Annual Report 2015

Center for Research on Sustainable Forest
University of Maine

Cover photo by Pam Wells

About the Center

The Center for Research on Sustainable Forests (CRSF) was founded in 2006 to build on a rich history of leading forest research and to enhance our understanding of Maine's forest resources in an increasingly complex world. The CRSF is currently built around four major research programs: Commercial Forests, Family Forests, Conservation Lands, and Nature-Based Tourism. Researchers in these programs work together and collaboratively with diverse stakeholders to solve the full array of problems facing Maine's forests, and contribute to the sustainability of Maine's forest resources.

Our mission is to *conduct and promote leading interdisciplinary research on issues affecting the management and sustainability of northern forest ecosystems and Maine's forest-based economy.*

Center for Research on Sustainable Forests University of Maine
5755 Nutting Hall
Orono, Maine 04469-5755
Tel. 207.581.3794
crsf.umaine.edu

Table of Contents

Director's Report

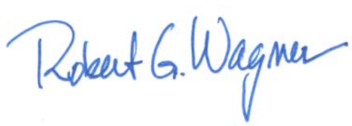
The Center for Research on Sustainable Forests (CRSF) had another productive year during 2014-15. We are especially pleased to announce the formation of our **Nature-based Tourism Research Program** led by **Dr. Sandra De Urioste-Stone**, who initiated a major new study to assess the economic impact of tourism in Maine.

Center programs were successful in a number of other areas. The Commercial Forests Research Program, headed by **Drs. Bob Wagner** and **Brian Roth**, led a dozen stakeholder-driven research projects for 35 member organizations through the Cooperative Forestry Research Unit (CFRU) representing half of Maine's forest, led development of a statewide spruce budworm assessment, and provided members with updated depth-to-water-table maps for the State of Maine. **Dr. Rob Lilieholm** made two new videos about the Maine Futures Community Mapper tool for the Conservation Lands Research Program. In the Family Forests Research Program, **Dr. Jessica Leahy** worked closely with the Small Woodland Owner Association of Maine (SWOAM) to assist small family forest owners with their estate planning needs, and to better understand the intergenerational transfer of forestlands which will affect the future of a third of Maine's forest in the coming decades.

The CRSF worked closely with the Maine Forest Products Council and Maine Forest Service to lead the Maine Spruce Budworm Task Force. In addition, the Howland Research Forest continues to be a valued research asset of the CRSF. Two new grants from the USFS Northern Research Station will allow **Dr. Shawn Fraver** and research assistant **John Lee** to continue making automated greenhouse gas, eddy covariance (flux), and numerous other atmospheric measurements as part of the national Ameriflux Network.

We welcomed **Dr. Arun Bose** to CRSF this year as Post-doctoral Research Fellow to coordinate several research projects associated with the National Science Foundation's Center for Advanced Forestry Systems (CAFS) that is part of the CFRU.

The overall success of the CRSF this year is also due in large measure to the hard work of many scientists, graduate students, and summer technicians that worked on CRSF research projects. Their hard work and accomplishments are described in the following report.



Robert G. Wagner
CRSF Director

People

Leadership & Staff

Robert Wagner, *Director*

Brian Roth, *Commercial Forests Program Leader & CFRU Associate Director*

Sandra de Urioste-Stone, *Nature-Based Tourism Program Leader*

Jessica Leahy, *Family Forest Program Leader*

Rob Lilieholm, *Conservation Lands Program Leader*

John Lee, *Research Associate, Howland Research Forest*

Arun Kantibose, *CFRU Post-Doctoral Research Scientist*

Meg Fergusson, *CRSF Administrative Assistant*

Cynthia Smith, *CFRU Administrative Assistant*

Cooperating Scientists

Jeffrey Benjamin *(CFRU)*

Daniel Harrison *(CFRU, NSRC)*

Robert Seymour *(NSRC)*

Aaron Weiskittel *(CFRU, NSRC)*

Project Scientists

Paul Arp, *University of New Brunswick (CFRU)*

Inornate Ringlet Butterfly - photo by Pam Wells

Mohammad Bataineh, *University of Arkansas (NSRC, CFRU)*

Eric Blomberg, *University of Maine (CFRU)*

Randall Boone, *Colorado State University (Conservation Lands)*

John Brissette, *USF-NRS (NSRC)*

Mark Castonguay, *University of New Brunswick, (CFRU)*

Sophan Chhin, *Michigan State University (NSRC)*

Stephen Colombo, *Ontario Forest Research Institute (NSRC)*

Anthony D'Amato, *Univ. of Minnesota (NSRC)*

John Daigle, *University of Maine (NSRC)*

Michael Day, *University of Maine (NSRC)*

Mark Ducey, *Univ. of New Hampshire (NSRC)*

Bob Evans, *USDA Forest Service (Howland)*)

Wood Duck - photo by Pamela Wells

Ivan Fernandez, *Univ. of Maine (NSRC)*

Shawn Fraver, *Univ. of Maine (NSRC, CFRU)*

Todd Gabe, *Univ. of Maine (Tourism)*

Chris Hennigar, *Univ. of New Brunswick (CFRU, NSRC)*

David Hollinger, *USDA Forest Service (NSRC, Howland)*

Holly Hughes, *Woods Hole Research Center (Howland)*

Michelle Johnson, *U.S. Forest Service (Conservation Lands)*

Tora Johnson, *Univ. of Maine-Machias (Conservation Lands)*

Jennifer Hushaw, *INRS, LLC. (NSRC)*

John Kershaw, *Univ. of New Brunswick (CFRU)*

Laura Kenefic, *USFS-NRS (NSRC CFRU)*

David Kittredge, *Univ. of Mass.* (Family Forests)

Christian Kuehne, *Univ. of Maine (NSRC)*

Eric Labelle, *Northern Hardwood Research Institute (CFRU)*

Kasey Legaard, *Univ. of Maine (CFRU, NSRC)*

Cynthia Loftin, *USFWS / Univ. of Maine (CFRU)*

Pengxin Lu, *Ontario Forest Research Institute (NSRC)*

Spencer Meyer, *Yale School of Forestry Environmental Studies (NSRC)*

Andrew Nelson, *Univ. of Arkansas at Monticello* (NSRC)

Jesse Njoka, *University of Nairobi, Kenya (Conservation Lands)*

Caroline Noblet, *Univ. of Maine (Family Forests, Tourism)*

Jae Ogilvie, *University of New Brunswick (CFRU)*

Joseph Ogulu, *International Livestock Research Institute (Conservation Lands)*

Dave Owen, *Maine Law School (Conservation Lands)*

Bill Parker, *Ontario Forest Research Institute (NSRC)*

Gaetan Pelletier*, Northern Hardwoods Research Institute (CFRU)*

Parinaz Rahimzadeh, *Univ. of Maine (CFRU)*

Robin Reid, *Colorado State University (Conservation Lands)*

Mohammed Said, *International Livestock Research Institute (Conservation Lands)*

Erin Simons-Legaard, *Univ. of Maine (CFRU, NSRC)*

Susan Stein, *USFS-NRS (NSRC)*

Crista Straub, *Univ. of Maine (Family Forests)*

Brian Sturtevant, *USFS-NRS (NSRC)*

Michael Ter-Mikaelian, *Ontario Ministry of Natural Resources (NSRC)*

Suraj Upadhaya, *Univ. of Kentucky (Conservation Lands)*

Jeremy Wilson, *Harris Center for Forest Conservation (NSRC)*

Jeffrey Worden, *African Conservation Centre, Nairobi, Kenya* (Conservation Lands)

Petra Wood , *USGS West Virginia Cooperative Fish Wildlife Research Unity (CFRU)*

Ronald Zalesny, *U.S. Forest Service* (NSRC)

GRADUATE STUDENTS

Caitlin Andrews *(NSRC)*

Patrick Clune *(CFRU)*

Jon Doty *(NSRC)*

Stephen Dunham *(CFRU)*

Rei Hayashi *(CFRU)*

Patrick Hiesl *(CFRU)*

Lydia Horne *(Conservation Lands)*

Michelle Johnson (*Conservation Lands, NSRC)*

Cody LaChance *(CFRU)*

C.J. Langley *(NSRC)*

Sabrina Morano *(CFRU)*

Bethany Munoz*, (NSRC)*

Sheryn Olson *(CFRU)*

Allison Price*, (NSRC)*

Ben Rice, *(NSRC, CFRU)*

Brian Rolek *(CFRU)*

Matthew Scaccia *(Tourism)*

Jared Stapp *(Conservation Lands)*

Joel Tebbenkamp *(CFRU)*

Kristen Weil *(Conservation Lands)*

Emily Wilkins *(Tourism)*

Nathan Weseley *(CFRU)*

Financial Report

Income and expenses for the CRSF during FY2014-15 are shown in Table 1. Income supporting the center came from programs administered by or that support the general operations of the CRSF ($1,085,940), UMaine competitive sources ($111,001), as well as extramural grants supporting specific research projects ($867,600) that were received by CRSF scientists from outside agencies. These extramural grants made up 42% of funding for the center (Figure 1). Total funding of the CRSF for FY 2014-15 was $2,064,521 million.

The proportion of total funding allocated to research programs making up the CRSF is shown in Figure 1: Commercial Forests (58%), Family Forests (10%), Nature-Based Tourism (5%), Conservation Lands (<1%), Howland Research Forest (10%), and Northeastern States Research Cooperative (17%), research projects supported by the. About 81% of the funding received by CRSF went directly to support research projects described in this report (Figure 1). The remaining funds supported personnel salaries (9%) and center operating expenses (10%).

A key source of financial support for the CRSF is provided by the Maine Economic Improvement Fund (MEIF). The $160,892 investment from MEIF helped leverage $925,028 from other CRSF sources, $111,001 from UMaine competitive sources, and $867,600 in extramural grants for a total of leverage of $1.9 million. This means that every dollar of MEIF fund leveraged $1,903,629 (or $11.83 for every dollar of MEIF funding) of additional research funding.

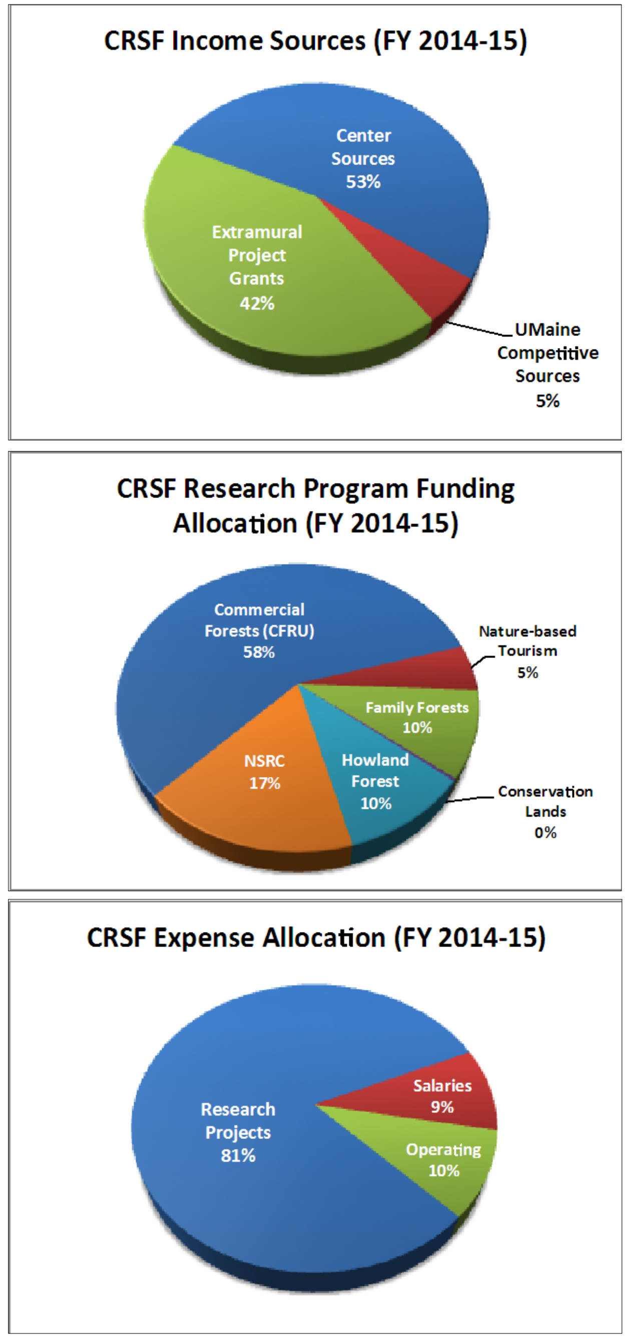


Figure 1 - Income sources, research program allocation, and expense allocation for CRSF during FY 2014-15.

Table 1 – FY2014-15 Budget for Center for Research on Sustainable Forests

INCOME	Funding Source	PI	Amount
Center Sources:			
Cooperative Forestry Research Unit	CFRU	Wagner	$ 505,025
US Forest Service-Northeastern States Research Cooperative Theme 3 (NSRC)	USDA	Wagner	$ 350,906
Maine Economic Improvement Fund	MEIF	Wagner	$ 160,892
Center for Advanced Forestry Systems (CAFS)	NSF	Wagner / Weiskittel	$ 60,000
CRSF Gift Fund	Gift	Wagner	$ 1,500
UMaine Munsungan Fund	Gift	Wagner	$ 7,597
		Center Source Total	**$ 1,085,920**
UMaine Competitive Sources:			
Community Resilience and Quality-of-Place in Maine: The Penobscot River Bay-to-Baxter Corridor Initiative	Maine Margaret Chase Smith Policy Center	De Urioste-Stone	$ 4,000
Economic Impact Study for Maine's Tourism Industry	UMaine's Office of the President	De Urioste-Stone	$ 24,719
Resilience of Rural Maine Communities to Climate Change: A Pilot Study of the Nature-based Tourism Industry	UMaine's Rising Tide Grants Program (NSF)	De Urioste-Stone	$ 7,487
Climate Change and Tourism	UMaine's Pretenure Research and Creative Activity Fellowship Program	De Urioste-Stone	$ 6,200
Promoting Economic Development and Quality-of-Place in Maine: The Penobscot River Bay-to-Baxter Corridor Initiative	SSI/EPSCoR	De Urioste-Stone	$ 10,000
Certification of Sustainable Forestry: A Critical Evaluation of Forest Management Performance Standards and Audit Protocols based on Established Science and Stakeholder Perceptions	SSI/EPSCoR	Seymour, Leahy, Fraver, De Urioste-Stone, & Sherwood	$ 58,595
		UMaine Competitive Source Total	**$ 111,001**
Extramural Research Grants:			
How Well Are We Serving the Outdoor Recreation Public?	USDA	De Urioste-Stone	$ 34,955
Supporting Carbon Cycle (Yr 4)	USDA NFS	Fernandez/Wagner	$ 49,200
Beginning Landowner Project	Maine Timberlands	Leahy	$ 60,000
Family Forest Ownership Decisions of Intergenerational Transfer	USDA NIFA AFRI	Leahy	$ 43,200
The Maine Woods Dashboard	State of Maine	Lilieholm	$ 5,000
CFRU Extramural Funds FY 13-14	CFRU	Cooperating Scientists	$ 554,716
Support of AmeriFlux Research at the Howland Research Forest	USDA NFS	Fraver	$ 120,529
		Extramural Research Grant Total	**$ 867,600**
		TOTAL INCOME	**$2,064,521**

American Toad – Photo by Pam Wells

Table 1 continued

ALLOCATION	Funding Source	PI		Amount
Salaries & Benefits:				
Director, Associate Director, Program Leaders, and Scientists				149,455
Support staff + grad students				44,108
		Salaries & Benefits Total		**193,563**
Operating Expenses:				**199,106**
		Salaries, Benefits, & Operating Total	**$**	**392,669**
Research Projects:				
Commercial Forests (CFRU):				
Commercial Thinning Research Network	CFRU	Wagner et al.	$	43,907
Machine Productivity and Cost	CFRU	Benjamin et al.	$	8,602
Austin Pond: Third Wave	CFRU	Wagner et al.	$	8,952
Young Hardwood Stand Responses	CFRU	Wagner et al.	$	23,295
Effects of Mechanized Harvesting Operations on Rsidual Stand Condition	CFRU	Benjamin et al.	$	14,680
Attributes of Old- and Second-Growth Northern White-Cedar Stands	CFRU	Weiskittel	$	12,000
Weymouth Point: Silvicultural Treatments on Long-Term Spruce-Fir Productivity	CFRU	Roth	$	12,811
Linking LiDAR to Ground-Based Inventory	CFRU	Weiskittel	$	30,275
Extending the Acadian variant of FVS to managed stands	CFRU	Weiskittel	$	18,936
Maine LiDAR Data Acquisition Project	CFRU	Young	$	10,000
Depth-to-Water Mapping	CFRU	Castonguay	$	48,400
Long-term Monitoring of Snowshoe Hare	CFRU	Harrison	$	71,021
Spruce Grouse Habitat	CFRU	Harrison	$	22,008
Effects of Forest Management Practices on Forest Bird Communities	CFRU	Harrison	$	29,896
CFRU Extramural Grants from Coooperating Scientest in FY 13-14	Various	Coop Sci	$	554,716
		Commercial Forests Project Total	**$**	**909,499**
NSF Center for Advanced Forestry Systems (CAFS):	NSF	Wagner/Weiskittel	$	60,000
		CAFS Total	**$**	**60,000**
Family Forests:				
Beginning Landowner Project	Maine Timb. Trust	Leahy	$	60,000
Family Forest Owner Decisions of Intergenerational Transfer	USDA NIFA AFRI	Leahy	$	43,200
Certification of Sustainable Forestry	SSI/EPSCoR	Leahy	$	58,595
		Family Forests Project Total	**$**	**161,795**
Nature-Based Tourism:				
How Well Are We Serving the Outdoor Recreation Public?	Dept. of Ag, Cons & Forestry	De Urioste-Stone	$	34,955
Community Resilience and Quality-of-Place in Maine	Margaret Chase Smith Policy Center	De Urioste-Stone	$	4,000
Economic Impact Study for Maine's Tourism Industry	UM President's Grant	De Urioste-Stone	$	24,719
Resilience of Rural Maine Communities to Climate Change	Rising Tide Grant/NSF	De Urioste-Stone	$	7,487
Climate Change and Tourism	UM Fellowship	De Urioste-Stone	$	6,200
Promoting Economic Development and Quality-of-Place in Maine	SSI/EPSCoR	De Urioste-Stone	$	10,000
		Nature-Based Tourism Project Total	**$**	**87,361**
Conservation Lands:				
Maine Woods Dashboard	State of Maine	Lilieholm	$	5,000
		Conservation Lands Project Total	**$**	**5,000**
NSRC Theme 3:				
Incorporating spruce budworm impacts into the Acadian variant of te forst	NSRC	Bataineh	$	69,747
Emeral Ash Borer in Maine	NSRC	Daigle	$	60,685
Perspective on Biomass Harvest	NSRC	Kenefic	$	68,800
Assessing the influence of tree form ad damage on commercial hardwoods	NSRC	Weiskittel	$	79,236
		NSRC Project Total	**$**	**278,468**
Howland Forest:				
Supporting Carbon Cycle, Yr 4	USDA	Fernandez/Wagner	$	49,200
Support of AmeriFlux research at the Howland Research Forest	USDA NFS	Fraver	$	120,529
		Howland Project Total	**$**	**169,729**
		Research Project Total	**$**	**1,671,852**
		TOTAL ALLOCATION		**$2,064,521**

Stakeholders

CRSF researchers strive to conduct not just cutting-edge forest science, but also real-world, applied science about Maine's forests, forest-based businesses, and the public that supports them. We build and foster relationships with a wide variety of organizations and their people to achieve common goals. Over the past year we have worked with the following partners:

Red Saddlebag Dragonfly - Photo by Pam Wells

Acadia National Park

Ameriflux

Androscoggin Valley Council of Governments

Appalachian Mountain Club

Baskahegan Corporation

Baxter State Park, Scientific Forest Management Area

BBC Land, LLC

Bear Brook Experimental Watershed

Canopy Timberlands Maine, LLC

Clayton Lake Woodlands Holding, LLC

Colorado State University

Downeast Lakes Land Trust

Eastern Maine Development Corp.

EMC Holdings, LLC

Field Timberlands

Forest Society of Maine

Frontier Forest, LLC

Highstead's Regional Conservation Partnership

Hilton Timberlands, LLC

Huber Engineered Woods, LLC

Institute of Forestry (Pokhara, Nepa;)

Irving Woodlands, LLC

Katahdin Forest Management, LLC

LandVest

Lincoln Institute of Land Policy

Maine Bureau of Parks and Lands

Maine Department of Agriculture, Conservation, and Forestry

Maine Department of Environmental Protection

Maine Department of Inland Fisheries and Wildlife

Maine Division of Parks and Public Lands

Maine Forest Service

Maine Forest Products Council

Maine Office of Tourism

Maine STEM Alliance

Maine Tree Foundation

Mosquito, LLC

National Science Foundation

Natural Resources Conservation Service

New Brunswick Tree Improvement Council

New Brunswick Department of Natural Resources

New England Forestry Foundation

North Woods Maine, LLC

Nova Scotia Department of Natural Resources

Orono Land Trust

PenBay Regional Land Trust

Penobscot Experimental Forest

Plum Creek Timber Company, Inc.

Portland Metropolitan Planning District

Prentiss & Carlisle Company, Inc.

Prince Edward Island Department of Natural Resources

Quebec Ministry of Natural Resources

ReEnergy Holdings, LLC

Robbins Lumber Company

SAPPI Fine Paper

Schoodic Institute

SeedTree Nepal

Seven Islands Land Company

Simorg North Forest, LLC

Small Woodland Owners Association of Maine

Snowshoe Timberlands, LLC

St. John Timber, LLC

Sylvan Timberlands, LLC

Social and Economic Sciences Research Center, Washington State University

The Forestland Group, LLC

The Nature Conservancy

Timbervest, LLC

University of Maine, Upward Bound

University of New Hampshire

University of Vermont, Rubenstein School of Environment and Natural Resources

UPM Madison Paper

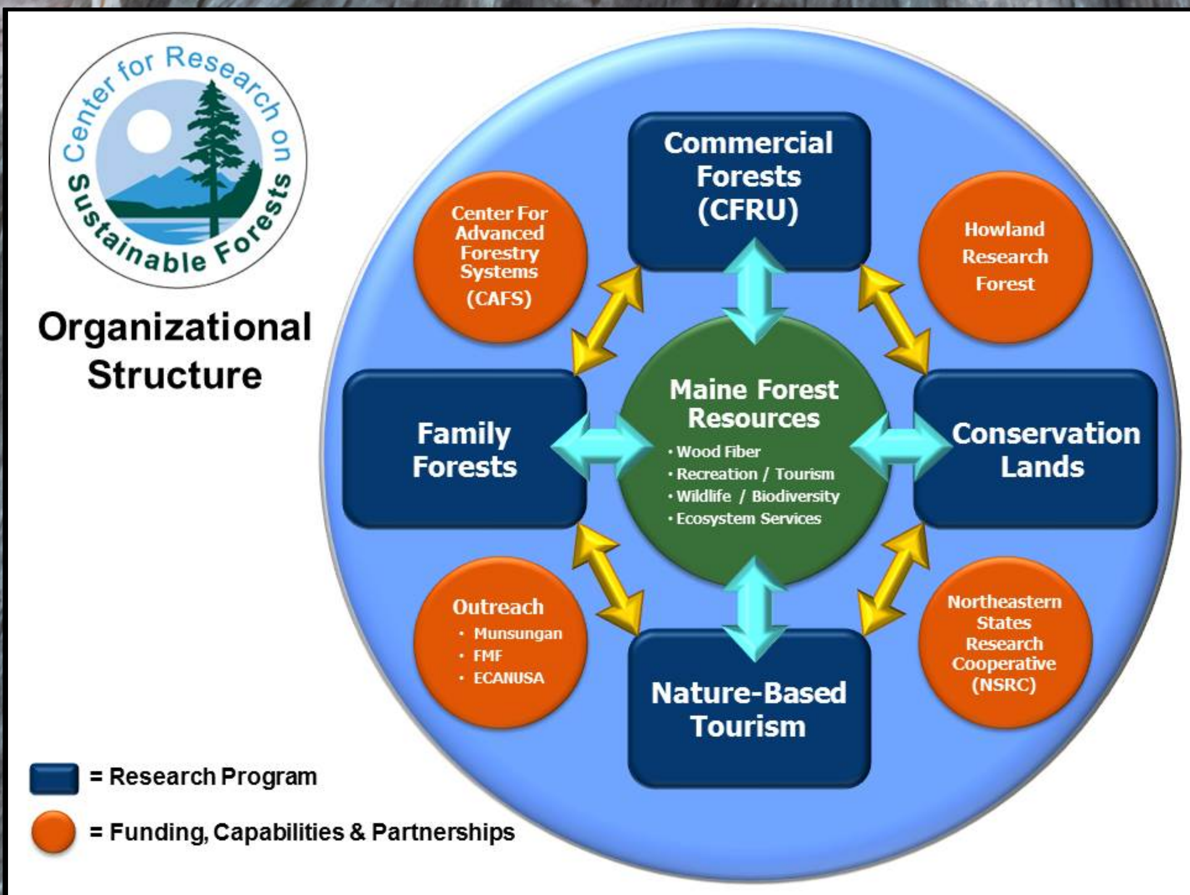
USDA, Forest Service, Northern Research Station

Wagner Forest Management

Woods Hole Research Center

World Wildlife Fun-Nepal

CRSF Research Programs



Nature-Based Tourism

The Nature-Based Tourism Program of the CRSF was established in 2014 and has quickly gained momentum. Tourism plays a vital role in the culture, economy, and future economic development of Maine's rural communities, as well as in the overall economy of the state. Tourism in Maine provides economic and non-economic values to its citizens, including nature conservation, cultural heritage maintenance and pride, and infrastructure and facility improvement. Maine's outstanding tourism assets, along with the diversity of outdoor recreation opportunities, attract millions of visitors annually to and within Maine. Challenges to capturing growth opportunities relate to changes in visitor travel behavior, economic crises, constrained integrated tourism planning and development, and extreme weather events/natural disasters. By regularly gathering, analyzing, and communicating information about the economic impact and trends of tourism in Maine we expect to increase the efficiency of and opportunities for Maine's tourism industry.

In its inaugural year, the program has received $87,361 in research funding and launched five sustainable tourism-related research projects, mailed 3,000 surveys on recreational use and changing socioeconomic and environmental conditions to residents along the Penobscot River, conducted field surveys in various recreational areas of the state, including Acadia National Park and Sebago Lake; and contributed survey data to the Maine State Comprehensive Outdoor Recreation Plan for 2014–2019.

Research assistants Lydia Horne and Ashley Cooper at Acadia National Park, Mount Desert Island, Maine - Photo by Emily Wilkins)

Understanding Visitor Perceptions about the Impacts of Climate Change to Tourism Destinations in Maine

Sandra DeUrioste-Stone
University of Maine

Final Report

Thunder Hole, Acadia National Park, Maine
Photo by Matt D. Scaccia

Summary:
Climate change is one of the most pressing global environmental issues facing the world today and one that has major social, economic and environmental repercussions (Yu, Schwartz, & Walsh, 2009). Among all economic sectors, tourism is considered one of the most vulnerable industries to climate change due to its frequent reliance on natural resources as primary assets (Lépy et al., 2014). In spite of this, research on the potential effects of climate change on tourism destinations remains scarce (Dawson & Scott, 2007). A comparative case study was conducted in two Maine tourism destinations to understand (1) visitor perceptions about the impacts of climate change on tourism, (2) visitor risk perceptions associated with climate change, and (3) potential travel substitution strategies in response to changing climatic conditions.

Project Objectives

- Understand the range of perceptions that visitors have about the effects of climate change on tourism in Maine.
- Determine if differences exist among visitors regarding their perceptions of the effects of climate change on tourism in Maine.
- Identify Maine visitor perceptions on the (1) likelihood of climate change impacts to occur, (2) climate change risk perceptions in relation to tourism, and (3) factors that may potentially influence future travel behavior.
- Inform management

Approach

- A case study methodology (Creswell, 2013) was used to measure visitor perceptions about the impacts of climate change on tourism in two study sites: Mount Desert Island region (MDI) and Katahdin region, Maine, US.

- The study comprised of two data collection and analysis phases:

    - Phase 1: included an intercept survey was used to collect data on visitor perceptions about the role of weather in destination selection, potential impacts of climate change to tourism in general, and visitor overall travel behavior. A two stage cluster probability sampling (Scheaffer, Mendenhall III, Ott, & Gerow, 2012) was used to randomly select visitor at selection tourism attractions in both study regions.

    - Phase 2: involved the application of an on-line survey that measured visitors risk perceptions associated with climate change, using Dillman's Tailored Design method (Dillman, Smyth, & Melani, 2014). The online survey inquired about purpose of travel, climate change risk perceptions, and travel substitution strategies.

- Quantitative data were analyzed using SPSS 22, and included independent samples t-test, One-way ANOVA, factor analyses with varimax rotation, and logistic regression.

- Qualitative data were analyzed in NVivo 10 using content analysis and thematic coding.

Key Findings / Accomplishments

<u>Phase 1</u>

- A total of 849 visitors participated in phase 1.

- The majority of participants believe that climate change will affect tourism destinations in Maine (62%). The results indicate the majority of visitors to are concerned with the negative effects that unpredictable weather may have to the regions, and the reduction in visitor numbers (Table 2).

- Statistically significant differences between age groups and gender about the effects of climate change on tourism were identified. By understanding the perceptions of the visitors suitable adaptive strategies and early preparedness actions may be developed to cope with the impacts of climate change to the nature-based tourism industry in national parks.

- In addition, as mentioned by several visitors, lack of information about climate change, or limited understanding of the regions' biophysical factors seriously affected some visitor perceptions of the influence of climate change to tourism in the region.
    - This finding on visitors' concern with the lack of information could be used as an educational opportunity for managers, who may capitalize on this to inform visitors about current biophysical changes to destinations as a result of climate change, visitors' role in reducing their carbon footprint, climate-friendly services offered by the park, adaptation strategies in place, and potential behaviors to encourage. As suggested by several studies (Brownlee, 2012; Brownlee, Hallo, & Krohn, 2013; Brownlee, Powell, & Hallo, 2013; Manning, 2011), assessing visitor perceptions about climate change is essential to develop appropriate management and interpretation strategies, and outdoor recreation programming.
    - Furthermore, research could help inform resource management decisions and aid in the development of targeted climate change education and interpretation programs in protected areas (United Nations, 1992) using tools that may enhance their ability to effectively communicate climate change information (Evans, Hicks, Fidelman, Tobin, & Perry, 2013).

<u>Phase 2</u>

- A total of 179 visitors to Acadia National Park (Mount Desert Island, Maine) completed the online questionnaire.
- Respondents' risk perceptions of climate change impacts as threats to visitors showed an increased importance of other environmental impacts such as increased presence of mosquitoes (60%) and ticks (58%); with extreme events as the key risk to visitors (68%). However, perceptions that pose potential personal risk to visitors gained in significance when considering their influence on travel behavior, including impacts such as disease outbreak and water scarcity. Factor analyses with varimax rotation identified four climate change impact factors associated with perceived vulnerability, perceptions of risk, and influence on future travel to MDI; the four factors generated were: weather patterns, impacts on wildlife, access and health, and physiological and safety needs. Results from logistical regression modeling suggest perceived vulnerability, perceived risks, factors that may influence travel behavior, sociodemographic variables (age and income), and reasons to visit the destination explain variance of importance of weather in the decision to travel to MDI (Table 2).

- Visitors to Acadia National Park perceived Mount Desert Island (MDI)-Acadia National Park to be vulnerable to climate change impacts, such as extreme weather, sea level rise, and increased ticks and mosquitoes.
- In terms of risk perception, visitors perceived potential climate change impacts such as increased presence of mosquitoes (60% of respondents) and increased presence of ticks (58% of respondents) to be among the most important threats to visitors to the area.
- Respondents rated extreme weather (60%), disease outbreak (59%), hurricanes (58%) and water scarcity (57%) as the top four threats to potentially influence visitors' decision to travel to MDI in the future. These results suggest that perceptions of potential threats to one's personal safety and well-being are important when considering potential travel. Studies on climate change perceptions have suggested that when impacts are expected to harm something a person values, concerns regarding the issue may increase (Brownlee, Hallo, Moore, Powell, & Wright, 2014; Stern, Dietz, Abel, Guagnano, & Kalof, 1999).

Sand Beach, Acadia National Park.

Table 2 - Mean responses of perceived likelihood, perceived risks, and influences for potential travel of potential climate change impacts according to responses by visitors to Mount Desert Island–Acadia National Park to the online survey, from September–December

	Mean		
	Perceived likelihood (vulnerability)	Perceived risks/threats	Influence for potential travel
Sea level rise	0.78	0.47	0.10
Extreme weather	0.91	0.77	0.56
Hurricanes	0.28	0.39	0.60
Wildlife migrate out	0.45	0.27	0.04
Wildlife migrate in	0.49	0.11	-0.03
Species extinction	0.23	0.05	-0.03
Reduced snow	0.30	0.16	-0.36
Increased ticks	0.69	0.64	0.48
Increased mosquitoes	0.70	0.65	0.58
Increased ice storms	0.46	0.47	0.08
Heat waves	0.53	0.31	0.21
Disease outbreaks	0.05	0.28	0.71
Damage to roads	0.62	0.40	0.29
Power outages	0.55	0.41	0.40
Water scarcity	-0.04	0.32	0.59
Food scarcity	-0.29	0.20	0.52

Note. Scales range from (-2) to (2)

Future Plans

- Share results with tourism stakeholders.
- Conduct additional research to explore visitor perceptions across climatic regions of Maine.

REFERENCES

Brownlee, M. (2012). Nature-based recreationists' perceptions of climate change and attitudes towards climate change mitigation in natural environments. ClemsonUniversity, Clemson, South Carolina.

Brownlee, M., Hallo, J., & Krohn, B. (2013). Botanical garden visitors' perceptions of local climate impacts: Awareness, concern, and behavioral responses. Managing Leisure, 18(2), 97-117.

Brownlee, M., Hallo, J., Moore, D., Powell, R., & Wright, B. (2014). Attitudes towards water conservation: The influence of site specific factors and beliefs in Environmental Education Research, 19(1), 1-20.

Creswell, J. W. (2013). Qualitative inquiry & research design: Choosing among five approaches (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Dawson, J., & Scott, D. (2007). Climate change vulnerability of the Vermont ski tourism industry (USA). Annals of Leisure Research, 10(3/4), 550-572.

Dillman, D. A., Smyth, J. D., & Melani, L. (2014). Internet, phone, mail, and mixed-mode surveys: The tailored design method (4th. ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Evans, L. S., Hicks, C. C., Fidelman, P., Tobin, R. C., & Perry, A. L. (2013). Future scenarios as a research tool: Investigating climate change impacts, adaptation options and outcomes for the Great Barrier Reef, Australia. Human Ecology: An Interdisciplinary Journal, 41(6), 841-857. doi: 10.1007/s10745-013-9601-0

Lépy, É., Heikkinen, H. I., Karjalainen, T. P., Tervo-Kankare, K., Kauppila, P., Suopajärvi, T., . . . Rautio, A. (2014). Multidisciplinary and participatory approach for assessing local vulnerability of tourism industry to climate change. Scandinavian Journal of Hospitality and Tourism, 14(1), 41-59. doi: 10.1080/15022250.2014.886373

Manning, R. (2011). Studies in outdoor recreation: Search and research for satisfaction. Corvallis, OR: Oregon State University Press.

Scheaffer, R. L., Mendenhall III, W., Ott, R. L., & Gerow, K. G. (2012). Elementary survey sampling (7th ed.). Boston, MA: Brooks/Cole.

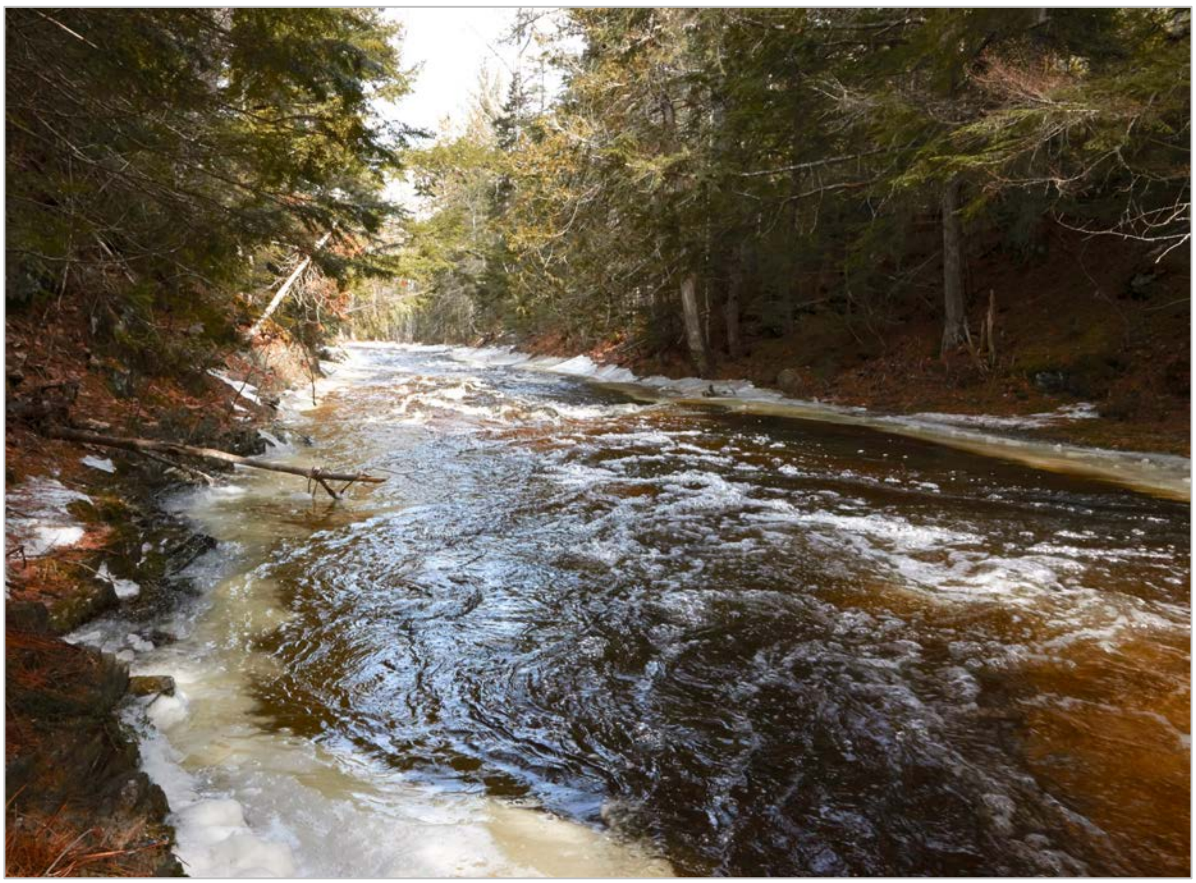
Stern, P., Dietz, T., Abel, T., Guagnano, G., & Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. Human Ecology Review, 6(2), 81-97.

United Nations. (1992). United Nations Framework Convention on Climate Change. Geneva, Switzerland: United Nations.

Yu, G., Schwartz, Z., & Walsh, J. E. (2009). Effects of climate change on the seasonality of weather for tourism in Alaska. Arctic, 62(4), 443-457. doi: 10.2307/40513335

Climate Change. Society & Natural Resources: An International Journal, 27(9), 964-982. doi: 10.1080/08941920.2014.929768

Brownlee, M., Powell, R., & Hallo, J. (2013). A review of the foundational processes that influence beliefs in climate change: Opportunities for environmental education research.



Sunkhaze Stream – Photo by Pam Wells

Analyzing the Economic Impact of Tourism in Maine

Sandra De Urioste-Stone, Caroline Noblet, and Todd Gabe
University of Maine

Progress Report, Year 1 of 2

Graduate research student Emily Wilkins at the Calais Visitor Center, Calais, Maine. (Photo by Lydia Horne)

Summary:
The travel and tourism industry plays a key role in Maine's economy, and the economic development of many communities in the state. By most measures, tourism is considered one of the largest industries in the state (Maine Development Foundation, 2004). In 2012, the industry generated over 20% of the state's jobs (Maine Department of Labor, 2013) and accounted for an estimated 17% of state tax revenue (Maine Revenue Services, 2013). Limited information exists on the economic activity generated by tourism in Maine. This study intends to contribute to the ongoing efforts by the Maine Office of Tourism to estimate the economic impact of the industry. The study includes two phases: (1) a pilot visitor survey (June 2014 - April 2015) to establish an effective and reliable methodology; and (2) a mixed-mode visitor survey (intercept and online) is being conducted in the state to understand travel behavior and spending.

Project Objectives

- Inform existing efforts by the Maine Office of Tourism to estimate the economic impact of the travel and tourism industry in the state.
- Develop an economic impact assessment methodology responding to Maine's needs and context.
- Contribute to the development of instruments to estimate the economic impact of tourism at the state level.

Approach

- Utilize an intercept survey to understand general travel behavior of visitors to Maine.
- Use of an online survey that applies Dillman's Tailored Design method (Dillman, Smyth, & Melani, 2014) to estimate visitors' spending and overall travel behavior.
- Select visitors using a two-stage cluster probability sampling design (Scheaffer, Mendenhall III, Ott, & Gerow, 2012) at tourist attractions, airports, visitor centers, national and state parks, camping areas, and selected chambers of commerce across Maine.
- The study comprises two data collection and analysis phases

Key Findings / Accomplishments

Phase 1 (August 2014-April 2015):

- A total of 229 visitors from Mount Desert Island and Katahdin tourism destinations participated in a pilot online survey.
- The majority of respondents where non-residents of Maine (86%), mostly visiting from New England (27%), South Atlantic (16%), and Middle Atlantic (13%) US regions.
- Over half of the respondents mentioned participating in the following activities: Sightseeing for pleasure (70%), Food experiences (69%), Enjoying nature (66%), Backpacking/hiking (55%), and Shopping (58%).
- In average, visitors who participated in the study spent $1,768.86 per trip in Maine (See Table 3). The top two regions with the highest visitor spending included:
    - The South Atlantic region, in average, spent more money in Maine ($3,411; amount does not include airline ticket) than any other group of visitors (Table 3). States with the highest visitor spending from the South Atlantic region included: Florida, followed by Georgia.
    - Mountain region was second highest spending group ($2,587; amount does not include airline ticket). Colorado was the state with the highest spending from the mountain region.

Table 3 - Visitors' Average Spending by Region of Origin.

Region of Origin*	Average spending per trip in Maine	Average spending per trip in Maine (includes airline expense)
Division 1: New England	$1,420	$1,472
Division 2: Middle Atlantic	$1,308	$1,335
Division 3: East North Central	$1,076	$1,126
Division 4: West North Central	$2,100	$2,250
Division 5: South Atlantic	$3,411	$4,518
Division 6: East South Central	$1,495	$1,613
Division 7: West South Central	$2,340	$2,490
Division 8: Mountain	$2,587	$3,053
Division 9: Pacific	$1,252	$1,618
International	$1,732	$3,295

*States where grouped into regions that correspond to the U.S. Census Bureau's Regions and Divisions.

Phase 2 (2015):

- By July 2015, a total of 1,155 visitors have participated in an intercept survey, while 347 visitors have completed an online survey.
- To-date, most participants where out-of-state visitors (89%), visiting from Massachusetts (18%), New York, (7.5%) New Hampshire (7.2%), and Pennsylvania (7%). Other states generating significant Maine visitor numbers included Florida, Ohio and Texas (Table 4). International visitors accounted for 7.1% of non-resident visitors to Maine.
- An estimated 28% of visitors where visiting Maine for the first time.
- The majority of visitors (30%) planned their trip 1-3 months in advance.

- The **average summer** visitor to Maine traveled in groups of two (57%), had completed a 4-year college degree (37%), and was 58 years old.
- Visitors spent in average two nights in Maine.

Future Plans

- Finalize summer, fall, and winter visitor surveys.
- Analyze spending, travel behavior, and climate change risk perception data.
- Share results with stakeholders.
- Conduct economic impact analysis using IMPLAN.
- Develop assessment methodology.

Table 4 - Top 15 States that Generate Visitors to Maine, May-June 2015

State of Origin*	Percent from Total Number of Visitors to Maine
1. Massachusetts	18.5%
2. New York	7.5%
3. New Hampshire	7.2%
4. Pennsylvania	7%
5. Connecticut	6.9%
6. Florida	6.6%
7. New Jersey	3.6%
8. Virginia	3.4%
9. Ohio	2.8%
10. Texas	2.5%
11. Maryland	2.3%
12. Michigan	2.2%
13. North Carolina	2.1%
14. California	1.9%
15. Georgia	1.8%

REFERENCES

Dillman, Don A., Smyth, Jolene D., & Melani, Leah. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method* (4th. ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Maine Department of Labor. (2013). *Quarterly and annual industry employment and wages* Retrieved from: http://www.maine.gov/labor/cwri/qcew1.html

Maine Development Foundation. (2004). Maine's natural resource-based industries 2004: Indicators of health (pp. 70). Augusta, ME: State Planning Office.

Maine Revenue Services. (2013). *Maine taxable retail sales*. Retrieved from: http://econ.maine.gov/index/build

Scheaffer, Richard L., Mendenhall III, William, Ott, R. Lyman, & Gerow, Kenneth G. (2012). *Elementary survey sampling* (7th ed.). Boston, MA: Brooks/Cole.

Drone Bee, Sunkhaze Meadows National Wildlife Refuge
Photo by Pam Wells

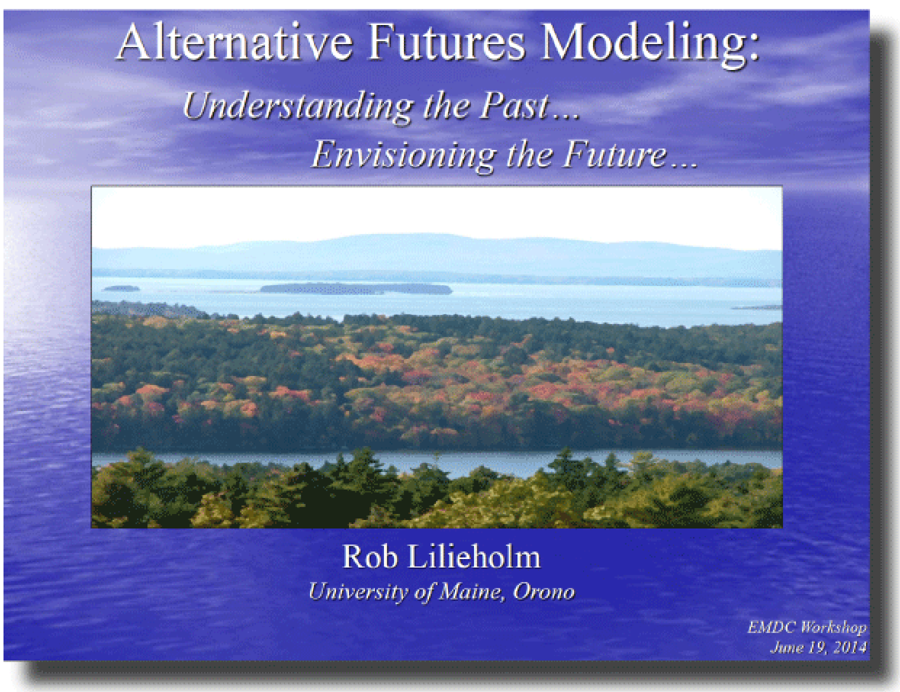
Conservation Lands & Public Values

Maine has led the nation in the development and application of innovative land conservation tools, especially when it comes to private lands and the protection of working forests. Maine currently has nearly 4 million acres of land protected from development. These lands provide a host of public and private benefits, ranging from parks and working forests, to wildlife habitat and biodiversity protection. Together, these protected areas provide both recreation and ecosystem services for current and future generations of Mainers, and have been protected through the combined efforts of federal (e.g., Forest Legacy), state (e.g., Land for Maine's Future) and a host of municipal and nongovernmental groups, including nearly 100 land trusts.

The landscape mosaic of developed and undeveloped lands in the northeastern U.S. has progressively changed at various spatial scales in response to land use and development pressures, socioeconomic influences, expansion of transportation networks, and non-uniform state and local regulatory frameworks. As ongoing processes of urbanization have transformed open spaces and agricultural property into developed land uses, there has been a remarkable counter-balancing expansion of public and private land conservation activities aimed at protecting biodiversity, scenic values, working forest lands, ecosystem services, recreational opportunities, and special natural areas in the remaining undeveloped land base. Because land use changes and conservation efforts in the region have occurred incrementally at multiple scales and in a variety of jurisdictions, it is challenging to assess the aggregate impacts of these cumulative land use decisions on environmental quality, resilience, and long-term sustainability across the overall landscape.

CRSF's research program on Conservation Lands & Public Values seeks to assist decision makers and planners as they look to the future and increasingly think strategically about balancing land conservation, working lands protection, and land development activities. Program activities are designed to: (1) help develop a clear understanding of the current status, extent, and landscape patterns of conserved lands across the region; (2) determine what kinds of values and conditions are represented in conserved parcels; (3) account for the dominant processes and criteria driving conservation activities across the different states of the Northeast; and (4) develop tools that help a wide range of stakeholders understand land use change and explore alternative future development paths.

Understanding how these lands are ultimately protected, managed, and valued by current and future generations will significantly affect the sustainability of Maine's communities and related forest-based industries, including forest processors and the recreation and tourism sector. As an important step in realizing these goals, we have released the Maine Futures Community Mapper – an award-winning online tool for assessing land use for forestry, agriculture, conservation and development across two large watersheds covering 4.4 million acres in Maine. To learn more, visit MaineLandUseFutures.org.

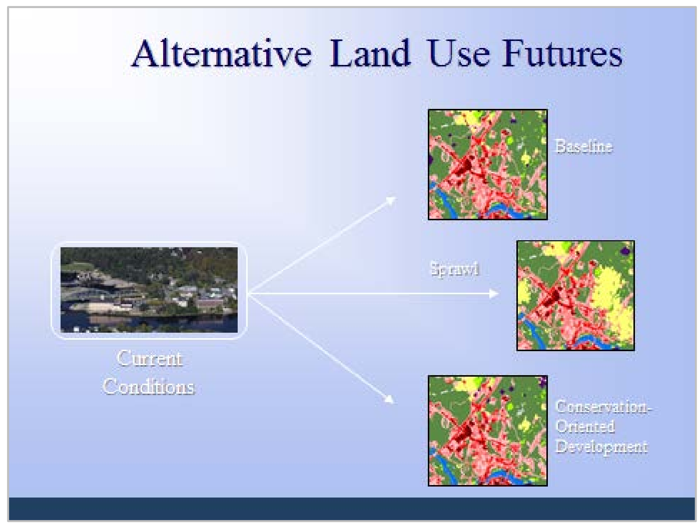


Alternative Futures Modeling for the Lower Penobscot and Lower Androscoggin River Watersheds in Maine

Robert J. Lilieholm, Spencer Meyer, Michelle Johnson, Christopher Cronan, Dave Owen, and Aaron Weiskittel
University of Maine

Progress Report, Year 1 of 3

Summary:
We developed stakeholder-derived land use suitability scores for nearly 4.5 million acres in two large Maine watersheds. The suitabilities, developed using Bayesian Belief Networks to integrate expert opinion and geospatial data, identify areas conducive to forestry, agriculture, conservation and development. A set of five alternative development scenarios were generated with stakeholder input to portray a range of develop options likely to occur over the next 30 years, identifying potential conflicts and compatibilities between our four land uses. Our research is available to the public through an interactive website (see http://www.mainelandusefutures.org), and in 2014 won the President's Research Impact Award at the University of Maine.



Project Objectives

- The overall goal of the project is to spatially assess the suitability of four critical land uses across these two watersheds: (1) economic development; (2) forestry; (3) conservation; and (4) agriculture. In assessing these suitabilities, compatibilities and potential conflicts can then be identified under a range of stakeholder-defined futures scenarios.
- Develop alternative future development and conservation scenarios for the two study watersheds.
- Assess the impact of future development and conservation scenarios on potential timber supplies for selected regions within the study areas.

Approach

- Land use-specific focus groups of 8 to 12 individuals were used to create and parameterize Bayesian Belief Networks of land suitability.
- Potential conflicts and compatibilities between land uses were explored.
- Stakeholder-derived future development scenarios were used to highlight where land uses such as forestry and agriculture are likely to be displaced.

Key Findings / Accomplishments

- Land suitabilities for forestry, development, agriculture and conservation differ substantially both across our two watersheds and within each watershed.
- Based on Maine's demographic and economic trends, limited development potential exists across large areas of our study watersheds.
- Limited development pressure in rural areas suggests that the limited development that does take place should be encouraged to enhance rather than detract from the region's natural and cultural amenities.

- Land suitabilities and conflicts/compatibilities are available for the public to explore on our interactive website at www.MaineLandUseFutures.org.

Future Plans

- For selected areas within our study watersheds, we will examine the potential impact on timber supplies of various development scenarios.
- Our work has highlighted the importance of economic diversification to the region – especially in rural areas. Based on this, we have begun to view the Penobscot River Corridor – i.e., the Bay-to-Baxter region – as an important asset to leverage economic development and protect quality of life. Two pending grants seek additional funding to quantify ecosystem services and explore community resilience in the region.

Partners / Stakeholders / Collaborators

Maine Department of Environmental protection, Maine Department of Inland Fisheries and Wildlife, Maine Forest Service, Maine Coast Heritage Trust, Schoodic Institute, Acadia National Park, UMaine Upward Bound, Eastern Maine Development Corp., Orono Land Trust, PenBay Regional Land Trust, Androscoggin Valley Council of Governments, Portland Metropolitan Planning District, Maine STEM Alliance, Highstead's Regional Conservation Partnership, Harvard University's NSF RCN-SEES on Forest Scenarios, Services and Society, Lincoln Institute of Land Policy.

Fish going over the dam in Orland, Maine – Photo by Pam Wells

Maine Woods Dashboard: Documenting the Economic, Ecological, and Social Impacts of Maine's Forest Resource

Canada Lily – Photo by Pam Wells

Robert J. Lilieholm
University of Maine

Progress Report, Year 1 of 2

Summary:
The Maine Forest Service (MFS) leads efforts to report on key measures of forest management throughout the state. Specifically, Maine statute requires MFS to periodically report on: (1) forest resource assessment; (2) forest sustainability; (3) the state of Maine's forests; (4) wood processor activity, including imports and exports; and (5) silvicultural activities. In addition, MFS also reports on forest inventory and best management practices. These and other state and federal activities provide valuable information to a host of stakeholders, making timely and accurate reporting paramount. Unfortunately, the dispersed nature of these data – including its limited availability in periodic printed reports as opposed to real-time datasets and analyses – hinders the capacity for long-term planning and productivity enhancements. This project leverages developments in database and web technologies to create a website where detailed and customized data queries about all aspects of Maine's forests can be generated to assist forest sector businesses and planning in the face of increasingly complex global markets.

Project Objectives

- Create a Maine Woods Data Portal (MWDP) that will house publically available data related to Maine's forests and forest sectors.
- Develop a Maine Woods Dashboard (MWD) that will allow users to readily access, analyze and display data within the MWD.

Approach

- Phase I: The Maine Woods Data Portal (MWDP) – The MWDP will provide access to all publicly available, relevant forest resources information. It will combine all available biophysical and socioeconomic information related to forest management (see MFS reporting requirements above). Data will be available for download through this portal, increasing accessibility to currently inaccessible information.

- Phase II: The Maine Woods Dashboard (MWD) – The MWD will be an outreach tool based on metrics housed in the MWDP, delivering timely, scientifically credible information about the economic, social, and environmental conditions and impacts of Maine's forests. MWD will host relevant information for a wide range of audiences, from the general public to business leaders, researchers to students. MWD will allow for the creation and presentation of data summaries (e.g., graphs, tables, infographics, etc.) in an easy-to-use graphical interface.

Key Findings / Accomplishments

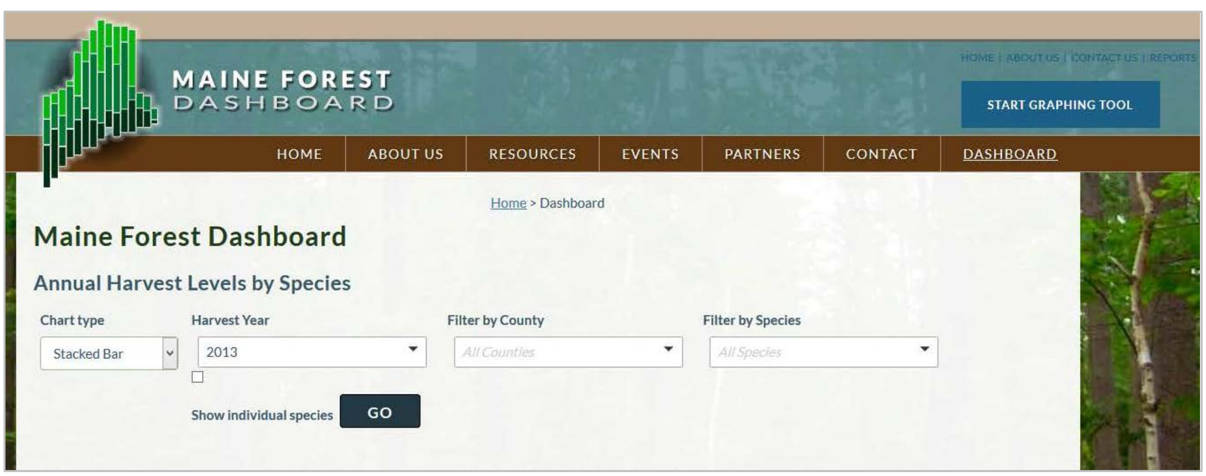
- Thus far, website design has been completed, and MFS forest-related databases secured. Data on timber harvests and processing are currently being entered into the system. This dataset will be used to develop the suite of analysis and display tools that will ultimately be available to users on the website.

Future Plans

- Continue with website development.

Partners / Stakeholders / Collaborators:

Maine Forest Service



Linking Attitudes, Policy, and Forest Cover Change in Buffer Zone Communities of Chitwan National Park, Nepal

Jared R. Stapp, Robert J. Lilieholm, S. Upadhaya, Jessica Leahy, Tora Johnson, Tim Waring, Carol Kinsey
University of Maine

Final Report

Summary:
Deforestation in Nepal threatens the functioning of complex social-ecological systems, including rural populations that depend on forests for subsistence. Nepal's forests are particularly important to the nation's poorest inhabitants, as many depend upon them for daily survival. Indeed, two-thirds of Nepal's population relies on forests for sustenance, and these pressures are likely to increase in the future. This, coupled with high population densities and rates of growth, highlights the importance of studying the relationship between human communities, forest cover and trends through time, and forest management institutions. Here, we explore how household attitudes associated with conservation-related behaviors in two rural communities in southern Nepal – one that has experienced significant forest loss, the other forest gain – compare with forest cover trends as indicated by satellite-derived forest loss and regeneration estimates between 1989, 2005 and 2013. We then constructed an agent-based model to explore the dynamics between land use, land cover, population growth and conservation policies.

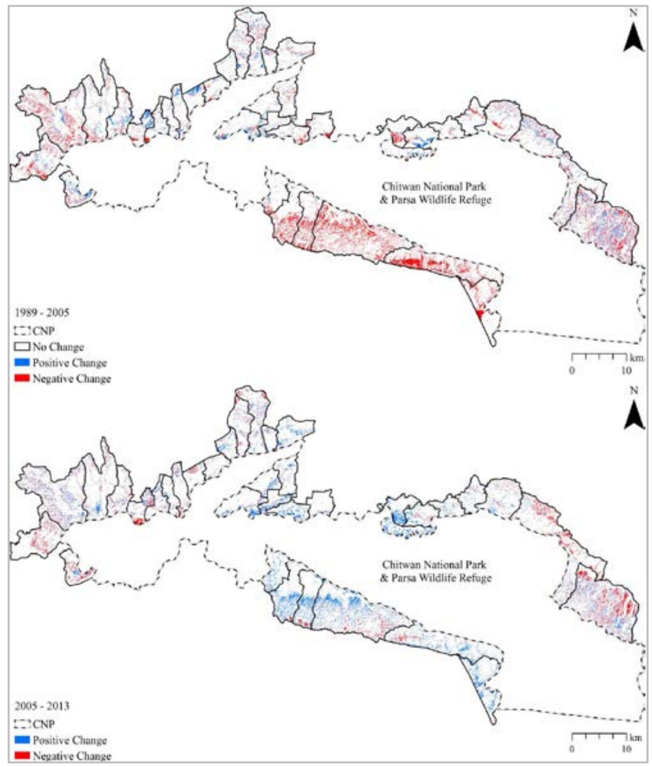
Project Objectives

- Quantify changes in forest cover in and around Chitwan National Park between 1989 and 2013.
- Understand household views towards forests and forest conservation in communities experiencing the greatest forest loss, and greatest forest gain.

- Develop an agent-based model to explore the dynamics between land use, land cover, population growth and conservation policies.

Approach

- Landsat imagery was used for the years 1989, 2005, and 2013 to compute a normalized difference vegetation index (NDVI) to analyze trends in forest cover for 36 buffer zone village development committees (VDCs).



- In high-forest-loss and high-forest-gain VDCs, a household survey was developed to elicit information about resident views towards forests (e.g., use, dependence, conservation), and the willingness to adopt conservation-oriented technologies (e.g., fuel-efficient stoves and home biogas).

- In total, 114 individuals were surveyed – 60 in Bachauli VDC, and 54 in Narayani VDC. The response rate was 100%.

- NetLogo was used to develop the agent-based model using remote-sensed forest change data and data extracted from our household surveys.

Key Findings / Accomplishments

- We found a significant difference in attitudes in the two areas studied, perhaps contributing to and reacting from current forest conditions and trends.

- In both study sites, participation in community forestry strengthened support for conservation, supportive forest conservation-related attitudes aligned with forest cover gain in recent years, and a negative relationship was found between economic status and having supportive forest conservation-related attitudes.

- On average, respondents were not satisfied with their District Forest Officers and did not feel that the current national political climate in Nepal supported sustainable forestry. These findings are especially important as Nepal's Master Plan for the Forestry

Sector has expired and the country is in the process of structuring a new Forestry Sector Strategy.

Future Plans

- Complete publication process for two articles under review.

Bluebird – Photo by Pam Wells

Family Forests

Two Old Friends - Wells Forest – Photo by Pam Wells

The Family Forests Program serves the estimated 120,000 private, individual forest landowners who own 5.7 million acres of forest land in Maine. These landowners, who own between 1-1,000 acres each, have largely been underserved in research and outreach that would enhance their forest stewardship. Therefore, the mission of the Family Forests Program is conduct to conduct applied scientific research and outreach that contributes to the sustainable management of Maine's family forests for desired products, services, and conditions in partnership with Maine's family forest stakeholders. These stakeholders range from the Small Woodland Owner Association of Maine (SWOAM), USDA Family Forest Research Center, UMaine Cooperative Extension, American Tree Farm System (ATFS), Maine Forest Service (MFS), Natural Resources Conservation Service (NRCS), USDA State and Private Forestry, American Consulting Foresters (ACF) and other consulting foresters, Professional Logging Contractors of Maine and forest management firms offering services to family forest owners (e.g., Prentiss and Carlisle, LandVest, etc.).

The Family Forests Program has pursued three general lines of research and outreach over the last year: (1) Developing and implementing social work models of landowner engagement and outreach; (2) Applying risk theory and other social science theories to predict woody biomass supply from family forest lands; and (3) Surveying the knowledge, attitudes, and behaviors of landowners toward invasive forest pests such as the emerald ash borer and Asian long-horned beetle.

Accomplishments include $161,795 in research and outreach funding from a variety of sources including the Northeastern States Research Cooperative, Small Woodland Owner Association of Maine, the U.S. Department of Agriculture, and the National Science Foundation (SSI).

Anticipating Emerald Ash Borer and Asian Longhorned Beetle in the Northern Forest: Opportunities for Community Leader and Landowner Cross-boundary Cooperation in Managing Forest Pests

Jessica E. Leahy, Janet Gorman, John Daigle, Sandra De Urioste-Stone, Crista Straub, and Stephanie Snyder

University of Maine

Asian Longhorned Beetle – Photo courtesy of the Nature Conservancy

Progress Report Year 2 of 3

Summary:

As nonnative invasive insects such as the emerald ash borer (*Agrilus planipennis*) and Asian longhorned beetle (*Anoplophora glabripennis*) permeate the Northern Forest and move closer to Maine, an exigent need arises to create cross-boundary management plans involving a variety of stakeholders. In order to create and implement effective early detection and long-term management against these forest pests, specific stakeholders such as community leaders and landowners must be recognized and understood. This study will focus on analyzing community trust and attitudes towards cross-boundary cooperation. In addition, trust and risk perception among an existing landowner dataset will be examined in order to better anticipate public reaction upon the arrival of one or both forest pests in Maine.

Project Objectives

- To determine commonalities between landowners who are willing to engage in forest pest management behaviors versus those who are unwilling in order to better anticipate reactions to new or continued forest pest management.
- To link community leader trust and attitudes about cross-boundary cooperation to management behavioral intentions.
- To apply relevant social theories to stakeholder attitudes in order to anticipate public reaction to various levels of forest pest management.

Approach

- We will conduct qualitative interviews with community conservation leaders, who are members of town government such as city planners, town managers, conservation commissioners, and mayors.

- Areas of New Hampshire that have been impacted by emerald ash borer will be a starting point for interviews, with three geographic study sites: infested communities, quarantine zone communities, and non-infested/non-quarantined nearby communities.

- We will also conduct quantitative surveys with landowners, who own between 10 and 1,000 acres in Maine, Vermont and New Hampshire. These study participants will be randomly selected from public tax records.

Key Findings / Accomplishments

Interviews were conducted with 18 community conservation leaders and are still ongoing. The overall response rate to the survey was 38% with 1,389 returned surveys across all three states. The survey results showed that landowners in Northern New England are concerned about forest pests (Table 5), yet are not very knowledgeable about forest pests (Table 6).

Landowners would like to learn more about how to identify forest pests (Table 7), where to report an insect, and what to do if they find a suspicious insect. They would prefer to learn about forest pests through websites and newsletters rather than social media. Most landowners have not looked for forest pests, but many plan to do so in the future, especially after reading outreach material about forest pests.

Table 5 - Concern about Emerald Ash Borer (EAB)

	Not at all concerned (1)	Slightly unconcerned (2)	Somewhat concerned (3)	Concerned (4)	Extremely concerned (5)	Total responses*	Mean
In your state	2%	1%	32%	28%	36%	313	3.97
In your community	1%	2%	20%	30%	47%	313	4.20
On your own land	1%	2%	18%	22%	57%	312	4.34
*This question was included only in the EAB Risk perception versions of the Survey							

Table 6 - How severe of a problem would Emerald Ash Borer (EAB) be…

Within the next five years, how severe of a problem would it be?	Not at all severe (1)	Slightly severe (2)	Somewhat severe (3)	Severe (4)	Extremely severe (5)	Total responses*	Mean
For the forest products industry in your state	3%	7%	38%	26%	26%	276	3.68
If emerald ash borer was discovered on your property	6%	10%	35%	19%	30%	279	3.57
For the biodiversity of forests in your state	3%	9%	38%	29%	21%	273	3.57
If emerald ash borer was discovered in your community	3%	9%	43%	24%	22%	280	3.54
For town and roadside trees	4%	9%	41%	24%	23%	269	3.53
If emerald ash borer was discovered in your state	3%	10%	46%	22%	20%	279	3.47
For the scenic beauty of the state	6%	14%	33%	27%	20%	274	3.41
For your timber values	13%	13%	32%	24%	18%	274	3.2
For Native American basket makers in your state	11%	14%	43%	19%	14%	264	3.1
For your property values	14%	19%	36%	18%	14%	276	2.98
For recreation and tourism in your state	13%	19%	39%	16%	13%	275	2.97
For your control over your land	24%	18%	31%	16%	11%	271	2.73
To lose tree for which you have sentimental value	22%	23%	30%	15%	11%	273	2.7
For your privacy	23%	23%	33%	10%	10%	274	2.61

*This question was included in all EAB version of the Risk perception surveys

Table 7 - Social acceptability of actions (Emerald Ash Borer detection and management items)

Would you be willing to...?	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)	Total Responses*	Mean
Host a purple prism trap	2%	1%	20%	22%	55%	291	4.26
Comply with emergency orders restricting harvested wood movement	2%	5%	20%	24%	49%	295	4.15
Allow officials to monitor predaceous wasps (biosurveillance) if a wasp colony is present on my land	6%	3%	16%	26%	49%	298	4.10
Allow officials onto property to properly identify forest pests	4%	4%	18%	27%	47%	297	4.09
Allow preventive treatment on my land	3%	4%	24%	26%	42%	293	3.98
Support biological control	4%	3%	28%	25%	41%	288	3.96
Work with my neighbors to prevent the spread of forest pests	2%	4%	30%	31%	33%	295	3.89
Girdle an ash tree on my property to serve as a trap tree	7%	2%	25%	28%	38%	287	3.86
Talk with my neighbors to share information about forest pests	2%	7%	28%	31%	32%	296	3.84
Attend a training to learn how to identify forest pests	5%	4%	30%	31%	30%	296	3.78
Attend public meetings to learn more about forest pests	4%	7%	29%	29%	31%	296	3.77
Avoid planting ash trees on my property	6%	6%	34%	21%	33%	294	3.69
Allow harvesters to come cut trees and chip to one inch in two dimension chips that too small for larvae to survive	13%	9%	35%	20%	22%	288	3.30
Participate in developing a community response plan	8%	11%	43%	21%	17%	294	3.28

*This question was included in all EAB version of the Risk perception surveys

Future Plans

In the future, we will continue with the qualitative interviews of community conservation leaders. Janet Gorman intends to finish her MS degree in the next year. Peer reviewed journal articles will be forthcoming in the next year, as well.

Funding

Maine Department of Agriculture, Conservation and Forestry

Maine Agricultural and Forest Experiment Station

Partners / Stakeholders / Collaborators

Maine Department of Agriculture, Conservation and Forestry

New England Forest Pest Council

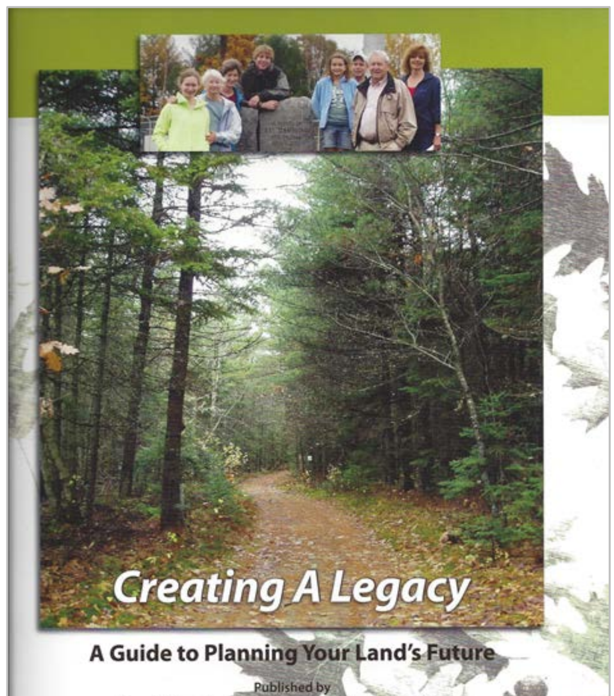
Green Winged Teal Duck – Photo by Pam Wells

Understanding and Informing Family Forest Owner Decisions of Intergenerational Land Transfer to Ensure Working Forested Landscapes

Jessica Leahy and Kathleen Bell
University of Maine

Progress Report, Year 1 of 3

Summary:
Family-owned tree farms, known simply as "family forest lands" provide tremendous amounts of wood products and ecosystem services in the U.S, particularly in the northeast where 52% of the land is held by family forest owners (FFOs). Due to an aging landowner population, in the coming years, almost half of the FFOs in the U.S. will be deciding the future of their land (i.e., convert to another use, parcelize, conserve). These decisions will be the most important determinants of the viability of working forests, because forest cover loss and parcel size reductions eliminate or lessen forest management opportunities. Stabilizing the forest land base by stemming the tide of conversion and parcelization is critical to ensuring a future of viable and competitive working forested landscapes. The project team, made up of the Universities of Massachusetts, Maine, Vermont and Cornell aim to help stabilize the forested land base by working to ensure that a significant proportion of FFO lands are passed from one generation of landowners to the next with minimal amount of forest conversion and parcelization. The research component of this project will use landowner interviews and a mail survey to better understand how FFOs make decisions about the future of their land. These research findings will inform regional extension programs that use peer network and train-the-trainers approaches to help inform FFO decisions. By working to stabilize the land base in this way, this project will assist in maintaining a viable forest industry, and, ultimately, vibrant rural communities.



Jessica Leahy, Co-author

Project Objectives

- Gain a better understanding of the timing and influences of bequest decisions in the northeast region.
- Use research findings to develop effective conservation-based estate planning extension resources and programs.
- Amplify the reach of extension efforts through the development and training of a network of professionals and peer landowners.
- Inform the land bequest decisions of family owned tree farms and help them move forward in the conservation-based estate planning process by providing them with links to more experienced peers and knowledgeable professionals.

Approach

This research will involve cognitive interviews to gain a more in-depth understanding of landowner thought processes regarding bequest and for survey development and pre-testing.

We will use draft survey questions to hold a series of cognitive interviews with FFOs living and owning land in the previously-defined priority areas of the four northeastern states. The feedback we obtain from an initial round of testing will enable us to review and modify a questionnaire.

In addition to developing a survey instrument, the cognitive interviews will involve asking semi-structured questions that probe our understanding of landowner motivations for bequest (traditional and conservation bequests), barriers to bequeathing land, the estate planning decision process, and issues that were identified in previous extension and research.

Having developed and tested our survey instrument, we will implement a mail survey in the priority landscapes of the four states with FFOs owning at least 10 acres of land. FFO survey recipients in Maine, Massachusetts, Vermont and New York will be randomly identified. We will use the Dillman's Tailored Design Method (Dillman et al. 2009) as a method for administering the survey.

The final research step involves developing and analyzing a state-of-the-art behavioral model of bequest motivation grounded in economic theory.

Key Findings / Accomplishments

A pre-screening survey was developed and administered across all four states. Initial results showed that there was a distribution of succession and estate planning actions taken by landowners. There was no detected non-response bias. Analysis is ongoing.

Approximately 50% of the qualitative interviews are completed with more ongoing.

The interviews are leading to new understanding about how the transtheoretical model applies to succession and estate planning.

Future Plans

Analysis of the pre-screening survey will continue, as well qualitative interviews. An extensive survey will be conducted in 2016 and will serve as the basis for the econometric model.

Hermit Thrush – Photo by Pam Wells

Resolving a Critical Question in Predicting Woody Biomass Supply to the Northern Forest Industry: Understanding Willingness to Harvest from Small Woodland Owners

Emily Silver Huff and Jessica Leahy
University of Maine

Final Report

Pulp Grade Harvest – Photo by Pam Wells

Summary:
Predicting and understanding timber supply is one central component to the viability of the bioenergy industry. This study seeks to understand the knowledge, attitudes, and willingness to harvest timber for bioenergy markets. Thirty-two semi-structured interviews were conducted with private woodland owners who had previously harvested timber, had never harvested timber, and had harvested timber for woody biomass markets. Results indicate that private woodland owners have little knowledge of biomass harvesting, but a desire to learn more. Attitudes toward biomass harvesting are mixed, with negative attitudes about nutrient removal, poor economics, and it being a poor end-use for wood products. Positive attitudes towards biomass pertained to fossil fuel replacement, a use for low-quality wood, and strengthening Maine's forest economy. Some owners expressed a willingness to supply timber for biomass, but not all that had harvested for bioenergy markets would do so again. These results help provide insight to available timber supply for the bioenergy industry and provide an assessment of landowner awareness of timber harvesting options (Table 8).

Project Objectives

- Create a comprehensive literature review on woodland owner attitudes towards multiple aspects of timber harvesting and woody biomass harvesting, in particular,
- Identify current policies and regulatory mechanisms that relate to landowner perception of biomass harvesting,
- Examine risk perception of small woodland owners specifically related to harvesting timber for biomass production, and

- Provide recommendations to state and local policy makers, town planners, regional conservation groups, and the forest products industry that suggest ways to provide outreach to small woodland owners and build collaborations between landowners, loggers, and biomass facilities.

Table 8 - Significant Predictors in the Decision to Harvest Timber by Private Woodland Owners

Variable	No. of citations	Influence	Evidence ratings (no. of citations and direction of influence)
Parcel size/forested acres	16	+	High (6), medium (5), low (5)
Income	8	+/−	High (1 positive; 2 negative), medium (2 negative), low (2 positive, 1 negative)
Harvest price per acre	7	+	High (7)
Absentee owner/distance from residence	6	−	High (1), medium (3), low (2)
Farmer	6	+/−	High (1 negative), medium (2 positive, 2 negative), low (1 negative)
Years of formal education	5	+	High (3), medium (2)
Age	5	−	High (2), medium (2), low (1)
Contact with a forester/technical assistance	4	+	High (1), medium (2), low (1)
Years the land has been in the family/inheritor/years owned	4	+	High (1), medium (2), low (1)
White collar occupation	3	+	High (3)
Management plan	3	+	High (1), medium (1), low (1)
Nontimber ownership objectives/amenity objectives	3	−	Medium (1), low (2)
Timber production ownership objective	3	+	Highest (1), medium (1), low (1)
Extension activity attendance/cooperation with Forest Service	2	+	Highest (1), high (1)
Timber stock	2	+	High (2)
Site value tax/site quality	2	+	High (1), medium (1)
Proportion of household income from forest	2	+	Medium (2)
Membership or contact with a wood owners association	2	+	Medium (1), low (1)
Debt-to-income ratio	2	+	High (1), medium (1)

Variables are in order of most to least citations.

Approach

- We conducted a literature and policy review, to explore existing survey data and interview transcripts for relevance to our study. Following this exploration of secondary data, we conducted semi-structured interviews with 32 landowners owning between 10-2,800 acres in Maine, Vermont, and New Hampshire. We recruited interview participants using the networks within landowner associations, state forestry agencies, Cooperative Extension, and others.

Key Findings / Accomplishments

- Key accomplishments in this final year were three peer-reviewed publications and a dissertation. The graduate student involved on this project secured full-time, permanent employment as a Research Forester with the USDA Forest Service.

- Timber harvesting behavior literature has increased over time with the vast majority of papers using a mail survey or an empirically-based economic model. Of the 81 articles that focused on timber harvesting behavior, 25 used a statistical technique that predicted intended or actual timber harvesting behavior. The variables that significantly predicted timber harvesting were parcel size, total forested acres, living on the forested land, and income. Researchers believe a mix of qualitative (i.e. focus groups and interviews) and quantitative (e.g. surveys) methods are best, but few studies utilize both. Additionally, the impact of landowner risk perception, in relation to a harvesting decision, has not been extensively studied. Many studies purportedly studied behavior, but actually measured stated preference or attitudes. Few studies validated stated preferences or attitudes by measuring observable harvesting behaviors.

- Definitions of biomass harvesting and bioenergy were highly variable and typically concern the type of harvest or the post-processing of woody materials. Knowledge of biomass harvesting and the bioenergy industry in Maine was low while the desire for more information is high. Attitudes toward biomass harvesting were mixed, with negative attitudes about nutrient removal, poor economics, and it being a poor end-use for wood products. Positive attitudes towards biomass pertained to fossil fuel replacement, a use for low-quality wood, and strengthening Maine's forest economy. Willingness to harvest biomass was low, and often context dependent (e.g. if another harvest were taking place already). Reactions to biomass harvesting scenarios (i.e. transportation, destination, end use, byproduct use) revealed that the majority of landowners do not care what happens after the wood leaves their property. Those that cared were primarily concerned that the energy recovered from their wood did not exceed the energy used to make a particular product. The landowners who had harvested biomass for bioenergy production were not qualitatively different from those who had not. They still expressed negative attitudes and sometimes an unwillingness to harvest despite having harvested for bioenergy previously. Risks to the forest included diseases and pests, and development pressure (Figure 2).

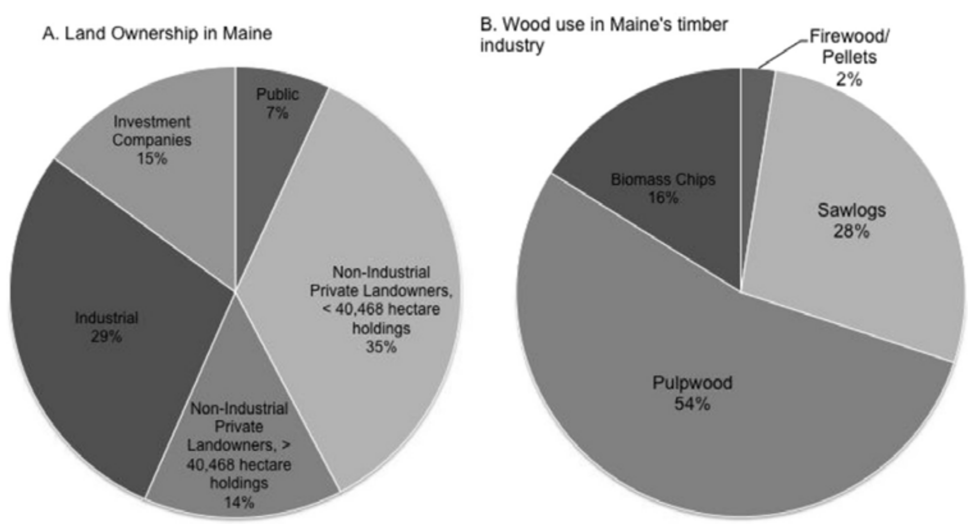


Figure 2 - Percentages of land ownership in Maine totaling roughly 7 million forested hectares (a) and percentages of wood use by the Maine timber industry (b)

Funding

University of Maine's Sustainability Solutions Initiative, NSF Sustainable Energies Pathways, and Northeastern States Research Cooperative

Partners / Stakeholders / Collaborators

Small Woodland Owners of Maine, Maine Forest Service, American Forest Foundation, Forest Bioproducts Research Initiative

Commercial Forests (CFRU)

Maine's commercial forests cover the northern half of the state and provide the backbone of the state's annual $8 billion forest products economy. These private landowners manage large tracts of land that involve complex decisions about a wide variety of forest resource issues over long periods of time. To help meet this challenge, these landowners recognized the need long ago for a strong applied research program to provide new information about how to best manage their lands. As a result, they partnered with the University of Maine in 1975 to form the Cooperative Forestry Research Unit (CFRU).

The mission of the CFRU is to *"conduct applied scientific research that contributes to the sustainable management of Maine's forests for desired products, services, and conditions."* Currently composed of 35 private and public forestland management organizations, wood processors, conservation organizations, and other members, the CFRU guides and supports research on key issues facing Maine's forest landowners and managers. These members represent 8.3 million acres, or half of Maine's forestland. The CFRU is one of the oldest industry/university forest research cooperatives in the United States, and serves as a model for stakeholder-driven research at the University of Maine.

This year, the CFRU raised $505,025 in member contributions and leveraged an additional $614,716 (48%) in extramural grants and in-kind support. Research from the past year focused on three primary areas: silviculture and productivity, growth & modeling, and wildlife habitat. Project highlights include 10-year results from the CTRN, an analysis of the third-wave of treatments for the Austin Pond study, new research to document the long-term effect of whole-tree harvesting on biomass production, evaluation of LiDAR coverage from a wide range of stand structures and species compositions, growth & yield data on the effects of management on future forest growth, analyses of harvesting on snowshoe hare habitat and Canada lynx diet, and an ongoing study of bird community responses to forest management.

CFRU Members:

Appalachian Mountain Club

Baskahegan Corporation

Baxter State Park, SFMA

BBC Land, LLC

Canopy Timberlands Maine, LLC

Clayton Lake Woodlands Holding, LLC

Downeast Lakes Land Trust

EMC Holdings, LLC

Field Timberlands

Forest Society of Maine

Frontier Forest, LLC

Huber Engineered Woods, LLC

Irving Woodlands, LLC

Katahdin Forest Management, LLC

LandVest

Maine Bureau of Parks & Public Lands

Mosquito, LLC

New England Forestry Foundation

North Woods Maine, LLC

Plum Creek Timber Company, Inc.

Prentiss and Carlisle Company, Inc.

ReEnergy Holdings, LLC

Robbins Lumber Company

SAPPI Fine Paper

Seven Islands Land Company

Simorg North Forest LLC

Snowshoe Timberlands, LLC

St. John Timber, LLC

Sylvan Timberlands, LLC

The Forestland Group, LLC

The Nature Conservancy

Timbervest, LLC

UPM Madison Paper

Wagner Forest Management

Pre-harvested mixed Stand – Photo Pam Wells

CFRU PROJECT SUMMARIES

Silviculture & Productivity

Commercial Thinning Research Network (CTRN)

Robert Wagner, Patrick Clune, and Brian Roth
University of Maine

Status: Progress Report, Year 2 of 4

Summary:
A 10-year analysis of results from the CTRN was completed this year. Growth & yield, residual stand structure, wood products, and financial value were compared following various commercial thinning methods (low, crown, dominant), removal intensities (33% and 50%), and timing of entry (thin immediately, delay 5 years) using two separate experiments on 12 study sites on CFRU member lands across northern Maine. Results from a completed MS Thesis (Clune 2013) indicated that older (34–70-year-old) spruce-fir stands that never received precommercial thinning (PCT) should not be commercially thinned (CT) from above due to wind losses to the residual stand. If CT is desired in older stands, low thinning by 33% produced the most resilient stand structure with highest net present value.

In younger (23–42-year-old) fir-spruce stands that received PCT, all CT treatments improved residual stand structure and increased growth over the unthinned control. Greatest gains in stem diameter resulted from 50% delayed thinning, while greatest increase in net merchantable volume periodic annual increment occurred with 50% early CT. Highest financial gains occurred with 33% early CT. If the objective was to increase mean tree size and reduce the age at which trees reach a minimum size, delayed CT at higher intensity removal (50%) was best. If the objective was to increase stand value and financial returns, early CT at medium intensity (33%) was indicated.

Austin Pond Study: Third Wave of Treatments to Assess Rotation-length Outcomes for Silvicultural Options in Maine’s Northern Forest

Brian Roth and Patrick Hiesl
University of Maine

Status: Final Report

Summary:
The third and final year of installing a third wave of treatments and evaluating harvesting

productivity at Austin Pond was completed. During the winters of 2012-13 and 2013-14, the Austin Pond research site was commercially thinned using cut-to-length (CTL) and whole-tree (WT) harvesting systems in PCT and non-PCT stands, respectively. Thinning prescriptions consisted of three nominal removal intensities (33%, 50%, and 66% of the standing softwood volume) in a randomized block design. Stand density, basal area, hardwood content, and removal intensity were not significant in explaining variation in harvester and feller-buncher productivity. The unit cost of production of wood chips using a WT system was less costly than the production of roundwood using a CTL system; however, profits were similar for both products harvested.

Weymouth Point: Monitoring the Effects of Whole Tree Harvesting and Intermediate Silvicultural Treatments on Long-term Spruce-Fir Productivity

Brian Roth, Robert Wagner, Robert Seymour, Aaron Weiskittel, Andrew Nelson, and Mohammad Bataineh
University of Maine

Status: Progress Report, Year 1 of 1

Summary:
Despite continued interest in the long-term effects of whole-tree harvesting (WT), there are only a limited number of locations in New England where these effects can be quantified. One such location is CFRU's Weymouth Point paired watershed study, where aboveground biomass was measured 32-years following harvesting (Briggs 2000, Smith 1984). In the summer of 2014, a network of fifth-acre plots was re-established from across three existing experiments and an inventory was completed. Silvicultural treatments included precommercial thinning and fertilization. Aerial LiDAR data were collected, a detailed digital elevation model created, and a depth-to-water table map was generated. Next steps will be to use these data to estimate biomass, analyze for differences between treatments, and examine relationships with drainage class.

Assessment of Productivity and Costs for Logging Equipment in Maine's Forest Industry

Jeffrey Benjamin and Patrick Hiesl
University of Maine

Status: Final Report

Summary:
Cycle time and productivity models for harvesting equipment commonly used in Maine's logging industry were developed for partial harvest operations. Time consumption data were collected per work cycle for each machine and productivity values were developed using tree volumes estimated with samples of dbh and tree height for individual species. Data were collected from seven whole-tree partial harvests with initial stand densities between 411 and 1,027 trees per acre. Basal area ranged from 109 to 238 square feet per acre. Removal intensities ranged from 15% to 67% of the initial basal area. Data were collected from five cut-to-length partial harvests with initial stand densities between 537 and 1,948 trees per acre. Basal area ranged from 116 to 203 square feet per acre. Removal intensities ranged from 25% to 90% of the initial basal area. Key variables that influence cycle time and productivity are stem size and number of stems per accumulation (feller-bunchers); stem size and species grouping (cut-to-length processor and stroke delimbers); skidding distance and load size (grapple skidders); and forwarding distance, log volume and logs per load (forwarders).

Effects of mechanized Harvesting Operations on Residual Stand Conditions

Jeffrey Benjamin, Eric R. Labelle, Robert Seymour, Brian Roth, and Ivan Fernandez
University of Maine

Status: Progress Report, Year 1 of 3

Summary:
Post-harvest stand condition, including residual stems and soil properties, is greatly influenced by mechanized operations and harvest trails in particular. Studies from other regions have considered the effect of trails on regeneration, crown closure and growth of nearby trees but there is a need to consider the influence of the trails on stand condition for this region in particular. Whole tree (WT) harvesting is often associated with extensive soil disturbance ranging from removal of the forest floor to severe compaction and rutting. A site disturbance assessment was conducted as part of the Weymouth Point paired watershed study to quantify the extent and magnitude of soil disturbance following mechanized harvesting, and an opportunity exists to re-evaluate regeneration and growth of crop trees three decades after harvest. Recent soil compaction studies in New Brunswick for cut-

to length (CTL) harvest systems provide great insight into site conditions following harvest, but there is a need to continue this research for WT harvest sites.

This study will determine the effects of mechanized harvest operations on residual stand condition and ultimately on the long-term growth of Maine's mixed wood forests. Specifically, this project will investigate the impact of soil disturbance on spruce-fir productivity 32 years following WT harvesting at the Weymouth Point paired watershed study. We will also establish a network of permanent research plots at 10 new harvest sites to (1) assess the impact of trails, site disturbance and soil compaction on residual stem growth, and (2) quantify damage to residual stems and determine the effect of wound size and severity level on future growth and quality. A team of experts in forest soils and stand development has been assembled from the University of Maine, the Northern Hardwood Research Institute, the Natural Resources Conservation Service, and engineering consultants to evaluate site disturbance (10-point qualitative scale and detailed terrain models pre- and post-harvest), soil compaction (nuclear moisture and density gauge and laboratory determined soil properties) and stem damage (wound size and severity ratings).

Penobscot River – Photo by Pam Wells

Growth & Modeling

Extending the Acadian Variant of FVS to Managed Stands

Aaron Weiskittel[1], Chris Hennigar[2], and John Kershaw[2]
[1]University of Maine and [2]University of New Brunswick

Status: Final Report

Summary:
Most forest growth & yield models do not adjust their predictions for certain management activities such as precommercial or commercial thinning, which can lead to significant biases. This project's primary goal was to modify the Acadian variant of the Forest Vegetation Simulator (FVS-ACD) to account for the primary forest management activities in the region. To accomplish this, an extensive regional database of individual tree measurements from different forest management regimes was compiled. Component equations of FVS-ACD were then tested for performance in the managed stands and modified accordingly. In particular, precommercial and commercial thinning were found to significantly modify growth following treatment and the response was governed by a variety of different factors. These modifiers were incorporated into FVS-ACD and this should ensure proper representation of key forest management activities in the region. Continual improvement and modification will be completed as new data becomes available.

Linking LiDAR and Ground-based Forest Inventory Plots for Improving Estimation of Key Attributes

Aaron Weiskittel[1] and John Kershaw[2]
[1]University of Maine and [2]University of New Brunswick

Status: Final Report

Summary:
LiDAR is emerging as a prominent technology for measuring key forest attributes like standing volume and dominant height. Limited research has been conducted on the effectiveness of LiDAR in structurally-complex, mixed-species forests that dominant in Maine. This project was initiated to evaluate the performance of LiDAR across a range of stand structures and species compositions that are typical for the region. In the process, a variety of important issues with using LiDAR for operational forest planning were evaluated including robustness of developed prediction models, sample size and selection method for model calibration, and the effect of prediction tile size on overall accuracy. We found that LiDAR is a promising tool that deserves further exploration, but there are some potential issues that need to be resolved.

Depth-to-Water Table Mapping for Maine using Latest DEM Coverage

Mark Castonguay, Jae Ogilvie, and Paul Arp
University of New Brunswick

Status: Final Report

Summary:
The objective of this project was to provide CFRU members with updated wet area maps (WAM) for their lands. The previous maps built by CFRU were developed in 2005-06, but improved digital elevation maps (DEM) for the state since then provided an opportunity to greatly improve the accuracy of these maps. The analysis was conducted using the latest available geospatial data sources (National Elevation Dataset – NED via USGS) at multiple resolutions (1/3 and 1/9 arc-second – 10 m and 3 m where available). Contiguous / continuous, updated spatial maps of base elevation DEM, predicted sub-surface wetness (WAM), and enhanced hydrological flow network (unmapped streams) were created through various algorithm / GIS data processing methods. Approximately 27 million acres (including all of Maine and watersheds beyond the state borders that influenced water flow) were remapped / updated at 10m resolution (with and without the inclusion of wetlands), and 3.5 million acres at a finer 3 m resolution (without wetlands).

Incorporating Young Hardwood Stand Responses to Various Levels of Silviculture and Stand Composition into New CFRU Growth & Yield Models

Andrew Nelson, Robert Wagner, and Aaron Weiskittel
University of Maine

Status: Final Report

Summary:
This report completes the third and final year of this project. We used an established experiment on the Penobscot Experimental Forest to: (1) examine the response of early successional stands to combinations of two management intensities (with and without enrichment planting and different levels of vegetation control) and three compositional objectives (hardwood, mixedwood and conifer); (2) compare the biomass production of planted white spruce and hybrid poplar plantations (four clones) in monoculture and in mixture of the two on a typical reforestation site in Maine; and (3) develop branch, crown and vertical leaf area distribution models for various hardwood species. A PhD dissertation was completed and three journal papers were published.

Wildlife Habitat

Relationships among Forest Harvesting, Snowshoe Hares, and Canada Lynx in Maine

Sheryn Olson and Daniel Harrison
University of Maine

Status: Final Report

Summary:
We investigated whether snowshoe hare pellet densities were different between two seasons across three forest stand-types: regenerating (RG) coniferous-dominated (19-39 years post-harvest), selection harvested (SEL) mixed coniferous-deciduous (8-18 years), and mature (42-80 years). We then evaluated which vegetation characteristics most strongly influenced hare densities between seasons across 26 forest stands. Hare densities, indexed by pellet densities, were measured semi-annually in 41 stands from 2005–2012. Densities were significantly higher during leaf-off (winter) than leaf-on (summer) periods in RG stands, but not in mature or SEL stands. Pellet densities were greater in RG than other stand-types during both seasons, and unexpectedly, significantly higher during the leaf-on season. These results suggest greater winter survival or movement to RG from summer to winter, and relatively higher summer survival and juvenile recruitment in RG. Seasonal differences in pellet densities across 26 stands were most strongly influenced by conifer sapling density [68% relative importance weight (RIW)] and total sapling density (11% RIW). During the leaf-off season when snow may interact with vegetation, the strongest influence on pellet densities was percent understory coverage of all conifer foliage (RIW 88.9%).

During 2014 we also completed our investigations of lynx food habits which were targeted at evaluating whether lynx are less specialized on hares at the southeastern limit of their range. We documented food habits using scats genetically confirmed as lynx during a summer-lower (2007-2012, 0.92 hares/ha, n=199 scats) and a winter-higher (2001-2006, 1.98 hares/ha, n=125) hare density period. Lynx had higher dietary breadth during the summer-low compared to the winter-high hare density period ($F_{4,322}$=0.0068). Frequency of occurrence of hares in lynx diets declined during the summer-low (75.2%, n=230 food item categories) period compared to during the winter-high (92.1%, n=127) hare density period. Despite evidence that lynx broaden their dietary niche during summer, high occurrence of hares in lynx diets during both seasons and across periods of changing hare density indicate that lynx are obligatory specialists on snowshoe hares near the southeastern limit of their geographic range. These results suggest that management for high-density snowshoe hare habitat should be a continued focus of lynx conservation in this region.

Patch Occupancy, Habitat Use, and Population Performance of Spruce Grouse in Commercially Managed Conifer Stands

Stephen Dunham and Daniel Harrison
University of Maine

Status: Progress Report, Year 3 of 4

Summary:
This study investigates patterns of breeding season patch occupancy, brood rearing home range characteristics, and annual survival trends of spruce grouse among stands representing 5 forest management treatments in Maine. During the 2012-2014 breeding seasons (May-June) and brood rearing seasons (June-Aug) we conducted repeated call-back surveys in 28-41 stands annually, which represented mature conifer/mixed stands, regenerating conifer-dominated clearcuts, two ages of precommercially thinned stands, and selection harvests. Responding grouse were captured and marked with colored leg bands, and females were equipped with a necklace mounted VHF transmitter. Marked individuals were monitored regularly until brood break-up (October 1). Vegetation data was collected both within the surveyed stands and within the home ranges of marked birds. Preliminary results indicate that males have a high probability of occupancy within the studied stands (~76%) and that they are more likely to be found in stands with increased density of conifers > 3 inches dbh and in stands with presence of dead limbs near the ground. Additionally, females were more likely to occupy previously clearcut and precommercially thinned stands, especially stands with relatively less dense overstory canopy and with increased lateral cover and edible cover (food resources with a height <0.5 m).

Bird Communities of Coniferous Forests in the Acadian Region: Habitat Associations and Responses to Forest Management

Brian Rolek, Daniel Harrison, Cynthia Loftin, and Petra Wood
University of Maine

Status: Progress Report, Year 2 of 3

Summary:
We sampled birds across sites located within the Acadian Forest Region, which coincides roughly with Bird Conservation Region 14 in the United States. In 2013, we established survey points in the North Maine Woods (Clayton Lake and Telos), Baxter State Park, and four National Wildlife Refuges (Nulhegan Basin Division of Silvio Conte NWR, Umbagog NWR, Moosehorn NWR, and Aroostook

NWR). In 2013, we surveyed 110 forest stands with approximately 3 to 8 survey locations per stand for a total of 609 sampled points. In 2014, we added 48 points in 7 stands to increase sample size in shelterwood harvests, increasing total samples to 657 point locations in 117 stands. Across all study areas, we recorded 19,431 detections of 123 bird species in 2013 and 22,784 detections of 134 bird species in 2014. We adapted methods from the Forest Inventory Analysis and Breeding Bird Research and Monitoring Database to measure vegetation at the location of each point count. Data collected included an array of structural and compositional measurements. We completed 1,320 vegetation plots and measured 15,024 trees during those surveys.

forests and wetlands, are being harvested at accelerating rates in Maine. The goals of this project are to increase our understanding of the effects of commercial forest management in northern Maine on patterns of habitat occupancy, habitat use, and reproductive success of spruce grouse. Data collection across a range of stand conditions is ongoing and consists of occupancy surveys, home range analysis of broods, and monitoring of survival and brood rearing success of adult females.

Spruce Grouse, Wells Forest – Photo by Pam Wells

Partnerships & Initiatives

An important dimension of the CRSF's mission is collaboration with other programs that can help advance research on various aspects of forest resources. These initiatives and partnerships strengthen our overall mission by leveraging funds, facilities, and talent, as well as fostering interdisciplinary cooperation on key issues facing forest resources.

For example, CRSF provided state leadership this year through in the Spruce Budworm Task Force to prepare a risk assessment and preparation plan for the coming outbreak in northern Maine. The CRSF also leads Theme 3 of the **Northeastern States Research Cooperative (NSRC)**, which provides competitive research funding for projects that advance understanding about forest productivity. The CFRU is part of the National Science Foundation's **Center for Advanced Forestry Systems (CAFS)**, which provides funding with nine other industry/university forest research cooperatives across the country. CRSF is the home for the **Howland Research Forest**, which is part of the national Ameriflux network measuring the atmospheric flux of carbon dioxide. CRSF is also a partner in **Forests for Maine's Future**, which provides a social media and website connection on important forest resource issues with the general public. In addition, CRSF partners with other UMaine research centers on collaborative projects, including the **Sustainability Solutions Initiative (SSI)** and **Forest Bioproducts Research Institute (FBRI)**.

In addition to the aforementioned stakeholders, this year CRSF participated in the following strategic partnership and initiatives:

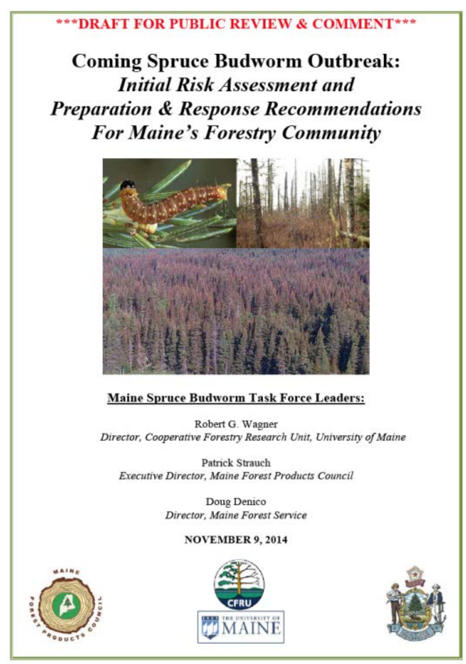
Spruce Budworm Assessment & Preparation Plan

About 40 years ago, the spruce budworm (SBW) was devastating spruce-fir forests across northern Maine. This outbreak was a regional event covering more than 130 million acres across Quebec, Northern New England, and the Maritime Provinces of Canada. That outbreak lasted about 15 years (1970-85) and shaped the forest, forestry politics, and careers of most foresters during this period. It was during this period that the CFRU also was formed to help forest landowners work together with the University of Maine to meet the challenges associated with the SBW.

Returning on a natural 30-60 year cycle, the next outbreak is now at Maine's doorstep. The current outbreak began in Quebec in around 2008 and has spread to cause severe defoliation on over 10 million acres of spruce-fir forest. Insect traps in northern Maine and New Brunswick have captured steadily increasing SBW moth counts over the past several years, and defoliation of spruce-fir stands is within a few miles of Maine's northern border. Therefore, Maine is likely only 2 to 3 years away from seeing the first defoliated trees.

To help Maine prepare for the coming outbreak, the CFRU, Maine Forest Service, and Maine Forest Products Council formed a joint SBW Task Force in 2013. More than 65 experts contributed to task teams this year to address:

- Monitoring strategies,
- Forest management strategies,
- Protection options,
- Policy, regulatory & funding issues,
- Wildlife habitat issues,
- Public communications & outreach, and
- Research priorities.



DRAFT FOR PUBLIC REVIEW & COMMENT

Coming Spruce Budworm Outbreak:
Initial Risk Assessment and Preparation & Response Recommendations For Maine's Forestry Community

Maine Spruce Budworm Task Force Leaders:

Robert G. Wagner
Director, Cooperative Forestry Research Unit, University of Maine

Patrick Strauch
Executive Director, Maine Forest Products Council

Doug Denico
Director, Maine Forest Service

NOVEMBER 9, 2014

The findings of the Task Force were compiled into a draft report that was released for public review in 2015. The report includes a detailed risk assessment and nearly 70 recommendations for how Maine's forestry community can begin preparing for and responding to the coming outbreak. The final report will be released in March 2016.

Center for Advanced Forestry Systems (CAFS)

Bob Wagner and Aaron Weiskittel

This year saw the completion of the fifth year of Phase I for the UMaine site under the Center for Advanced Forestry Systems (CAFS). CAFS is funded by the National Science Foundation (NSF) Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. CAFS is a partnership between CFRU members and I/UCRC to support a University of Maine research site for CAFS. CAFS unites ten university forest research programs with forest industry members across the US to collaborate on solving complex, industry-wide problems at multiple scales. The mission of CAFS is *to optimize genetic and cultural systems to produce high quality raw forest materials for new and existing products by conducting collaborative research that transcends species, regions, and disciplinary boundaries*. CAFS is a multi-university center that works to solve forestry problems using multi-faceted approaches and questions at multiple scales, including molecular, cellular, individual-tree, stand, and ecosystem levels. Collaboration among scientists with expertise in biological sciences (biotechnology, genomics, ecology, physiology, and soils) and management (silviculture, bioinformatics, modeling, remote sensing, and spatial analysis) is at the core of CAFS research.

Phase 1 of CAFS contributed $70,000 per year to the center as long as CFRU members contributed a minimum of $300,000 per year to support the work of the site. This past year of CAFS funding jointly supported the advancing growth and yield models in commercially thinned stands in the Northeast. Using CAFS support, Patrick Clune (MS student) and Dr. Mohammad Bataineh modeled the growth of stands and individual trees in the CTRN.

This year, **Bob Wagner** and **Aaron Weiskittel** submitted a successful proposal to NSF for the Maine CAFS site to enter Phase II of the I/UCRC. In Phase II, NSF will provide $60,000 per year for 5 years if CFRU members contribute a minimum of $350,000 per year. Detailed proposals for CAFS research will be developed by Wagner and Weiskittel in the coming year.

CFRU staff and several Advisory Committee members represented the Maine CAFS site at the Seventh Annual CAFS Industrial Advisory Board (IAB) Meeting held May 20-22, 2014 in Coeur d'Alene, ID. The meeting was well attended by scientists, graduate students, and forest industry representatives who met to review and approve all CAFS projects nationwide. CFRU looks forward to another 5-years of collaboration with the NSF I/UCRC through CAFS.

The Northeastern States Research Cooperative (NSRC)

The Northeastern States Research Cooperative (NSRC) is a competitive grant program funded by the USDA Forest Service that supports cross-disciplinary, collaborative research in the Northern Forest — a 26-million acre working landscape that is home to more than one million residents and stretches from eastern Maine through New Hampshire and Vermont and into northern New York. The NSRC addresses the importance of the Northern Forest to society and the need for research to have relevance and benefit to the people who live there, work with its resources, use its products, visit it, and care about it.

The program is jointly directed through the USDA Forest Service, Northern Research Station, and a designated institution in each of the four Northern Forest states: The Rubenstein School of Environment and Natural Resources at the University of Vermont, the University of New Hampshire in cooperation with the Hubbard Brook Research Foundation in New Hampshire, the Center for Research on Sustainable Forests at the University of Maine, and the State University of New York College of Environmental Science and Forestry.

Since 2001, the NSRC has awarded over 295 research grants, totaling over $22 million, to researchers throughout the region. Each year, the NSRC supports Northern Forest research that fits into four research themes:

Theme 1 (Vermont): *Sustaining Productive Forest Communities: Balancing Ecological, Social, and Economic Considerations*
Theme 2 (New Hampshire): *Sustaining Ecosystem Health in Northern Forests*
Theme 3 (Maine): *Forest Productivity and Forest Products*
Theme 4 (New York): *Biodiversity and Protected Area Management*

Theme 3 at CRSF

NSRC Theme 3 is managed by the CRSF and supports research that will quantify, improve, and sustain productivity of the products-based economy of the Northern Forest. Aspects of primary interest include underlying biological processes, management practices, and methods of prediction that will influence future wood supplies and forest conditions. Dr. Bob Wagner and Meg Fergusson manage the NSRC within CRSF.

During FY 2013-14, four new project proposals on the Northern Forest were approved for funding through Theme 3, while CRSF continues to support over a dozen ongoing NSRC projects granted in past years. Summaries of the final reports from past projects and progress reports from current Theme 3 projects follow (full reports available on the NSRC web site at nsrcforest.org).

NSRC THEME 3 FINAL REPORT SUMMARIES

Managing an Aging Resource: Influence of Age on Leaf Area Index, Stemwood Growth, Growth Efficiency, and Carbon Sequestration of Eastern White Pine

Robert S. Seymour
University of Maine

Progress Report, Year 4

Summary:
The main goal of this study was to quantify the key attributes of the production ecology of eastern white pine over a 200+-year chronosequence, for the purpose of formulating optimal rotations and regeneration strategies for the maturing pine resource of New England. Objectives are to:

1. Quantify the effects of age and stand density on leaf area index (LAI), following the models of Long and Smith (1992) and DeRose and Seymour (2010).
2. Quantify the stemwood and total above-ground productivity (biomass, Carbon) and growth efficiency over this same chronosequence.
3. Compare the patterns documented to those predicted by the Fire and Fuels Extension of the Forest Vegetation Simulator (Dixon 2001).

Objective 1 was fully addressed by Adam Bland's MS thesis, as fully documented therein as well as in my 2013 progress report. Before he left our graduate program last year, Nathan Rutenbeck was working on addressing objectives 2 and 3. Limited progress was made, owing to Rutenbeck's part-time status and other responsibilities (teaching assistant, etc). A proposal was submitted to the Cooperative Forestry Research Unit to fund a remeasurement of these plots, but despite a strong vote in favor by the CFRU Advisory Committee, was not funded owing to budget priorities and other program limitations. My tenure as Cooperating Scientist for CFRU has ended, and I have not resubmitted this proposal.

Since the last progress report, all plots were visited twice to collect litter samples and make additional tree and plot measurements. A backlog of litter samples was partially reduced, but not eliminated, owing to our difficulty finding students to work in the lab. The funds remaining in last-year's account were largely spent for this purpose, leaving a bit over $100 remaining in the account. While not ideal, the extension of this project has allowed collection of three additional years of litterfall data which, once fully analyzed, will add strength and validation to the leaf area predictions made from allometric equations. We will make every effort to get these samples processed and analyzed by March 2016, so that a final report can be prepared. PI Seymour is still

looking for another graduate student to take over this study; we were unable to recruit one last fall.

A manuscript documenting the white pine density management diagram developed by Adam Bland is nearly ready for submission to Forest Science (Applied). Another paper addressing Objective 2 from Bland's thesis is also in preparation, likely for the Canadian Journal of Forest Research.

Kate Baldwin has requested that I give a NSRC-sponsored webinar on this and other white-pine related projects, which I plan to do early in 2016.

White Pine Stand, Wells Forest – Photo by Pam Wells

Potential Impacts of Alternative Future Land Uses on Forest Management and Wood Supply across Maine

Spencer R. Meyer
Yale University

Progress Report Year 3 of 4

Log Yard – Photo by Pam Wells

Summary:
Maine is the most heavily forested state in the United States, with 95% of its forests in private ownership. These forests support rural economies across the state through forest-based manufacturing as well as outdoor recreation and tourism. Maine's rural character, attractive quality-of-place, and relatively low land cost continues to encourage development, which in turn places pressure on private forest resources. The likely prospect of future development poses a risk to the wood supply upon which Maine's forest products economy relies. In this project, we are using a mixed-methods approach that combines land use planning with an assessment of the wood supply that could be affected by future development patterns. Using Bayesian belief networks (BBN), we integrated geospatial data and expert opinion to development land suitability models for four land uses (development, forestry, conservation and agriculture) across two major watersheds. Initial projections of future development suggest limited impact on timber supplies. Land parcelization, however, is likely to be more of a concern in the short-run.

Project Objectives:

- Create spatial maps of future development in selected locations in Maine.
- Summarize current development impact on forests.
- Project future forest cover and volume.
- Evaluate trends and spatial patterns of impacts of future development on forests.

Approach:

- Focus groups were used to solicit stakeholder input on landscape/parcel factors affecting suitability for four key land uses – development, forestry, conservation and agriculture (Figure 3).

- Bayesian belief networks (BBN) were co-developed with stakeholders from the focus groups. These networks combined expert knowledge with over 100 geospatial datasets to spatially identify areas of suitability for our four land uses.
- All stakeholders were convened to review and comment on BBN output. At these workshops, we also solicited a set of alternative future development scenarios (Figure 4).
- An agent based model was used to apply stakeholder-derived scenarios under varying assumptions across our two study areas (Figure 5).
- The intersection between likely future development and productive forestland will be used to estimate future timber supply impacts (Figure 6).

Key Findings / Accomplishments:

Stakeholders were able to serve a critical role in developing land use specific BBNs for our two Maine watersheds. The all-stakeholder workshop led to a successful set of future scenarios

Scenario generation is difficult. Most scenarios envision slight changes to the status quo. In our case, the Penobscot River Watershed has lost several major pulp and paper mills. The magnitude of the change in processing capacity far outweighed anything our stakeholders might have envisioned. A lesson learned is that "unrealistic" scenarios that forecast significant change have a role to play in futures analyses.

The anemic rate of development in Maine following the 2008 financial crisis continues to linger. This suggests that, at least for the immediate future, timber demand/processing capacity is a more critical concern and limiting factor than the traditional focus on the amount of forestland and fiber supply.

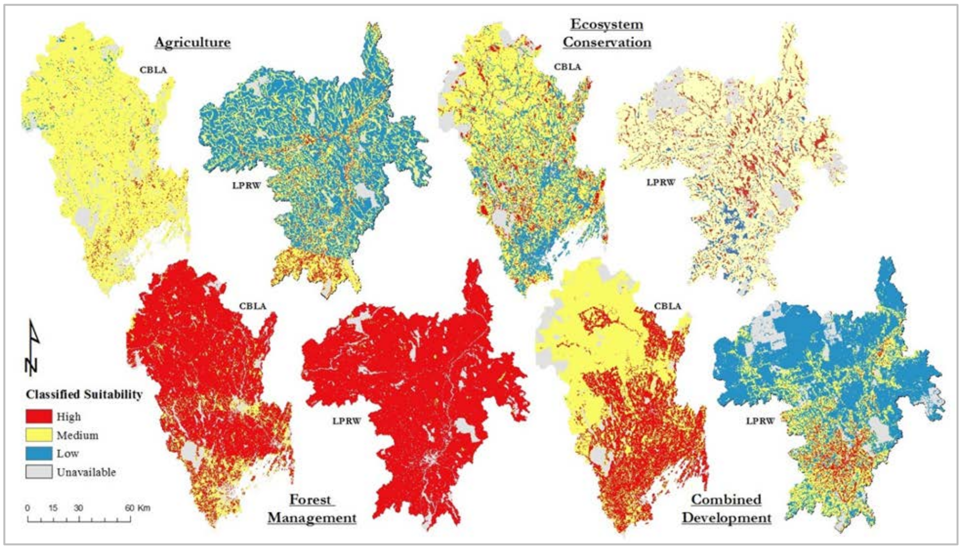


Figure 3 - Complete suitability maps for both watersheds

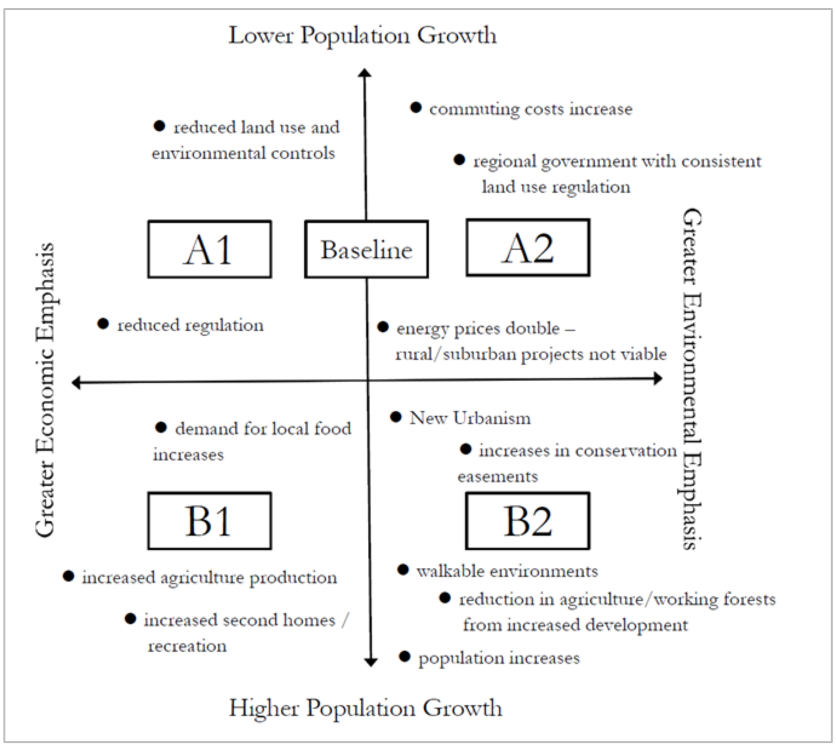


Figure 4 - Scenario matrix for future development, forestry, conservation, and agriculture trends, based on input by stakeholders.

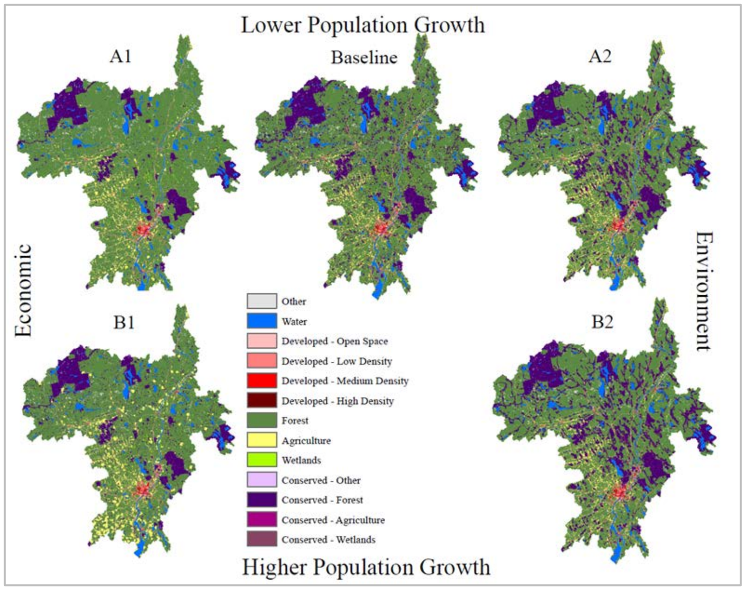


Figure 5 - Scenario results for 2036 showing changes in land use categories.

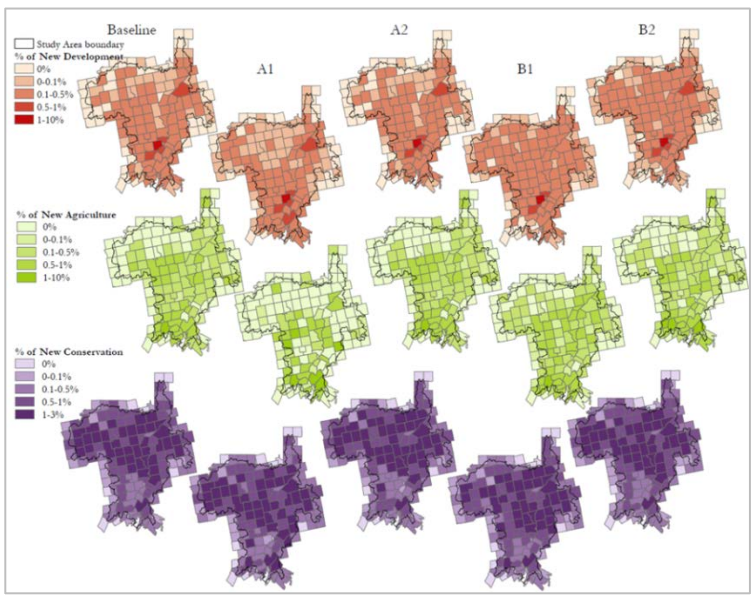


Figure 6 - First phase of spatial analysis to determine extent of impact of development and changing land use on forest cover.

Future Plans

- Further refine future development scenarios
- Refine agent based model to better predict development in rural areas
- Use forest BBN suitability measures and USDA Forest Service FIA data to estimate lost forest acreage and fiber productivity due to future development

Influence of Commercial Thinning on Resistance to and Recovery from Defoliation in Spruce-Fir Forests

Michael E. Day and C. J. Langley
University of Maine

Progress Report, Year 2 of 3

Summary:
Recent decades have experienced an increasing interest in thinning treatments to enhance productivity in spruce-fir forest types, resulting in the establishment of a large scale study by the University of Maine Cooperative Forest Research Unit (CFRU). The Commercial Thinning Network study, supported by funding from large-scale landowners, has made substantial progress in understanding effects of spacing treatments in spruce-fir silviculture, but how thinned stands will respond to repeated defoliation in a budworm outbreak remains unclear. Studies have repeatedly demonstrated that stand recovery is highly correlated with spruce-fir composition. However, studies comparing spaced and unspaced stands have provided mixed results on survival and recovery of productivity

The study attempts to quantitatively establish the influence of thinning treatments on potentially the two most important tree-level variables related to survival and re-establishing post-defoliation productivity in spruce-fir: foliar resistance to larval feeding and ability to recover leaf area after repeated defoliation. The results will directly illuminate the physiological basis for the differential post-defoliation recovery of spruce and fir, provide input for process-based predictive modeling relating thinning to recovery from defoliation. In addition, this research will establish a baseline for a second-phase study on resource dynamics following artificial defoliation of individuals in thinned and unthinned stands.

Project Objectives

1. The overarching objective of this study is to establish the physiological basis for greater mortality and loss of productivity associated with balsam fir than red spruce following defoliation by spruce budworm larvae. Specific hypotheses/questions are:

2. Increased carbohydrate reserves (non-structural carbohydrates, NSC) enhance recovery from defoliation in red spruce compared to balsam fir.

3. Post-defoliation foliage in red spruce is more robust due to greater lignin (phenolics) and tannins stimulated by feeding on needles, providing red spruce with enhanced resistance in multiple years of defoliation.

4. The ability to establish NSC reserves for post-defoliation recovery and production of more robust foliage is enhanced by precommercial thinning treatments by increased resource availability.

Approach

- Compare non-structural carbohydrate reserves in red spruce and balsam fir trees at three thinned and non-thinned CFRU Thinning Study sites.
- Experimentally manipulate branches in spruce and fir trees in the thinned treatments by (1) removing all foliage and (2) cutting existing foliage in half to simulate insect feeding.
- Compare responses in new foliage to simulated feeding treatments by quantifying phenolics content.

Key Findings / Accomplishments

- Samples of bole wood, large roots, large branches and fine branches were processed in lab for total non-structural carbohydrates (NSC: sugars + starch).
- Data for NSC were analyzed for species, thinning treatment and organ effects
.
- Calibration curves were developed for photospectrometric analysis of non-structural phenolics.
- Samples of needles from treatment and control branches were collected and are currently being processed for total non-structural phenolic content.
- Information on this project has been included in region-wide compendia of research efforts focused on responses to spruce budworm outbreaks.

Future Plans

- A full-time graduate student is supported by the project to lead sample and data analysis and will develop a MS thesis based on the results. We anticipate publishing results in peer- reviewed journals and dissemination at regional conferences.
- This field season we are (1) visiting all field sites to collect current year foliage from experimental and control branches, and (2) analyzing foliar samples for phenolic content.
- Results of non-structural carbohydrate analysis are being presented at a meeting of the Acadian Entomological Society (August, 2015, Fredericton, NB).

- Project results will be tentatively presented at a field meeting of the UMaine Cooperative Forestry Research Unit in October, 2015, at the Weeks Brook field site.

- Presentations of project results are planned for the New England annual meeting of the Society of American Foresters in March, 2016.

Products Delivered

Conference Papers

Results of non-structural carbohydrate analysis presented at a meeting of the Acadian Entomological Society (Fredericton, NB).

Norway Spruce Seedling – Photo by Pam Wells

Analysis of Wood Resource Availability in the Northeastern United States

Jennifer J. Hushaw
Innovative Natural Resource Solutions, LLC

Progress Report, Year 2 of 2

Summary:
At the time of this progress report, the majority of the intended spatial data layers have been created, representing a suite of terrain, logistic, and market access variables that affect the likelihood of harvest in a given area. These datasets will be useful stand-alone products for stakeholders interested in particular questions related to wood resource availability, but the final phase of the analysis will also involve an aggregation of these data layers into a single map of relative harvest likelihood for the entire study area. Now that the data acquisition and analysis phases have largely been completed, we will begin compiling the documentation, user-friendly downloadable products, and other enhancements that will make these data accessible and useful for a wide variety of stakeholders.

Project Objectives

- Spatially map and quantify the accessibility of wood supply in the northeast region, using variables related to the environmental, social, management or logistical constraints to harvesting.
- Generate regression models to predict the effect of parcelization on operable forest property size.
- Facilitate utilization of generated data layers by producing thorough documentation, making them freely available for download on-line, and by integrating them with an existing wood supply modeling tool.
- Compile all data layers into a final map of the relative likelihood of harvest.
- Identify existing data gaps.

Approach

- Use ArcGIS software to create spatial datasets that represent real-world factors that affect harvest accessibility of standing timber, such as distance from roads, protected areas, stream buffers, existing harvest demand, and others.

- Convert each data layer to a binary format that represents the presence or absence of a barrier to harvesting, where a 'barrier' is a condition that increases the environmental, social, or financial cost of harvest operations (e.g. areas within stream buffers are a barrier with a higher 'cost' than areas without).

- Combine all binary data layers to produce a cost surface, where 'high cost' areas have multiple harvest barriers present (e.g. protected area within a stream buffer in steep terrain) and 'low cost' areas have few barriers to accessibility. This acts as a proxy representation of the relative likelihood of harvesting – the greater the cumulative 'cost,' the lower the likelihood of harvesting.

- Use individual parcel boundary data from towns across the Northern Forest region, in conjunction with land cover data and data on land protection status, to identify parcel size distribution and the size distribution of individual parcels of forest land. Use regression on data from the U.S. Census to predict the size distribution of forest parcels for towns that do not have publically-available parcel boundary data.

Key Findings / Accomplishments

- Completed a spatial analysis of access to low-grade wood markets.

- Completed analysis of variable riparian buffers based on state-specific BMPs, as applied to waterbodies, streams, and wetlands in the region.

- Created a Voronoi map based on point features representing road bridges that met a certain trucking weight limit threshold.

- Created a data layer representing limits to road access based on typical maximum skidding distance.

- Compiled an integrated dataset of protected areas and conservation easements where there are some harvesting limitations in place.

- Compiled town-level parcel data for Maine, New Hampshire, Vermont, and New York, and performed a pilot analysis using New Hampshire data. Currently extending the analysis to the full data set with a goal of mapping forest parcelization impact for the entire Northern Forest over the next month.

Future Plans

- Creation of harvest likelihood map combining all data layers.
- Creation of tabular datasets summarizing each data layer by town.
- Thorough documentation of data sources and methodology used to generate each dataset.
- Packaging spatial and tabular datasets for download.
- Incorporate results into an existing wood supply modeling tool (Northern Forest Biomass Project Evaluator: www.nefainfo.org/BPE.html)

Products Delivered

Presentations / Workshops / Meetings / Field Tours

Ducey, M.J. 2014. Poster: Spatial data for modeling wood resource availability in the Northeastern United States. Eastern Canada-United States of America Forest Sciences Conference, 7th ECANUSA, October 17, 2014, Rimouski, Quebec, Canada.

A Long-Term Perspective on Biomass Harvesting: Northern Conifer Forest Productivity 50 Years after Whole-Tree and Stem-Only Harvesting

Laura Kenefic
USDA Forest Service, Northern Research Station

Progress Report, Year 1 of 2

Summary:
Beginning summer 2014, 23 permanent sample plots (PSPs) were installed in Compartment 33, located within the Penobscot Experimental Forest (Figure 7). Treatments include an unharvested reference, whole-tree harvesting (WTH), and stem-only harvesting (SOH). For analysis, stand attributes such as basal area (m2/ha), total volume (m3/ha), merchantable volume (m3/ha), total biomass (Mg/ha), stem density (#/ha), quadratic mean diameter (cm), average height (m), and percent hardwood biomass for all live trees within the unharvested reference, WTH, and SOH units were calculated and compared. In addition, total biomass and volume were calculated for both standing dead trees and down woody debris as well as regeneration density by species. Soil and foliage samples were collected and processed through the Maine Agricultural and Forest Experiment Station (MAFES). Statistical analysis revealed differences in average aboveground species biomass, with more aspen (*Populus spp.*) in WTH units. Results were presented at both national and international conferences.

Project Objectives

- Quantify site productivity (soil and foliar nutrients) and stand attributes (biomass and composition) 50 years after treatment in a designed experiment of clearcutting with WTH and SOH
- Determine the effect, if any, of incremental (SOH vs WTH) biomass removal on productivity
- Synthesize our findings with those from other studies of WTH in the Northern Forest (e.g. Roxby 2012, Roxby and Howard 2013, Roth et al. in progress) to provide insight for future sustainable biomass harvesting guidelines

Approach

- At each PSP, height, diameter at breast height (dbh, 1.37 m), and species of living and standing dead trees were measured for stand structure and composition analysis

- For plant-available nutrient measurements, we installed ion exchange resin membranes (IERMs) at the bases of two red maple (*Acer rubrum*) and two balsam fir (*Abies balsamea*) trees demonstrating dominant characteristics within each unit (i.e., each tree had one cation and one anion IERM strip placed side by side, at a distance ~10x the dbh of the tree, azimuth of 180°)

- Foliage samples were then obtained on the upper 1/3 canopy from each of those trees, targeting the current year's growth

- Down woody debris ≥ 10 cm in diameter was measured using modified Brown's transects on all PSPs (van Wagner 1968, Brown 1971, Brown 1974)

- Regeneration up to < 1.37 m in height was inventoried on all PSPs

- Depth of the 'O' horizon within the soil was measured, as well as both parent material and soil drainage type confirmed in field, for use as potential explanatory variables on all PSPs

Key Findings / Accomplishments

- May – August 2014: **4** permanent sample plots (PSPs) were installed in the unharvested reference area, **7** within WTH experimental units (EUs), and **5** within SOH EUs, in Compartment 33.

    - Both stand structural attribute data and soil and foliar samples collected on each PSP

- July 2014: Basal area (ft2/ac) and trees per acre summary statistics presented during New England Society of American Foresters (NESAF) Management and Utilization Working Group Tour, Penobscot Experimental Forest

- July – August 2014: **315** IERM extracts and **62** foliage samples submitted to MAFES for processing

    - Plant-available nutrient results returned August 2014

    - Foliage sample results returned March 2015

- July – December 2014: Data analysis for stand structural attributes completed

    - Key Finding: Statistical analysis of standing live, aboveground biomass revealed differences in average species biomass, with more aspen (*Populus spp.*) in WTH units, regardless of soil drainage type

- October 2014: Presentation of findings at 2014 International Union of Forest Research Organizations (IUFRO) World Congress, Salt Lake City, UT (Oral Presentation), AND 2014 Society of American Foresters National Convention, Salt Lake City, UT (Oral Presentation)

- May – June 2015: Installation of **6** PSPs within stem-only harvest with burn (SOHB) EUs and **1** PSP within an SOH EU, in Compartment 33 (Figure 7).
    - Only stand structural attribute data collected
    - Collected for comparison of stand structural attributes between SOH and SOHB

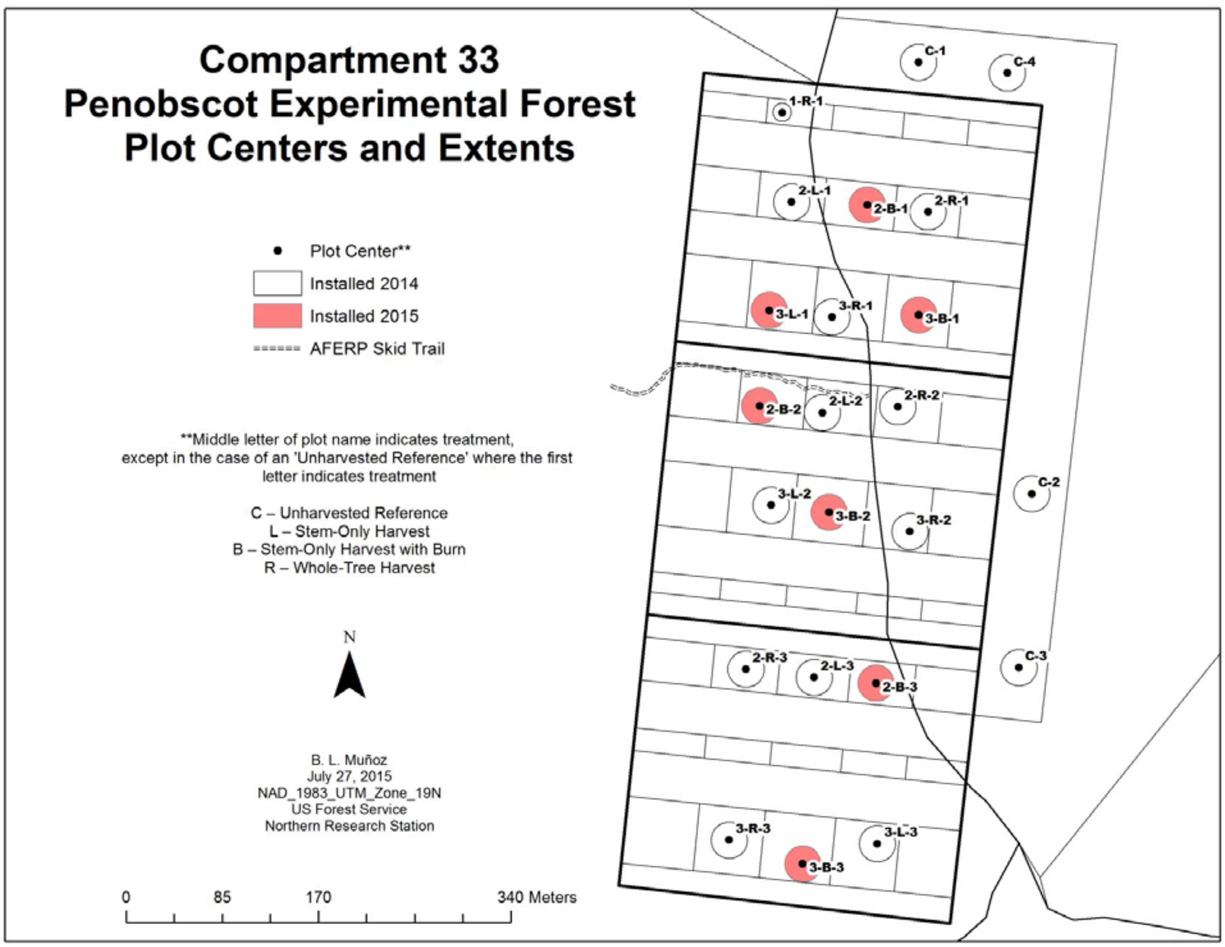


Figure 7 - Map of Compartment 33 plot centers and extents.

Future Plans

- July 2015 – June 2016: Muñoz will complete data analysis, producing three chapters in her dissertation dedicated to this project
    - Chapters will be submitted for publication, targeting Forest Ecology and Management and other natural resource journals

  Chapter 1: Comparison of WTH and SOH stand structural and compositional attributes (no comparison to unharvested reference)
  Chapter 2: Comparison of WTH, SOH, and Unharvested Reference soil and foliar nutrition
  Chapter 3: Comparison of SOHB and SOH stand structural and compositional attributes

- December 2016: Presentation of all results at Muñoz dissertation defense

Products Delivered

Presentations / Workshops / Meetings / Field Tours

Muñoz, B. 2014. A Long-Term Perspective on Biomass Harvesting: Northern Conifer Forest Productivity 50 Years after Whole-Tree and Stem-Only Harvesting. New England Society of American Foresters (NESAF), Management and Utilization Working Group Tour, July 24, 2014, Penobscot Experimental Forest, Bradley, ME.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez, J. Benjamin, and S. Fraver. 2014. A Long-Term Perspective on Biomass Harvesting: Northern Mixedwood Forest Productivity 50 Years after Whole-Tree and Stem-Only Harvesting. International Union of Forest Research Organizations (IUFRO) World Congress, October 7, 2014, The Salt Palace Convention Center, Salt Lake City, UT.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez, J. Benjamin, and S. Fraver. 2014. Northern Mixedwood Forest Productivity 50 Years after Whole- Tree and Stem-Only Harvesting. Society of American Foresters National Convention, October 10, 2014, The Salt Palace Convention Center, Salt Lake City, UT.

References

Brown, J.K. 1971. A planar intersect method for sampling fuel volume and surface area. Forest Science 17(1): 96-102.

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report INT-16. 24 p.

Roxby, G.E. 2012. Effects of whole-tree harvesting on site productivity and species composition of a northern hardwoods forest. M.S. Thesis, University of New Hampshire, Durham, NH. Roxby, G.E. and T.E. Howard. 2013. Whole-tree harvesting and site productivity: twenty-nine northern hardwood sites in central New Hampshire and western Maine. Forest Ecology and Management 293: 114-121.

Van Wagner, C.E. 1968. The lineintersect method in forest fuel sampling. Forest Science 14(1): 20-26.

How Does Nitrogen Deposition Affect In-stream Dissolved Organic Nitrogen Processing and Its Role in Regulating Watershed Nitrogen Export?

Madeleine M. Mineau
Earth Systems Research Center, University of New Hampshire

Final Report

Summary:
We investigated the effect of nitrogen (N) deposition on dissolved organic nitrogen (DON) uptake and the coupling of dissolved organic carbon (DOC) and DON in forested headwater streams in the northeastern US. In fall 2012, we found that DON uptake decreased as inorganic nitrogen availability increased across sites but DOC uptake was unrelated to N availability resulting in the decoupling of DOC and DON uptake. However, this pattern did not occur during the following summer or fall. We think that N demand was high in fall 2012 due to biofilms accruing following "super storm Sandy" which resulted in the high demand for DON where inorganic N was low. N-acquiring enzyme activity was significantly higher in the stream with the highest DOC. When we experimentally increased nitrate concentration in a stream while simultaneously measuring DOC and DON uptake, we found that DON uptake increased and DOC uptake was not affected.

Project Objectives

- Understand how in-stream demand and processing affects DON export from northeastern U.S. forested watersheds across a gradient of N deposition
- Understand how inorganic nitrogen availability affect the coupling of dissolved organic carbon and dissolved organic nitrogen in forested headwater streams

Approach

- Reach-scale DOC and DON uptake measurements in 6 streams across gradient of ambient and experimentally elevated N deposition.
- Reach-scale DOC and DON uptake measurements with experimental manipulation of nitrate concentration.
- DOC and DON bioavailability assays
- Biofilm microbial enzyme activity measurements

Key Findings / Accomplishments (July 2014 – June 2015)

- Contrary to our hypothesis, experimentally increasing nitrate concentration increased DON uptake and did not affect DOC uptake. This does provide supporting evidence that DOC and DON processing can be decoupled and influenced by inorganic nitrogen availability however, these results are contrary to our previous findings that increased nitrate availability reduced DON uptake.

Allison Price collecting water samples during a DOC-DON uptake measurement at the Catskills sites.

Madeleine Mineau collecting biofilm samples for microbial enzyme activity assays.

Silvicultural Effects on Environmental Conditions and Resulting Aboveground Productivity and Carbon Sequestration of Northeastern Mixedwood Forests

Andrew Nelson, Robert G. Wagner, Michael E. Day, and Ivan J. Fernandez
University of Maine

Final Report

Summary:
Early successional forests in Maine comprise nearly 12% of all forestlands in the state, yet their response to different intensities of silviculture is poorly understood. One way to understand the mechanisms driving silvicultural responses is to study quantify resource capture and resource-use efficiency of individual trees and stands. Therefore, the goal of this project was the explore resource capture and resource-use efficiency of trees and stands in the SIComp experiment on the Penobscot Experimental Forest in eastern Maine. SIComp consists of factorial treatment combinations of silvicultural intensity and species compositional objectives. The distinct developmental trajectories provide an ideal setting to explore mechanistic drivers on forest productivity in the region.

First, we developed individual tree leaf area models for common early successional species in the region. We found that species differed considerably in the amount of leaf area they produce and how the leaf area was partitioned within their crowns. These models were then linked with SIComp inventory data to examine temporal changes in stand leaf area index (LAI) in response to the contrasting silvicultural treatments. Although LAI was reduced considerably in all treatments, LAI approached pre-treatment values seven years after treatment but shifted LAI to different species groups. LAI in both the conifer-dominated and mixedwood stands were shifted to conifer species and shade tolerant hardwood species, while LAI in hardwood-dominated treatments remained in shade intolerant hardwood species. Treatments also affected the vertical partitioning of LAI though the canopy, with the most rapid upward partitioning occurring in shade intolerant species. In contrast, conifer species allocated LAI laterally even after release. Last, we explored how contrasting growing conditions (plantations vs. natural stands) affected light capture and light-use efficiency of individual white spruce trees. For the average sized tree, trees in plantations absorb substantially more light than trees in natural stands due to lower neighborhood competition. In comparison, the efficiency that captured light was converted to aboveground biomass was greater in natural stands than plantations, likely due to the moderate shade tolerance of white spruce. Overall, the results from this project provide initial findings to better understand the coexistence of multiple species in early successional stands in Maine that may assist in the refining silvicultural prescriptions and modeling efforts.

Project Objectives

- Light capture and light-use efficiency can be directly assessed using light-intercept models, providing a mechanistic understanding of how trees respond to neighborhood growing conditions

- Examining patterns in light capture and use efficiency in response to silviculture provides a broader understanding of the underlying processes affecting growth and may assist in refining growth and yield models.

Approach:

Individual Tree Leaf Area Models

- Trees were sampled from the SIComp experiment on the Penobscot Experimental Forest in eastern Maine in summer 2011

- Trees were cut at the base and branches were subsampled to develop branch-level projected leaf area models

- Branch models were used to predict leaf area of all branches within a tree and summed to obtain total leaf area estimates

- Nonlinear regression was used to fit total tree leaf area models by species

Stand Leaf Area Index

- Leaf area index was estimated for trees in the SIComp experiment on the Penobscot Experimental Forest using the individual tree leaf area models developed for trees at the site.

- SIComp was designed to explore the effects of factorial combinations of silvicultural intensity and species compositional objectives in early successional stands.

- We used eight years of long-term inventory data and individual tree leaf area models to examine how treatments affected stand productivity

- Leaf area was summed for all trees within each plot to estimate leaf area index

- Leaf area index was then calculated separately for three broad species groups: shade intolerant hardwoods, shade tolerant hardwoods, and conifers.

- Vertical distribution of canopy leaf area index was estimated using the right-truncated Weibull distribution models developed for individual trees.

- New right-truncated Weibull distribution models were then fit for each treatment plot and measurement year for (a) all trees combined, and (b) for the individual species groups.

White Spruce Light-Use Efficiency

- The study was conducted on the SIComp experiment on the Penobscot experimental forest.

- Trees were selected from treatments with contrasting growing conditions: (a) white spruce enrichment planting in stands shifted to conifer and mixedwood dominance, and (b) white spruce planted in pure and mixed plantations with hybrid poplar trees.

- All trees within a 6 m radius of the focal white spruce tree were identified to species, stem mapped, and their size was measured (stem diameter, height, crown width, crown length).

- MAESTRA, an individual tree light capture model, was used to estimate the amount of light captured by each individual white spruce tree throughout the growing season by accounting for the shading by neighboring trees.

- Analysis of covariance was used to explore the effects of distance-weighted competition and tree size on light capture and use efficiency across the treatments.

Key Findings / Accomplishments:

Our results demonstrate:

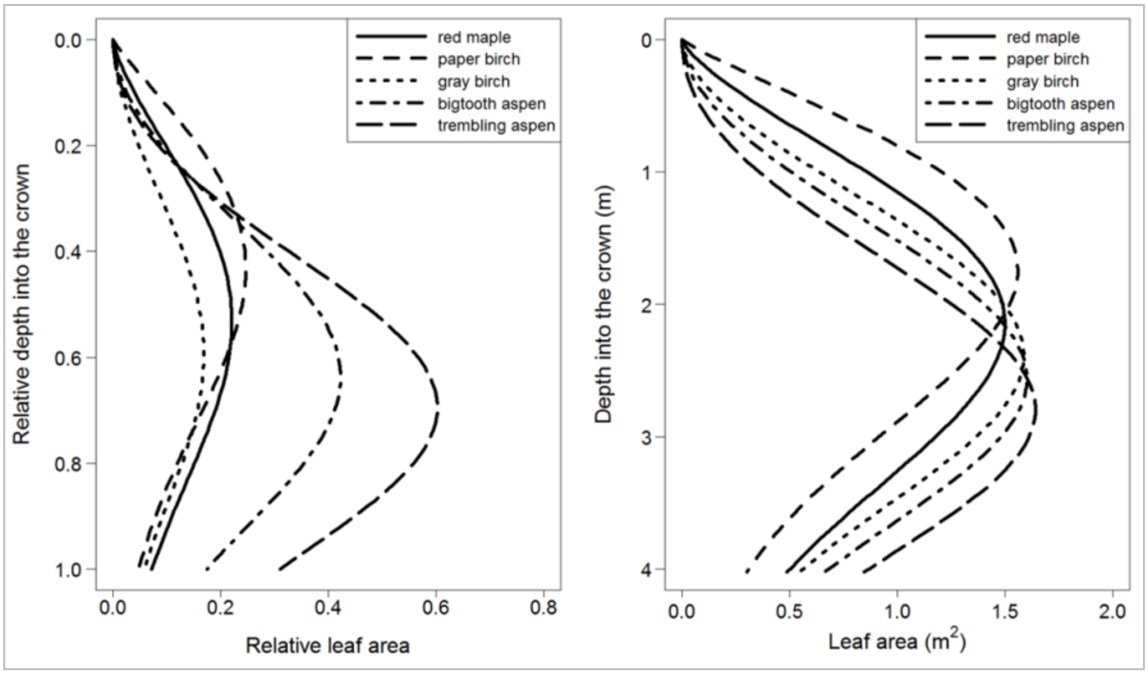
- Early successional hardwood species differ considerably in their strategies for producing leaf area and partitioning leaf area within their crowns.

- These different leaf area strategies among species allow for coexistence in mixed-species stands.

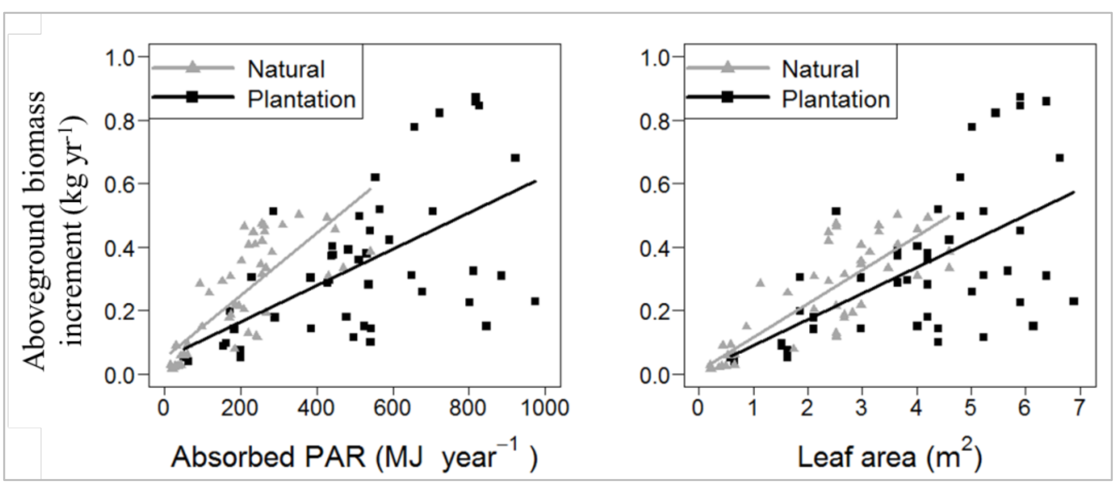
- When scaled to a stand-level, these different strategies help explain some of the underlying effects of silvicultural treatments on aboveground productivity.

- White spruce trees growing on contrasting environments differ considerably in light capture and light-use efficiency, with trees growing in natural stands exhibiting greater efficiency of converting captured light into biomass than plantation trees.

Vertical Leaf Area Models: Vertical leaf area distributions for the five naturally regenerated hardwood species. Vertical distributions were fit with a right-truncated Weibull distribution from the tip of the tree to the base of the crown. Shown are both relative leaf area with relative depth into the crown and absolute leaf area with absolute depth into the crown for the averaged size tree across species.



White Spruce Light-Use Efficiency: Figures the correlations between APAR and annual aboveground biomass increment and the correlation between leaf area and aboveground biomass increment. The different lines were estimated with ANCOVA to explore differences in the correlations between trees in plantations and natural stands.



Future Plans:

- Expand individual tree leaf area models to more species common on Northeastern forests, especially shade tolerant hardwood species. This will provide a better understanding of species differences in light capture and coexistence.
- Assess light-use efficiency of white spruce trees in different treatment once trees begin to interact aboveground after crown closure. Then, a better understanding of the effects of pure- versus mixed-species forests on light capture an efficiency can be assessed.
- Explore the effects of belowground resource availability on light capture and light-use efficiency.

Products Delivered

Refereed Journal Publications

Nelson, A.S., Wagner, R.G., Day, M.E., Fernandez, I.J., Weiskittel, A.R., and Saunders, M.R. *In Review*. Effects of contrasting growing conditions on aboveground net primary productivity, efficiency, and foliar δ^{13}C composition of juvenile white spruce trees. Trees– Structure and Function.

Nelson, A.S., Wagner, R.G., Weiskittel, A.R., and Saunders, M.R. 2015. Effects of species composition, management intensity, and shade tolerance on vertical distribution of leaf area index in juvenile stands in Maine, U.S.A. European Journal of Forest Research 134: 281-291.

Nelson, A.S., Weiskittel, A.R., and Wagner, R.G. 2014. Development of branch, crown, and vertical distribution leaf area models for contrasting hardwood species in Maine, U.S.A. Trees– Structure and Function 28(1): 17-30

Research Reports:

Nelson, A.S., and Wagner, R.G. 2011. Influence of silvicultural intensity and species composition on the productivity of early successional stands in Maine. *In* Cooperative Forestry Research Unit 2011 Annual Report. *Edited by* B. Roth, Orono, ME. pp. 22-26

Conference Papers:

Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Vertical distribution and total tree leaf area equations of juvenile trees in eastern Maine. *Presented at:* Southern Mensurationist 2012 Annual Meeting. Jacksonville, FL.

Nelson, A.S., Weiskittel, A.R., and Wagner, R.G. 2011. Crown and total biomass equations of young, naturally regenerated hardwood species in central Maine. *Presented at:* 15th Annual Northeastern Mensurationists Organization Meeting. Quebec City, Quebec, Canada.

Future Distribution and Productivity of Spruce-Fir Forests under Climate Change: A Comparison of the Northeast and the Lake States

Erin M. Simons-Legaard, Aaron Weiskittel, Kasey Legaard, Anthony D'Amato, and Brian Sturtevant
University of Maine

Progress Report, Year 2 of 3

Summary:
The ecologically- and economically-important spruce-fir forests of the Northeast and Great Lakes regions are expected to be highly susceptible to the negative effects of climate change, as this forest type is already at the latitudinal limit of its southern range within the northern United States. This project uses a meta-modeling approach that includes bioclimatic envelope models and an integrated forest projection system to explore climate change effects. Within this framework, long-term projections of species distributions and productivity under varying climate and disturbance regimes are being produced. Species modeling and simulations allow for sensitivity evaluation of forest response to climate and disturbance, as well as identification of areas of potential refugia for this important forest type. Our goal is to improve understanding of how climate change will impact species directly and indirectly through interactions with other disturbance agents, including timber harvesting and eastern spruce budworm.

Project Objectives

- Produce high-resolution (temporal and spatial) projections of spruce-fir forest type using a meta-modeling framework;
- Estimate future changes in the distribution and productivity of the spruce-fir forest type due to potential changes in climate;
- Identify physiographic settings that ameliorate the effects of climate change and provide refugia for spruce-fir tree species; Evaluate the sensitivity of the projected future forest distribution and productivity to disturbance agents like the spruce budworm;
- Compare the findings for the Northeast to similar work being done in the Great Lake states to understand key differences between regions.

Approach

- Use an extensive database of forest inventory plots compiled in Year 1, consisting of more than 10 million observations from the Northeast (Maine, Vermont, New Hampshire), the Great Lakes (Michigan, Wisconsin, Minnesota), and Canada (Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, Prince Edward Island), to identify plots with balsam fir, black spruce, red spruce, or white spruce.

- Develop bioclimatic envelope models that link species specific data (e.g., presence/absence, basal area, stem density) with climate and topographic variables using the nonparametric random forest algorithm with balanced sampling.

- Use envelope models to predict and map the spatial distribution of suitable habitat conditions for each species under the ENSEMBLE RCP6 climate model.

- Compare modeled outcomes with and without the inclusion of historical tree data.

- Evaluate sensitivity of projected species distributions and future productivity to additional disturbance agents such as timber harvesting and eastern spruce budworm using the LANDIS-II forest landscape model (Scheller et al. 2007).

- Develop methods to modify key species parameters, including maximum annual net primary productivity ($ANPP_{max}$) and probability of establishment (P_{est}) using PnET-II (Aber et al. 1995), in order to model the effects of an increase in annual temperature, as is predicted for our study area (i.e., 4-5 °F by 2050; Fernandez et al. 2015).

Key Findings / Accomplishments

Balsam fir, white spruce, black spruce, and red spruce were located in 15.4%, 6.6%, 9.1%, and 4.1% of plots, respectively.

Occurrence models yielded excellent statistical results, as measured by area under the operating curve (AUC), with AUC > 0.90 for all species, and maps of likelihood of occurrence revealed strong correspondence with patterns of basal area concentration (Figure 8).

Abundance models performed well but not as well as presence/absence models and with greater differences between species. White spruce was consistently the most difficult species to accurately predict with the lowest R^2 (65-68%), whereas black spruce models were the most accurate (87-88% R^2). Overall, abundance models were good at detecting mid-range values, but overestimated low abundance and underestimated high abundance.

Occurrence and abundance models exhibited similarity in regards to selected variables. The predictor variable PRMTCM (i.e., the ratio between growing season precipitation and mean annual precipitation multiplied by the mean temperature in the coldest month) was always high ranking, indicating that areas where winter precipitation matches or exceeds growing season precipitation and mean temperature in the coldest month is lower than the average of the study area are suitable habitat for the species considered in this analysis.

Projections from the bioclimatic models suggest a net loss of suitable habitat for all species in the future as result of climate change.

Maps generated for the years 2030, 2060, and 2090 suggest that suitable habitat for white and black spruce will disappear from the U.S. by 2060 and from the Acadian Region by 2090 (Figure 9). Patches of suitable habitat for balsam fir and red spruce are projected to remain in the U.S. ca. 2060, but dwindle to only a few located at high altitudes along the Appalachian Mountains by 2090.

In addition to persistence in some areas, projections further suggest that suitable habitat will expand north of the Acadian Region for balsam fir and white spruce, and north and east for red spruce. Black spruce is likely to occupy regions past the northern extent of the study area used in this analysis.

The inclusion of historical tree data into the analysis (321, 5, 33, and 544 additional plots respectively for balsam fir, white spruce, black spruce, and red spruce) was influential on the predictions of suitable habitat for all species, suggesting persistence in areas that models would have otherwise indicated recession (Figure 9).

Preliminary results from forest landscape modeling suggest that interactions between climate change and timber harvesting may contribute to declines in balsam fir and white spruce, but provide some amelioration for black and red spruce (Figure 10).

Compared to a timber harvesting only scenario, projections of area dominance under harvesting and climate change suggest that the positive effect of timber harvesting on balsam fir regeneration in particular will be negatively offset by increasing temperature if there is no additional precipitation to reduce soil moisture stress. White spruce, which projections also suggest garners some regeneration benefit from timber harvesting, will likely experience a net loss of forest area with climate change.

By comparison, differences in area dominance between scenarios are positive for red and black spruce. This difference appears to be a partial result of the negative effect of climate change on paper birch and red maple. As a consequence, rates of site turnover from red or black spruce to intolerant hardwoods are reduced with climate change.

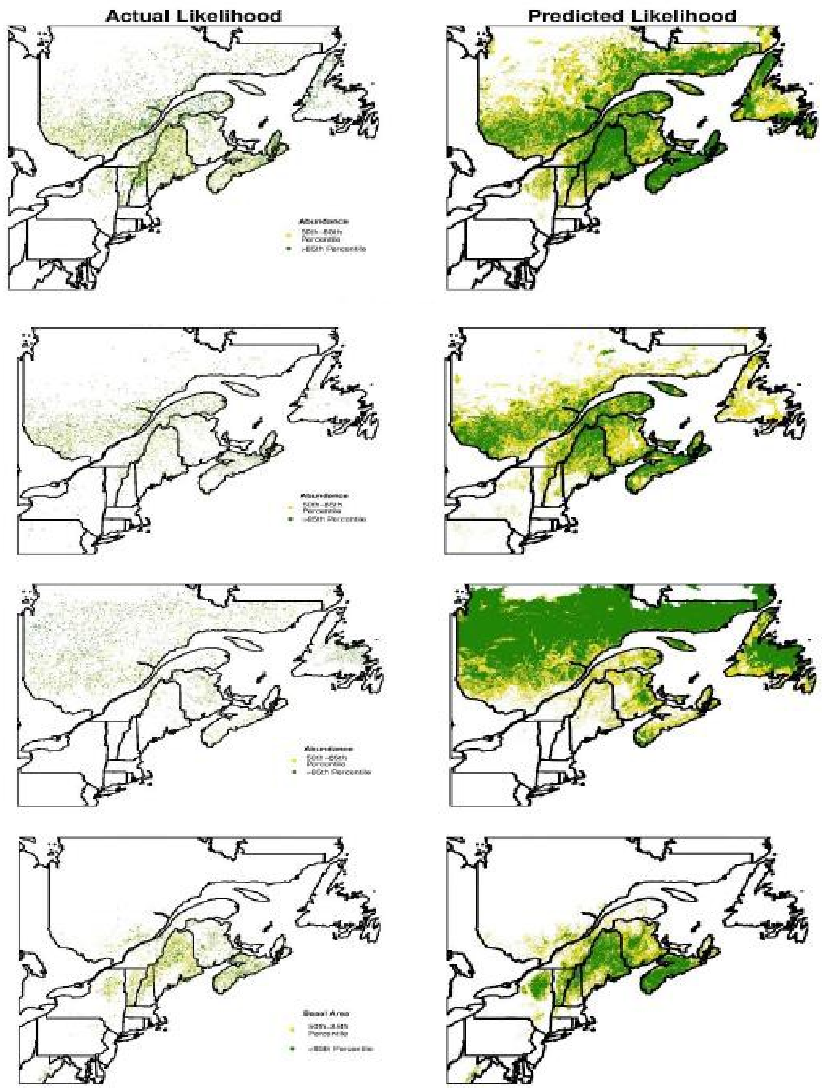


Figure 8 - Actual and predicted likelihood for (a) balsam fir, (a) white spruce, (c) black spruce, and (d) red spruce. The actual likelihood represents observed plot- level basal area displayed for plots in the 85th percentile (green) and the 50th to 85th (yellow). Predicted likelihood represents a likelihood of >85% (green) or 50-85% (yellow). Adapted from Andrews (2015).

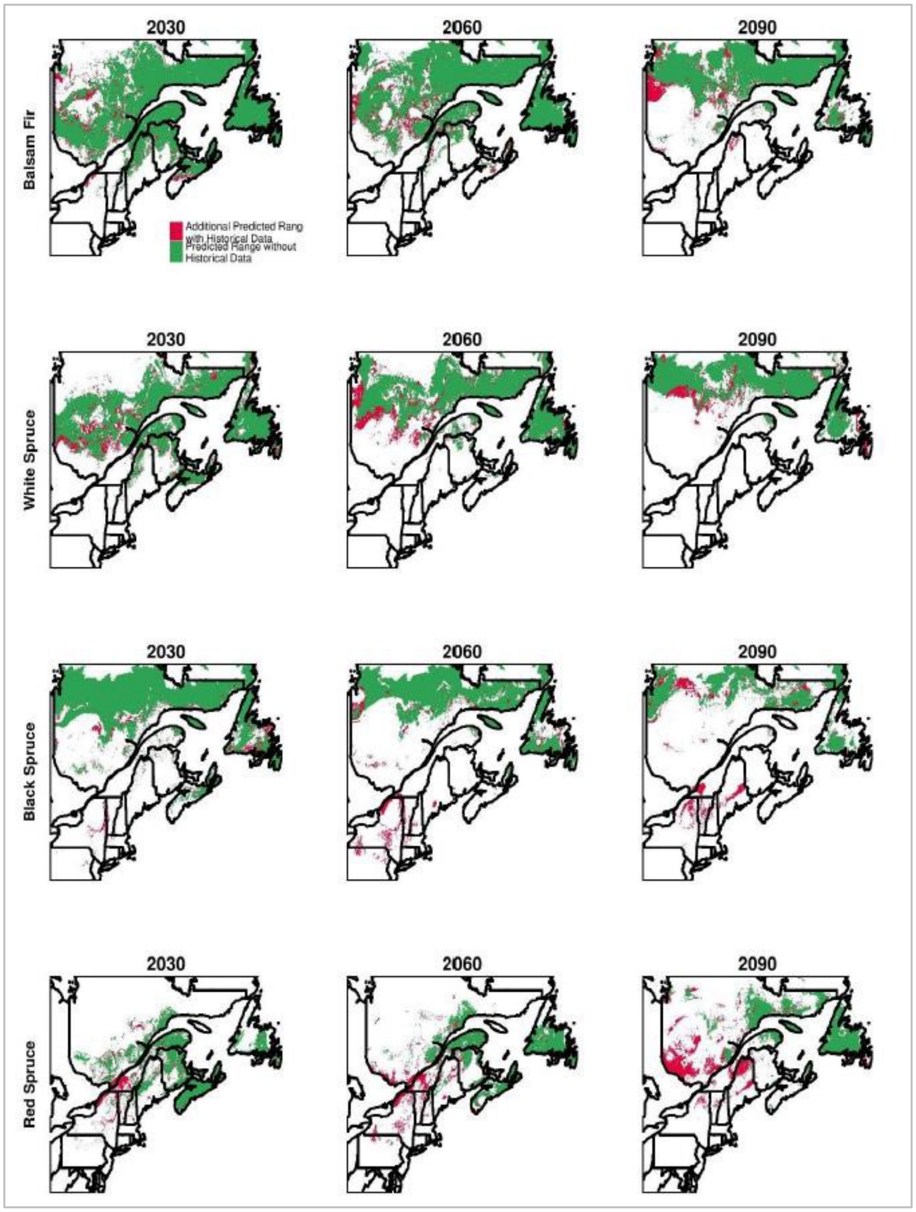


Figure 9 - Predicted occurrence (>50% likelihood), with and without historical data, for each species in 2030, 2060, 2090 under the ENSEMBLE RCP6 climate scenario. Additional areas of suitable habitat predicted with the inclusion of historical data are shown in red. Adapted from Andrews (2015).

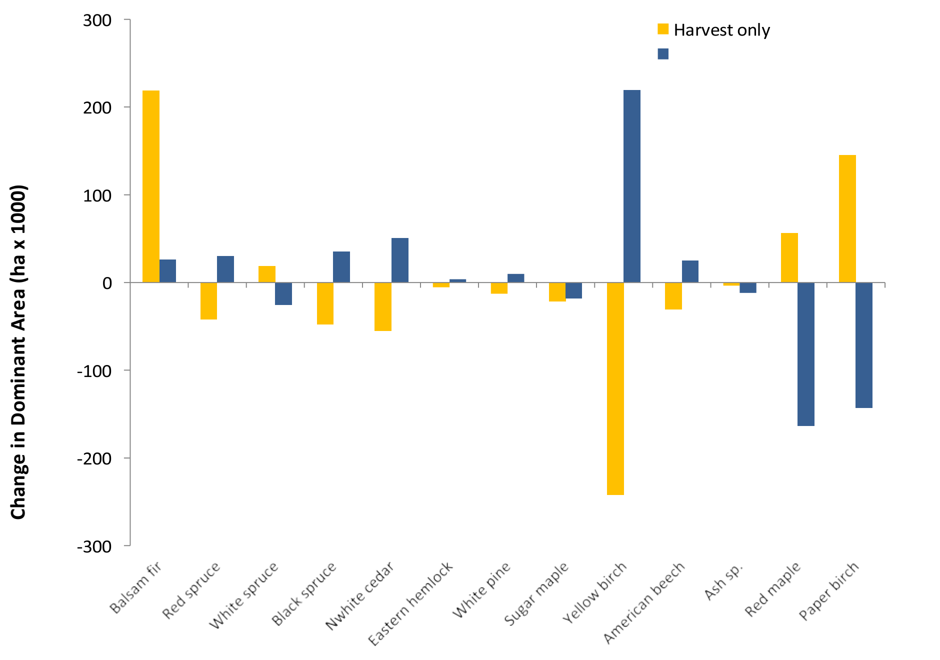


Figure 10 - Projected change in area dominance for the 13 most abundant tree species in Maine between 2010 and 2060, with (blue) and without (yellow) climate change.

Future Plans

In Year 3 of this project we will be continuing our use of LANDIS-II to model and explore interactions between climate change, timber harvesting, and spruce budworm

Products Delivered

***These**:*

Andrews, C. 2015. Modeling and forecasting the influence of current and future climate on eastern North America spruce-fir (Picea-Abies) forests. Master's Thesis, University of Maine, Orono, ME.

Presentations / Workshops / Meetings / Field Tours

Simons-Legaard, E., Legaard, K., Weiskittel, A., Andrews, C., D'Amato, A. Future distribution and productivity of spruce-fir forests under climate change in Maine. Maine Sustainability & Water Conference. March 31, 2015. Augusta, Maine.

References

Aber, J.D., Ollinger, S.V, Federer, C.A., Reich, P.B., Goulden, M.L., Kicklighter, D.W., Lathrop, R.G. 1995. Predicting the effects of climate change on water yield and forest production in the northeastern United States. Climate Research, 5, 207–222.

Andrews, C. 2015. Modeling and forecasting the influence of current and future climate on eastern North America spruce-fir (*Picea-Abies*) forests. Master's Thesis, University of Maine, Orono, ME.

Fernandez, I.J., Schmitt, C.V., Birkel, S.D., Stancioff, E., Pershing, A.J., Kelley, J.T., Runge, J.A., Jacobson, G.L., Mayewski, P.A. 2015. Maine's Climate Future: 2015 Update. Orono, ME: University of Maine. 24pp.

Scheller, R.M., Domingo, J.B., Sturtevant, B.R., Williams, J.S., Rudy, A., Gustafson, E.J., Mladenoff., D.J. 2007. Design, development, and application of LANDIS-II, a spatial landscape simulation model with flexible temporal and spatial resolution. Ecological Modelling, 201, 409–419.

Partners / Stakeholders / Collaborators:

Dr. Phil Radtke, Virginia Tech

Nick Crookston, U.S. Forest Service Dr. Shawn Fraver, U.S. Forest Service

Extending the Acadian Variant of the Forest Vegetation Simulator (FVS) to Managed Stands in the Northeast US

Aaron Weiskittel, Chris Hennigar, Jeremy Wilson, and Christian Kuehne
University of Maine

Progress Report, Year 2 of 2

Summary:
This project was intended to evaluate and modify the behavior of the Acadian Variant of the Forest Vegetation Simulator (FVS-ACD) for managed stands. An extensive regional database on managed stand data was compiled and used for the analysis. The database included plots with precommercial and commercial thinning, varying degrees of vegetation control, and alternative forest harvesting methods. Model performance was tested using the database and modifiers developed to address the influence of management. Currently, modifiers have been developed to project the short-term influence of commercial thinning on balsam fir and red spruce growth and mortality have been developed. The modifiers indicate that red spruce has a higher relative response in diameter growth when compared to balsam fir, but the response is relatively short-term (<6-8 years). These modifiers have been incorporated into the Acadian Variant and used to project alternative silvicultural regimes forward.

Project Objectives

Compile, document, and summarize a regional database of permanent plots in managed stands; calibrate and test the performance of the current FVS-ACD equations across a range of management activities; develop species- and management-specific equation modifiers to improve prediction performance; and provide means to forecast stand growth with these modifiers for various management regimes with FVS-ACD and demonstrate their use.

Approach

- Permanent plot data from Maine, New Brunswick, Nova Scotia, Prince Edward Island, and Quebec was obtained, cleaned, and compiled into a standardized relational database.
- Evaluate component equations (tree height, height to crown base, diameter and height increment, mortality) using equivalence tests
- Develop species- and management-specific equation modifiers using nonlinear regression when sufficient data is available and equivalence test suggest dissimilarity between observed and predicted values
- Incorporate the developed modifiers into FVS-ACD and Open Stand Model (OSM) that has been developed and maintained by Dr. Hennigar

Key Findings / Accomplishments:

A total of over 3 million trees from 20,068 plots across a range of locations and management regimes was obtained (Table 9). OSM has been fully documented, tested, and capability to conduct thinning/partial harvesting has been implemented. Modifiers for red spruce and balsam fir diameter growth response to commercial thinning was developed using the CFRU Commercial Thinning Research Network (CTRN), which was of the the following form:

$\Delta DBH_{adj} = \Delta DBH_{unadj}$ *[1+(b0*(%BA_{RM}*((QMD_B/QMD_A)^b1))*
exp(b2*log(TST+1)+b3*(TST^2)))],

where ΔDBH_{adj} is the adjusted annual diameter increment (cm yr^{-1}), ΔDBH_{unadj} is the unadjusted annual diameter increment (cm yr^{-1}), %BA_{RM} is the % of total basal area removed in the thinning, QMD_B is the quadratic mean diameter before thinning (cm), QMD_A is the quadratic mean diameter after thinning (cm), TST is the time since treatment (yrs), and b_i are species-specific parameters estimated from the data (Table 10).

Results from the analysis indicated that red spruce generally showed a greater relative response to the commercial thinning treatments and that the diameter growth response generally peaked 5 year since the treatment, but the response varied by the intensity and type of the removal applied (Figure 11)

These modifiers have been incorporated into FVS-ACD and long-term simulations for a financial assessment of commercial thinning are currently be conducted on the CTRN dataset by PhD student Patrick Hiesl.

Table 9 - Summary of plots, # of remeasurements, and tree-level measurements by geographic location and management regime.

Management	Plots	# of Plot re-measurements			Tree re-measurements (outliers excluded)*				
		Total	Mean	Max	Total	DBH	ΔDBH	HT	ΔHT
					Maine				
All	10,985	30,481	14	30	551,019	495,867	281,977	382,373	165,322
None	9,369	25,993	2.8	12	478,222	427,302	241,369	326,262	136,780
Partial Cut	1,391	3,743	2.7	3	40,755	37,360	17,171	29,438	11,968
PCT	45	289	6.4	12	26,700	26,244	21,117	23,171	15,176
Planted	180	456	2.5	3	5,342	4,961	2,320	3,502	1,398
					New Brunswick				

All	4,095	5,088	13	28	1,410,834	1,021,258	633,244	634,344	379,228
None	2,324	8,988	3.9	7	661,260	613,187	388,631	87,100	45,751
Partial Cut	205	414	2.0	4	61,127	54,684	19,929	14,222	5,085
PCT	508	1,611	3.2	9	383,685	204,056	130,757	246,529	150,859
Planted	1,058	4,075	3.9	8	304,762	149,331	93,927	286,493	177,533
Nova Scotia									
All	3,574	18,554	22	37	733,315	662,375	443,648	586,014	380,759
None	2,413	11,250	4.7	9	427,185	395,417	256,803	378,954	241,498
Partial Cut	807	5,690	7.1	9	215,730	186,094	125,599	182,750	121,914
PCT	53	302	5.7	8	17,238	14,939	11,895	4,540	3,383
Planted	301	1,312	4.4	11	73,162	65,925	49,351	19,770	13,964
Prince Edward Island									
All	731	4,843	21	30	287,533	287,527	212,824	21,773	16,864
None	153	1,007	6.6	11	71,470	71,467	52,923	4,643	3,607
Partial Cut	40	293	7.3	9	14,644	14,643	10,910	1,278	1,001
Planted	538	3,543	6.6	10	201,419	201,417	148,991	15,852	12,256
Quebec									
All	683	2,134	6	10	82,842	70,209	31,284	12,334	4,676
None	359	911	2.5	5	34,605	32,447	14,840	5,692	2,268
Partial Cut	324	1,223	3.8	5	48,237	37,762	16,444	6,642	2,408
Total	20,068	71,100	76	135	3,065,543	2,537,236	1,602,977	1,636,838	946,849

Table 10 - Parameter estimates and p-values for the commercial thinning modifier by species.

Parameter	Balsam fir		Red spruce	
	Estimate	P-value	Estimate	P-value
b_0	0.0050	<0.0001	0.0021	<0.0001
b_1	0.5424	0.1331	0.5841	0.2235
b_2	0.6169	0.0345	1.3937	0.0007
b_3	-0.0151	<0.0001	-0.0236	<0.0001

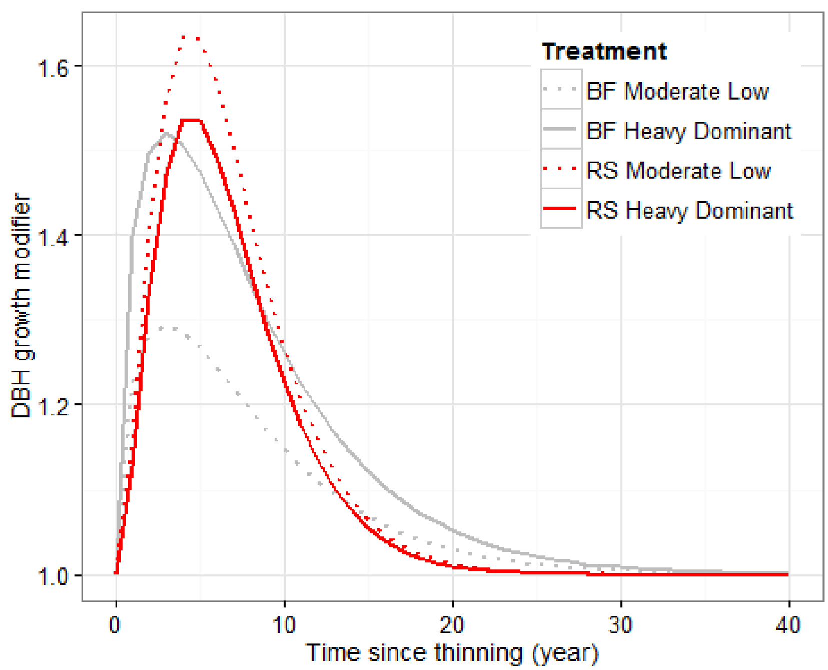


Figure 11 - Balsam fir (BF, gray lines) and red spruce (RS, red lines) diameter growth relative responsiveness to different commercial thinnings over time since thinning.

Future Plans

- Modifiers for additional forest management activities such as precommercial thinning, planting, and partial harvesting will be developed and tested.
- Modifiers will be incorporated into FVS-ACD and OSM, which will allow model users to evaluate the short- and long-term influence of alternative forest management regimes.

Products Delivered

Refereed Journal Publications:

Russell, M.B., Weiskittel, A.R., and Kershaw Jr., J.A. 2014. Comparing strategies for modeling individual-tree height and height-to-crown base increment in mixed-species Acadian forests of northeastern North America. *European Journal of Forest Research* 133: 1121-1135.

Presentations / Workshops / Meetings / Field Tours

Weiskittel, A. and Wagner, R. 2015. Extending the Acadian Variant of the Forest Vegetation Simulator to managed stands in the Northeast US. National Science Foundation Center for Advanced Forestry Systems Annual Meeting. Asheville, NC. May 19-21.

Partners / Stakeholders / Collaborators

Plum Creek, JD Irving, Quebec Ministry of Natural Resources, New Brunswick Tree Improvement Council, New Brunswick Department of Natural Resources (DNR), Nova Scotia DNR, and Prince Edward Island DNR have provided access to managed stand data.

Effects of Climate Change on Growth, Productivity, and Wood Properties of White Pine in Northern Forest Ecosystems

Ronald S. Zalesny Jr., John Brissette, Sophan Chhin, Steve Colombo, Les Groom, Pengxin Lu, Bill Parker, and Michael Ter-Mikaelian
Northern Research Station, U.S Forest Service

Progress Report, Year 4 or 5

Summary:
During the last year we spent the majority of our efforts on objectives 1, 2, and 4; however, we also worked on objectives 3 and 5. For objective 1, Les Groom nearly completed all xray densitometry analyses, and Sophan Chhin conducted requisite QA/QC on all cores and began developing growth response functions based on height and diameter. Similarly, Michael Ter-Mikaelian developed growth response functions for biomass. For objective 2, Ron Zalesny synthesized annual diameter information from the Lake States and projected carbon sequestration potential (see manuscript below). In his analyses for objective 1, Michael Ter-Mikaelian quantified the range of genetic variation in response to climate variables. Both Sophan Chhin and Michael Ter-Mikaelian developed universal response functions for the traits described in objective 1. All of these efforts contributed to projections for objective 5.

Project Objectives

- Predict the effects of climate change on growth, productivity, and wood properties of existing white pine forests;
- Estimate C sequestration potential of white pine under new climate regimes;
- Quantify range of genetic variation in climatic response and adaptive traits of white pine;
- Develop seed transfer models from historic climate data and provenance trial data from a subset of test locations;
- Use validated models from (4) and future climate projections to: a) predict radial and stem growth response of white pine in the northeastern U.S., and b) contribute to provisional seed transfer recommendations for assisted migration of white pine seed sources to help adapt northern forests to future climate.

Approach

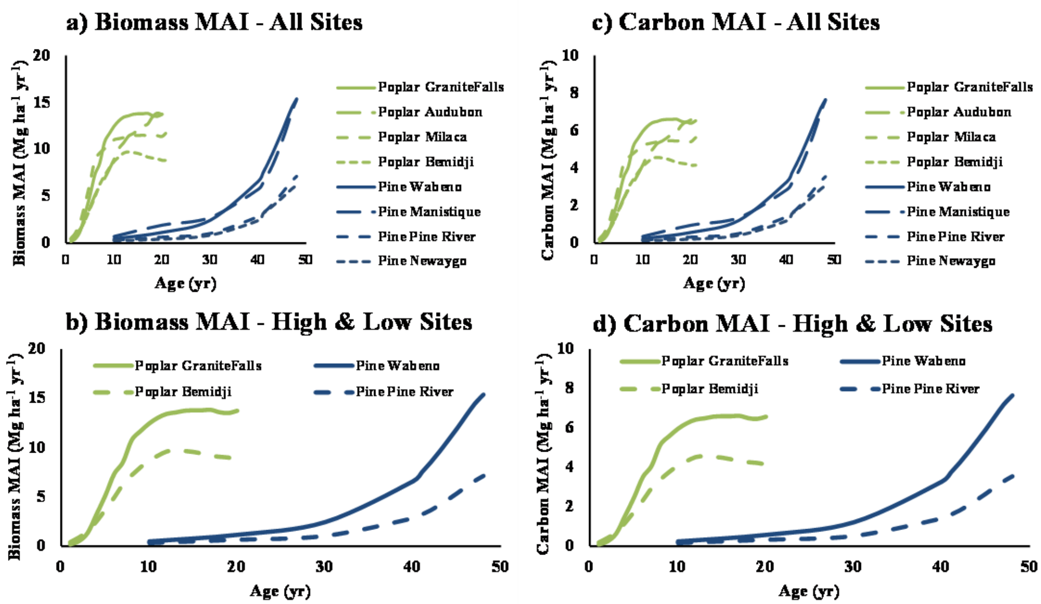
- Height, diameter at breast height (dbh), and survival were recorded for each experimental tree located at each of seven sites (Wabeno, WI; Manistique, MI; Pine River, MI; Newaygo, MI; Turkey Point, ON; Ganaraska Forest, ON; Orono, ME).
- Two wood cores were collected from each tree and permanently mounted and sanded to prepare them for radial growth trend analysis using standard dendrochronology procedures and x-ray densitometry (see below).

- Scanned images of individual cores were processed with cross-dating (COFECHA) and tree ring analysis (WinDENDRO, Regent Instruments, Quebec) software.
- Mean tree ring width, mean annual basal area increment, and total tree ring basal area increment over the period 1980 to 2004 were estimated for each provenance.
- Quantitative genetic and dendrochronological analyses were used to develop the universal response functions.
- X-ray densitometry was used to measure intra and inter tree-ring density.

Key Findings / Accomplishments

- QA/QC of cores and scanned images were completed.
- Over half of the x-ray densitometry analyses are completed.
- Preliminary universal response functions were developed for biomass, height, and diameter.
- A synthesis was conducted to compare biomass and carbon storage of white pine to short rotation woody crops in the Lake States. Key findings included (see manuscript below):
    - Comparable 10-yr hybrid poplar stand biomass and carbon sequestration for white pine were not achieved until 45 yrs (biomass @ 45 to 47 years; carbon @ 45 to 46 years).
    - Specific genotype × environment interactions resulted in white pine exceeding 10-yr-old hybrid poplar at ages younger than 45 years.
    - White pine was not comparable to 20-yr-old hybrid poplar at 48 years.
    - While the timing and magnitude of biomass/carbon differ between the genera, producing both provides greater ecosystems services across the landscape.

White pine provenance trial in Manistique, Michigan.
Photo by Ron Zalesny,US Forest Service.



Biomass$_{MAI}$ (a,b) and carbon$_{MAI}$ (c,d) production curves throughout plantation development for poplar at four sites in Minnesota, USA through age 20 years and white pine in Wisconsin, USA (one site) and Michigan, USA (three sites) through age 48 years. From Zalesny and Headlee (2015) (see below).

Future Plans

- Finish all x-ray densitometry analyses.
- Continue to work on fulfilling all objectives, as outlined above.
- Prepare and submit peer-reviewed manuscripts.
- Prepare and submit final report.

Products Delivered

Refereed Journal Publications

Zalesny, R.S. Jr., and Headlee, W.L. 2015. Developing woody crops for the enhancement of ecosystem services under changing climates in the North Central United States. Journal of Forest and Experimental Science 31:78-90

Conference Papers

Zalesny, R.S. Jr., and Headlee, W.L. 2014. Developing woody crops for the enhancement of ecosystem services under changing climates in the North Central United States. In: International Symposium on Tree Breeding Strategies to Cope with Climate Change; September 15-19, 2014; Suwon, Republic of Korea.

Presentations / Workshops / Meetings / Field Tours

Zalesny, R.S. Jr., and Headlee, W.L. 2014. Comparing aboveground, stand-level carbon storage potential of intensively-managed poplar with plantation-grown eastern white pine in the North Central United States. In: International Poplar Symposium VI; July 20-23, 2014; Vancouver, British Columbia, Canada.

Zalesny, R.S. Jr., Headlee, W.L., Bauer, E.O., Birr, B.A., Hall, R.B., Parker, B., and Wiese, A.H. 2014. Contrasting ecosystem services of hybrid poplar and white pine in the upper-Midwest, USA. In: 10th Biennial Conference of the Short Rotation Woody Crops Operations Working Group; July 17-19, 2014; Seattle, WA, USA.

Canadian Geese Family – Photo by Pam Wells

Howland Research Forest

The CRSF welcomed the Howland Research Forest under its umbrella in 2015. The Howland Forest is a continuously operating forest ecosystem research site established in 1986 by University of Maine researchers with the cooperation of International Paper. It is located approximately 30 miles north of Orono, Maine, and situated within an expansive low elevation conifer/northern hardwood transitional forest.

Initially funded to conduct biogeochemical cycling and acid rain research, Howland Forest has since been host to various model and sensor development efforts as well as numerous studies focusing on nutrient cycling, forest ecology, ecosystem modeling, acid deposition, remote sensing, climate change, and carbon sequestration. Howland Forest, with its long fetch and low surface roughness, is an ideally situated tower research site for micrometeorological measurements. With infrastructure in place and a comprehensive data train of ecological monitoring from below the soil to above the tree canopy, the site continues to attract scientists from around the globe associated with numerous universities, independent research organizations, and federal agencies (such as the USDA Forest Service, NOAA, NASA, EPA, DOE, and DOD).

Already a member of several research networks, Howland Forest became the first base site for the Ameriflux network in 1996. The current research focus is based around our ability to measure the flux of carbon dioxide (i.e. the forest-atmosphere exchange). This, along with the many ancillary ecological and atmospheric data measurement systems, provides valuable information about how the landscape breathes and grows, and is the foundation for related research to further our understanding of how the environment works. Howland Forest is managed by the Environmental Physics group of the University of Maine, and is currently funded by the Department of Energy through its Ameriflux program and the USDA Forest Service through its Global Change Program.

Appendices

Publications and Presentations

CRSF scientists disseminated results from their research in a wide variety of ways this year. They delivered 17 journal publications, 1 book chapter, 12 research reports and working papers, 3 conference proceedings, 5 theses, more than 50 presentations (including posters, filed tours, media presentations, and workshops), and contributed to 18 media publications (including newspapers, periodicals, television, and web pages).

Refereed Journal Publications (*Graduate student; +Undergraduate student)

Greenwood, M.S., B. E. Roth, D. Maass and L. C. Irland. 2015. Near rotation-length performance of selected hybrid larch in Central Maine. *Silvae Genetica 64*(1-2):73-80.

Huff, E.S.*, Leahy, J.E., Weiskittel, A.W., Hiebeler, D., Noblet, C.L. 2015c. An agent-based model of private forest owner management behavior using social interactions, information flow, and peer-to-peer networks. *PLoS ONE* 10(11):e0142453

Johnson, M.L., S.R. Meyer, R.J. Lilieholm, and C.S. Cronan. 2015. Development and application of a patch-scale Bayesian network–cellular automata model for exploratory land use scenarios at a regional extent. *Landscape and Urban Planning* (in revision).

Meyer, S.R., C.S. Cronan, R.J. Lilieholm, M.L. Johnson, and D.R. Foster. 2014. Land conservation in northern New England: Historic trends and alternative conservation futures. *Biological Conservation 174*(2014):152-160.

Meyer, S.R., M.K. Beard, C.S. Cronan, and R.J. Lilieholm. 2015. An analysis of spatio-temporal landscape patterns for protected areas in northern New England: 1900-2010. *Landscape Ecology 30*:1291-1305.

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, and C.S. Cronan. 2014. Development of a Stakeholder-driven spatial modeling framework for strategic landscape planning using Bayesian networks across two urban-rural gradients in Maine, USA. *Ecological Modelling 291*:42-57. DOI: 10.1016

Nelson, A.S., R.G. Wagner, M.E. Day, A.R. Weiskittel, and M.R. Saunders. 2015. Effects of species composition, management intensity, and shade tolerance on vertical distribution of leaf area index in juvenile stands in Maine, USA. *European Journal of Forest Research 134*(2): 281-291.

Nelson, A.S., Weiskittel, A.R., R.G. Wagner, and M.R. Saunders. 2014. Development and evaluation of aboveground small tree biomass models for naturally regenerated and planted species in eastern Maine, U.S.A. *Biomass and Bioenergy 68*: 215-227.

Nelson, A.S., and R.G. Wagner. 2014. Spatial coexistence of American beech and sugar maple regeneration in post-harvest northern hardwood forests. *Annals of Forest Science 71*: 781–789.

Nelson, A.S., A.R. Weiskittel, and R.G. Wagner. 2014. Development of branch, crown, and vertical distribution leaf area models for contrasting hardwood species in Maine, USA. *Trees 28*(1): 17-30.

Rice, B., A.R. Weiskittel, and R.G. Wagner. 2014. Efficiency of alternative forest inventory methods in partially harvested stands. *European Journal of Forest Research 133*(2): 261-272.

Silver, E.J., Leahy, J.E., Kittredge, D.B., Noblet, C.L., Weiskittel, A.R. 2015a. An evidence-based review of timber harvesting behavior among private woodland owners. *Journal of Forestry 113*(5): 490 - 499.

Silver, E.J., Leahy, J.E., Noblet, C.L., Weiskittel, A.R. 2015b. Maine woodland owner perceptions of long rotation woody biomass harvesting and bioenergy. *Biomass and Bioenergy 76*: 69-78.

Stapp, J.R., J.E. Leahy, R.J. Lilieholm and T. Waring. 2015. Using agent-based modeling to examine land use/land cover change in decision-making in Bachauli, Nepal: A summary of challenges. Ecology and Society (in review).

Stapp, J.R., R.J. Lilieholm, J.E. Leahy, and S. Upadhaya. 2015. Linking attitudes, policy, and forest cover change in the buffer zone of Chitwan National Park, Nepal. Environmental Management (in review).

Stapp, J.R., R.J. Lilieholm, S. Upadhaya, and T. Johnson. 2015. Evaluating the impacts of forest management policies and community-level institutions in the buffer zone of Chitwan National Park, Nepal. *Journal of Sustainable Forestry 34*(5):445-464.

Books and Book Chapters

Lilieholm R.J., C.S. Cronan, M. Johnson, S. Meyer, and D. Owen. 2014. Alternative Futures modeling in Maine's Penobscot River watershed: Forging a regional identity for river restoration. Pages 171-204 (Chapter 9) in J. Levitt, ed., *The Academy as Nature's Agent*. Lincoln Institute of Land Policy, Cambridge, MA. 350 pages.

Research Reports (*Graduate student)

De Urioste-Stone, S.M., Gabe, T. & C. Noblet. (2015). Progress report on visitor spending and visitation in Maine. Submitted to University of Maine Office of the President.

Doak, T., Leahy, J., and Merk, R. 2015. *Creating a legacy: A guide to planning your land's future*. Outreach Publication of the Small Woodland Owners Association of Maine. Augusta, ME.

*Dunham, S., and D. Harrison. 2014. Patch occupancy, habitat use, and population performance of spruce grouse in commercially managed conifer stands. Pages 75-79 in R.G. Wagner, editor, *Cooperative Forestry Research Unit: 2014 Annual Report*, University of Maine, Orono.

Harrison, D., and S. Olson. 2015. Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine. Pages 68-74 in R.G. Wagner, editor, *Cooperative Forestry Research Unit: 2014 Annual Report*, University of Maine, Orono.

Hutchinson, S., A. Weiskittel, D. MacKay, and R. Lilieholm. 2015. Estimating timberland parcel value in the northeast United States using acreage and commercial timber value. Center for Research on Sustainable Forests, University of Maine, NEFIS Publication 169, Orono, ME.

*Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management. Pages 80-88 in R.G. Wagner, editor, *Cooperative Forestry Research Unit: 2014 Annual Report*, University of Maine, Orono.

*Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest managemen. Annual report to Baxter State Park.

*Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest managemen. Annual report to Fish and Wildlife Service and National Wildlife Refuges.

*Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management. Annual report to USGS Maine Cooperative Fish and Wildlife Research Unit.

*Scaccia, M. & S.M. De Urioste-Stone. (2015). Exploring visitor perceptions on climate change impacts to Acadia National Park-Mount Desert Island, Maine. Report submitted to Acadia National Park.

*Scaccia, M. & S.M. De Urioste-Stone. (2015). Understanding the role of climate change on guiding tourism at the Katahdin region, Maine. Report submitted to Baxter State Park

Wagner, R.G., J. Bryant, B. Burgason, M. Doty, B.E. Roth, P. Strauch, D. Struble, and D. Denico. 2014. *Coming spruce budworm outbreak: Initial risk assessment and preparation & response recommendations for Maine's forestry community*. Draft report for public review. 90 pages.

Theses

Hiesl, P. 2015. Forest harvesting productivity and cost in Maine: New tools and processes. Ph.D. Dissertation, University of Maine, Orono. 142 p.

Johnson, S. L. 2014. Engaging the future with land use scenarios. Ph.D. Dissertation. The University of Maine, Orono.

Olson, S. 2015. Seasonal influences on habitat use by snowshoe hares: implications for Canada lynx in northern Maine. M.S. Thesis, University of Maine, Orono, 153pp.

Silver, E. 2015. Understanding private woodland owner forest management: Qualitative and quantitative applications. Ph.D. Dissertation. University of Maine. Orono, ME.

Stapp, J.R. 2015. Linking attitudes, policy, and forest cover change in buffer zone communities of Chitwan National Park, Nepal. M.S. Thesis, The University of Maine, Orono. 158 pages.

Conference Papers

Day, M. (2015). Results of non-structural carbohydrate analysis. Presented at a meeting of the Acadian Entomological Society (Fredericton, NB).

De Urioste-Stone, S.M., & M. Scaccia. (2015). Understanding perceptions of nature-based tourism stakeholders' adaptive capacity to climate change in Maine. *Proceedings of the Northeastern Recreation Research Symposium*.

Ducey, M. J. 2014. Poster: Spatial data for modeling wood resource availability in the Northeastern United States. Eastern Canada-United States of America Forest Sciences Conference, 7th ECANUSA, October 17, 2014, Rimouski, Quebec, Canada.

Presentations / Workshops / Meetings / Field Tours

Conservation for People & Communities: Open space, health and wellness. 2015. National Science Foundation Research Collaboration Network (RCN) 3-day Workshop on Services, Scenarios, and Solutions. Migis Lodge on Sebago Lake, South Casco, Maine. (Johnson Presenting, with Lilieholm, Meyer & Cronan).

De Urioste-Stone, S.M. 2015. Stakeholder perceptions on vulnerability and adaptive capacity of tourism destinations to climate change in Maine. School of Biology and Ecology Spring Seminar Series, Orono, Maine, March 20.

De Urioste-Stone, S.M. 2015. Resilience of rural Maine communities to climate change: A pilot study of the nature-based tourism industry. ADVANCE Grant Awardee Luncheon, Pecha Kucha, Orono, Maine, March 22.

Dunham, S.W., and D.J. Harrison. 2014. Spruce grouse breeding season patch occupancy and female home range use across forest management treatments in Maine. Poster presented at the Annual Conference of The Wildlife Society, Pittsburgh, Pennsylvania, October 27-28.

Dunham, S.W., D.J. Harrison, and E.J. Blomberg. 2015. Spruce grouse (*Falcipennis canadensis)* patch occupancy and abundance estimates in the commercially managed forests of Maine. Presentation at the 13th International Grouse Symposium, Reykjavik, Iceland, September 8.

Dunham, S. W., and D. J. Harrison. 2015. Spruce grouse breeding season patch occupancy and female home range use across forest management treatments in Maine. Poster presented at the Annual USGS Maine Cooperative Fish and Wildlife Research Unit Coordinating Committee Meeting, Orono, Maine.

Gorman J., and Leahy, J. 2015. Invasive insects in New England: Stakeholder perceptions and responding with cross-boundary collaboration. Friends of Dr. Edith Marion Patch Annual Student Ceremony, Orono, Maine, April 2015.

Gorman, J. 2015. Forest pests in New England: Stakeholder perceptions and the potential for cross-boundary collaboration. University of Maine Graduate Expo., Orono, Maine, April.

Gorman, J., and Leahy, J. 2015. Anticipating emerald ash borer and Asian longhorned beetle in the Northeast: Stakeholder perceptions and the potential for cross-boundary collaboration. Northeast Forest Pest Council Meeting, Hanover, New Hampshire, March.

Hennigar, C. 2015. Acadian site model: New Brunswick results. Presentation, New Brunswick Growth and Yield Unit, Fredericton, New Brunswick, February 11.

Hennigar, C. 2015. Acadian site model: Nova Scotia results. Presentation, Nova Scotia Department of Natural Resources, Truro, Nova Scotia, January 22.

Hiesl, P., J.G. Benjamin, and B.E. Roth. 2015. PCT/non-PCT Study: Austin Pond – A case study. NERCOFE Workshop, Wells Conference Center, University of Maine. Orono, Maine, March 10.

Kenefic, L.S., C. Larouche, G. Lessard, J.C. Ruel, C. Tardif, S. Tremblay, and Wesely, N. 2014. New northern White-Cedar research and opportunities for collaboration. Cedar Club Research Meeting, Rimouski, Quebec, October 16.

Kenefic, L.S., C. Larouche, J.M Lussier, J.C. Ruel, C. Tardif, and N. Wesely. 2015. Northern White-Cedar management in the Acadian forest: New findings. Maine SAF Field Tour, Solon, Maine, September 23.

Lilieholm, R.J. [Host]. 2014. Scenarios to solutions. National Science Foundation Research Collaboration Network 3-day Workshop on Services, Scenarios, and Solutions, Migis Lodge on Sebago Lake, South Casco, Maine, October.

Lilieholm, R.J. 2014-15. Training workshop for the Maine Futures Community Mapper, Androscoggin Valley Council of Governments' 27th Annual Planning Day, Auburn, Maine; Eastern Maine Development Corp and the University of Maine, Nutting Hall, Orono, Maine; and Portland, Maine.

Lilieholm, R.J. 2015. Forestry research in Maine and beyond. Maine Science Festival, Cross Convention Center, Bangor, Maine.

Lilieholm, R.J. 2015. Future forest scenarios. Pacific Northwest College of the Arts, Portland, Oregon.

Lilieholm, R.J. 2015. A new Maine national park would stimulate the region's economy. Testimony before the Economic Development Committee, Bangor City Council, Bangor, Maine, March.

Lilieholm, R.J. 2015. Linking attitudes, policy, and forest cover change in buffer zone communities of Chitwan National Park, Nepal. Presentation at the 21st International Symposium on Society and Resource Management. College of Charleston, South Carolina.

Lilieholm, R.J. 2015. Mapping forest dynamics in the buffer zone of Chitwan National Park, Nepal. Ecological Society of America Annual Meeting, Sacramento, CA.

Lilieholm, R.J. 2015. Wildland fire outlook: Status, trends, and emerging issues. 9th Annual Wildland Fire Litigation Conference, Monterey, California, May.

Lilieholm, R.J., Cronan, C., Loftin, C., Greig, H., Johnson, M., Meyer, S., and Weil, K. 2015. A spatial analysis of biophysical watershed characteristics affecting stream response to land-use changes in Maine, USA. Ecological Society of America Annual Meeting, Sacramento, CA.

Lilieholm, R.J., & Meyer, S. 2014-15. Alternative futures modeling: Understanding the past . . . Envisioning the future. Presentations at 3rd Landscape Sustainability Science Forum, Beijing Normal University, China; Texas A&M University, College Station; Lower Penobscot River Coalition, Fields Pond Nature Center, Holden, Maine; Orono Land Trust, Orono, Maine; Maine EPSCoR State Conference, University of Maine, Orono, Maine; Michigan Technological University, Houghton, MI; Michigan State Library, Lansing, hosted by Michigan Technological University, Michigan Department of Natural Resources, Michigan Department of Agriculture & Rural Development, Michigan Department of Environmental Quality, Michigan Association of Regions, and the Michigan Association of Conservation Districts; National Science Foundation Research Collaboration Network (RCN) 3-day Workshop on Services, Scenarios, and Solutions. Migis Lodge on Sebago Lake, South Casco, Maine; PenBay Regional Land Trust, Belfast, Maine.

Lilieholm, R.J. and Meyer, S. 2015. Creating a decision support tool for strategic development using an expert knowledge-derived Bayesian Belief Network to identify streams vulnerable to urbanization across the State of Maine. Presentation at the 21st International Symposium on Society and Resource Management, College of Charleston, South Carolina.

Lilieholm, R.J., S. Meyer, M. Johnson, C., Cronan, and D. Owen. 2014. Scenarios to solutions: Alternative futures modeling across two Maine watersheds. Society for Human Ecology Annual Meeting, Bar Harbor, October 22-25.

Meyer, S., R.J. Lilieholm, M. Johnson, and C., Cronan. 2014. Whose Models are these Anyway? Stakeholder Lessons from the Maine Alternative Futures Project. National Science Foundation Research Collaboration Network (RCN) 3-day Workshop on Services, Scenarios, and Solutions. Migis Lodge on Sebago Lake, South Casco, Maine, October.

Muñoz, B. 2014. A long-term perspective on biomass harvesting: Northern conifer forest productivity 50 years after whole-tree and stem-only harvesting. New England Society of American Foresters (NESAF), Management and Utilization Working Group Tour, Penobscot Experimental Forest, Bradley, Maine, July 24.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez, J. Benjamin, and S. Fraver. 2014. A long-term perspective on biomass harvesting: Northern mixedwood forest productivity 50 years after whole-tree and stem-only harvesting. International

Union of Forest Research Organizations (IUFRO) World Congress, The Salt Palace Convention Center, Salt Lake City, Utah, October 7-10.

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Softwood forest birds and silviculture in New England. Baxter State Park Annual Meeting, Augusta, Maine, Spring.

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Softwood forest birds and silviculture in New England. USGS Coordinating Committee Meeting, Orono, Maine, March 25.

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Habitat associations, forestry, and coniferous forest birds. Downeast Birding Festival, Machias, Maine, May 22.

Roth, B.E. 2015. Herbicide, PCT and commercial thinning in the CTRN & Austin Pond studies. NERCOFE Workshop, Wells Conference Center, University of Maine, Orono, Maine, March 10.

Roth, B.E. 2015. Communications update at CFRU Advisory Committee meeting. Houlton, Maine, October 28.

Scaccia, M., S. De Urioste-Stone, & E. Wilkins. 2015. The future of destination selection in a changing seasonal climate: Implications for visitation to Acadia National Park and Mount Desert Island, Maine. National Outdoor Recreation Conference: Land, Water and Conservation: Celebrating the Past and Crafting the Future of Outdoor Recreation, Northeastern Resource Recreation Symposium and Society of Outdoor Recreation Professionals, Annapolis, Maryland, April 12-16.

Scaccia, M., S. De Urioste-Stone, J. Foster, A. Scaccia, A., & D. Howe-Poteet. 2014. Visitors' perceived effects of climate change on outdoor recreation and tourism in Acadia National Park and Mount Desert Island. Acadia National Park Science Symposium, SERC, Winter Harbor, Maine, October 1.

Silver E.J., J.E. Leahy, D. Hiebeler, and A.R. Weiskittel. 2015. An agent-based model of private woodland owner timber harvesting behavior using social interactions, risk perception, and peer-to-peer networking. International Symposium on Society and Resource Management, Charleston, South Carolina, June.

Silver, E.J., J.E. Leahy, D.B. Kittredge, D. Hiebeler, and A.R. Weiskittel. 2014. Modeling private woodland owner timber harvesting behavior using social interactions, risk perception, and peer-to-peer networking. International Union of Forest Research Organizations World Congress, Salt Lake City, Utah, October.

Tebbenkamp, J. M., E. Blomberg, D. Harrison, B. Allen, and K. Sullivan. 2015. Spruce grouse demography and population status in commercially-harvested forests of northern Maine. Poster Presentation, Maine Cooperative Fish and Wildlife Research Unit Annual Meeting.

Wagner, R.G. 2014. Maine spruce budworm task force report. Keeping Maine's Forests Meeting, Augusta, Maine, November 18.

Wagner, R.G. 2014. Maine spruce budworm task force report. CFRU Spruce Budworm Workshop, Wells Conference Center, University of Maine, Orono, Maine, October 30.

Wagner, R.G. 2014. Outcome-based forestry policy implementation. One-day field tour with Maine Legislature Agriculture, Forestry, and Conservation Committee, JD Irving lands, Presque Isle, Maine.

Wagner, R.G. 2015. The spruce budworm is back: Maine's preparation and response plan. National Council for Air and Stream Improvement (NCASI) Regional Forestry Meeting, Portland, Maine, May 13.

Wagner, R.G., and M. Doty. 2015. Coming spruce budworm outbreak: Initial risk assessment and preparation & response recommendations for Maine's forestry community. Professional Logging Contractor's of Maine, Augusta, Maine, March 26.

Wagner, R.G. 2015. They're back: Risk assessment & preparation plan for Maine's coming spruce budworm outbreak. Forestry Noontime Seminar, University of Maine, Orono.

Weiskittel, A., and Hennigar, C. 2015. Acadian site model: Maine draft results. Presentation, CFRU Spring meeting, University of Maine, Orono, Maine, April 22.

Wilkins, E., S. De Urioste-Stone, T. Gabe, & A. Weiskittel**.** 2015. The effects of changing weather on nature-based tourism: Visitation and economic impacts on Mount Desert Island, Maine." 21st International Symposium on Society and Natural Resource Management (ISSRM): Understanding and Adapting to Change, Charleston, South Carolina, June 13-18.

Awards

De Urioste-Stone, S. 2015. College of Natural Sciences, Forestry and Agriculture Mentor Award, Graduate Student Government, University of Maine.

Meyer, S. 2014. President's Research Impact Award, University of Maine.

Scaccia, M.D. (MS student). 2015. Graduate Student Government (GSG) award to attend the 2015 National Outdoor Recreation Conference—Land, water, and conservation: Celebrating the past and crafting the future of outdoor recreation. Annapolis, Maryland. April, 2015.

Wilkins, E. (MS student). 2015. Society of Outdoor Recreation Professionals (SORP) student conference scholarship to attend the 2015 National Outdoor Recreation Conference—Land, water, and conservation: Celebrating the past and crafting the future of outdoor recreation. Annapolis, MD. April, 2015.

Newspapers / Periodicals / Television / Web Pages / Software

$1 Million for Conservation Set Aside after Meeting in Nashua: Private, Public Organizations, Partners hope to Preserve Millions of Acres of Land. *Nashua Patch*, November 19, 2014 (By Tony Schinella). http://patch.com/new-hampshire/nashua/1m-conservation-set-aside-after-meeting-nashua-0

A New Maine National Park would Stimulate the Region's Economy. Economic Development Committee, Bangor City Council, Bangor, Maine.

Alternative Futures: Research Focuses on Helping Communities in Maine and Beyond Visualize How and Why Landscapes Evolve. 2015. (By Elyse Kahl, University of Maine). UMaine Today Spring/Summer 2015:50-58.

Bay to Baxter: As the River Changes, So Must We. *Bangor Daily News*, July 11, 2014. http://bangordailynews.com/2014/07/11/opinion/contributors/bay-to-baxter-as-the-penobscot-river-changes-so-must-we/

Businesses Announce Support for Proposed National Park. March 26, 2015. http://wabi.tv/2015/03/26/businesses-announce-support-for-proposed-national-park/

iForest: Apple gets into Forest Conservation in China and the US. *The Guardian*, May 14, 2015 (By Ucila Wang). http://www.theguardian.com/sustainable-business/2015/may/14/apple-forest-conservation-china-world-wildlife-fund

In the Katahdin Area, a National Park can Transform a Region. January 19, 2015. http://bangordailynews.com/2015/01/19/opinion/contributors/in-the-katahdin-area-a-national-park-can-transform-a-region-we-take-for-granted/

It Takes a Village. 2015. (By Elyse Kahl, University of Maine). *UMaine Today* Spring/Summer 2015:57.

Keeping up with Maine's Changing Climate. Bangor Daily News, June 25th, 2014. (By BDN

Editor).http://bangordailynews.com/2014/06/25/opinion/editorials/keeping-up-with-maines-changing-climate/

LAS files, 1 meter digital elevation models, 2' contour lines, hillshade and slope models. Available at Maine GIS catalogue website.

Letter to Senator Susan Collins regarding the proposed Katahdin Gateway National Park (with Colgan and Vail).

Penobscot Potential Polled in Survey. April 5, 2015. http://news.mpbn.net/post/penobscot-potential-polled-survey.

Site predictions for Acadian Region as a 20 X 20 m raster grid; available on CFRU website.

Surveying in the Bay-to-Baxter Corridor. 2015. (By Elyse Kahl, University of Maine). UMaine Today Spring/Summer 2015:57.

The Maine Futures Community Mapper. 2014. 15-minute training video.

The Maine Futures Community Mapper. 2014. 3-minute video.

Two Hundred Local Businesses Endorse Proposed Maine National Park. Cross Convention Center, Bangor, Maine.http://bangordailynews.com/2015/03/26/news/bangor/200-maine-businesses-endorse-proposed-katahdin-area-national-park/

Two Hundred Local Businesses Endorse Proposed Maine National Park. Cross Convention Center, Bangor, Maine. http://bangordailynews.com/2015/03/26/news/bangor/200-maine-businesses-endorse-proposed-katahdin-area-national-park/