Silvicultural Strategies for Mitigating Northern Forest Carbon Reversal Due To Spruce Budworm

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- Salvage harvesting results in greater initial net emissions through year 10, but generally improves to parity or net sequestration by year 20.
- Decisions to salvage dead or dying trees should weigh the climate change implications of near-term net emissions and economic benefits vs. potential long-term recovery of forest carbon.

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http://www.nsrcforest.org

Project Summary

The next major eastern spruce budworm (*Choristoneura fumiferana*) outbreak is likely to begin impacting the forests of the northeastern US over the next few years. More than 4.7 million ha of forest and 94.8 million metric tons of carbon in spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) are at risk. Vegetation shifts in at-risk forest stands are likely to occur as a direct result of mortality caused by spruce budworm and through post-outbreak salvage harvest operations designed to minimize economic impact. Management interventions have short-term and long-term consequences for the terrestrial carbon budget and have significant implications for the role of the region's forests as a natural climate solution. We used regional forest inventory data and 40-year growth and harvest simulations from the USDA Forest Service Forest Vegetation Simulator to quantify a range of forest carbon outcomes for alternative silvicultural interventions in the northeastern US. We performed a life cycle assessment of harvested wood products, including bioenergy, to evaluate the full greenhouse gas (GHG) emissions consequences of salvage and business as usual silvicultural scenarios across a range of stand risk profiles in the presence and absence of spruce budworm attack. Salvaging dead trees in the most at-risk stands tends to produce net emissions of carbon dioxide for at least ten years compared to a baseline where dead trees are left standing. In most scenarios, GHG emissions reached parity with the baseline by year 20. Changes in forest carbon stocks were the biggest driver of net emission differences between salvage and no salvage scenarios. A benchmark scenario without timber harvesting or the occurrence of a spruce budworm outbreak had the greatest net carbon sequestration profile after 40 years compared to all other scenarios. Salvaging trees killed by a severe and widespread insect infestation has potential negative short-term implications for GHG emissions, but long-term resilience of these climate benefits is possible in the absence of future outbreaks or subsequent harvest activities. The results provide guidance on silvicultural interventions to minimize the impact of spruce budworm on forest carbon.

Background and Justification

- The next major eastern spruce budworm (Choristoneura fumiferana) outbreak is already ongoing in eastern Canada (right) and likely to begin impacting the Northern Forest region (Maine, New Hampshire, Vermont, and northern New York) over the next few years.
- More than 4.7 million ha of forest and 94.8 million Mg of carbon (C) in balsam fir (*Abies balsamea*) and spruce (*Picea* spp.) are at risk (Table 1 and Figure 1).
- Vegetation shifts in at-risk forest stands are likely to occur as a direct result of mortality caused by spruce budworm (SBW) and through anthropogenic response to an outbreak through salvage harvests designed to minimize economic impact.
- Forest management interventions have short-term and long-term consequences for the terrestrial C budget and have significant implications for the role of the region's forests as a natural climate solution.

Background and Justification

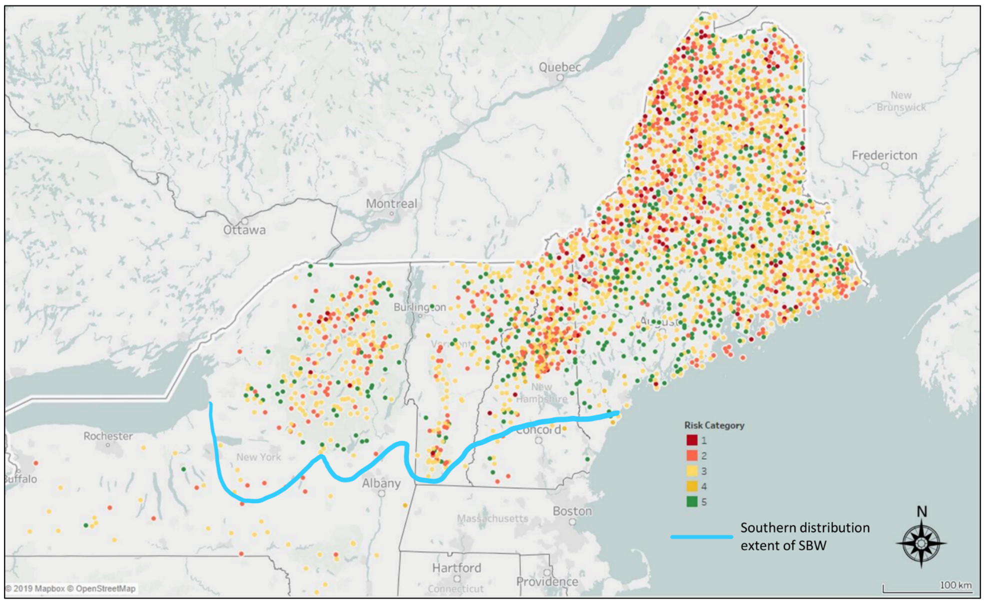


Figure 1. Approximate location of US Forest Service Forest Inventory and Analysis (FIA) plots in the northeastern United States. Colors indicate Risk Category determined by criteria described in Methods below. Southern range distribution line is adapted from Natural Resources Canada.

Table 1. Carbon At Risk

- At risk plots are <u>not</u> the most carbon dense across the landscape, however …
- If defoliation rates are high, existing carbon stocks will be severely impacted

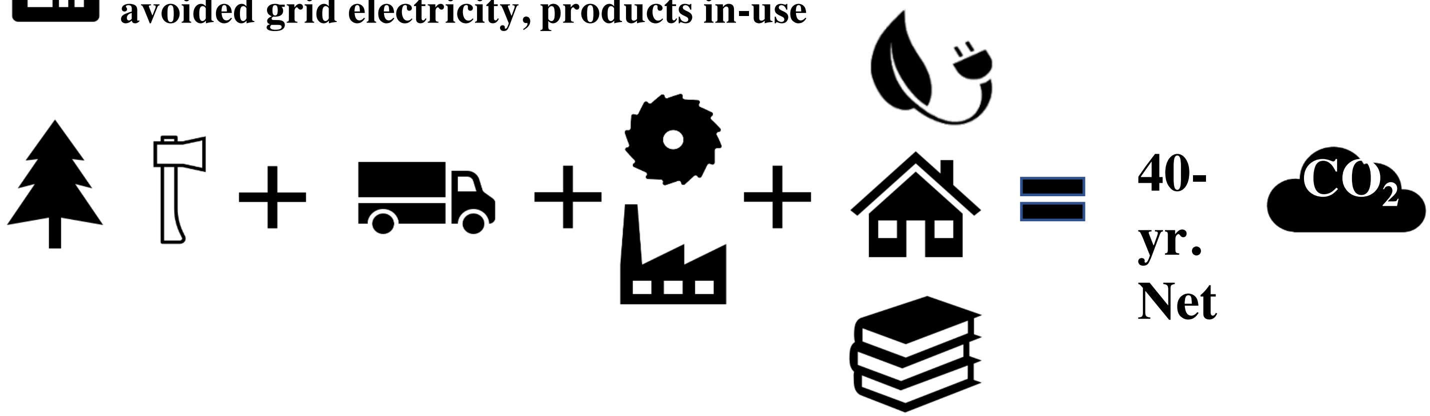
		Carbon, MT /ha, spruce-fir	Carbon, MT /ha, total	% of C Stock at Risk
Maine				
Risk Categories	1	27.01	30.44	88%
	2	22.98	34.74	68%
	3	14.51	42.01	36%
	4	10.16	31.60	36%
	5	6.25	47.72	15%
New Hampshire				
Risk Categories	1	31.46	34.67	88%
	2	33.95	48.01	71%
	3	19.18	57.58	33%
	4	7.04	31.80	26%
	5	7.68	59.53	14%
New York				
Risk Categories	1	25.13	30.67	81%
	2	28.32	43.29	66%
	3	17.27	56.66	32%
	4	1.90	5.24	35%
	5	7.24	65.88	11%
Vermont				
Risk Categories	1	32.32	36.79	84%
	2	28.47	45.25	66%
	3	17.74	59.06	30%
	4	6.55	34.57	26%
	5	6.99	59.38	12%

Methods

- Used regional forest inventory data (USDA Forest Service Forest Inventory and Assessment) and growth and harvest simulations from the Forest Vegetation Simulator to quantify forest carbon outcomes for alternative forest management and silvicultural interventions (Table 2) in the Northern Forest.
- Tracked forest carbon stocks (e.g., live and dead trees, belowground roots, leaf litter) and life cycle GHG emissions of harvested wood products for 40 years (Figure 2). 70% of low-quality harvested material was used to make pulp/paper; 30% to make electricity.
- Calculated the Net Cumulative Emissions Difference between Salvage/No Salvage scenarios within each Forest Management Scenario at 10-year time steps (10,20, 30, & 40 years post treatment).

Methods

Figure 2. Life cycle assessment (LCA) of net CO2e emissions: forest C stock change, harvest, transport, manufacturing, avoided grid electricity, products in-use



Methods

Table 2. Management scenario descriptions and Forest Vegetation Simulator (FVS) model harvest guidelines.

Scenario Name	Silvicultural System/Harvest Regime	Harvest Intensity[1]	Description (harvest guidelines)
Benchmark	No timber harvesting, no SBW outbreak	Low	No trees harvested, no mortality in spruce spp. and balsam fir
NoMgmt	No timber harvesting	Low	No trees harvested
Comm-Ind	Even-aged management / Exploitative Harvesting (commercial or industrial clearcut, distinguished from silvicultural clearcuts as in Belair and Ducey (2018))	High	Removals heavy in larger size classes (>80% for trees > 20 cm dbh) and primarily of most valuable species.[2]
Heavy	Even-aged management	High	Removals heavy in larger size classes (>80% for trees > 20.3 cm dbh). No species preference.
HighGrade	Exploitative Harvesting ("high-grading")	Moderate	Moderate removals in larger size classes (30-50% for trees > 20 cm dbh) and primarily of most valuable species*.
Moderate	Uneven-aged Management / Two-aged Management	Moderate	Moderate removals (45-55%) but balanced across size classes. No species preference.
Light	Uneven-aged Management	Low	Light removals (25-35%) but balanced across size classes. No species preference.

Results

- Salvage harvesting in nearly every comparison produced greater initial net emissions through year 10, but generally improved to parity with the baseline or net sequestration by year 20 (Figure 3).

- Changes in forest C stocks were the biggest driver of net cumulative emissions differences. Operations emissions (harvest, transport, pulp mill, and sawmill) are a minor component of overall emissions when considered relative to the forest C pool (Figure 4).

- Differences in long-term carbon sequestration emerge when we consider differences between the scenarios. Overall the C balance (net sequestration) at year 40 was greatest in the Benchmark scenario (no harvest, no SBW outbreak), though the difference diminishes in Risk Categories 4 and 5 (Figure 5).

Results

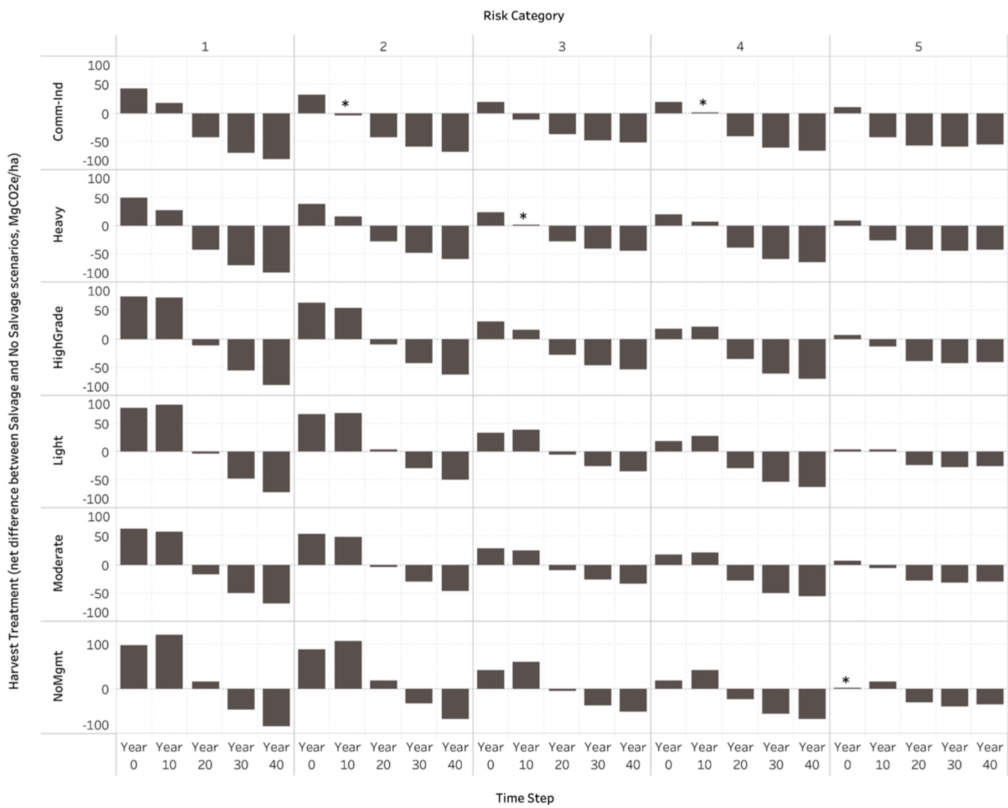


Figure 3. Mean difference between net cumulative emissions of Salvage vs. No Salvage comparisons for each forest management scenario (at 10-year time steps). * indicates not significantly different from 0 ($p > 0.01$). All other comparisons are significantly different from 0 ($p \leq 0.01$).

Results

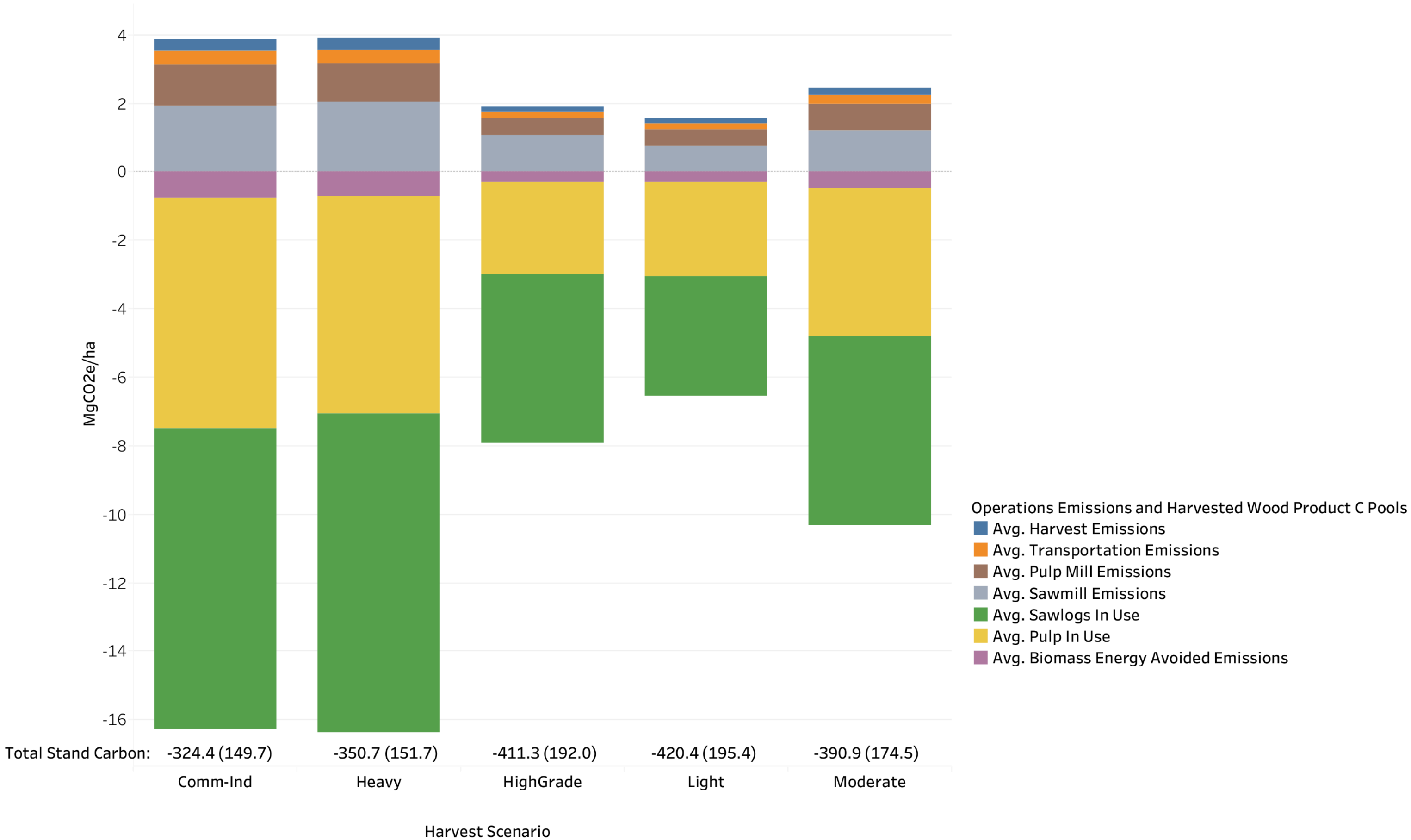


Figure 4. Post-harvest C pools at year 0 for each harvest scenario and risk category (n = 4926 for each scenario). Positive values denote C emissions, negative values denote C sequestered. Total stand carbon is presented as the mean value with SD in brackets and includes the following pools calculated in FVS: live trees (including stems, branches, and foliage, but not including roots), belowground live (the roots of live trees), belowground dead (the roots of dead and cut trees), standing dead (dead trees, including stems and any branches and foliage still present, but not including roots), forest down dead wood (all woody material, regardless of size), forest floor (litter and duff), and herbs and shrubs. Note: soil carbon is not included in this value since FIA data do not include this parameter.

Results

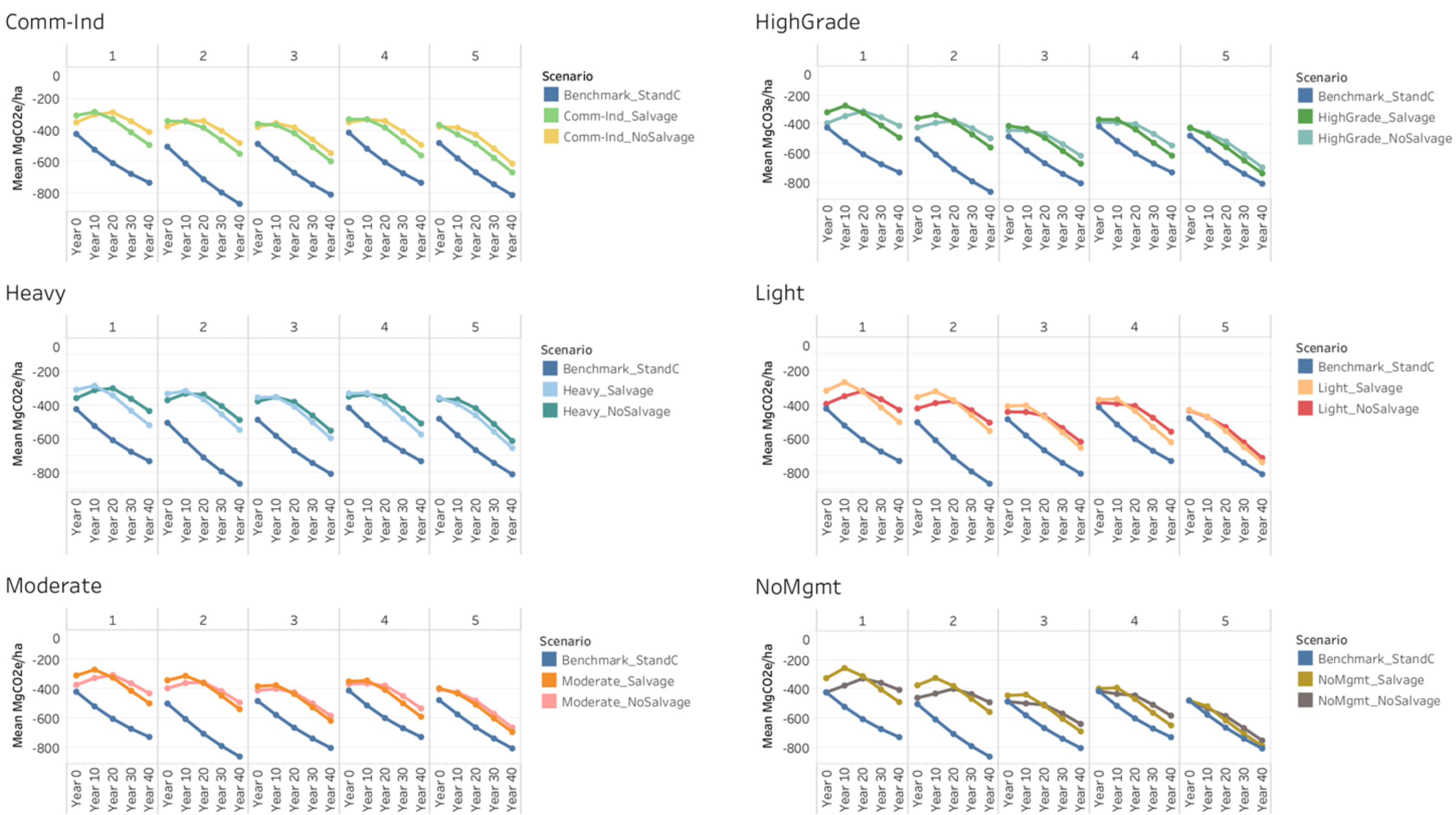


Figure 5. Mean total net greenhouse gas emissions balance (negative values = sequestration) for all management scenarios (Salvage and No Salvage) compared to benchmark scenario with no harvesting and no SBW outbreak.

Implications and applications in the Northern Forest region

- With looming outbreaks of both native and non-native insect pests, landowners and forest managers in the Northern Forest region are likely to face more frequent situations where they will need to decide whether salvage harvesting is an appropriate management response.

- We found that forest management actions such as salvage harvesting designed to mitigate pest impacts over time can have positive impacts on overall C balances by reducing the risk of catastrophic loss in susceptible stands and landscapes and by shifting C from at-risk or dying trees to wood used as building materials or displacing fossil-fuel intensive energy sources.

- However, this C resilience comes at a short-term cost to the atmosphere that can last up to 20 years. Therefore, the resilience is dependent upon the recovery of the forest C stocks in the absence of subsequent natural or anthropogenic disturbances. If forest management interventions or large-scale mortality interrupt the growth response of the post salvage forest, then there is likely to be a longer period of time required to reach parity with the baseline scenarios.

Future directions

- Gunn and Ducey are currently working with UNH Computer Science Assistant Professor and a graduate student to evaluate the optimal economic decision to salvage based on tradeoffs in the social cost of carbon and timber revenue. This work is expected to be completed by June 2020.

List of products

Refereed Journal Publications:

Gunn, J.S., M.J. Ducey, and E.P. Belair. 2019. Evaluating degradation in a North American temperate forest. *Forest Ecology and Management* 432: 415-426.

Gunn, J.S., M.J. Ducey, T. Buchholz, and E.P. Belair. 2020. Forest Carbon Resilience of Eastern Spruce Budworm (*Choristoneura fumiferana*) Salvage Harvesting in the Northeastern United States. Frontiers in Forests and Global Change. *In Press*.

Presentations / Workshops / Meetings / Field Tours:

Gunn, J.S., M.J. Ducey, and E.P. Belair. 2017. Quantifying and Mapping Risk of Spruce Budworm Carbon and Timber Resource Impacts in New England. New England Society of American Foresters Winter Meeting, Bangor, Maine, March 8-10, 2017.

Gunn, J.S., M.J. Ducey, T. Buchholz, and E.P. Belair. 2018. Silvicultural strategies for mitigating northern forest carbon loss due to spruce budworm (*Choristoneura fumiferana*). American Geophysical Union, Fall Meeting, Washington, D.C., December 10-14, 2018.

Newspapers / Periodicals / Television / Web Pages:

A web page has been developed to allow users to interactively query and explore the FIA data and simulation results from this project, using the Tableau interface for maps and graphics:
https://public.tableau.com/profile/john.gunn#!/vizhome/SpruceBudwormRiskMapv2/Dashboard