**

[1] Peavey Corporation had $137 outstanding balance at the end of FY10-11

Table 2. CFRU expenses by source during FY09-10 (October 1, 2009 to September 30, 2010).

PROJECT	Principal Investigator	Approved	Revised Approved	Total Spent	Balance	% Balance
ADMINISTRATION		**$178,332**	**$178,332**	**$174,274**	**$4,058**	**2.3%**
Administration		$166,948	$166,948	$163,763	$3,184	**1.9%**
Silviculture Post-Doc		$11,384	$11,384	$10,510	$874	**7.7%**
RESEARCH PROJECTS						
Silviculture and Productivity		**$54,068**	**$54,068**	**$54,068**	**$0**	**0.0%**
Commercial Thinning Research Network	Wagner et al.	$40,902	$40,902	$40,902	$0	**0.0%**
Improving the Species Composition of Hardwood Regeneration	Wagner	$13,166	$13,166	$13,166	$0	**0.0%**
Growth & Yield Modeling		**$61,034**	**$61,034**	**$58,148**	**$2,886**	**4.7%**
Refinement of FVS-NE Individual Tree Model	Weiskittel	$25,816	$25,816	$25,816	$0	**0.0%**
Development of Regional Taper Equations	Weiskittel	$35,218	$35,218	$32,332	$2,886	**8.2%**
Wildlife Habitat & Biodiversity		**$130,190**	**$99,390**	**$96,946**	**$2,444**	**2.5%**
Trends in Habitat Supply	Harrison & Krohn	$34,000	$34,000	$33,957	$43	**0.1%**
Spruce Grouse Habitat[1]	Harrison	$30,800	$0	$0	$0	**-**
Long-term Monitoring of Snowshoe Hare Populations	Harrison	$28,790	$28,790	$28,790	$0	**0.0%**
Documenting the Response of Lynx to Hare Populations	Vashon	$26,600	$26,600	$26,600	$0	**0.0%**
ForCAST Initiative	Wiersma et al.	$10,000	$10,000	$7,599	$2,401	**24.0%**
TOTAL		**$423,624**	**$392,824**	**$383,436**	**$9,388**	**2.4%**

[1] Start of approved 4-year budget delayed one year by approval of Advisory Committee at 4-14-2010 meeting.



Andrew Nelson speaking about understory beech development and control at the 2009 NEFHFW field tour. *Photo by Spencer R. Meyer*

ACTIVITIES

Advisory Committee

The CFRU is guided by a group of forest managers who represent our cooperators forming the CFRU Advisory Committee. They are led by the Executive Committee, which this year consisted of Mark Doty of Plum Creek (Chair), Bill Patterson of The Nature Conservancy (Vice-Chair), John Bryant of Black Bear Forest, LLC (Financial Officer), and Kip Nichols of Seven Islands Land Company (Member-at-Large).

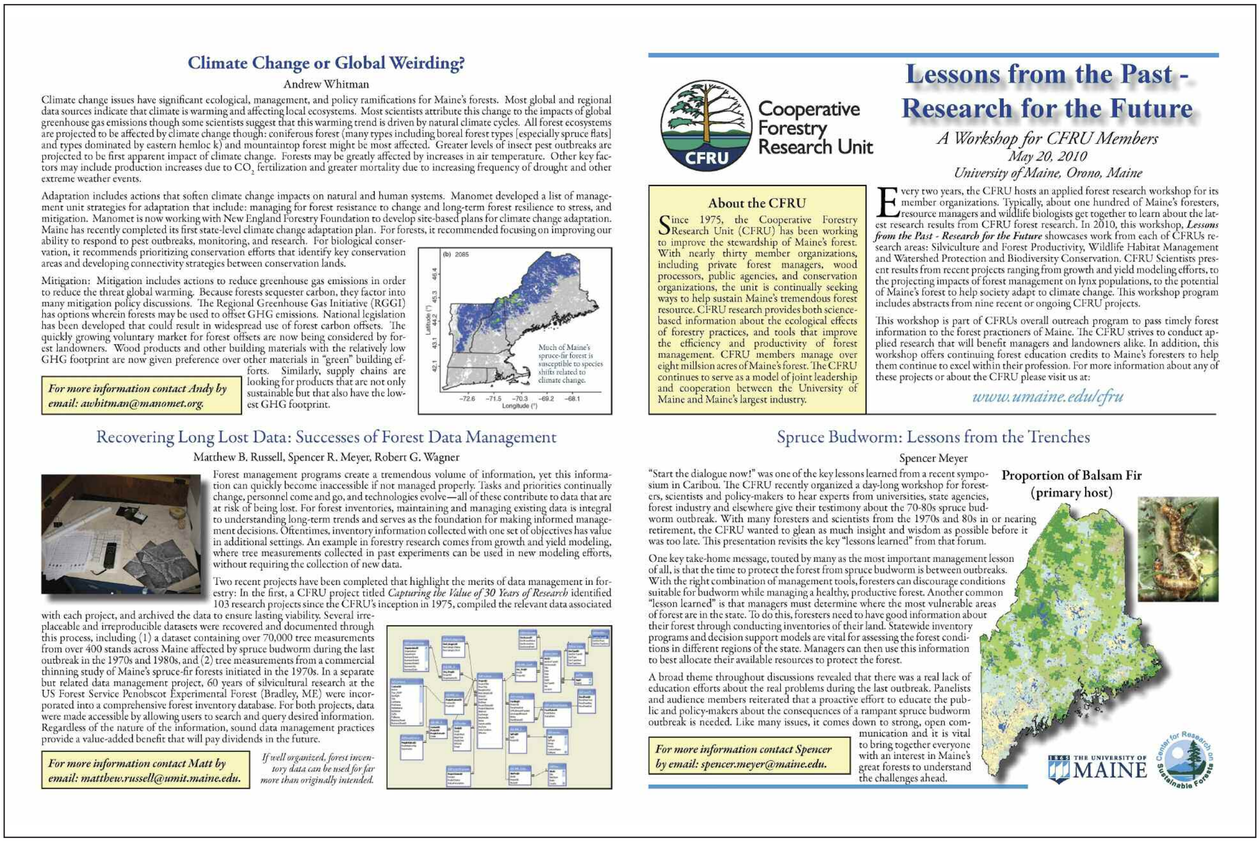
The Advisory Committee meets three times a year for business meetings. The first business meeting of the fiscal year was held on October 28, 2009 in Caribou in conjunction with the Fall Field Tour entitled "Spruce Budworm: What's Past is Prologue" (2009 Annual Report). At the second meeting of the year, held on January 27, 2010, at the University of Maine, 13 pre-proposals were presented to the Advisory Committee. Of these proposals, 7 were approved to go on to the full proposal stage, 5 were presented at the April 14, 2010 business meeting, and all 5 presented projects were approved for funding starting on October 1, 2010. Look for updates on these projects in future annual reports.

Cooperators

This year the CFRU is happy to welcome three new cooperators, North Woods ME Timberlands, LLC, St. John Timber, LLC, and Sylvan Timberlands, LLC. All three cooperators are managed and represented on the CFRU Advisory Committee by Huber Resources. Given that these cooperators purchased their land from the J.M Huber Corporation, the total number of acres represented by the CFRU remains essentially the same this year.

Personnel

This year the CFRU saw its Associate Director, Spencer Meyer, transition out of the CFRU to become a part of the Center for Research on Sustainable Forests as an Associate Scientist for Forest Stewardship. While working in this position he will also be pursuing a doctoral degree. We would like to thank Spencer for his years of dedicated service and hard work for the CFRU and we wish him the best of luck in his future endeavors. While a search committee made up of University personnel and CFRU cooperator representatives conducted a search to permanently fill the Associate Director position, Wilfred Mercier joined the CFRU team as the Interim Research and Communications Coordinator.



Climate Change or Global Weirding?

Andrew Whitman

Climate change issues have significant ecological, management, and policy ramifications for Maine's forests. Most global and regional data sources indicate that climate is warming and affecting local ecosystems. Most scientists attribute this change to the impacts of global greenhouse gas emissions though some scientists suggest that this warming trend is driven by natural climate cycles. All forest ecosystems are projected to be affected by climate change though: coniferous forest (many types including boreal forest types [especially spruce flats] and types dominated by eastern hemloc k) and mountaintop forest might be most affected. Greater levels of insect pest outbreaks are projected to be first apparent impact of climate change. Forests may be greatly affected by increases in air temperature. Other key factors may include production increases due to CO_2 fertilization and greater mortality due to increasing frequency of drought and other extreme weather events.

Adaptation includes actions that soften climate change impacts on natural and human systems. Manomet developed a list of management unit strategies for adaptation that include: managing for forest resistance to change and long-term forest resilience to stress, and mitigation. Manomet is now working with New England Forestry Foundation to develop site-based plans for climate change adaptation. Maine has recently completed its first state-level climate change adaptation plan. For forests, it recommended focusing on improving our ability to respond to pest outbreaks, monitoring, and research. For biological conservation, it recommends prioritizing conservation efforts that identify key conservation areas and developing connectivity strategies between conservation lands.

Mitigation: Mitigation includes actions to reduce greenhouse gas emissions in order to reduce the threat global warming. Because forests sequester carbon, they factor into many mitigation policy discussions. The Regional Greenhouse Gas Initiative (RGGI) has options wherein forests may be used to offset GHG emissions. National legislation has been developed that could result in widespread use of forest carbon offsets. The quickly growing voluntary market for forest offsets are now being considered by forest landowners. Wood products and other building materials with the relatively low GHG footprint are now given preference over other materials in "green" building efforts. Similarly, supply chains are looking for products that are not only sustainable but that also have the lowest GHG footprint.

(b) 2085

Latitude (°)

Longitude (°)

Much of Maine's spruce-fir forest is susceptible to species shifts related to climate change.

For more information contact Andy by email: awhitman@manomet.org.

Recovering Long Lost Data: Successes of Forest Data Management

Matthew B. Russell, Spencer R. Meyer, Robert G. Wagner

Forest management programs create a tremendous volume of information, yet this information can quickly become inaccessible if not managed properly. Tasks and priorities continually change, personnel come and go, and technologies evolve—all of these contribute to data that are at risk of being lost. For forest inventories, maintaining and managing existing data is integral to understanding long-term trends and serves as the foundation for making informed management decisions. Oftentimes, inventory information collected with one set of objectives has value in additional settings. An example in forestry research comes from growth and yield modeling, where tree measurements collected in past experiments can be used in new modeling efforts, without requiring the collection of new data.

Two recent projects have been completed that highlight the merits of data management in forestry: In the first, a CFRU project titled *Capturing the Value of 30 Years of Research* identified 103 research projects since the CFRU's inception in 1975, compiled the relevant data associated with each project, and archived the data to ensure lasting viability. Several irreplaceable and irreproducible datasets were recovered and documented through this process, including (1) a dataset containing over 70,000 tree measurements from over 400 stands across Maine affected by spruce budworm during the last outbreak in the 1970s and 1980s, and (2) tree measurements from a commercial thinning study of Maine's spruce-fir forests initiated in the 1970s. In a separate but related data management project, 60 years of silvicultural research at the US Forest Service Penobscot Experimental Forest (Bradley, ME) were incorporated into a comprehensive forest inventory database. For both projects, data were made accessible by allowing users to search and query desired information. Regardless of the nature of the information, sound data management practices provide a value-added benefit that will pay dividends in the future.

For more information contact Matt by email: matthew.russell@umit.maine.edu.

If well organized, forest inventory data can be used for far more than originally intended.

Cooperative Forestry Research Unit

CFRU

Lessons from the Past - Research for the Future

A Workshop for CFRU Members
May 20, 2010
University of Maine, Orono, Maine

About the CFRU

Since 1975, the Cooperative Forestry Research Unit (CFRU) has been working to improve the stewardship of Maine's forest. With nearly thirty member organizations, including private forest managers, wood processors, public agencies, and conservation organizations, the unit is continually seeking ways to help sustain Maine's tremendous forest resource. CFRU research provides both science-based information about the ecological effects of forestry practices, and tools that improve the efficiency and productivity of forest management. CFRU members manage over eight millsion acres of Maine's forest. The CFRU continues to serve as a model of joint leadership and cooperation between the University of Maine and Maine's largest industry.

Every two years, the CFRU hosts an applied forest research workshop for its member organizations. Typically, about one hundred of Maine's foresters, resource managers and wildlife biologists get together to learn about the latest research results from CFRU forest research. In 2010, this workshop, ***Lessons from the Past - Research for the Future*** showcases work from each of CFRUs research areas: Silviculture and Forest Productivity, Wildlife Habitat Management and Watershed Protection and Biodiversity Conservation. CFRU Scientists present results from recent projects ranging from growth and yield modeling efforts, to the projecting impacts of forest management on lynx populations, to the potential of Maine's forest to help society adapt to climate change. This workshop program includes abstracts from nine recent or ongoing CFRU projects.

This workshop is part of CFRUs overall outreach program to pass timely forest information to the forest practioners of Maine. The CFRU strives to conduct applied research that will benefit managers and landowners alike. In addition, this workshop offers continuing forest education credits to Maine's foresters to help them continue to excel within their profession. For more information about any of these projects or about the CFRU please visit us at:

www.umaine.edu/cfru

Spruce Budworm: Lessons from the Trenches

Spencer Meyer

"Start the dialogue now!" was one of the key lessons learned from a recent symposium in Caribou. The CFRU recently organized a day-long workshop for foresters, scientists and policy-makers to hear experts from universities, state agencies, forest industry and elsewhere give their testimony about the 70-80s spruce budworm outbreak. With many foresters and scientists from the 1970s and 80s in or nearing retirement, the CFRU wanted to glean as much insight and wisdom as possible before it was too late. This presentation revisits the key "lessons learned" from that forum.

One key take-home message, touted by many as the most important management lesson of all, is that the time to protect the forest from spruce budworm is between outbreaks. With the right combination of management tools, foresters can discourage conditions suitable for budworm while managing a healthy, productive forest. Another common "lesson learned" is that managers must determine where the most vulnerable areas of forest are in the state. To do this, foresters need to have good information about their forest through conducting inventories of their land. Statewide inventory programs and decision support models are vital for assessing the forest conditions in different regions of the state. Managers can then use this information to best allocate their available resources to protect the forest.

A broad theme throughout discussions revealed that there was a real lack of education efforts about the real problems during the last outbreak. Panelists and audience members reiterated that a proactive effort to educate the public and policy-makers about the consequences of a rampant spruce budworm outbreak is needed. Like many issues, it comes down to strong, open communication and it is vital to bring together everyone with an interest in Maine's great forests to understand the challenges ahead.

Proportion of Balsam Fir (primary host)

For more information contact Spencer by email: spencer.meyer@maine.edu.

THE UNIVERSITY OF MAINE

Center for Research on Sustainable Forests

2010 Cooperator's Workshop handout

2010 Cooperators Workshop

On May 20, 2010 the CFRU held its biennial Spring Forester's Workshop, which is intended as a way of transferring current CFRU research to the foresters who manage the land of our cooperators. This year's workshop was entitled "Lessons from the Past – Research for the Future" and was held at the Wells Conference Center on the University of Maine campus. Presentations covering issues such as silviculture, modeling, wildlife, biodiversity, and climate change were presented by a variety of CFRU Cooperating Scientists, Staff, and Project Scientists. More information on this event can be found on the CFRU website. The participating foresters left the day updated on the latest CFRU research with perspective on how it can apply to future issues, as well as some recurring issues, such as the spruce budworm.

Old Town Fuel & Fiber mill

Wood Chips at Old Town Mill *Photo: Reuters/Brian Snyder*

2010 Fall Field Tour

On October 7, 2010 the CFRU held its annual Fall Field Tour. This year's tour, entitled "Maine's Bioenergy Marketplace: What You Need To Know" began with lectures that examined how the past, present, and future roles of biomass fueled thermal energy plants, wood pellet plants, and liquid biofuels have created the current bioenergy marketplace within the state of Maine. Further talks addressed wood supply, harvesting technology, and economic issues associated with using biomass to produce energy. A third set of talks looked at special "hot topics", and included impacts of biomass harvesting on soils, a discussion of the recently released report from Manomet on the use of woody biomass to produce energy, as well as the results from a survey that examined the social acceptability of biorefineries in Maine. The day concluded with a brief presentation on the Old Town Fuel and Fiber facility, which is a pilot plant for producing liquid biofuels while still producing pulp, followed by a tour of the facility. The day was a success in informing CFRU members regarding a topic of growing importance to the forest industry.

Students

Several CFRU graduate students completed their degrees this year. Chris and Kate Zellers completed their Master's degrees under the advisement of Dr. Bob Seymour. We wish them the best of luck as they pursue Doctorate degrees in forestry at Purdue University. Andrew Nelson completed his Master's degree under the advisement of Dr. Bob Wagner. Andrew has decided to continue his studies here at the University of Maine, pursuing a Doctorate degree in forestry, so the CFRU can look forward to more excellent work from Andrew.

This year we also welcome a new graduate student, Patrick Clune. Patrick came to us from the state of Washington with a Bachelor's degree in forestry from the University of Washington to work on a Master's degree under the advisement of Dr. Bob Wagner. He will be analyzing data from the Commercial Thinning Research Network to produce 10 year results.

SILVICULTURE AND MODELING

Commercial Thinning Research Network: 2010 Update

Productivity of Hybrid Poplar on Forested Sites in Maine

Refinement of the Forest Vegetation Simulator Northeastern Variant Growth and Yield Model: Phase 2

Development of Regional Stem Taper and Volume Equations

Commercial Thinning Research Network: 2010 Update

Spencer Meyer

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Introduction

The CFRU Commercial Thinning Research Network (CTRN) completed its 10th season this year. As outlined in the last several CFRU Annual Reports, the network consists of two controlled studies examining commercial thinning responses in Maine spruce-fir stands. A dozen study sites were established on CFRU cooperator lands across the state beginning in 2000. The first study was established in mature balsam fir stands on six sites that had previously received precommercial thinning (PCT) and quantifies the growth and yield responses from the timing of first commercial thinning (i.e., now, delay five years, and delay 10 years) and level of residual relative density (i.e., 33% and 50% relative density reduction). The second study, also established on six sites, was installed in mature spruce-fir stands without previous PCT ("No-PCT") to quantify the growth and yield response from commercial thinning methods (i.e., low, crown, and dominant) and level of residual relative density (i.e., 33% and 50% relative density reduction). See previous Annual Reports for more thorough description of the experimental design and implementation.

Field Season

New Medium Quality PCT Sites

In 2008, the CFRU Advisory Committee approved funds to establish three new PCT sites to help us better understand the applicability of commercial thinning treatments on medium quality sites (MC-PCT). After searching the northern half of Maine in 2008 and 2009 for ideal sites, three new sites were selected. The new sites are: *PEF Compartment 29a* on the Penobscot Experimental Forest, *Dow Road* on land managed by Prentiss and Carlisle (P&C), and *Katahdin Ironworks* on land owned by the Appalachian Mountain Club and managed by Huber Resources (Figure 3). Each of the new sites received the standard CTRN treatment array, calling for seven plots to be installed with one remaining an untreated control and two each receiving a 33% or 50% thinning treatment every five years. The PEF block was only large enough to install five plots so the final treatment (otherwise planned for 2020) was eliminated at this site. After all the plots were installed at each site, complete pre-treatment

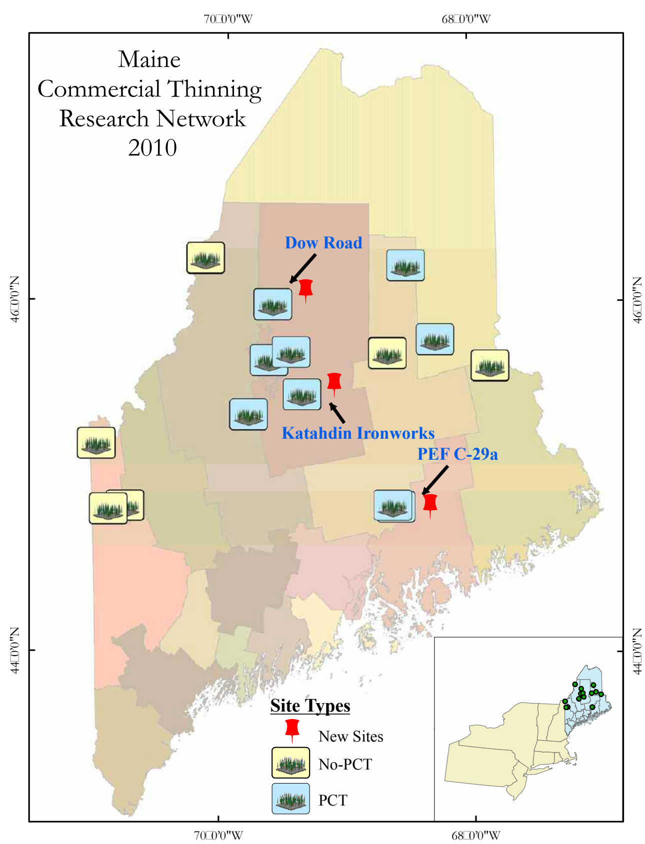

Figure 3. Map showing the location of the new CTRN MQ-PCT sites.

inventories were conducted, adding more than 3,000 more trees to the CTRN database.

The PEF harvest was conducted in February, 2010 by Gene Goodine. University Forests staff members, Robin Avery, Francis Avery and Al Kimball, were all instrumental in arrangements and contracts. In May, Huber Resources contracted with Pelletier Brothers, Inc. (of American Loggers fame) to conduct the thinning on two plots. The harvest was conducted over about a week and CFRU crews returned to the site shortly thereafter to do some final cleanup. On July 29, CFRU Interim Research and Communications Coordinator, Wil Mercier, hosted a presentation on the site for more than a dozen high school teachers as part of the Maine Tree Foundation's Teacher Tour. Finally, in early October, P & C arranged to have the Dow Road site thinned. This time, Kevin Dow of P&C and Jeannot Carrier of E.J. Carrier, Inc. arranged with John Deere and Nortrax to conduct a demonstration at the site. About 30 loggers, foresters and others convened at the Dow Road site during October 4-6 to watch a new Deere processor and forwarder team thin the stand. We were very grateful for efforts by Kevin and Jeannot for organizing the day and making sure the integrity of the study came first.

Throughout the 2010 field season, the field crew completed the annual remeasurement schedule for the PCT and No-PCT sites. Ian Foerstch (crew leader), Patrick Clune, Laura Lorenz, Amanda Sacks, Jeb Appleton, Sarah Johnson, Adam Bland, Drew Woodham, Hugh Valitus, and Wil Mercier all worked on the CTRN field crew at some point during the field season. Additionally, the crew completed the first post-treatment measurements at the Katahdin Ironworks and PEF sites.

Database Upgrades

The CTRN database developed by Spencer Meyer between 2005 and 2010 has been a valuable contribution to the project over the years providing a well organized and efficient means of storing the large volume of data collected for the CTRN. This

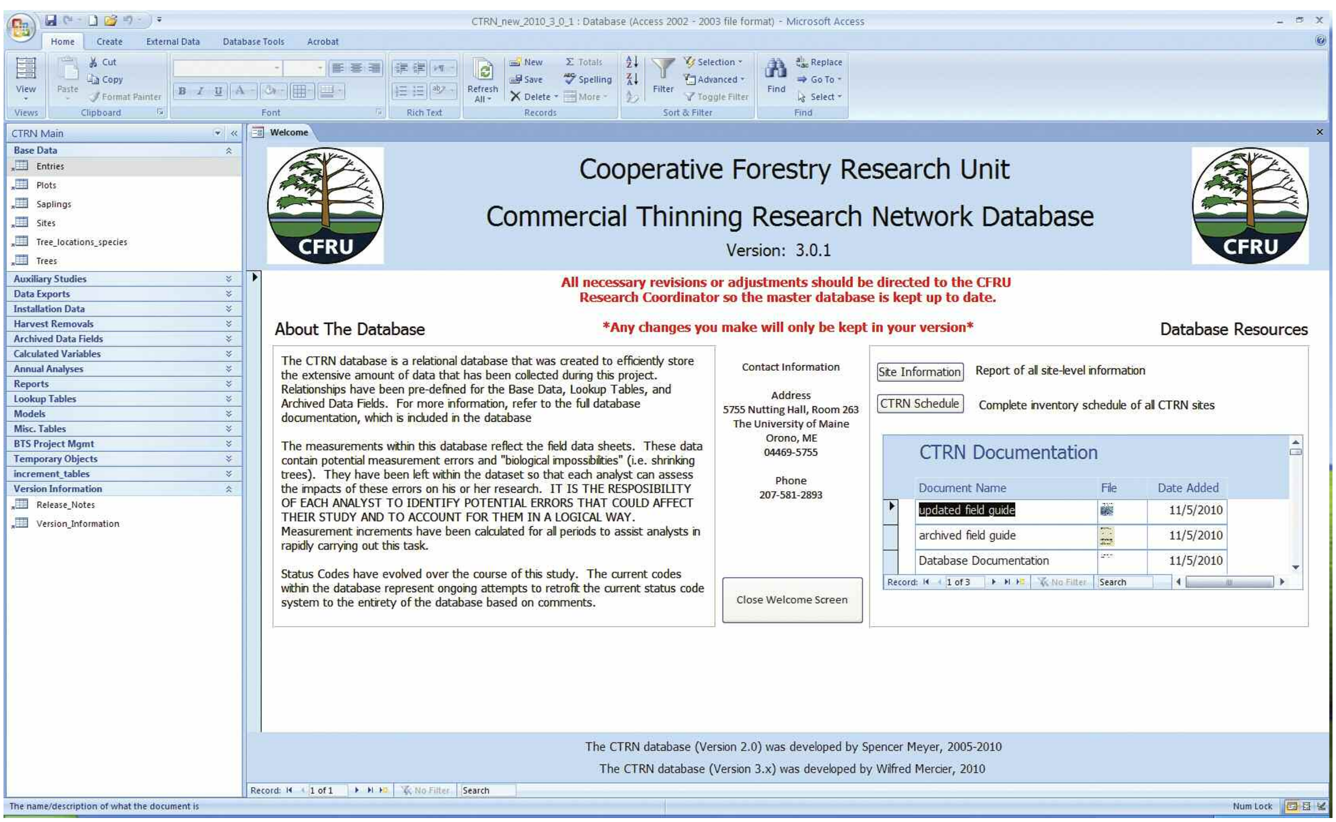

Figure 4. Screenshot of the welcome menu for the new CTRN Database.

Thinning demonstration at the CTRN Dow Road site. *Photo by Spencer R. Meyer*

year the CTRN database underwent a substantial upgrade, conducted by Wil Mercier, bringing the database to version 3.0 (Figure 4). The core structure that scientists and cooperators are familiar with is the same, but several key improvements have been made to help carry the database forward. Improvements include upgrading the Microsoft Access data file to a more recent version to improve compatibility, removal of artifact objects that have accumulated over time, and development of increment tables that allow analysts to rapidly clean the data. The changes found in the new version of the CTRN database should add to the long-term value of this already crucial tool.

Conclusion

The CTRN is now over ten years old. As growth and yield continues to be a top priority for the CFRU, this database is a crucial part of our ongoing growth and yield efforts and serves as the backbone for several modeling projects. With the three new MQ-PCT sites, the complete CTRN database now contains about 113,106 unique tree measurements on 15 sites across the state of Maine. A new M.S. student, Patrick Clune, has joined the team this year and will be advised by Bob Wagner. Patrick comes to the CFRU on a CAFS assistantship and his work will help synthesize the first ten years of growth response in the study.

Productivity of Hybrid Poplar on Forested Sites in Maine

Robert Wagner

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Hardwood Regeneration Improvement Project Update

Since our last update on the Hardwood Improvement Project in the 2009 CFRU Annual Report, we completed all analyses and reporting on the Beech Control and Hardwood Spatial Patterns studies, and presented them in Andrew Nelson's M.S. thesis. A manuscript describing the 3rd-year results from the beech control study has been accepted for publication in the Northern Journal of Applied Forestry, and we plan to submit the Hardwood Spatial Pattern manuscript as a companion paper in the same journal. Andrew Nelson also has applied to and been accepted as a Ph.D. student in UMaine's School of Forest Resources, and is developing a dissertation project that will continue his focus on hardwood silviculture. Initial plans for this research include investigating the environmental factors limiting forest productivity in young hardwood and mixedwood stands. The results presented here are from a preliminary study examining the early performance of four clones of hybrid poplar in a controlled experiment on the Penobscot Experimental Forest. These results were recently presented at the Eastern Canada-USA Forest Science Conference in Edmundston, NB in October 2010.

Hybrid Poplar Productivity

Introduction

Over the last decade, interest in growing short-rotation woody crops (SRWC) has increased in the Northeast in an effort to supplement bioenergy production. In their 2010 Maine State Forest Assessment and Strategies report, the Maine Forest Service outlined one of the overall goals for Maine's forests in the future is to "contribute to meeting Maine's energy needs by reducing our dependence on fossil fuels and high energy costs" (MFS 2010, p. 2). SRWC plantations have the ability to supplement current production of woody biomass in the state, since these stands can achieve much higher yields per hectare and in a much shorter time than naturally regenerated stands (Weiskittel and Timmons 2010).

One of the major limitations to supplemental SRWC production in Maine and the greater Northeast region is the lack of suitable lands for growth (Weiskittel and Timmons 2010). Hybrid poplar, which is a popular form of SRWC in many parts of the world, are typically planted on post-agricultural or abandoned pasture sites where site conditions tend to be productive and relatively uniform (e.g. Karacic et al. 2003, Dowell et al. 2009). Homogenous site conditions allow managers to manipulate resource availability to maximize use of nutrients and water, since hybrid poplar clones tend to be very demanding of both (Hansen et al. 1992). Unfortunately, a majority of the Maine landscape is dominated by forested sites with sub-optimal growing conditions (shallow, rocky, poorly-drained soils), and may be inadequate to achieve desirable hybrid poplar yields. Weiskittel and Timmons (2010) found that FIA land-use inventories in the state classify only about 625,000 acres (less than 3% of total land area) ideal for SRWC production, while forested sites with less than ideal conditions account for nearly 17.5 million acres (about 85% of the total land area).

Therefore, the overall goal of this study was to investigate the growth and survival of four different clones of hybrid poplar on typical forested sites in Maine to test their suitability for and quantify their productivity on sub-optimal sites.

Methods

We used measurements from an existing experiment that was established in 2003 on UMaine's Penobscot Experimental Forest (Agenda 2020 study). The experiment consists of nine factorial treatments of different species composition (softwood, mixedwood, and hardwood) and three silvicultural intensities (low, medium, and high), plus an untreated control (Figure 5). The stand was clearcut harvested in 1995 and regenerated naturally to primarily aspen (trembling and bigtooth), birch (paper and grey) and red maple, with scattered patches of overtopped white pine, balsam fir and spruce (red and white). In 2003, the factorial experimental design was initiated by managing the stands to meet specific density and species compositional objectives. Four plots of each treatment were created for a total of 40 measurement plots. The crop-trees in the low intensity treatments received a one-time release from competition. In the medium intensity treatments, periodic control of neighbors was performed early on to ensure the survival of the crop trees. In the highest intensity treatments, all natural vegetation was removed with brushsaws and herbicides, and then planted with genetically improved white spruce and four clones of hybrid poplar that were assessed to have potential on relatively harsh sites.

The current study focuses only on two of the silvicultural intensities where hybrid poplar clones were planted, high and medium. The high treatments were planted to either complete hybrid poplar (high hardwood - HH) plantations or intermixed with

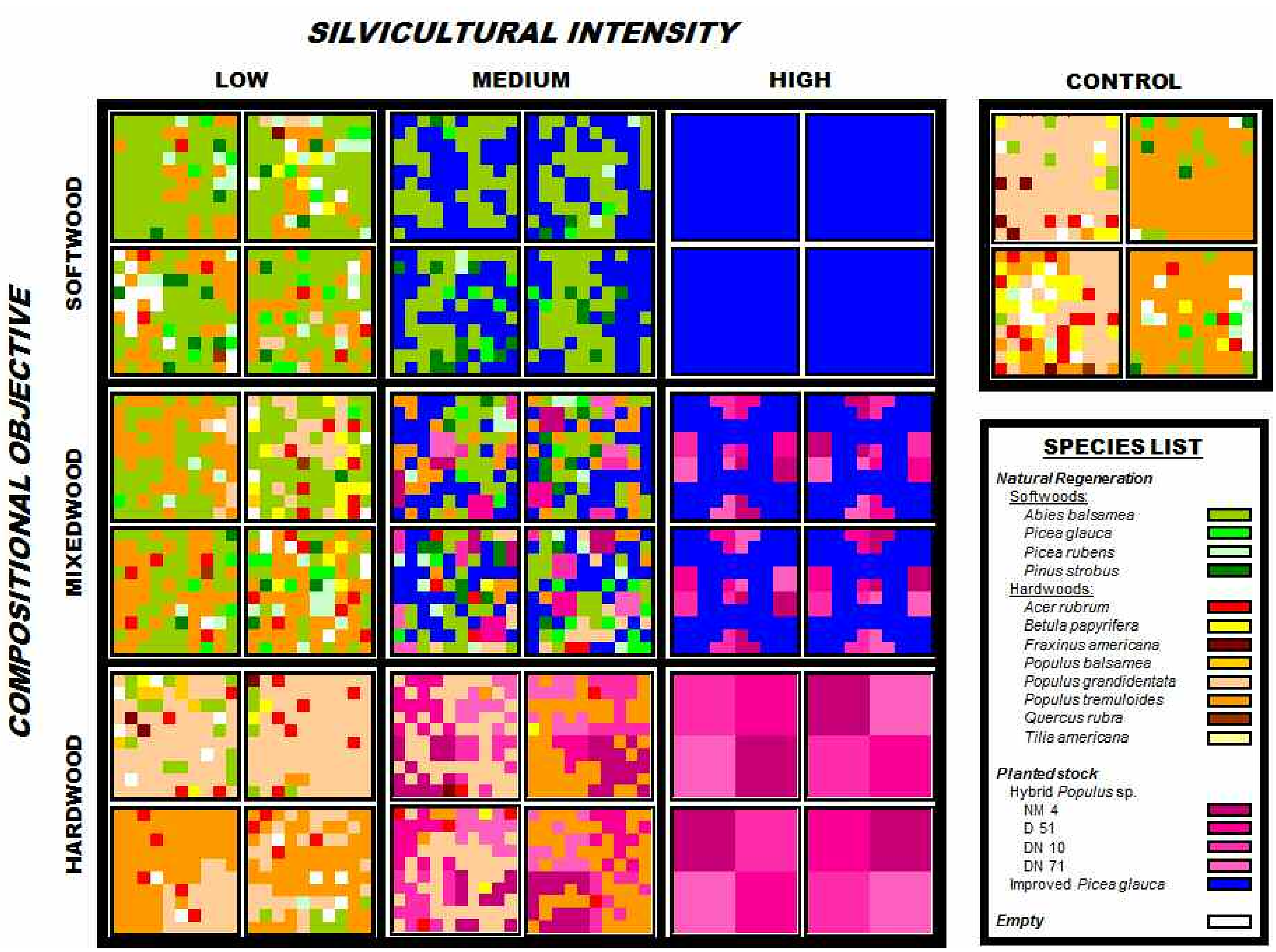


Figure 5. Experimental Design of the Agenda 2020 Study installed in 2003 in a previously clearcut stand.

planted white spruce (high mixedwood - HM) on a 2 x 2 m spacing. In the medium treatments (medium hardwood - MH and medium mixedwood - MM), hybrid poplar cutting were planted with natural regeneration to increase the stocking. Within the high and medium intensity treatments, four different clones of hybrid poplar were planted: D51 – *Populus deltoides x nigra,* DN10 – *Populus deltoides x nigra,* DN70 – *P. deltoides x nigra,* and NM6 – *P. nigra x maximowiczii*. Each clone was planted in equal quantities of 625, 200, 300 and 100 trees per hectare (tph) in the HH, HM, MH, and MM treatments, respectively. Hybrid poplar cuttings were obtained from the State University of New York (SUNY) Short-rotation Woody Crops Program.

For this analysis, we pooled results to focus on silvicultural intensity (HH-HM and MH-MM) since compositional objectives were not a significant factor in exploratory analysis. We calculated the average survival, average individual tree height, and average dry weight aboveground woody biomass (Mg/ha) of the four clones in the high and medium intensity treatments over the six years of measurement. Hybrid poplar biomass production was estimated using the regression model of Czapowskyj and Safford (1993) for hybrid poplar planted on forest sites in Maine.

Results

Overall, hybrid poplar performance was substantially greater in high intensity treatments than medium intensity treatments. Hybrid poplar performance was substantially reduced in the medium intensity treatments primarily due to competition from other hardwood species that were well established (Figure 6). Survival was too low in the medium intensity treatment to assess the productivity of the four clones and we do not believe that the planted hybrid poplar will be a major contributor to future stand dynamics in these medium-intensity treatments. It is only in the high intensity treatments, when all competing vegetation was completely removed and continuously treated on an annual basis, that the genetic expression can be observed. In the high intensity treatments, Clone NM6 *(P. nigra x maximowiczii)* had the greatest survival after six years, averaging 78%, followed by DN 70 *(P. deltoides x nigra)* with 64%, D51 (*Populus deltoides x nigra*) with 45%, and finally DN10 (*P. deltoides x nigra*) with 28%.

Clonal expression of average tree height in the high intensity plots followed the same pattern as survival (Figure 7), averaging 7.4 m for clone NM6, 5.6 m for DN70, 4.8 m for D51, and 4.4 m for DN10. Height in the medium intensity treatments did not exceed 1.2 m for any of the clones.

Stand-level aboveground woody biomass production of NM6 in the high intensity treatments was the greatest among clones, averaging 5.0 Mg/ha (Figure 8). The same decreasing order was observed in the data as found for survival and height: 3.4 for DN70, 1.7 for D51, and 1.3 mg/ha for DN10. The cumulative biomass growth of the hybrid poplar clones in the medium intensity treatments were all below 0.5 Mg/ha.

Although clone NM6 was best performer among the clones, it is important to show our results in comparison to other published studies on hybrid poplar production (Figure 9). Karacic et al. (2003) studied the production of *P. trichocarpa x deltoides* and *P. maximowiczii x trichocarpa* clones on agricultural lands in Sweden with results presented on 9 years of growth. Dowell et al. (2009) studied the production of a *P. deltoides x nigra* clone on agricultural land in Missouri, and results were based on 5 years of growth. The closest investigation of hybrid poplar performance, both geographically and with similar sites was that of Czapowskyj and Safford (1993) who planted *P. maximowiczii x trichocarpa* in eastern Maine and present the 7 year growth results. All four of our clones performed substantially lower than the clones planted on agricultural land, both in cold climates (Kracic et al. 2003) and in a warm, humid climate (Dowell et al. 2009). The clone tested by Czapowskyj and Safford (1993) had slightly greater aboveground woody biomass production after seven years than all four of the clones we tested.

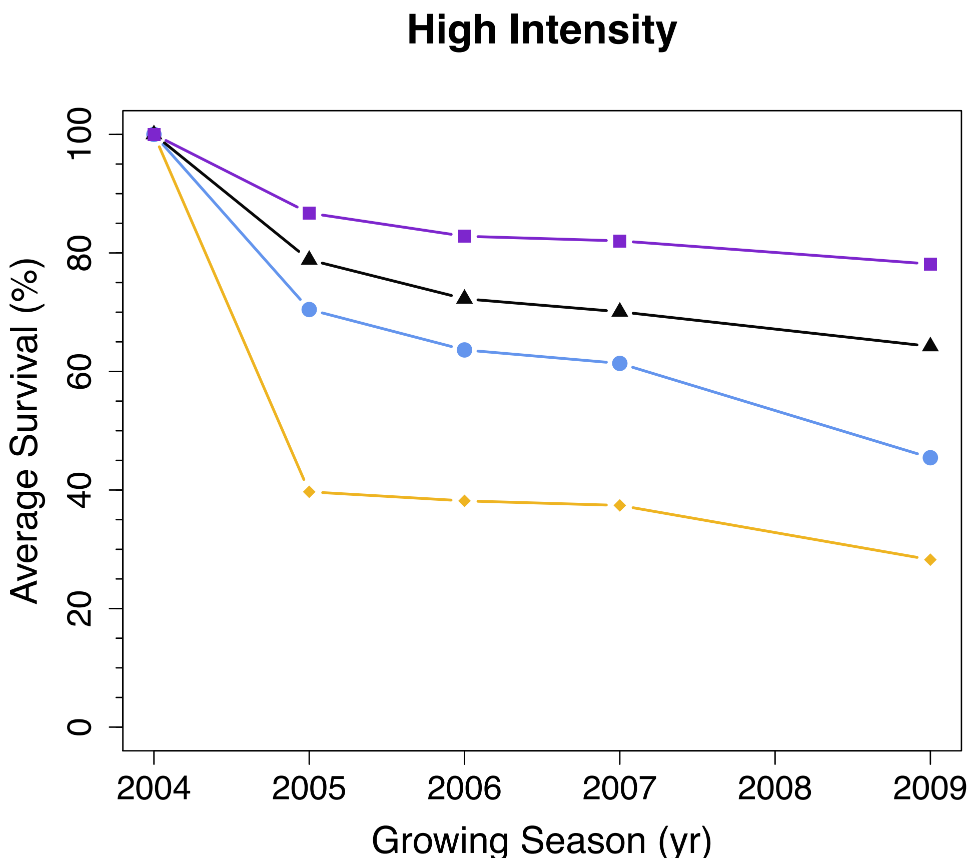
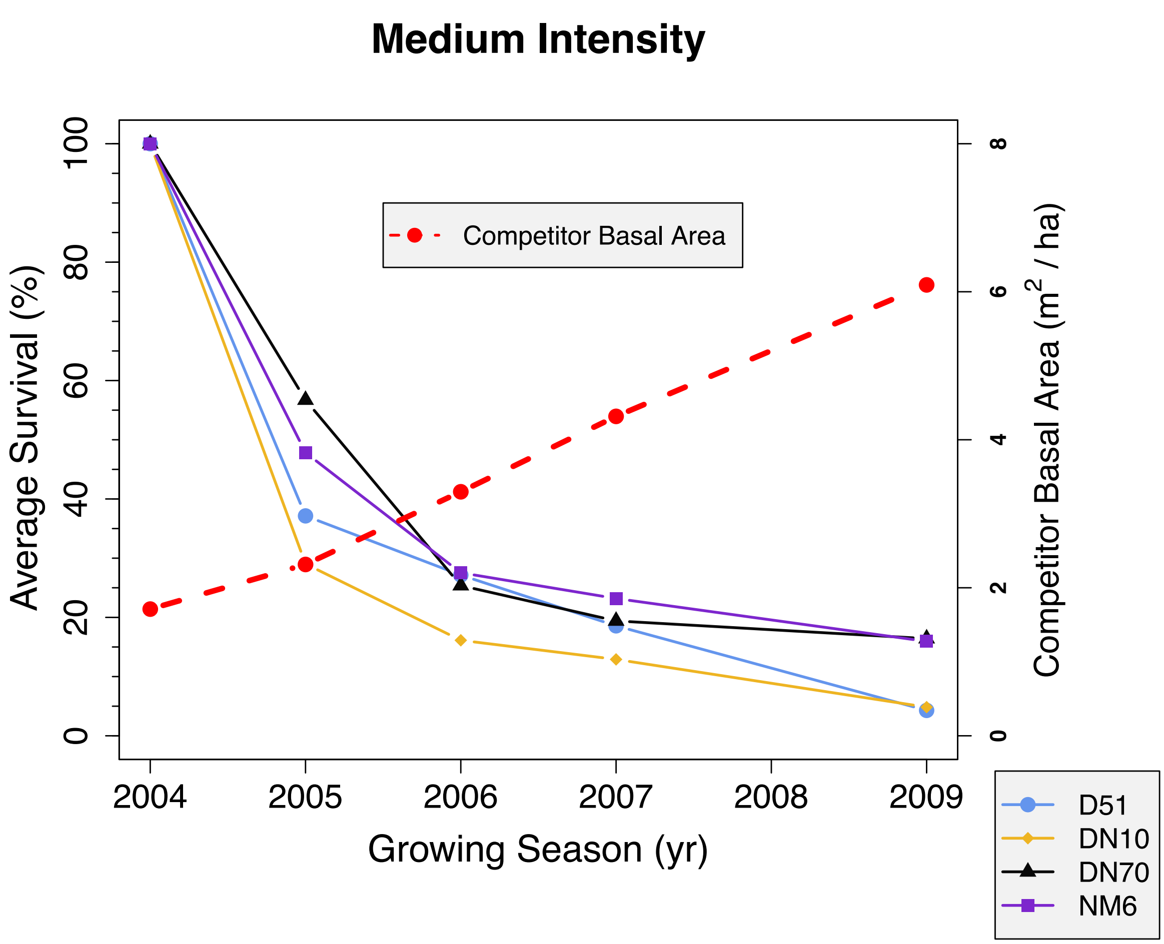


Figure 6. Survival of four hybrid poplar clones in the high intensity treatments where all competing vegetation is controlled annually and in medium intensity treatments where the clones were interplanted with natural regeneration. The red line in the medium intensity treatment shows increasing competitor basal area over time and the associated decrease in hybrid poplar survival.



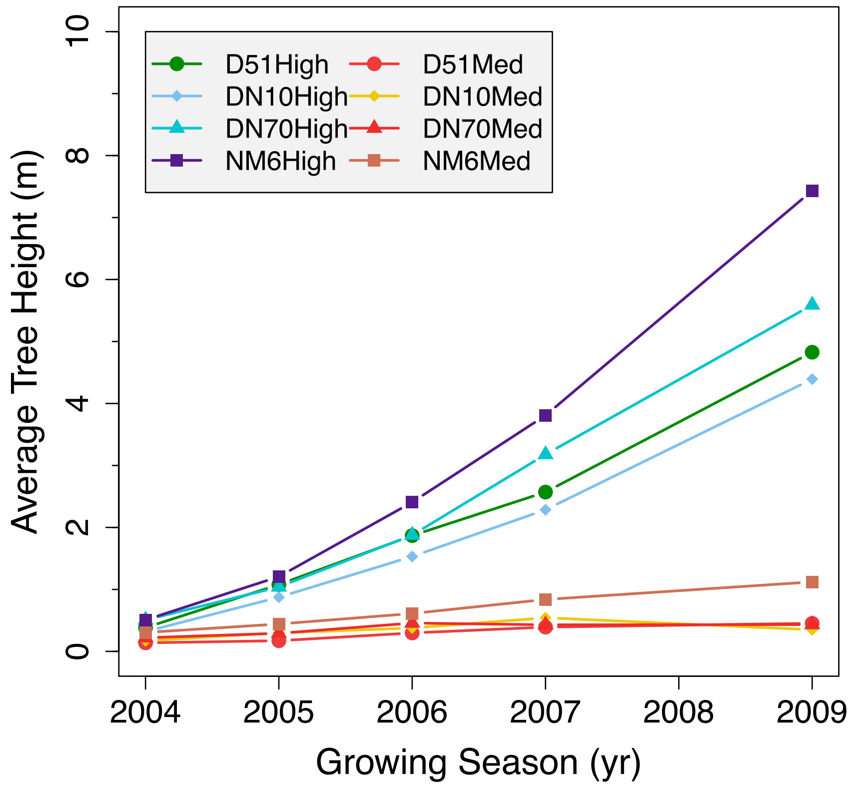


Figure 7. Change in average tree height for four clones of hybrid poplar in the high and medium intensity treatments.

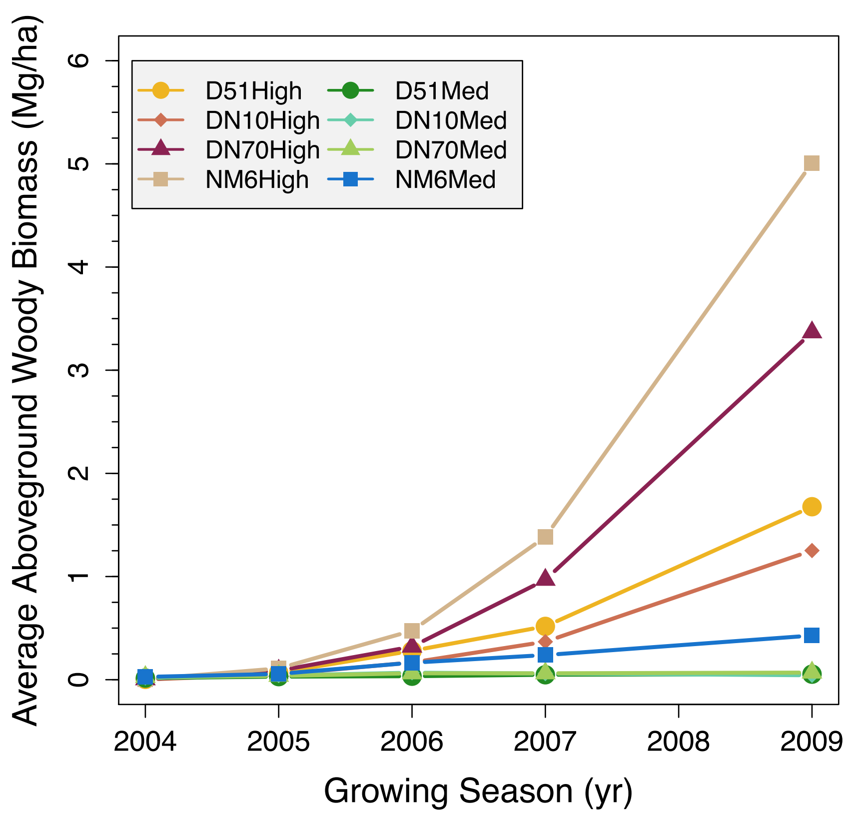


Figure 8. Cumulative biomass yield in Mg/ha over the six years of measurements for four clones in the high and medium intensity treatments.

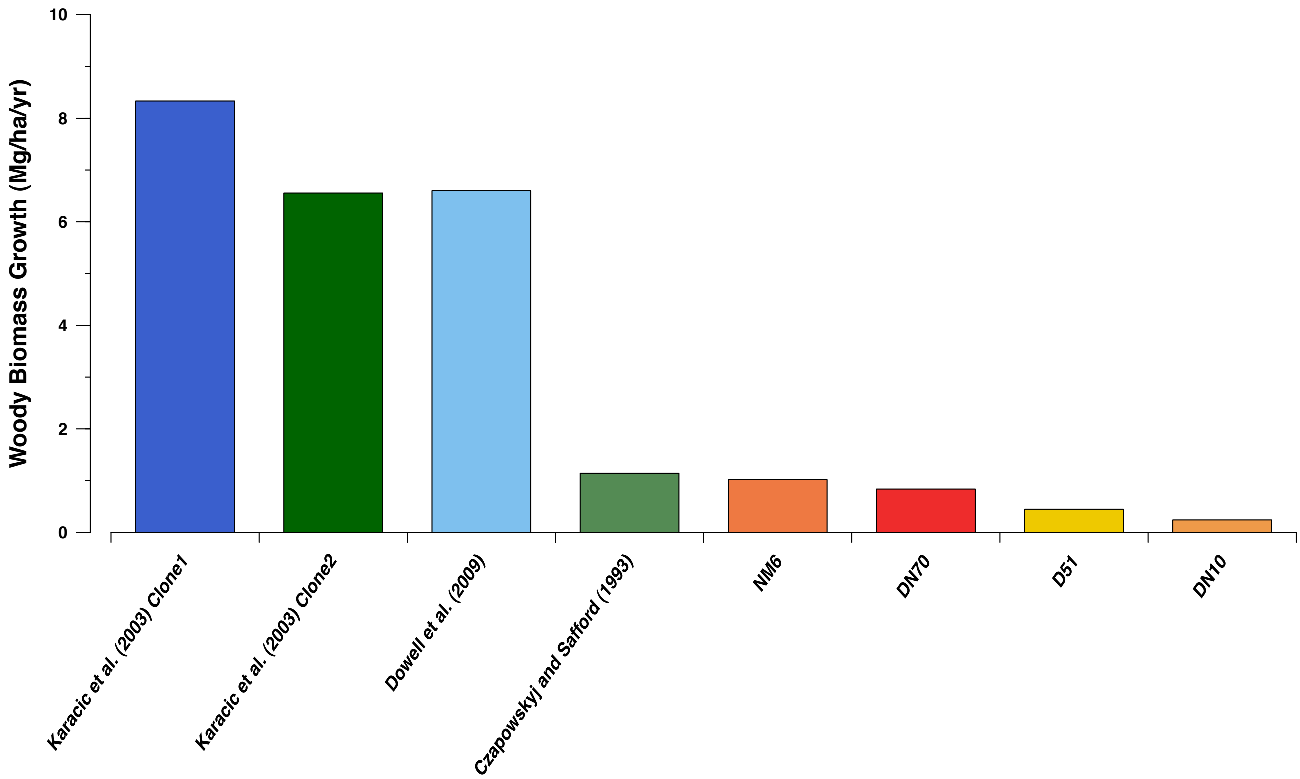


Figure 9. Comparison of the stand-level growth of the four clones tested in the high intensity plots (NM6, DN70, D51 and DN10) and published results from other studies. Karacic et al. (2003) clone 1 (*P. trichocarpa x deltoides,* Karacic et al. (2003) clone 2 (*P. maximowiczii x trichocarpa*), Dowell et al. (2009) (*P. deltoides x nigra*), and Czapowskyj and Safford (1993) (*P. maximowiczii x trichocarpa*).

Conclusion

Differences in performance of the four hybrid poplar clones were only observed in the high intensity treatments for all the metrics measured. Based on these results, we can rank the performance of the clones in the following decreasing order: NM6 > DN70 > D51 > DN10. This study has documented the growth of hybrid poplar on a sub-optimal site in Maine, and that growth in the high intensity treatments do not compare to early-growth of hybrid poplar clones on agricultural sites where growing conditions are better and far more uniform (Karacic et al 2003, Dowell et a. 2009). Our results indicate that it is very important to select clone(s) that are best suited to the local climate and site conditions, since two of our clones (D51 and DN10) had very poor performance, despite high intensity treatments. Karacic et al. (2003) selected clones that were adapted to cold climates (between 55 and 60 degrees north latitude), and well exceeded our growth. This study revealed that soil conditions are extremely important for hybrid poplar growth, especially in glaciated regions where poor soil aeration and rockiness can be widespread. Based on the lack of availability of suitable sites and relatively poor performance on typical forested sites in Maine, it may be unlikely that intensively managed hybrid poplar plantations will become a common occurrence in the region in the near future.

Six year old hybrid poplar plantation at the Agenda 2020 experiment site on the Penobscot Experimental Forest

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Refinement of the Forest Vegetation Simulator Northeastern Variant Growth and Yield Model: Phase 2


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Introduction

Last year, the CFRU Forest Vegetation Simulator (FVS) project completed the preliminary development of an extensive regional database of permanent growth and yield plots. These data will be the foundation for the construction of equations needed by the growth and yield model. The necessary model equations and expected completion date are given in Table 3.

Specific objectives for the second year of the project were to: (1) identify and fix errors in the database; (2) develop height to crown base (HCB) equations; (3) construct a regional index of potential productivity; and (4) begin preliminary analysis of the diameter increment equation.

Table 3. Equations to be estimated and likely completion date for the revised FVS growth and yield model.

Equation	Purpose	Completion Date
Maximum and largest crown width	Predict crown width for estimating crown competition factor (CCF) and crown closure	October 2010
Total height	Fill in missing heights for a given input tree list	December 2010
Height to crown base	Fill in missing height to crown base for a given input tree list	February 2011
Diameter increment	Predict annual changes in tree DBH	May 2011
Height increment	Predict annual changes in tree total height	August 2011
Crown recession	Predict annual changes in height to crown base	July 2011
Mortality	Predict the probability of tree survival	August 2011
Ingrowth	Predict the occurrence, frequency, and composition of ingrowth	April 2011
Stem taper	Estimate total and merchantable volume	December 2010 (conifers) February 2011 (hardwoods)
Thinning modifiers	Account of the influence of thinning on diameter and height increment	September 2011

School of Forest Resources students inventorying a white pine stand

Methods

Permanent growth and yield datasets from the CFRU, several Canadian provincial government agencies, the Maine Forest Service, and the US Forest Service were obtained and compiled. The data contains over 2.9 and nearly 1.6 million observations of diameter at breast height (DBH) and total tree height (HT), respectively.

Height to Crown Base

Using this database, a regional height to crown base equation was developed for the primary commercial species. The equation was of the following form:

[1]

$$HCB = \frac{HT}{\left(1 + e^{\left[-\left(b_0 + b_1 \cdot DBH + b_2 \cdot CCF + b_3 \cdot BAL\right)\right]}\right)^{\left(\frac{1}{6}\right)}}$$

Where HCB is height to crown base (lowest live branch, m), DBH is diameter at breast height (DBH, cm), CCF is Krajicek et al. (1961) crown competition factor determined using the maximum crown width equations of Russell and Weiskittel (2010), BAL is basal area in larger trees (m^2/ha), and the b_i's are parameters to be estimated from the data. The equation was fit using nonlinear mixed effects.

Site Productivity

To estimate regional site productivity, the US Forest Service Forest Inventory and Analysis (FIA) database from states east of the Mississippi River was combined with the database from this project. Individual tree height-age data were extracted and used to estimate a species-specific site index value with the equations of Carmean et al. (1989) (n = 337,783). Climate data was then obtained for each plot based on latitude, longitude, and elevation from the US Forest Rocky Mountain Research Station Moscow Laboratory. Thirty-five climate summary variables were constructed according to those used in Rehfeldt et al. (2006). The variables were then used to predict site index using a nonparametric regression technique called random forests (Breiman 2001).

Diameter Increment

A preliminary species specific diameter increment model was fit to the remeasurement data. The equation was of the following form:

[2]

Where ΔDBH is annualized diameter increment,

$$\Delta\, DBH = e^{\left[b_0 + b_1 \cdot \ln(DBH+1) + b_2 \cdot DBH + b_3 \cdot \ln(SI_{Climate}) + b_4 \cdot \ln(BAL) + b_5 \cdot \sqrt{BA}\right]}$$

$SI_{Climate}$ is the site index predicted from climate variables, BAL is basal area in larger trees(m^2/ha), BA is stand total basal (m^2/ha), and the b_i's are parameters to be estimated from the data. The equation was fit using a technique described in Weiskittel et al. (2007).

Results

An extensive effort was made to continue compiling and cleaning the data. A significant number of individual observations had fatal flaws such as changes in tree species, dead trees becoming alive again, and shrinking DBHs. Efforts were made to resolve these errors.

Height to Crown Base

The height to crown base equation fit well as tree DBH by itself explained between 40 to 72% of the original variation (Table 4). The addition of BAL and CCF to the equation increased the R^2 to 47-76%, while decreasing the root mean square error by 6% on average. For a given DBH, eastern hemlock tended to have the highest crown ratio, while red oak had the lowest across the species examined (Figure 10).

Table 4. Parameter estimates, R^2, and root mean square error (RMSE; m) for the height to crown base equation fit with diameter at breast height (DBH) only and with additional covariates by species.

Species	DBH-only				DBH with additional covariates					
	b_0	b_1	R^2	RMSE	b_0	b_1	b_2	b_3	R^2	RMSE
Hardwoods										
American beech	-2.1613	-0.0352	0.5260	1.6414	-4.0146	-0.0207	0.0019	0.0154	0.5590	1.5740
Gray birch	-2.9922	0.0254	0.6814	1.2918	-3.8044	0.0017	0.0008	0.0371	0.7370	1.1670
Red maple	-2.1249	-0.0345	0.5870	1.5819	-3.3923	-0.0161	0.0011	0.0190	0.6230	1.5124
Red oak	-1.9309	-0.0329	0.6741	1.4321	-2.6308	-0.0320	0.0012	0.0020	0.6810	1.4187
Paper birch	-2.4076	-0.0282	0.7170	1.5583	-4.0534	0.0099	0.0011	0.0261	0.7580	1.4556
Sugar maple	-2.0695	-0.0345	0.6220	1.5878	-3.0806	-0.0198	0.0007	0.0155	0.6310	1.5660
Yellow birch	-2.7490	-0.0276	0.5795	1.6796	-4.5435	-0.0058	0.0015	0.0242	0.6180	1.5923
Softwoods										
Balsam fir	-3.3088	-0.0260	0.5660	1.6564	-5.0220	0.0088	0.0011	0.0332	0.6240	1.5326
Black spruce	-3.0996	-0.0209	0.4650	1.9221	-3.2526	-0.0234	-0.0008	0.0349	0.4720	1.9041
Eastern hemlock	-3.3674	-0.0400	0.4020	2.3184	-7.2990	0.0154	0.0018	0.0653	0.5070	2.1242
Red spruce	-2.4545	-0.0309	0.6740	1.8333	-4.2529	0.0030	0.0007	0.0416	0.7040	1.7521
White pine	-2.4488	-0.0261	0.7032	2.1010	-4.6551	0.0034	0.0013	0.0522	0.7640	1.8640
White spruce	-3.8832	0.0095	0.6439	1.8029	-6.1165	0.0267	0.0022	0.0509	0.7090	1.6198

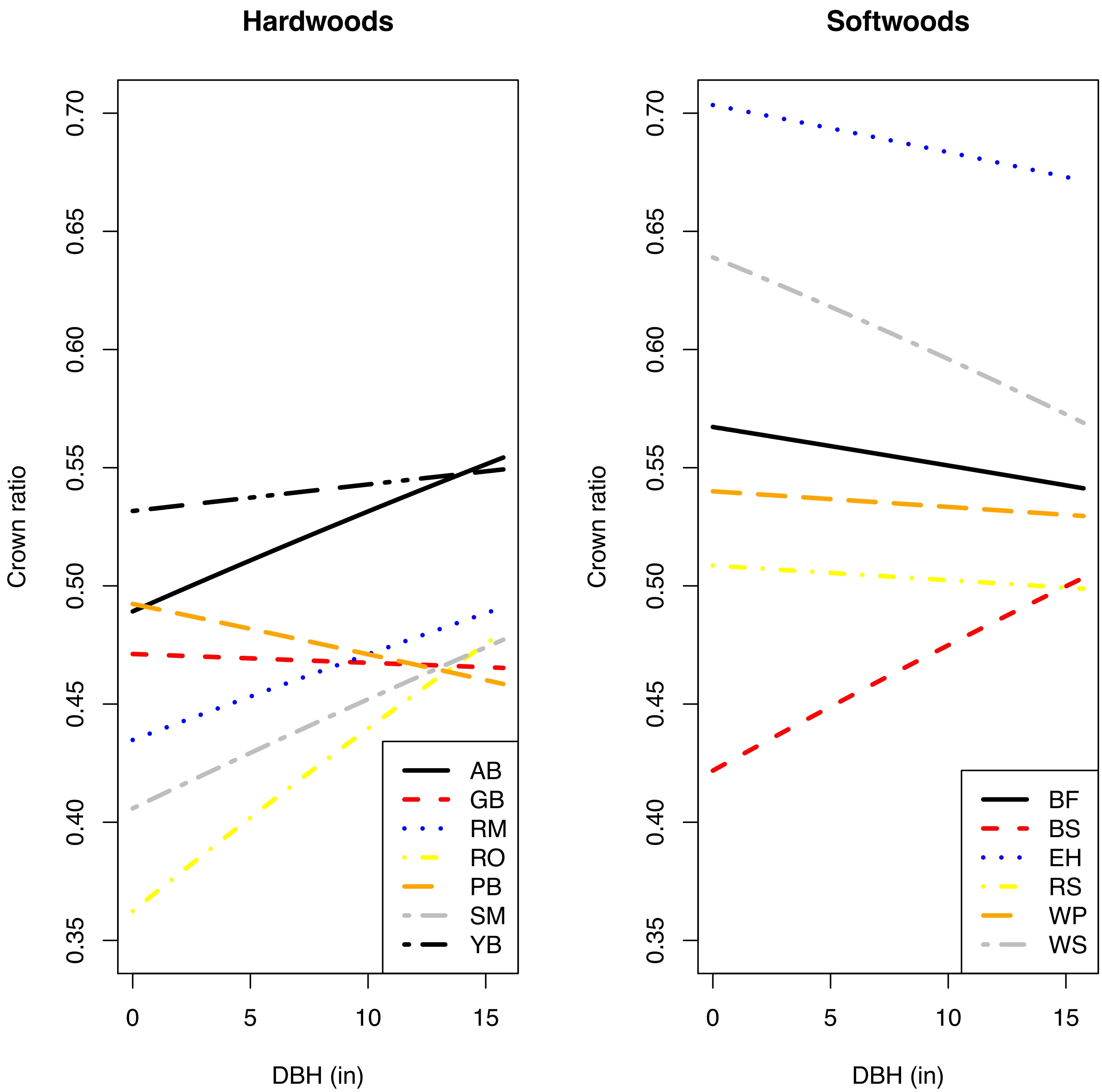

Figure 10. Predicted open-grown crown ratio by species using the regional height and height to crown base equations across a range of tree sizes.

Site Productivity

The random forest explained 74% of the original variation in site index and had a RMSE of 1.04 m using just seven climatic variables. The most important climate variables were mean temperature of the warmest month, the temperature difference between the warmest and coldest month, and the ratio of precipitation received during the growing season to total annual precipitation. The model produced a logical prediction of site productivity across the region (Figure 11). This raster file is available via the CFRU website (Acadian SI map).

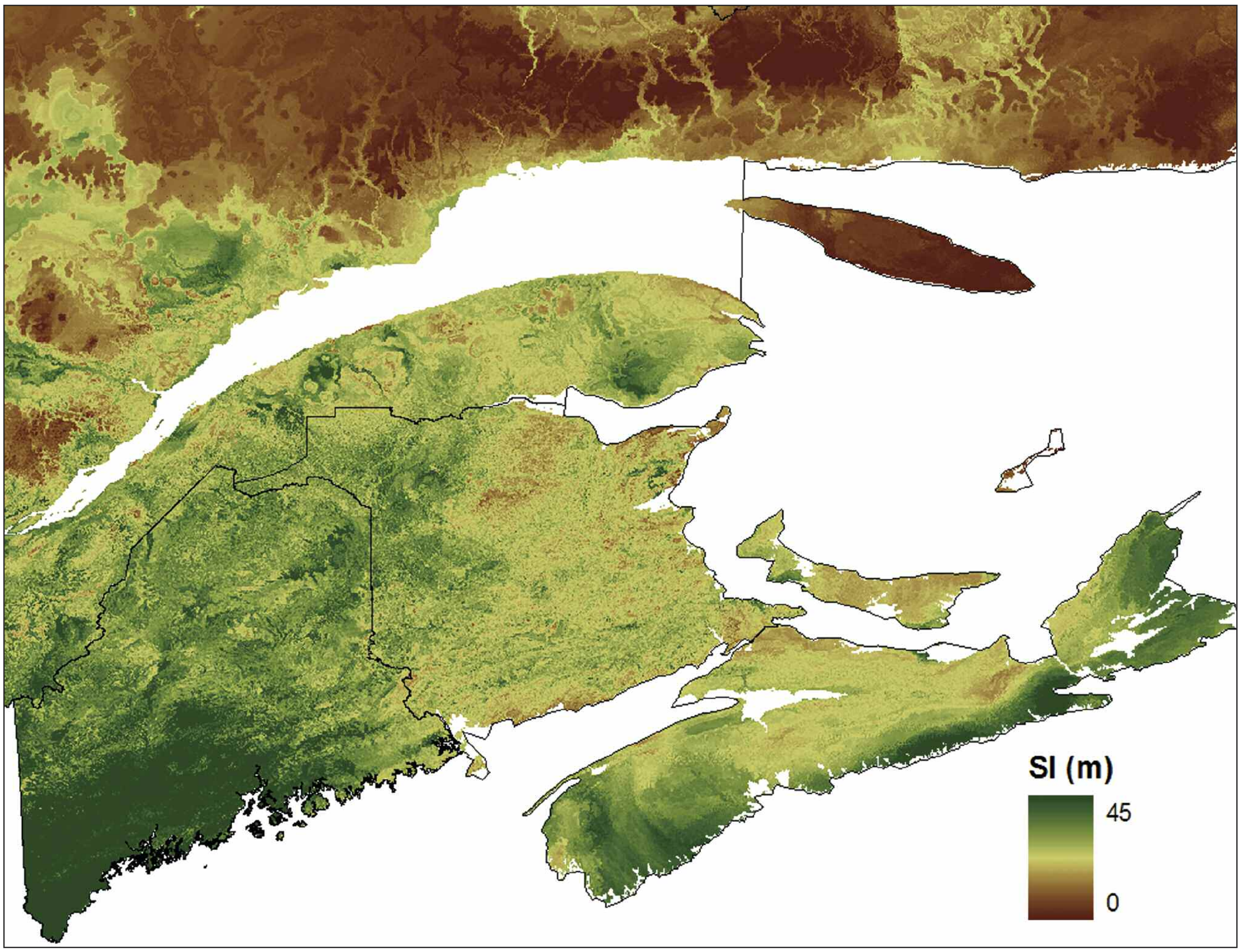

Figure 11. Map of predicted site index (m) predicted from climatic variables at a 1 km^2 resolution.

Diameter Increment

The diameter increment equation explained between 53 to 90% of the original variation (Table 5). The 6 model parameters were statistically significant for all species examined, except American beech, black spruce, jack pine, red spruce, and yellow birch. For a given DBH, white pine maintained the highest diameter increment of the species examined (Figure 12).

Discussion

Overall, the development of the regional growth model project appears to be on track and preliminary results are promising. The focus of the upcoming year will be on finalizing the model fitting datasets, refining the diameter and height increment equations, and assessing the need for thinning modifiers. By the summer of 2011, a beta version of the model should be available for user testing.

Table 5. The number of observations (n), parameter estimates, R^2, mean bias and root mean square error (RMSE) for the annualized diameter increment equation by species.

Species	n	b_0	b_1	b_2	b_3	b_4	b_5	R^2	Mean bias (cm/yr)	RMSE (cm/yr)
American beech	31,951	-3.6508	0.5888	-0.0121	0.6145	-	-0.1764	52.9	-0.0094	0.1844
Balsam fir	452,471	-2.3413	0.2949	-0.0146	0.5827	-0.1972	-0.1148	89.2	0.0069	0.1803
Eastern hemlock	30,595	-2.2246	0.2545	0.0003	0.4326	-0.0533	-0.1570	82.5	0.0157	0.1616
Jack pine	11,208	0.6847	0.2128	-0.0863	-	-0.3798	-0.1087	80.6	0.0354	0.2085
Paper birch	73,534	-3.3046	0.1666	-0.0086	0.8333	-0.1341	-0.1178	72.4	0.0115	0.1443
Quaking aspen	10,137	-4.4650	0.7282	-0.0194	0.9045	-0.1662	-0.1219	90.3	0.0151	0.1881
Red maple	129,042	-3.3862	0.4514	-0.0053	0.4907	-0.0424	-0.0925	75.8	0.0017	0.1528
Red spruce	152,389	-1.0550	0.1488	-	0.0804	-0.1267	-0.1386	77.9	0.0109	0.1735
Sugar maple	64,043	-4.0831	1.0149	-0.0235	0.4934	-0.0062	-0.2300	66.5	-0.0002	0.1751
Northern white cedar	36,717	-2.8174	0.5857	-0.0121	0.0918	-0.0125	-0.0897	68.4	0.0104	0.1413
White pine	19,331	-1.6071	0.3313	-0.0091	0.3433	-0.1038	-0.1411	74.6	0.0154	0.2840
White spruce	56,366	-1.6882	0.3030	-0.0175	0.3957	-0.1882	-0.1376	85.2	-0.0003	0.2037
Yellow birch	36,607	-3.3548	0.8600	-0.0272	0.3799	-	-0.1971	71.4	0.0031	0.1686

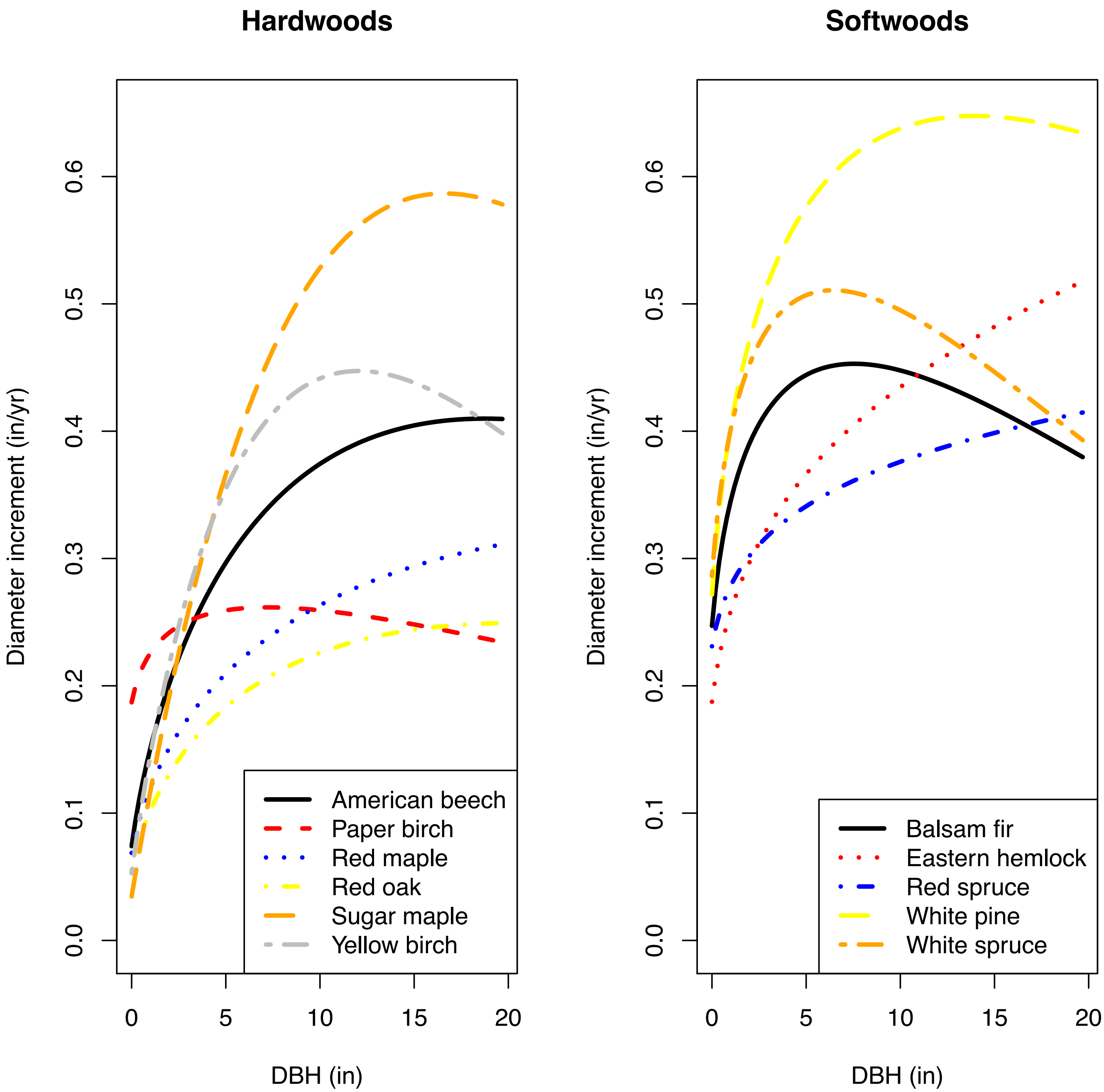

Figure 12. Predicted diameter increment of an open-grown tree by species across a range of tree sizes.

A significant challenge for the project thus far has been finding a consistent and unbiased estimate of site productivity. The habitat type approach used in FIBER is too simplistic and there is often high within-habitat-type variation in site productivity. Furthermore, habitat type is a rather subjective assessment and not easily mapped. Incorporation of soil attributes is of prime interest, but suffers from several key disadvantages. First, site productivity is often a function of several rather than a single soil attribute. Second, soil drainage class and depth to water class are likely factors, but are inconsistently mapped across the regional database. Efforts to resolve these limitations will be continued. For now, the climate-derived site index value appears to be a good substitute as it is significantly and positively related to diameter increment. Plus, the climate derived site index allows the ability to assess site productivity into the future as demonstrated by Crookston et al.(2010).

The biggest concern moving forward is not the development of the equations, but finding a software interface that addresses the majority of user's needs. A relatively simple software interface will be provided with the release of the model. The software will also be released as dynamic link library (DLL), which will allow the model to be utilized by other existing software systems with some custom code. More sophisticated systems that are capable of processing large forest inventories, developing yield curves, or complex management scenarios will need to be either developed with future projects or done commercially.

As always, user participation and feedback on any part of the modeling process is encouraged.

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Conifer seedlings regenerating on a stump

Development of Regional Stem Taper and Volume Equations

Aaron Weiskittel

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Introduction

Accurate estimates of stem form and volume are needed for most forest management decisions. Stem taper equations are generally considered the most effective method for predicting both stem form and volume. Numerous taper equation forms are available in the forestry literature, but relatively few taper equations are available for Maine. Solomon et al. (1989) developed taper equations for red spruce and balsam fir, but they were based on a relatively small sample size and used a relatively inflexible equation form of Max and Burkhart (1976). For example, Li and Weiskittel (2010) found the Max and Burkhart (1976) equation to not perform as well as other model forms for balsam fir, white pine, and red spruce.

The objectives of this analysis were to: (1) develop species-specific taper equation for the primary conifer species; (2) compare stem form differences between planted and naturally-regenerated stands; and (3) assess performance of taper equations for predicting total volume when compared to existing equations. This report will only provide a brief overview of the findings. Specific details are given in Li and Weiskittel (2010) as well as the CFRU technical reports available online.

Methods

Stem taper data were obtained from a variety of sources including Honer (1965), Solomon et al. (1989), New Brunswick Department of Natural Resources, and Quebec Ministry of Natural Resources. In each dataset, the trees were measured for diameter at breast height (DBH) and total height (H), felled, and then sectioned into 10-15 pieces with diameter inside (DIB) and outside bark (DOB) measured at each location. In addition to this stem taper data, several datasets of individual tree volume were available for validation. These datasets included O'Keefe et al. (2004), Townsend (1996), Pitt and Lanteigne (2008), and Lemin and Briggs (1993).

Based on the results of Li and Weiskittel (2010), the Kozak (2004) equation form was selected for use in this analysis. The equation has the following form:

[3]

$$d = \alpha_0 D^{\alpha_1} H^{\alpha_2} X^{\beta_1 z^4 + \beta_2 (1/e^{D/H}) + \beta_3 X^{0.1} + \beta_4 H^Q + \beta_6 X + \beta_7 I}$$

where $X = \frac{1 - z^{1/3}}{1 - p^{1/3}}$, $Q = 1 - z^{1/3}$, d is DIB (cm), H is total tree height from ground (m), D is diameter at breast height (cm), h = section height from ground (m), $p = 1.3/H$, $z = h/H$, and the α_i's and β_i's are parameters to be estimated using nonlinear mixed effects, I=0 if the stands are naturally regenerated and I=1 if the stands are planted.

Since the New Brunswick Department of Natural Resources was largely collected from intensively managed plantations, an indicator variable was added to equation 3 to test for differences in stem form for trees from naturally regenerated stands and those from plantations.

Results

The taper models using the Kozak (2004) equation performed well for all 11 conifer species. The root mean square error (RMSE) ranged from 0.8 cm to 2.4 cm for DOB for all the species, except eastern hemlock (Table 6). Separating planted and natural stands led to a modest gain in the model performance. In general, naturally regenerated stands tended to have greater diameter estimates in the middle section of tree stem when compared to planted stands for a given

DBH and H (Figure 13). Relatively similar predictions of balsam fir and red spruce stem form were obtained from the Kozak (2004) taper equation and that of Solomon et al. (1989), but there were some key differences (Figure 14).

The taper equations performed quite well in predicting total volume when compared to the Honer (1965) regional equation (Table 7). Similar results were obtained when the equation was used on the independent datasets.

Table 6. Number of observations (n), parameter estimates, and root mean square error (RMSE) for the diameter outside bark (DOB) stem taper equation by species.

Species	n	α_0	α_1	α_2	β_1	β_2	β_3	β_4	β_5	β_6	β_7	RMSE (cm)
Balsam fir	4113	0.7909	0.9745	0.1198	0.2688	-0.5513	0.5612	0.9007	0.1257	-0.6708	-	-1.2664
Black spruce	2667	0.8580	0.9611	0.1050	0.2604	-0.3409	0.4797	0.5008	0.1097	-0.4952	0.0969	1.2618
White spruce	2103	0.7317	0.9577	0.1593	0.2638	-0.4246	0.5505	-0.1269	0.1145	-0.6249	0.0880	2.0580
Red spruce	2242	0.8758	0.9920	0.0633	0.4128	-0.6877	0.4413	1.1818	0.1131	-0.4356	0.1042	1.2099
Jack pine	3017	1.0214	0.9817	0.0147	0.3753	-0.7954	0.4990	2.0407	0.0768	-0.3335	0.0408	1.0552
Red pine	1149	1.0962	1.0060	-0.0352	0.5000	-0.9959	0.3007	4.6358	0.0473	-0.0500	-	1.5585
White pine	1511	1.0202	0.9850	0.0149	0.3697	-0.7512	0.3536	3.8496	0.1074	-0.5131	-	1.9649
Norway spruce	87	1.0974	0.9462	0.0186	-0.2901	-0.7306	-4.3291	2.6078	0.0567	0.3667	4.1512	0.8098
Eastern hemlock	368	0.8681	0.9160	0.1558	0.4067	-0.6163	0.4177	3.6257	0.1686	-0.8829	-	3.2033
Northern white cedar	749	0.9020	0.9676	0.0850	0.3204	-0.4336	0.5212	0.0157	0.1370	-0.4585	-	2.3690
Eastern larch	380	0.7387	0.9716	0.1431	0.2710	-0.4958	0.6508	-0.3887	0.1324	-0.7035	-	1.7063

Table 7. Absolute mean bias (MAB), root mean square error (RMSE), mean percentage of absolute bias (MPAB), mean bias (MB), and mean percent bias (MPB) of stem volume outside bark (VOB) using the taper equations developed in this analysis and the Honer (1965) regional volume equation for 11 conifer species.

Species	Taper Equation					Honer (1965)				
	MAB (m^3)	RMSE (m^3)	MAPB (%)	MB (m^3)	MPB (%)	MAB (m^3)	RMSE (m^3)	MAPB (%)	MB (m^3)	MPB (%)
BF	0.0138	0.0268	8.12	0.0034	2.01	0.0198	0.0337	11.64	0.0139	8.17
BS	0.0191	0.0395	9.02	0.0040	1.87	0.0241	0.0444	11.36	0.0195	9.18
WS	0.0302	0.0547	6.88	-0.0039	-0.90	0.0388	0.0713	8.86	0.0181	4.14
RS	0.0137	0.0315	7.93	-0.0003	-0.19	0.0184	0.0459	10.64	0.0128	7.42
JP	0.0148	0.0256	7.43	0.0006	0.30	0.0208	0.0356	10.43	0.0162	8.12
RP	0.0529	0.0912	5.97	-0.0054	-0.61	0.0868	0.1407	9.80	0.0770	8.69
WP	0.0862	0.2120	11.18	0.0435	5.64	0.1293	0.3064	16.77	0.1176	15.25
NS	0.0049	0.0090	5.94	-0.0007	-0.85	0.0053	0.0095	6.35	-0.0012	-1.47
EH	0.0880	0.1892	14.19	0.0257	4.15	-	-	-	-	-
NWC	0.0382	0.1022	11.10	0.0186	5.41	-	-	-	-	-
EL	0.0252	0.0447	10.04	0.0093	3.70	-	-	-	-	-

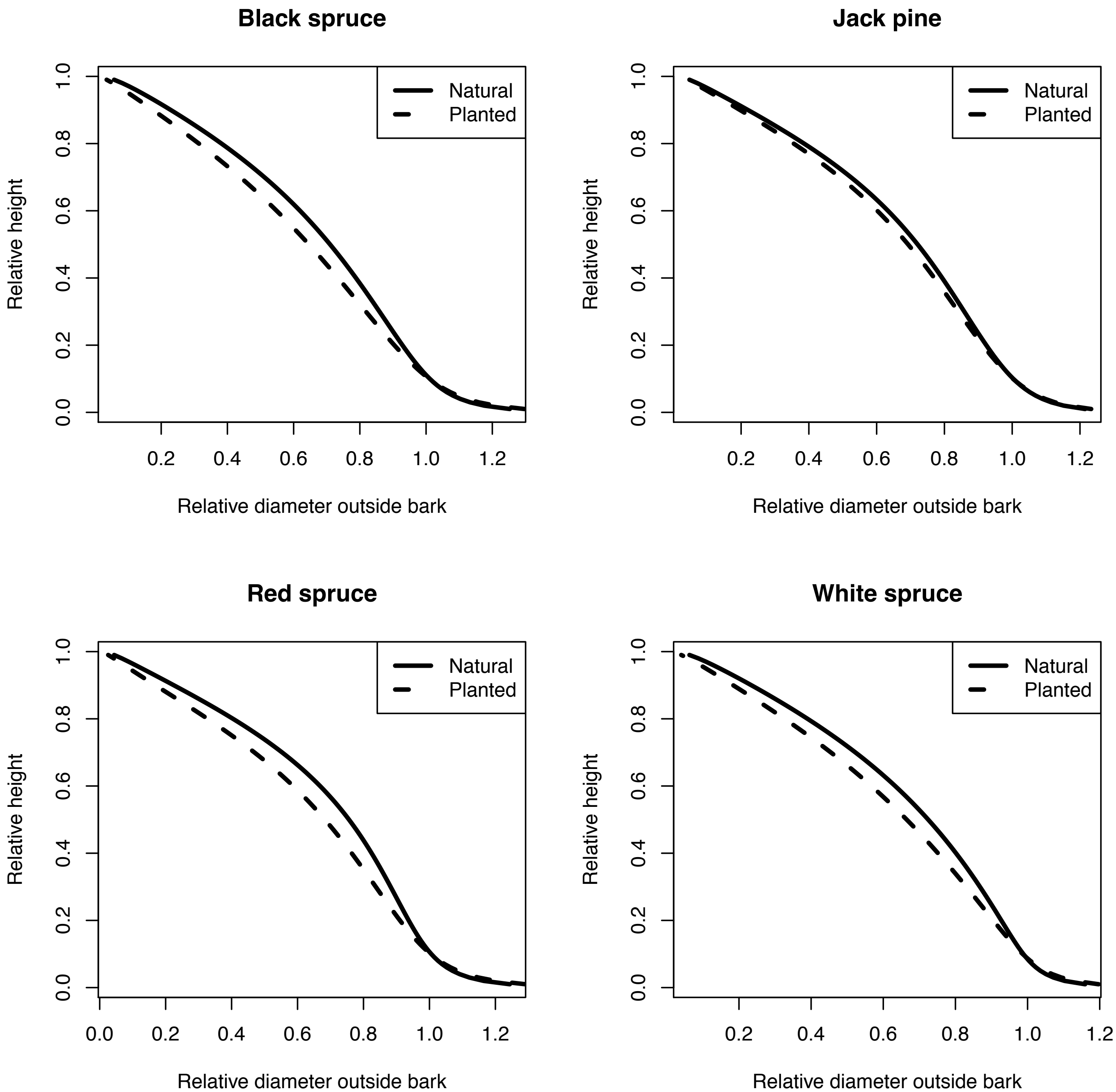

Figure 13. Predicted relative outside diameter over relative height for typical trees with average total tree height and DBH for 4 species in plantations and naturally regenerated.

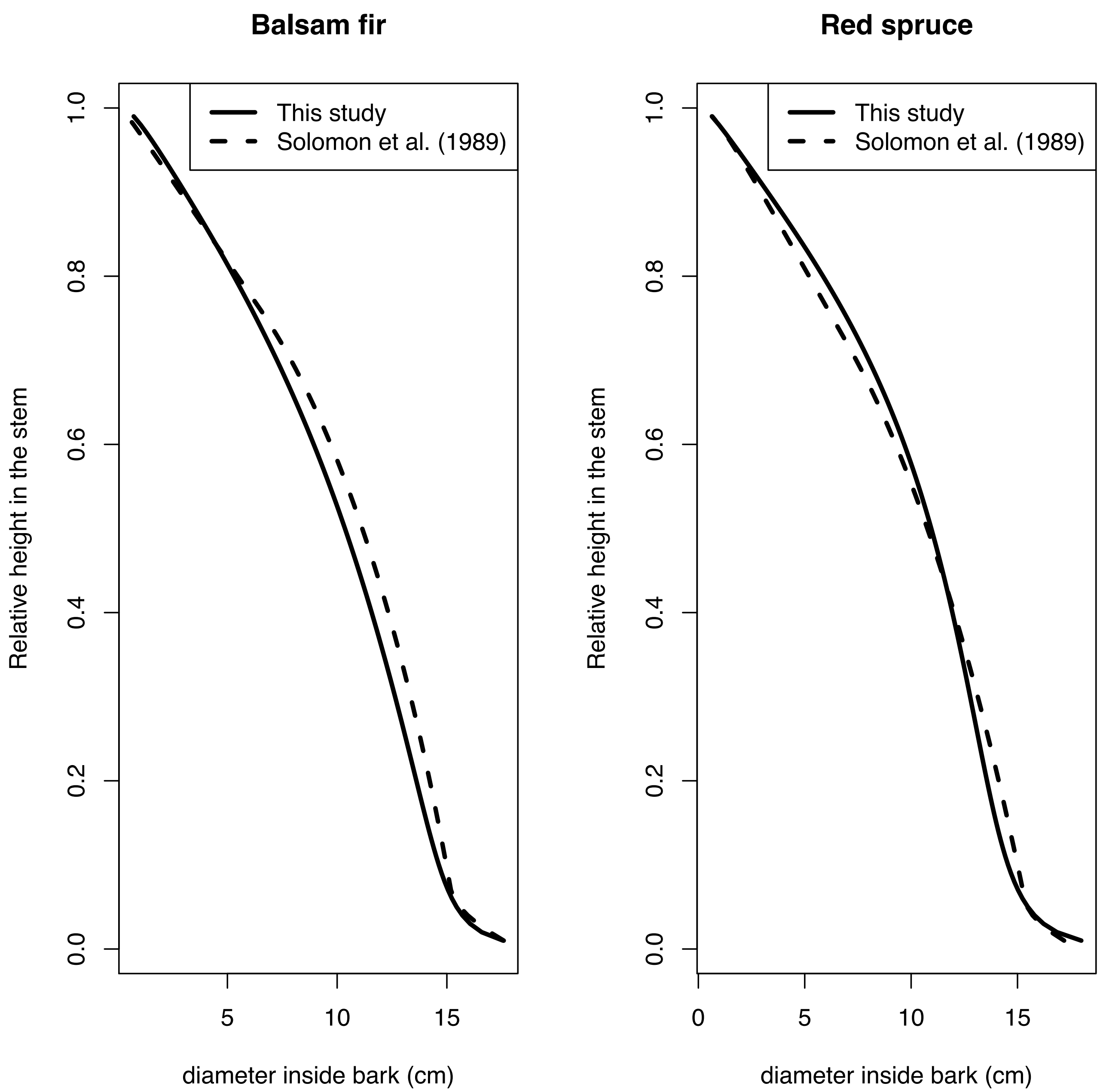

Figure 14. Comparison of balsam fir and red spruce stem form predictions using the Kozak (2004) equation (this study) and that of Solomon et al. (1989).

Discussion

Taper equations are important tools as they can reconstruct individual tree stem form, which can be used to estimate total and merchantable volume. The key advantage of a taper equation when compared to a volume equation is that they can be used to estimate merchantable volume to any desired specification. These specifications can be based on length or top diameter. This flexibility is key for optimizing merchandising decisions. In addition, when these equations are combined with species-specific estimates of wood density, relatively accurate estimates of stem biomass by size class are obtainable, particularly when compared to estimates derived from allometric equations like those of Jenkins et al. (2004) (Figure 15).

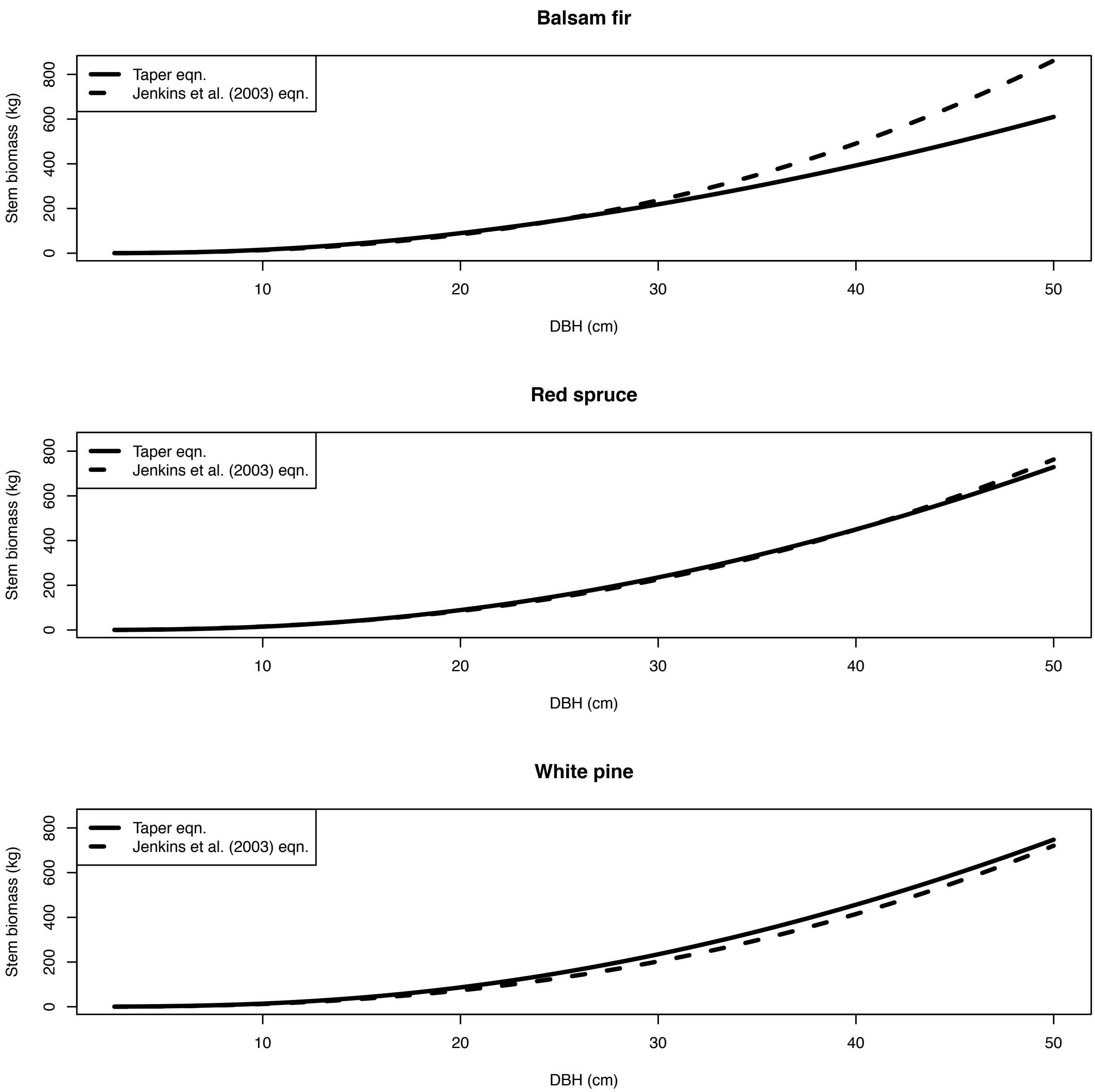

Figure 15. Estimates of total stem biomass without bark for balsam fir, red spruce, and white pine using a taper equation with a regional average wood density and the Jenkins et al. (2004) allometric equations.

The taper equations provide predictions of DOB and when combined with the existing bark thickness equations, estimates of DIB can be obtained. Both the taper equation and bark thickness equations can be locally calibrated with 1 or 2 new observations. For bark thickness, the location of the new observation had no impact on the equation performance so breast height is the logical choice. For stem taper, observations higher in the stem are generally more effective so the height of the first log is usually utilized and is relatively easy to measure with today's existing dendrometers.

These equations and the bark thickness ones will be incorporated into the forthcoming update to the FVS growth and yield model. Additional software may also be developed depending on cooperator interest. The logical choices would be to update the CFRU SPOT tool (McConville 2004) and the product ratio calculator of Kershaw et al.(2007).

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WILDLIFE HABITAT AND BIODIVERSITY

The Effectiveness of State Regulation to Protect Deer Wintering Areas in Maine: Did the designation of LURC-zoned deer yards achieve desired objectives during the period 1975-2007?

Snowshoe Hare Spatio-Temporal Dynamics and Implications for Canada Lynx in Managed Landscapes

Documenting the Response of Canada Lynx to Declining Snowshoe Hare Populations in an Intensively Managed Private Forest Landscape in Northern Maine

The Effectiveness of State Regulation to Protect Deer Wintering Areas in Maine: Did the designation of LURC-zoned deer yards achieve desired objectives during the period 1975-2007?

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Background

Deer Wintering Areas (DWAs) provide an important component of habitat quality for white-tailed deer near the northern extent of the species' geographic range and a unique challenge for habitat management. White-tailed deer migrate to and congregate in wintering habitat when snow conditions restrict mobility (Parker et al. 1984) and access to preferred forage (Dumont et al. 1998, Dumont 2005). On average white-tailed deer migrate >6 miles (10 km) from their summer range to overwinter in a winter range that generally represents 5-15% of an individual's annual home range (Verme 1973, Oyer and Porter 2004, Pekins and Tarr 2008). DWAs provide white-tailed deer with an opportunity to reduce foraging and thermoregulatory costs, allowing them to conserve energy and body fat, and, ultimately, to improve survival. For white-tailed deer populations in the northeastern U.S. and Canada, stands of mature conifer forest are a key component of deer wintering habitat, providing critical cover from wind and snow (Verme 1973, Moen 1976, Potvin and Huot 1983, Lishawa et al. 2007). Reduced snow depths within mature softwood stands (Potvin 1980, Nelson and Mech 1981, Lishawa et al. 2007) improves mobility and reduces costs associated with maintaining trails systems that increase access to forage both within and outside the DWA (Potvin and Huot 1983, Parker et al.1984). White-tailed deer express strong fidelity to their natal wintering area (Verme 1973, Morrison et al. 2003). Although reluctant to leave, white-tailed deer will abandon their DWA if cover is removed (Verme 1973, Boer 1992, Van Deelen 1999, Morrison et al. 2003). What effects DWA abandonment has on the individual deer or the white-tailed deer population at large is largely unknown (Pekins and Tarr 2008).

Maine is one of a few states that protect DWAs through zoning and regulation (Pekins and Tarr 2008). Application of existing laws in Maine has resulted in the zoning of approximately 190,000 acres of DWAs through the Land Use Regulation Commission (LURC) process of defining wildlife protection subdistricts (P-FW, Dept. of Conservation, Maine LURC 1997, LURC statute TITLE 12, M.R.S.A., Chapter 206-A LAND USE REGULATION, Chapter 10 Land Use Districts and Standards defines Fish and Wildlife Protection Subdistricts). Within these subdistricts, land-use activities such as timber harvesting are regulated to conserve important fish and wildlife habitats, including DWAs. Despite this protection, loss of deer wintering habitat has been identified as the major limiting factor preventing efforts to increase the size of the deer herd in northern and eastern Maine. The Maine Department of Inland Fisheries and Wildlife (MDIFW) has estimated that quality deer wintering habitat in those areas has declined from ~10% to <5% since the early 1970s. Natural disturbance (e.g., spruce budworm) and stand dynamic (e.g., senescence of over-mature balsam fir stands) processes have contributed to the decline in mature softwood (MDIFW 2007). Increased rates of softwood harvesting in the 1970s, 1980s, and 1990s, during and following the most recent outbreak of spruce budworm have, however, likely had a substantial effect on the broad-scale suitability of commercial forestlands for wintering deer and may contribute to a legacy that may constrain the ability for future landscapes to support deer at previous higher densities. In fact, conservation of mature spruce-fir stands that provide critical winter cover for deer often represent the highest value spruce-fir timber (Pekins and Tarr 2008).

To ensure sufficient wintering habitat that can support desired population goals for deer management in northern and western Maine, MDIFW has proposed to substantially increase zoning for DWAs. MDIFW has a long-term objective to increase zoning for white-tailed deer management to 8-10% of the land base in northern and western Maine (by 2030 or sooner) (MDIFW 2007). Such changes could have a substantial influence on the productivity of Maine's forest. The potential economic impacts of additional acreage in DWAs include loss in market value of timberland, reduction in annual stumpage income to landowners, and a reduction in the number of jobs statewide. With the potential for significant economic losses to landowners associated with expanded zoning and the apparent failure of past zoning to prevent population declines in northern and eastern Maine, a comprehensive evaluation of the current condition of existing zoned DWAs was needed to evaluate if past compromises in softwood productivity from Maine's forests have achieved ecological objectives for deer management and to determine if increased zoning is a cost-effective and ecologically viable option for managing deer populations into the future.

Habitat loss and fragmentation are often considered the primary threats to biological diversity (Wilcox and Murphy 1985, Fahrig 1997) as these processes can lead to reductions in population size, increased isolation of populations, and decreased rates of colonization (Lawton 1995). Currently, the colonization process of previously unused patches of wintering habitat by white-tailed deer in a fragmented landscape is unknown, but rates of colonization are expected to be low as a result of deer's fidelity to a previously used DWA (Pekins and Tarr 2008). The extent of habitat loss and fragmentation within DWAs and the adjacent forest habitats surrounding them has not previously been documented from a landscape perspective. Thus, our goal was to evaluate how well 58,560 ac (23,698 ha) of zoned DWAs on commercial forestlands functioned in protecting deer wintering habitat in northern Maine during the period 1975-2007.

Objectives

1. Document the extent and rate of habitat change within LURC-zoned Deer Wintering Areas (DWAs) during the period 1975-2007.

2. Evaluate changes in landscape composition, connectivity, and fragmentation within buffers around DWAs to inform current policy and future research.

3. Simulate the effects of increased zoning restrictions to meet the MDIFW objective of 8-10% of the land base in zoned yards and to evaluate potential losses in forest productivity.

4. Evaluate how well DWAs function as a coarse-filter for biodiversity conservation.

Study Area

Our study area was defined based on overlap between Landsat satellite imagery used to detect and map habitat change and the northwestern border of Maine (Figure 16). This area included all or part of 174 unorganized townships owned by 71 entities ca. 2007, including a variety of industrial forest products companies, family-owned corporations, and

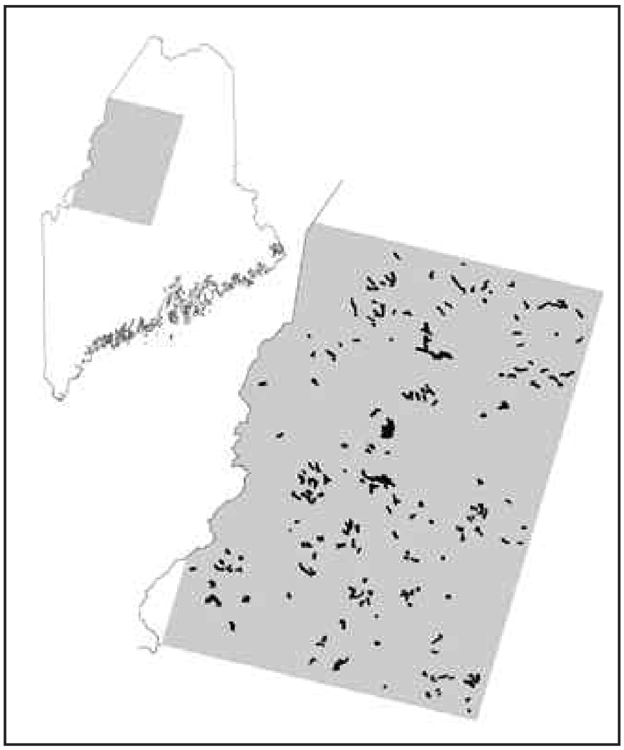

Figure 16. Project study area (gray shaded) overlapped 187 LURC-zoned deer wintering areas (black polygons), and was defined based on extent of the Landsat satellite archive (Path 12 Row 28) used to map timber harvests and the Maine state boundary.

Lower snow accumulation in conifer stands provides greater mobility for deer in the winter

investment entities. Recent history of ownership changes within this area was broadly representative of unorganized townships in northern Maine (Hagan et al. 2005, Jin and Sader 2006). This area included approximately 4 million acres of commercial forestland, of which approximately 58,560 ac was zoned by LURC as PFWs primarily for the protection of deer wintering habitat (hereafter referred to as zoned DWAs). Zoned DWAs within our study area ranged in size from 8 ac (3 ha) to 4,027 ac (1,629 ha).

Approach

We documented the extent and rate of habitat change within 187 zoned DWAs (Objective 1) using a satellite-derived time series of forest harvest history. The time series captured forest change (1975-2007) at 1-4 year intervals across approximately 4 million acres of commercial forestland in northern Maine (Legaard et al., Maine Image Analysis Laboratory, University of Maine, In preparation). Timber harvests within this area were identified and mapped using established change detection methods based on Landsat satellite imagery (e.g., Sader and Winne 1992, Sader et al. 2003). With these data we were able to evaluate the magnitude and temporal pattern of forest biomass loss caused by timber harvesting activities. We combined harvest history information with satellite-derived information on forest overstory composition to quantify the effects of timber harvesting on the proportion of mature forest (conifer, deciduous, and mixedwood) and regenerating forest within DWAs and the change in composition of forest within DWAs during the period 1975-2007. We intersected satellite-derived data with a polygon map of zoned DWAs to determine the annual acreage harvested, proportion of zoned DWAs harvested, and cumulative proportion of forest within DWAs harvested by interval. Following the same methods as we used for Objective 1, we also documented the extent and rate of habitat change within 1.25 mile (2 km) buffers around zoned DWAs to evaluate the potential influences of habitat loss and fragmentation in the larger landscape on wintering deer (Objective 2). Analyses related to objective #3 are ongoing and will be presented in a final report to be posted on the CFRU website by 31 March 2011.

Summary of Preliminary Findings

Across the 187 DWAs occurring on our study area, harvesting within DWAs was a common practice. In fact, 60% of DWAs received a stand replacing harvest between 1975 and 1991, and >90% had stand-replacing harvests that occurred within the zoned area during the period 1975-2007. Overall, 23% of mature forests within DWAs received some form of harvest and the amount of regenerating forest habitat, which was nearly absent in 1975, increased by >5.5-fold within DWAs. Although interspersion of hardwood browse in regenerating stands adjacent to mature cover can be beneficial to deer, and may have been a targeted management objective in some harvested areas, our results indicate that the representation of softwood forests with DWAs is expected to decrease, whereas the composition of hardwood forests is expected to increase appreciably during the next generation of mature forests. Relative to adjacent areas without protective regulations, DWAs achieved some level of habitat conservation. In fact, approximately half of the mature forest that existed outside, but within 1.25 miles of the boundaries of DWAs, received some form of timber harvest during the period 1975-2007, and approximately one-third of the mature forest that existed within those boundary areas was converted to regenerating forest. Further, the remaining patches of habitat with boundary areas were increasingly fragmented (Figure 17). The number of mature softwood patches nearly tripled, the average size of the remaining softwood patches decreased to one-third of previous levels, perimeter-area ratio (i.e., edge density) nearly doubled, and the distance that a deer could walk and remain protected within a mature softwood patch decreased by greater than one-half. Further, future stand conditions within the 1.25-mile buffers adjacent to DWAs are expected to support decreased representation of mature conifer forest habitats and substantial increases in the future representation of deciduous forests. Additionally, LURC-zoned DWAs encompass <2% of the forestland area within our study area and are unlikely to be effective in achieving deer population objectives established by MDIFW. Correspondingly, MDIFW has expressed an objective to increase the amount of zoned DWAs to 8-10% of the landscape, which our data suggest could only be achieved within our study area by immediately protecting virtually all remaining patches (circa 2007) of mature softwood habitat >12.4 acres (5 ha) in area. Most of those patches would likely have limited value to deer because of their small size and extent of fragmentation. Importantly, approximately 190,000 acres of DWAs have already been zoned by LURC at substantial economic cost to forest landowners and our results, as well as recent downward trends in deer harvests, suggest that population-level objectives for deer have likely not been achieved. Thus, careful consideration of alternative approaches should be considered before increasing the extent of zoning to protect additional small fragmented patches of deer wintering habitat. In summary, we

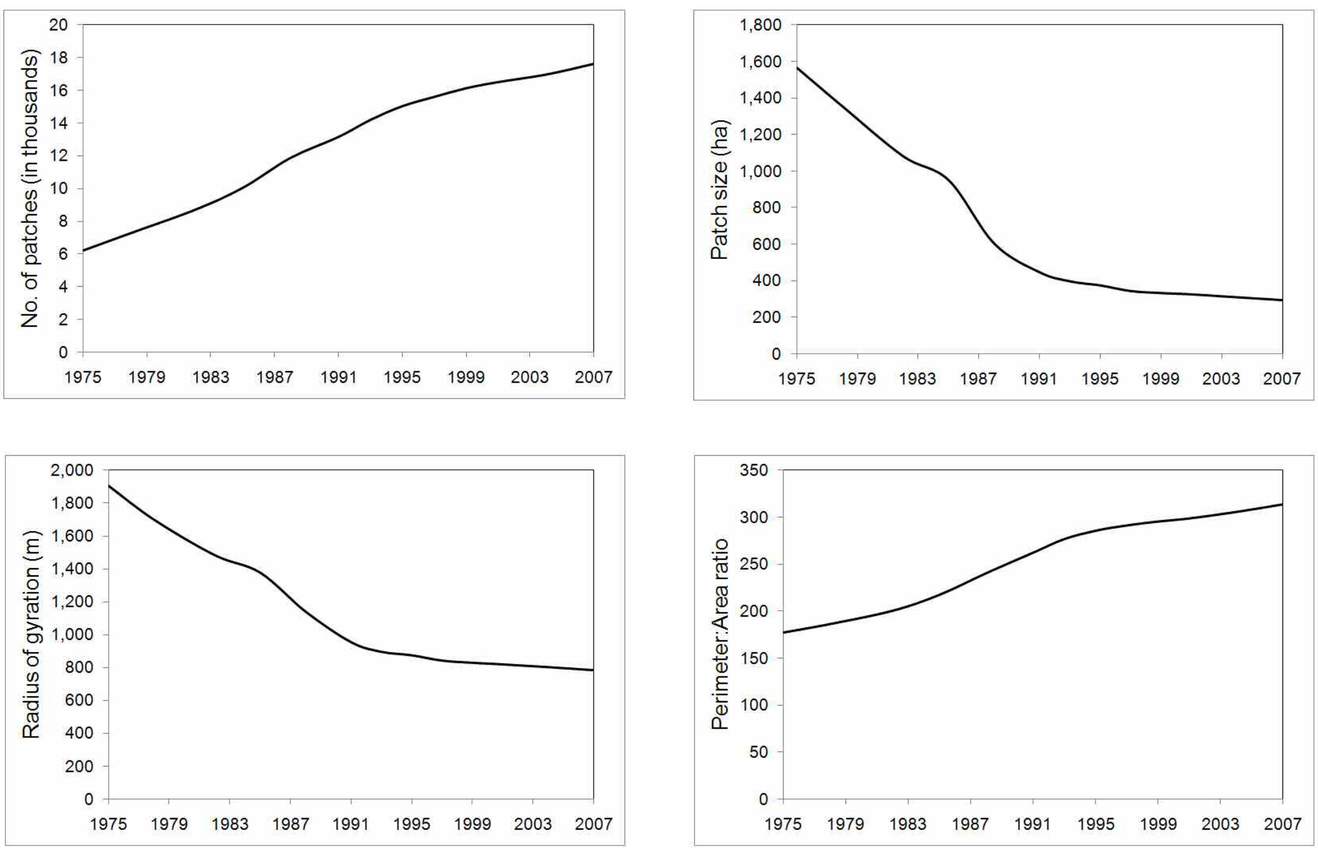

Figure 17. Landscape metrics reflecting changes in configuration of patches of mature conifer within 1.25 miles (2 km) of LURC-zoned deer wintering areas (DWAs) during the period 1975-2010.

conclude that zoning to protect deer wintering areas is not achieving desired objectives, that additional zoning will likely not meet the desired deer management objectives expressed by MDIFW for the future, and that creative landscape-scale approaches would be required to increase the future extent, connectivity and functional quality of deer wintering habitat in northern and western Maine. We caution, however, that the legacy of past forest harvesting and the spruce budworm outbreak of the 1970's and 1980's will not likely allow the future forests of Maine to support the extent and configuration of deer wintering habitat that existed previously.

Future Plans

We are in the final stages of analysis and report writing and will present our complete findings at the January 2011 meeting of the CFRU Advisory Committee. The final report will be posted on the CFRU website by March 2011.

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Snowshoe Hare Spatio-Temporal Dynamics and Implications for Canada Lynx in Managed Landscapes

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Project Overview and Accomplishments

The Canada lynx (*Lynx canadensis*), a U.S. Federally Threatened species, occurs throughout northwestern Maine. In 2009, 2.5 million hectares, or 9,447 square miles of northern Maine was designated Critical Habitat for Canada lynx (Figure 18) (U.S. Department of the Interior 2009). Because the snowshoe hare (*Lepus americanus*) comprises up to 97% of lynx diets and because low hare densities affect lynx reproductive potential, adequate snowshoe hare densities are required for lynx persistence (Nellis et al. 1972, Brand and Keith 1979, Apps 2000).

Since 2001 the CFRU has funded a biannual snowshoe hare monitoring program in the managed forests of Maine. The goal has been to quantify snowshoe hare densities as a function of representative forest stand types that have different

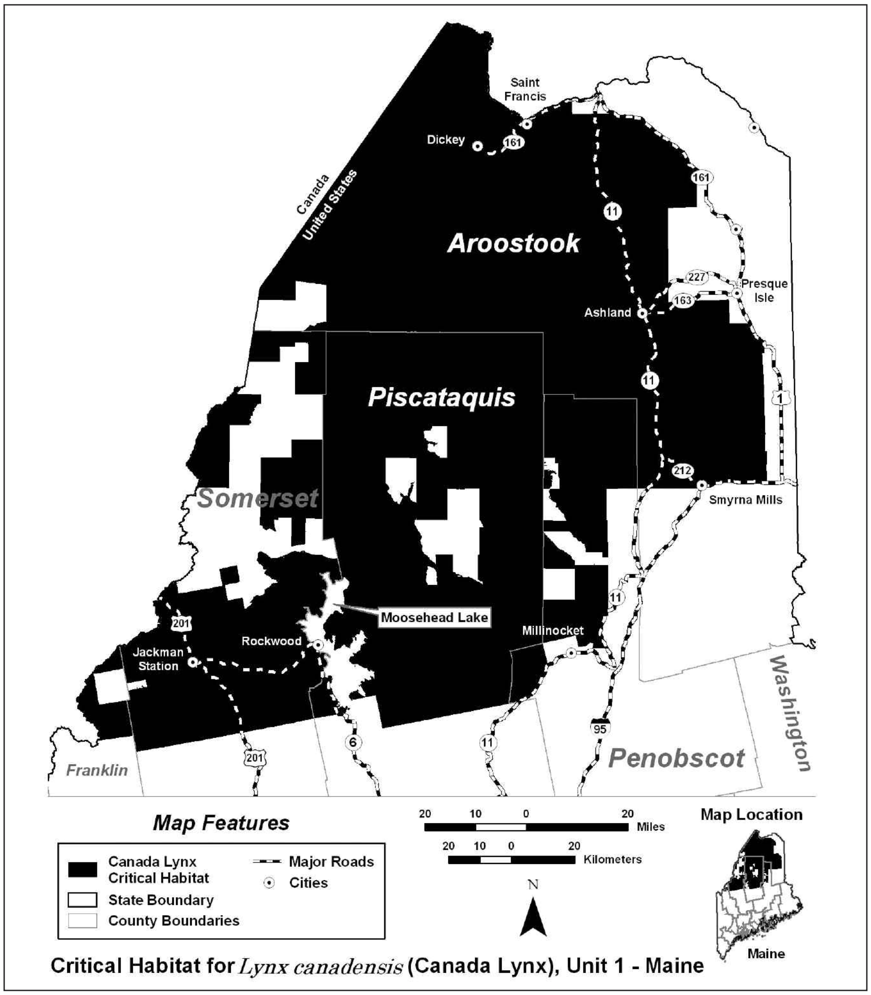

Figure 18. Northern Maine's Canada lynx Critical Habitat is 9,447 square miles. Most is in private ownership and managed for forest products.

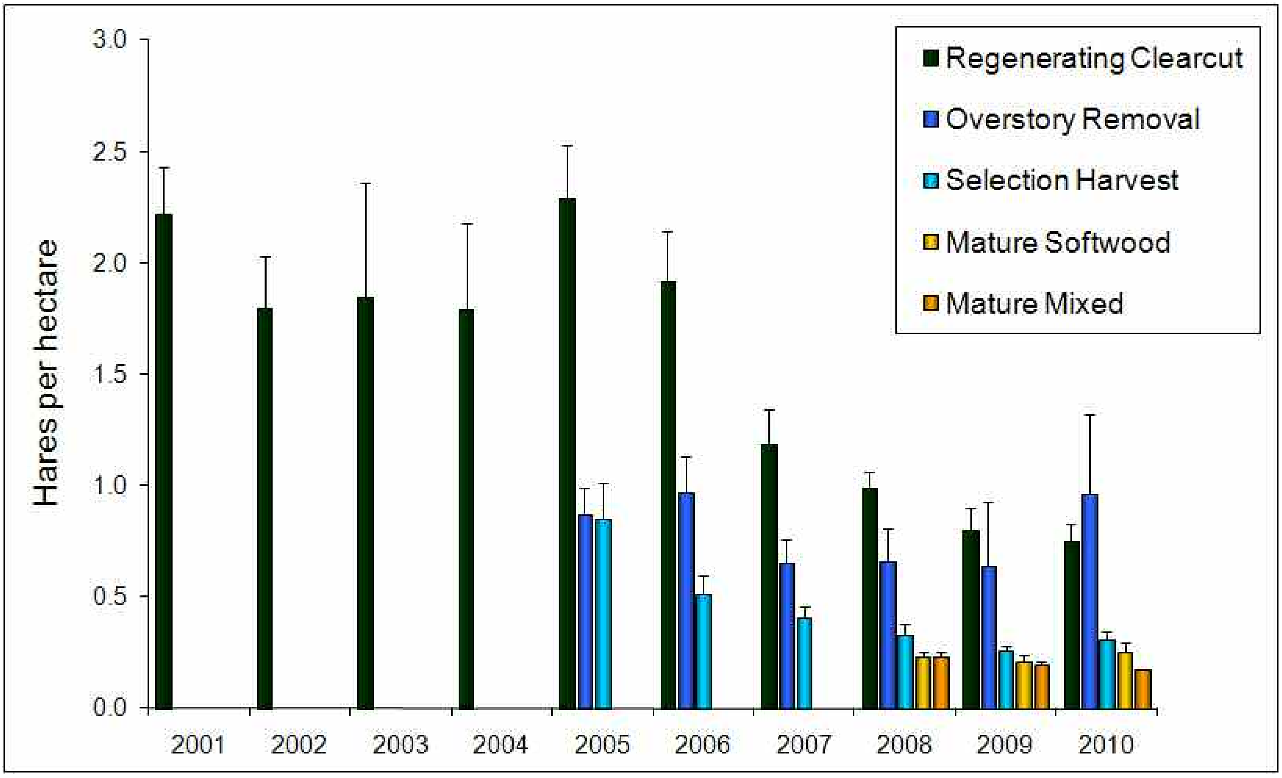

Figure 19. Based on leaf-off (winter) season fecal pellet counts, estimated snowshoe hare density in five forest stand types during the period 2001-2010. Partial harvest stands were incorporated into the long-term monitoring protocol in 2005, and pellet plots in mature stands were established in 2008. Bars represent mean densities across a stand type and whiskers represent one standard error.

harvest and silvicultural management histories (Homyack 2003, Robinson 2006, Fuller et. al 2007, Scott 2009). This research has determined snowshoe hare densities are highest in early successional, dense, regenerating conifer stands with a past history of herbicide treatment compared to other forest stand types (Figure 19). We observed a nadir in hare densities during 2009-2010, which were the lowest hare densities observed during our ten-year time series. Additionally, we observed that harvested stands with 2nd stage overstory removals following shelterwood harvesting are beginning to support hare densities comparable (hares/ha) to regenerating conifer stands following clearcut harvesting and herbicide application.

Models have predicted that fluctuating hare densities can influence lynx occurrence at a landscape scale (Simons 2009, Scott 2009). However, at a finer scale, lynx were shown to prefer stands with less dense vegetation and lower hare densities compared to most dense conifer regenerating stands with the highest hare densities, where hunting is likely easier (Fuller et. al 2007). Fine scale habitat components such as vegetation structure, and seasonal changes in vegetation structure and composition, may be the major drivers of variations in snowshoe hare abundance across the landscape, and work in 2011 will explore these seasonal differences.

The biannual sampling frequency affords an opportunity to explore seasonal differences among different stand types, and to determine how seasonality affects snowshoe hare population densities. Vegetation structure and species composition change seasonally within stands, and vary among different stand types. Snowshoe hares shift from dense conifer habitats in winter to herbaceous and shrubby habitats in summer to exploit higher quality forage (Wolff 1980, Griffin and Mills 2009). The seasonal distribution and densities of snowshoe hares among different forest stand types may play a critical role during the limiting late spring and summer seasons for lynx kitten survival and subsequent young-of-the-year recruitment for lynx. If snowshoe hare exhibit different abundances across the landscape in different seasons, lynx productivity may be affected. Telemetry monitored lynx females with kittens in Maine were shown to have home ranges almost three times smaller than males, suggesting central place foraging takes place while lynx are denning (Vashon et al. 2008).

In spring and fall 2010, fecal pellet surveys were completed in 30 forest stands of five types, adding to the time series initiated in 2001. Using winter pellet counts, snowshoe hare densities for winter seasons show a trend of decreasing densities in 15 regenerating conifer stands, though 2009 and 2010 may represent the nadir (Figure 20). During the lower hare density period from 2007 – 2009, landscape scale hare densities greater than 0.5 hares/ha occurred on less than 5% of the landscape (Scott 2009). In 2011, fecal pellet monitoring will reveal if snowshoe hare densities will continue to plateau or begin to cycle toward higher densities.

In 2008, Scott (2009) established hare monitoring plots in mature softwood and mature mixed stands. Inclusion of mature forest stands provide a comparison for hare density estimates among different forest stands, and three years of data comparing snowshoe hare densities in five forest stand types (Figure 21) are scheduled for further analysis to determine if forest stand types with consistently lower hare densities may be acting as a population sink. An additional two seasons of hare fecal pellet density data will be added to this data set in 2011.

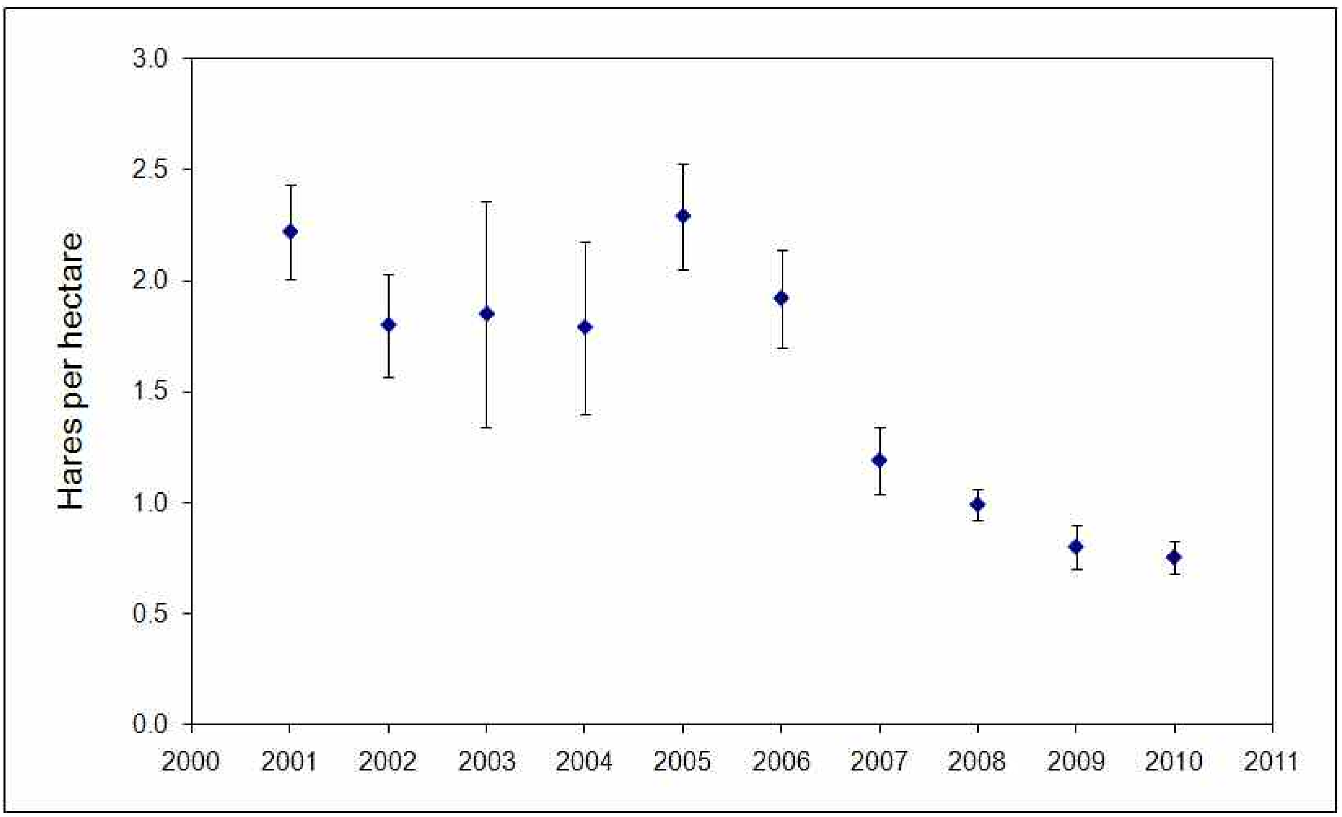

Figure 20. Leaf-off (winter) stand-scale snowshoe hare density in regenerating conifer stands that were herbicided one to ten years post clearcut. The lower hare densities may show a plateau at 2009 and 2010, indicating a twenty year fluctuating cycle. Diamonds represent mean densities across regenerated clearcuts following herbicide application, and whiskers represent one standard error.

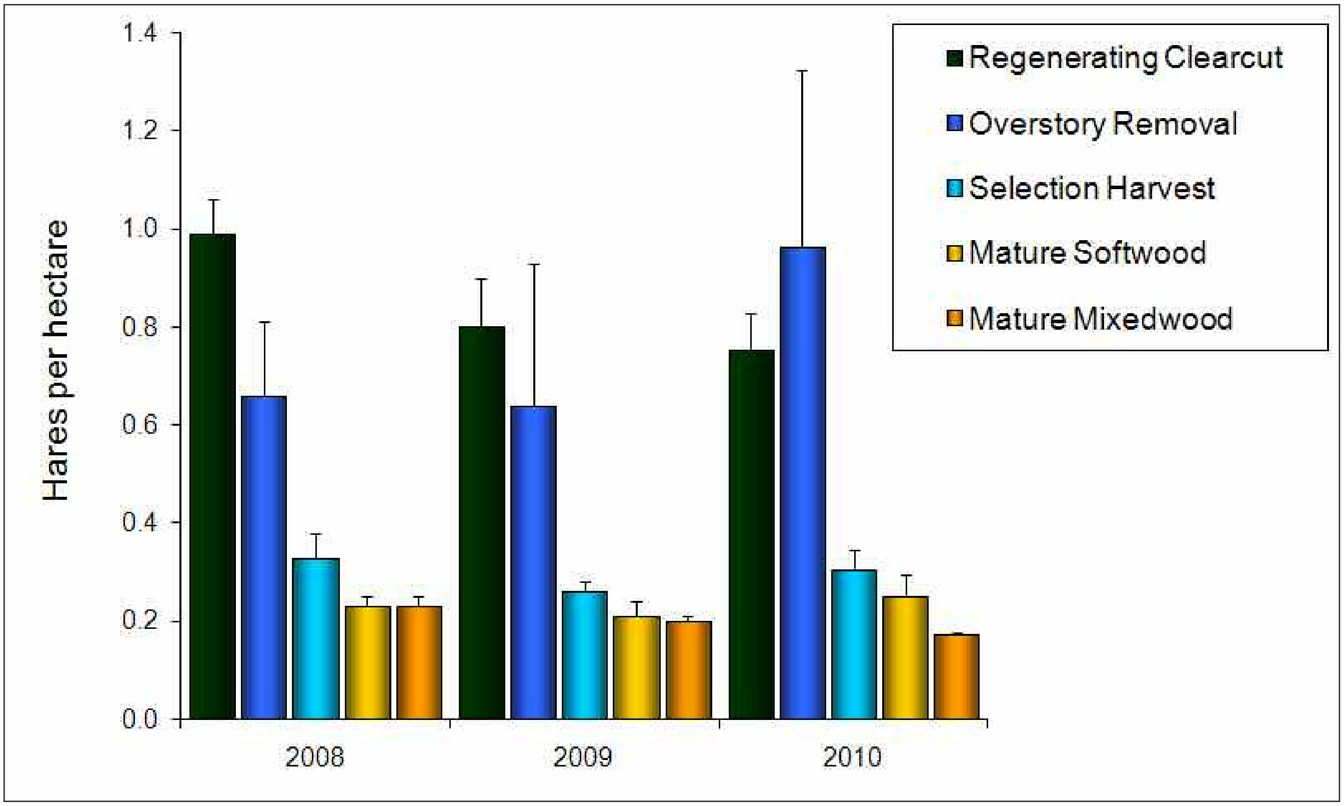

Figure 21. Leaf-off (winter) season density of snowshoe hares among five forest stand types during 2008-2010. Regenerating clearcut stands were monitored 22-37 years post-harvest, whereas 2nd stage overstory removals and first-entry shelterwoods were monitored 7 to 19 years post-harvest. Selection harvests were monitored 13 to 15 years after harvesting and all mature stands were last harvested prior to 1981. Bars represent mean densities across a stand type and whiskers represent one standard error.

Future Plans

The 2011 goals of the project are to continue the long-term monitoring of over-winter hare densities in the regenerating, shelterwood, overstory removal, selection, and mature stands; and to examine seasonal stand-scale dynamics of snowshoe hare densities and vegetation. Additionally, in collaboration with Maine Department of Inland Fisheries and Wildlife, we will complete ongoing studies of the effects on changing hare densities on spatial dynamics and habitat relationships of lynx. The objectives of this portion of the project are to:

1) Extend out time series of over-winter hare densities among our 5 major stand types to help determine if populations cycle, and if so, at what level of magnitude and periodicity.

2) Evaluate differences in hare density between summer and winter seasons among the different forest stand types for the seven-year period 2005-2011.

3) Quantify winter vegetation characteristics to compare with summer vegetation characteristics among the different stand types to determine which suite of vegetation variables most strongly influence habitat quality for snowshoe hares.

4) Evaluate the effects of changing hare densities on spatial dynamics and habitat relationships of lynx (data collection is complete and analyses are proceeding with completion of this objective scheduled for May 2011).

Though fecal pellet surveys have been conducted after leaf-off (winter) and leaf-on (summer) seasons since 2001, the data set has been used to estimate leaf-off season hare densities. In 2011, analyses are also planned to explore how biannual fecal pellet counts perform as a predictive estimate of hare densities. Fecal pellet surveys are a proxy to estimate actual snowshoe hare densities, which are most accurate when measured by an extensive and costly census effort in the form of capture-mark-recapture or individual genetic tagging. Homyack et al. (2007) developed an equation to predict stand level hare density based upon winter only pellet surveys by validating the winter pellet count data with an end of winter capture effort. We hope to determine whether pellet surveys from summer only, or from annual pellet counts pooled across seasons perform as well as predictive models of hare density based only on winter pellet surveys.

During January and March 2011, we plan to measure winter vegetation in three forest stand types. A repeat measure of vegetation will be done in July and August for comparison with winter vegetation. Figure 22 is a preliminary plot of percentage changes in fecal pellet density within stands from winter to summer. The two different stand types, regenerating conifer clearcut (Figure 22a) and partial harvest (Figure 22b) show

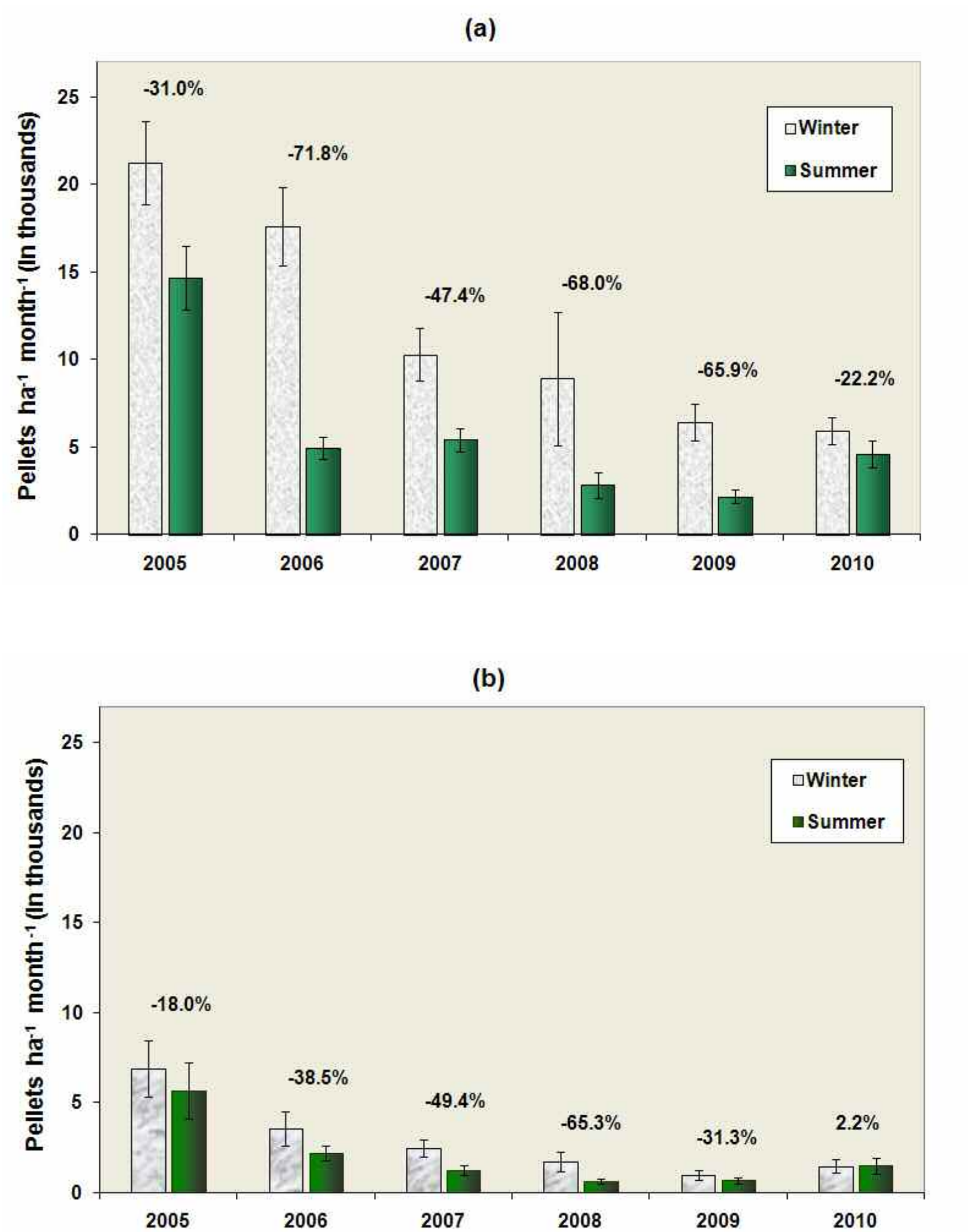

Figure 22. Snowshoe hare summer compared to winter pellet densities (pellets/ha/month) during 2005-2010. Bars represent mean densities across a stand type and whiskers represent one standard error. Figure 22a depicts results for regenerating clearcut fir-spruce dominated stands 22 to 37 years post harvest.
Figure 22b depicts results for selection- harvest stands.

different relative changes in fecal pellet densities across seasons during most years. We hypothesize that different forest stand types show proportionately different hare densities seasonally because individuals move toward better forage and more cover. A 2011 investigation is planned to evaluate seasonal density differences among the forest stand types and to relate those findings to seasonal changes in vegetation structure.

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The white fur of the snowshoe hare in winter draws less attention to predators

Documenting the Response of Canada Lynx to Declining Snowshoe Hare Populations in an Intensively Managed Private Forest Landscape in Northern Maine

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Summary of Progress

This is the last year of a three year effort to document the response of lynx to lower hare densities by monitoring 20 lynx a year with GPS collars. At the start of 2009-2010 field effort, 19 of 25 lynx (ten males and nine females) were equipped with a GPS collar with an additional lynx equipped with a GPS collar in 2010. The objectives of our field efforts in 2010 were to: 1) recover data from GPS collars, 2) maintain a sample of radio-collared female lynx to document reproduction, 3) document mortalities, and 4) monitor snowshoe hare densities within the study area.

In 2010, we recovered data from 17 of the 20 GPS-collared lynx. Currently two female lynx are still equipped with GPS collars (their release mechanism did not deploy) and three lynx are missing. During the 2010 season, twelve lynx (nine males and three females) were captured 37 times, including three new individuals (all males) during an 83-day winter and a 45-day summer/fall field effort, involving a six and three person field crew, respectively. We released three new male lynx without a GPS collar because the collars would deploy before providing sufficient data to document their movements and habitat preferences. In 2010, a total of nine lynx (five males and four females) died, which included six lynx (three males and three females) equipped with GPS collars.

During the winter of 2010 we tracked seven radio-collared adult female lynx to determine if they had kittens (i.e., observed tracks of kittens with the adult female in the snow). None of those females tracked were observed with kittens. In the spring, we monitored radio-collared adult female lynx and found that all five females had given birth to kittens. At the end of October 2010, we were monitoring five lynx equipped with GPS collars and two lynx equipped with satellite collars. However, one satellite and three GPS collars are not emitting a signal.

Project Overview

In 1999, the Maine Department of Inland Fisheries and Wildlife (MDIFW) and our partners initiated a telemetry study to document the status of the federally threatened Canada lynx (*Lynx canadensis*) in northern Maine. Maine is one of only four states and the only northeastern state that has a confirmed resident lynx population. This telemetry-based study was initiated to gain a better understanding of lynx and snowshoe hare (their primary food source) populations in the northeast. Our initial 5-year study provided information on the status and habitat needs of lynx during high hare densities. However, a 5-year study was inadequate to address whether Maine's lynx population would persist if prey densities declined. Therefore in 2004 we acquired sufficient funds to continue this study for another 5 years to document behavioral and demographic changes in Maine's lynx population during a period when local hare populations may fluctuate downward.

By 2006, there was some evidence that snowshoe hare populations were beginning to decline in northern Maine's regenerating spruce-fir clearcuts. At the same time, we observed a reduction in the number of reproducing female lynx. By 2007, snowshoe hare densities had declined to less than one per hectare in Maine's regenerating conifer clearcuts and subsequently none of the female lynx produced litters. In 2007, the University of Maine, MDIFW, and the US Fish and

Wildlife Service initiated a cooperative study to assess the variability in lynx population demographics and possible threshold densities of hares needed to support lynx in Maine. This study continues the ongoing lynx telemetry efforts in northern Maine, but with the benefit of using GPS technology. We received a two year grant from the CFRU to assist with this effort. In 2010, support from the CFRU and its members provided the matching funds that leveraged an additional $78,000 in federal grants.

Primary Activities in 2010

From January 8th to April 1st, a 6-person field crew set cage traps to capture lynx and conducted track surveys to document the presence of kittens in the Musquacook Lakes study area by tracking, on foot, each radio-collared adult female and counting the number of kitten tracks. To monitor lynx reproductive effort in 2010, we replaced the GPS collars on female lynx captured during the winter with GPS collars set to release on July 1, otherwise GPS collars would have released in March before females gave birth to kitten. We also downloaded locational data from every lynx captured this winter before releasing the animals. In early May, we set traps for seven days in an attempt to recapture a female lynx to determine if she would produce kittens in June. Beginning in May, all radio-collared female lynx were located at least twice a week to document den initiation and the production of kittens. In June, we located and visited den sites to count, mark, sex, and measure kittens. Although we did not plan to trap lynx this summer, we set traps for 12 days in July and 45 days this fall to capture three adult female lynx whose GPS collars did not release as scheduled. Throughout the year, Warden Service pilots monitored the mortality signal on each lynx collar to determine if the lynx was still alive. Mortality flights occurred once a week during the winter, once a month during the spring and summer, and twice a month during the fall. We investigated each mortality site and performed necropsies to determine the cause of death.

Preliminary Results

Field Efforts

Throughout 2010, we monitored 25 radio-collared lynx (14 males and 11 females) including 20 lynx wearing GPS collars. We captured twelve different lynx (nine males and three females) 37 times, including three new lynx (all males). Although we did not equip these new cats with collars, early in the winter the satellite collar on one male lynx was replaced with a GPS collar to obtain better locational data. This also provided us the opportunity to further evaluate a collar release mechanism for GPS collars.

When we started our winter capture effort, three of nine females were equipped with GPS collars that would release in March. During the winter season, we captured two of the females and equipped them with a GPS collar scheduled to release in July, after we visited dens. The collar of the other female released on March 30th and we made a brief attempt in early May to recapture her before she gave birth to kittens, but were unsuccessful. We recovered GPS data from 17 of 20 GPS collars (Table 8). Seven of nine GPS collars released on their schedule release date allowing us to recover their data: five at the end of March and one in both July and August. In the fall, we captured and recovered the data from one lynx whose GPS collar did not release. We also removed two GPS collars from lynx during our trapping efforts and recovered data from six GPS collars when the lynx died. Two female lynx are still equipped with functioning GPS collars that failed to release in July. Fortunately, we recovered data when we caught one in March to replace her GPS release mechanism.

Table 8. Status of GPS collars equipped on 20 lynx (11 males and 9 females) in 2010.

Data Recovered	**Male**	**Female**	**Total**
Collars Released	5	2	7
Collars Removed	1	1	2
Mortalities	3	3	6
Active Collars	0	1	1
MIA	1	0	1
Total Recovered	10	7	17
Collars not recovered			
MIA	1	1	2
Active collars	0	1	1
Total Not Recovered	1	2	3

In 2010, nine lynx (five males and four females) including six lynx (three males and three females) equipped with GPS collars died. Four lynx were killed by fisher, one lynx was likely killed by a fisher, one died of starvation, one was struck by a vehicle, one died of unknown causes, and one was killed in a snare in Quebec. The lynx killed in a snare was the only lynx still equipped with a VHF collar.

During the winter of 2010, we backtracked five female lynx captured for the first time in the fall of 2009 to assess whether they had produced a litter of kittens during the spring of 2009. We also backtracked two of four female lynx that did not appear to give birth to kittens in 2009. We did not observe kitten tracks while backtracking, nor did we observe kitten tracks at any of the capture sites this winter. Thus, it appears that not only the four females monitored during the spring of 2009, but also the five lynx captured the following fall did not produce a litter of kittens in 2009.

By the spring of 2010, we were monitoring eight lynx (including five adult females). After two years of no reproduction, all five radio-collared adult female lynx produced litters of two to three healthy kittens. We examined and marked twelve kittens (five males and seven females) in five litters. Forest management staff from Orion Timberlands LLC and LandVest Timberlands accompanied us to den visits this spring.

We monitored prey densities on the lynx study area in the fall, spring, and winter. During the winter, we counted prey tracks along established permanent transects within our study area on January 31st, February 10th, and March 2nd and 3rd. Unfortunately the lack of snow restricted additional efforts in late March. In May and September, we counted snowshoe hare fecal pellets at 16 sites to document hare densities in our study area.

Data Analysis

David Mallett, a graduate research assistant at the University of Maine, analyzed locational error and fix success of GPS collars in different habitats and completed the first chapter of his thesis during the summer and fall of 2010. Of the 27 lynx monitored with GPS collars since 2007, there was sufficient data to document home range size and habitat use for sixteen lynx (ten males and six females). He is currently analyzing VHF telemetry data from a period of higher hare densities and GPS locational data from a period of lower hare densities to assess if home range size, territoriality, and use of high quality hare habitat changed (Table 9).

Plans for 2011

Over the next year, we will prepare a final report and forest management recommendations and attend CFRU meetings to share our findings. David Mallett anticipates completing his analyses and defending his thesis in the spring.

Table 9. Comparison of available data to summarize lynx home range and habitat use at different prey densities.

Period	Location type	Years	Males	Females	Total
High hare density period	VHF only	2001-2005	13	10	23
Declining hare density period	GPS only	2007-2010	10	6	16

APPENDICES

OUTREACH

CFRU at the New England Society of American Foresters meeting in Nashua, NH.

Journal Publications

Benjamin, J.G., R.J. Lilieholm, and C.E. Coup. 2010. Forest Biomass Harvesting in the Northeast: A "Special Needs" Harvest Operation? Northern Journal of Applied Forestry 27(2):45-49.

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