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MP742: 4th Annual Munsungan Conference Proceedings: Forest Health

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4th Annual Munsungan Conference Proceedings: Forest Health

September 24-25, 1998

edited by
William D. Ostrofsky
and
T.J. Dragon

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MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
University of Maine

4th Annual Munsungan Conference Proceedings: Forest Health

September 24-25, 1998

edited by

William D. Ostrofsky, Director

and

T.J. Dragon, Administrative Assistant

Office of Professional Development

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PREFACE

Forest managers, landowners, and scientists have long appreciated the direct effects that insects, diseases and damaging weather can have on forests. Over the past fifty years the Maine landscape has been affected by numerous outbreaks of defoliators such as the gypsy moth and the spruce budworm, by white pine blister rust and beech bark disease, and most recently by severe ice storm damage, along with countless other pests and catastrophic storms.

During the past several years, the public also has become increasingly aware of the subject of forest health and the factors that can result in the decline of forest health. Thus, our understanding of what forest health encompasses has grown well beyond the direct effects of insects and diseases to a more complete, ecological view. We now realize that the health of forests, measured by their ability to recover from stress, depends on factors of atmosphere, soils, water, and the status of associated plant and animal populations, as well as it does on healthy trees. Furthermore, all these aspects need to be in an appropriate balance if a healthy forest is to be maintained. To this end, this conference provides viewpoints on a variety of these important and defining aspects of forest health.

The conference begins with a historical overview of the forest and forest development in Maine and provides an updated status of the spatial location and sustainability of the resource. Details of the influences of forest management activities on forest soils, on wildlife biodiversity and on timber quality are highlighted in the subsequent three discussions. These discussions “set the stage” for the presentations focusing on each of three major timber types in Maine—the northern hardwood type, white pine and oak type, and the spruce-fir type. The final two presentations address the professional and public concerns regarding issues of forest health and sustainability in the social context.

The topic of forest health was conceived for this conference long before the famous ice storm of 1998, which clearly demonstrated to residents of the Northeast that the health and well-being of the forests is at constant risk. Perhaps one of the most important functions of a conference such as this is to increase our awareness and appreciation of the complexity of forces, both natural and societal, within which the broad practice of forestry operates. Summarily, maintaining forest health will likely require a two-fold strategy. First, we must find and use methods and technologies that will minimize the negative effects of the harmful agents or practices. Secondly, we must find and use methods and technologies that will maximize the resiliency of the forest so that it can respond favorably and rapidly to both natural and artificial disturbances. This conference and the thoughtful application and challenge of the expressed ideas will help us to realize that goal.

William D. Ostrofsky
Office of Professional Development

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HISTORICAL CHANGES IN MAINE'S FORESTS: AN OVERVIEW

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Introduction

Historically, when the word "health" was used in a forestry setting, it usually was applied to individual trees; a tree was considered healthy if it looked intact and had no evidence of any insect or disease problems. In recent years the term "forest health" has become common and is applied in a broad range of contexts. Indeed, we now talk about the health of trees, stands, forests, and ecosystems. To further complicate things, we have learned that by some definitions what is healthy at one level is not necessarily healthy at another. For example, a healthy forest may include some unhealthy stands, and healthy stands include some unhealthy trees.

Just how should we define forest health for Maine's forests? Fortunately, I was not asked to provide such a definition for this conference! However, there are at least two assumptions common to most definitions. First, we need a frame of reference. It only makes sense to use the term forest health if we intend to evaluate the condition of our forest and for that we need a frame of reference. Second, that frame of reference must recognize that no forest, healthy or otherwise, is static. Thus, the frame of reference must incorporate forest dynamics.

In light of the above, my goal in this paper is to give a brief overview of the ecological history of Maine's forests. In particular, I will describe how our forests have changed over time and discuss the role disturbances have played in causing those changes. Time and space constraints prohibit this from being an exhaustive literature review; instead, I will focus on general trends and use examples from key studies. There are three primary sources of information on historical changes: paleoecology (in the context of this paper, primarily the study of pollen, macro fossils, and charcoal), historical documents and surveys, and old-growth forests. Each will be discussed separately, although results overlap somewhat.

Paleoecology

Paleoecology provides us with the longest records, often extending for thousands of years. This research field is based on the resistance to decay of pollen, macro fossils, charcoal, and other biological material when it occurs in primarily anaerobic environments such as lake sediments

and peatlands. This material is deposited annually, allowing a relationship between depth and age to be developed with the help of radiocarbon dating. By tracking the relative changes in abundance of pollen, we can learn much about how forests have changed over time.

Jacobson and Davis (1988) summarized many such studies done in Maine and produced a generalized pollen diagram for central Maine. This diagram illustrates how our forests have gone through several stages, including tundra and open woodlands (13,000 to 9000 years BP [before present]); early closed, boreal-like forests (12,000 to 9000 years BP); white pine, white birch, and oak (10,000 to 7000 years BP); hemlock, yellow birch, and beech (8000 to 5000 years BP); hemlock decline (5000 years BP); recovery of hemlock, birch, and beech (4000 to 1000 years BP); and finally, the modern forests, which have existed over the last 1000 to 1500 years. Their summary (Jacobson and Davis 1988) highlights several points. First, our forests have never been static; change is the rule. Second, climate seems to be the primary driver of change. For example, the pine, birch, and oak stage was warmer and drier than the hemlock, birch, and beech stage. Third, disturbances are tied to climate and vegetation, as illustrated by the abundance of charcoal during the warm, dry period dominated by pine, oak, and birch. Fourth, catastrophic declines can occur, such as that experienced by hemlock around 5000 years ago. That decline occurred throughout hemlock's range and is widely believed to be the result of some insect or pathogen. Ironically, hemlock is currently experiencing another major threat, this time from the introduced hemlock woolly adelgid (Orwig and Foster 1998). Finally, spruce, so important to Maine's forest industry, only achieved widespread abundance within the last 1000 years or less (Schauffler 1998) and may be the result of a cooling trend of less than 1° C (Jacobson, personal communication).

Two recent studies (Russell et al. 1993; Fuller et al. 1998) have also employed paleoecological techniques to look at more recent changes (over the last 1000 years or so) in greater detail, their goal being to compare the few hundred years before European settlement to the period after European settlement. Both studies found the pre-settlement to post-settlement transition to be a period of rapid change. In

fact, Fuller et al. (1998) found that the rate of change during the post-settlement period in central Massachusetts to be the highest recorded in the last 1000 years and that the relative species composition during the post-settlement period was unique, not having occurred in the pre-settlement era. Furthermore, they found that whereas vegetation distribution (they used several sites) was closely linked to climate, soils, and fire prior to settlement, land clearing and subsequent re-colonization by early successional species following land abandonment in post-settlement years obscured those relationships. It is interesting to note that a parallel study to Fuller et al. (1998) that used historical data from the same region (Foster et al. 1998) drew similar conclusions. Although Russell et al. (1993) looked at multiple sites over a larger area (the northeastern U.S.), they found similar trends. Birch increased following the disturbances associated with settlement, and hemlock and beech decreased, partly in response to increased fires shortly after settlement, and in the case of hemlock, logging for the tannin industry. They also noted an increase in fir in the northern part of the region.

Historical Analysis

Historical writings and surveys can yield considerable information about early forests. Some of the earliest writings may be difficult to obtain directly, but books like those by Conkling (1981) and Bennett (1996) contain many interesting quotes of early explorers and observers of nature. However, one must keep in mind that these early writers were not necessarily trying to provide an unbiased view.

Another source of information was early government surveys, such as those of the General Land Office. During the process of surveying township boundaries, surveyors were required to note changes in forest types and evidence of disturbance along the lines and to mark witness trees at township line intersections and at one-mile sections along the lines. Lorimer (1977) used information from surveys done in the late 1700s and early 1800s in northern Maine to describe the forests at that time and to estimate kinds of disturbances and their frequency and scale. He found that most (> 90%) witness trees were shade tolerant and typical of late successional communities. He also found that catastrophic fires and major windfalls were rare, with recurrence intervals of 806 years and 1150 years, respectively. Although he notes that these estimates can vary somewhat according to what assumptions are made, the occurrence of stand-replacing disturbances was relatively rare,

albeit conspicuous. Interestingly, there was little mention of insect outbreaks in the survey records. The conclusion from disturbance estimates and species of witness trees is that much of the forest in northern Maine was old and in a late successional stage prior to extensive settlement.

Early land clearing for agriculture and subsequent abandonment has also played a significant role in some parts of Maine, especially southern Maine, where agricultural censuses indicate that in some counties up to 50% of the land base was in crops and pasture in the mid-1800s. As farms were abandoned over the last 100 years or so, most of these cleared lands reverted to forests. Consequently, many of these forests have a composition and structure that are related to the interaction of past land use, time since land abandonment, soils, climate, and the forest matrix that existed at the time of abandonment. Presumably, many of the conclusions by Fuller et al. (1998) and Foster et al. (1998), noted above, also apply to Maine.

Another historical source is the writings of foresters, botanists, geologists, and other field experts who observed some of the last areas of old-growth as well as earlier disturbances. Seymour (1992) assimilated the writings and observations of familiar names like Cary, Graves, Hosmer, and others to paint the following picture of how our forests have changed as a consequence of the interactive effects of natural disturbance and logging history (note that Maine's logging history is well-documented by Wood [1935], Coolidge [1963], Smith [1972], and Judd [1989]). Old-growth stands in the spruce-fir type were dominated by large, old red spruce with some fir, especially in sub-canopy positions. Harvesting from 1860 to 1890 removed many of the larger spruce, allowing small, previously suppressed spruce and fir, as well as advance seedlings, to accelerate their growth. Firs do well in this type of situation and consequently dominated many stands by the early 1900s, by which time spruce was being harvested for pulp and the next outbreak of spruce budworm occurred. Because fir is far more susceptible to the budworm than spruce, mortality was high. However, fir was able to take advantage of the open environments provided by the budworm outbreak, as well as any stands that had been heavily cut, and came to dominate stands prior to the 1970s outbreak. Thus we see that earlier patterns of cutting interacted with a natural mortality agent to produce a disturbance different from what might have occurred naturally. This is just one example of the utility of historical sources.

One topic that always arises in the discussion of past forests is the role of Native Americans. Several

viewpoints exist and are based on historical, archaeological, and paleoecological sources (Cronon 1983; Whitney 1994; Patterson and Sassaman 1988). The prevailing view is that through their use of fire and agriculture, Native Americans had a significant effect on parts of the eastern forests. In New England, that effect was greatest close to the southern coast and along major rivers and diminished as one went inland or northward (Patterson and Sassaman 1988; O'Keefe and Foster 1998). It seems likely, therefore, that the impact of Native Americans on Maine's forests was localized, not extensive.

Old-Growth Forests

Old-growth forests are the third source of information, and in many respects the rarest. Far less than 1% of Maine's forests remain in old-growth. Much of this is in small (<20 ha) stands (Maine Critical Areas Program 1983) that exist because they were inaccessible and on poor sites for farming or growing trees, thus making it difficult to know just how representative they are of the larger landscape. One exception to this is Big Reed Forest Reserve (BRFR) in northern Maine. At almost 2000 ha, this is the largest known tract of old-growth forest in New England and is large enough to be representative of the surrounding landscape.

Chokkalingam (1998) used increment cores, stem mapping, and historical information to analyze mixed wood and northern hardwood stands at BRFR. She found that the dbh structure of these stands resembled the expected reverse-J or negative exponential pattern. The age structure was uneven-aged, but not all age classes were well-represented; instead, there were definite pulses of recruitment that were associated with stand disturbances. These disturbances were typically small gaps < 120 m² with only a few as large as 400–700 m², meaning that mortality was at a scale of one to a few trees.

If the stands studied by Chokkalingam (1998) are typical of the presettlement forest, then we can infer that such forests were typically dominated by shade-tolerant, late-successional species, and the primary disturbances were small gaps that allowed the species to perpetuate themselves. Such an inference is consistent with the paleoecological and historical evidence presented earlier in this paper.

Conclusions

There are several conclusions that can be drawn from the various sources discussed above.

1. Maine's forests are dynamic now and have been since the glaciers retreated.

2. Climate is one of the primary drivers of vegetation dynamics and whatever human beings do to the forests is superimposed on that.
3. Natural disturbances were predominantly small in scale, at least during the last 1500 years. Large-scale disturbances were relatively rare, but could have a long-lasting effect where they occurred.
4. Native American agriculture and use of fire may have been significant in some local areas, but probably were not a major influence on most of the landscape.
5. Because disturbances were primarily small in scale, presettlement forests typically were older than those of today and contained higher numbers of large trees, as is the case with old-growth stands at Big Reed Forest Reserve.
6. Land-use history has influenced a significant portion of Maine's landscape, especially in southern Maine.
7. Effects of early logging influenced early stand dynamics and set the stage for subsequent natural and human effects.
8. Early successional species are more common on the landscape now than just prior to European settlement, resulting in a more homogenous forest composition.

In summary, our forests are different today in terms of their relative species composition, size and age structure, and the types of disturbances influencing them. That leaves us with the question of whether "different" means "unhealthy". The answer depends on one's definition of "forest health".

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TIMBER SUPPLY OUTLOOK FOR MAINE: 1995-2045

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Executive Summary

The Department of Conservation - Maine Forest Service, in cooperation with the USDA Forest Service, has conducted an analysis of future timber supply from Maine forestlands. This analysis utilizes the most recent statewide forest inventory of Maine (completed in December 1995) and computer models to simulate forest growth, harvest levels, and silvicultural practices. The analysis conducts a series of timber supply projections. The results of each projection are examined for long-term balance between growth and harvest. This analysis provides an overall assessment of future timber supply in Maine. It does not address every detailed question of forest management, forest health, and forest productivity.

Both the data and procedures used in this analysis include margins of error that affect the results. However, this report is intended to represent the most accurate overall assessment possible. The analysis is considered a solid baseline assessment of future timber supply. However, it must be regarded as a first step in an ongoing evaluation that incrementally improves through the collection of new data and refined analysis.

Summary of Timber Supply Projections

- The first analysis is a 50-year timber supply projection that evaluates the consequences of current management and harvest activities on Maine's 17 million acres of forestland. While inventory levels remain adequate to support current harvest levels for the entire forecast period, a continued imbalance between growth and harvest is not considered sustainable. The report concludes that current management is capable of sustaining 86% of current harvest levels. The report also identifies that substantial growth increases can be obtained with incremental improvements in overall forest management activities.

- The second analysis identifies one possible scenario of improved forest management activities that achieves a sustainable balance between growth and 100% of current harvest levels by (1) Increasing forest growth through improved partial harvesting techniques; (2) Increasing the number of acres under high-yield silvicultural practices to a cumulative total of 9% of Maine's forestland by the year 2015.

In order to realize improvements in productivity, the above activities should be aggressively pursued over the next two decades.

- The third timber supply projection repeats the procedures of the first two projections for two separate ownership size classes—landowners owning 100,000 acres or more and all other landowners (53% and 47% of Maine's total forested acres, respectively). The report concludes that harvest rates for both landowner groups are higher than current management practices can sustain, with the large landowners representing the majority of the deficit. (Note: These results represent an overall averaging of many different landowners and do not accurately represent the status of any individual landowner.) The improved yield scenario for each landowner group demonstrates that the identified improvements in silvicultural practices can result in a long-term balance between growth and current harvest levels.

Conclusion

The current rate of growth in Maine's forests cannot sustain indefinitely the current level of timber harvest. However, Maine's forests have a growth potential that has not been fully realized. With investments in intensive silviculture and improved management of Maine's natural forest stands, we are capable of fully sustaining the current harvest level. Activities to improve forest productivity need to be broadly implemented over the next two decades.

LET'S TAKE A LOOK FROM ABOVE: MAINE FORESTS FROM THE SATELLITE PERSPECTIVE—1993

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Introduction

Forest and land cover type mapping has long been an important endeavor for foresters and natural resource managers. Since the late 1930s, aerial photography has provided time-savings to assist forest mapping, especially when dealing with large and/or remote areas. In recent years, the use of satellite remote sensing as a tool in forest ecosystems management is gaining acceptance among resource managers, and the analysis of data in a digital format allows for increased automation of the process. Satellite remote sensing and Geographic Information System technology provide us with the ability to map forest cover and identify and update changes in land cover over time.

Land Cover Map of Maine

The Maine Image Analysis Laboratory, Department of Forest Management, University of Maine, and the Maine Cooperative Fish and Wildlife Research Unit, and U.S. Geological Survey's (USGS) Division of Biological Resources have been cooperating to produce a map of Maine's land cover and wildlife habitats. The map, being compiled at 1:100,000 scale, is derived from Landsat-Thematic Mapper (TM) satellite data from 1991 to 1993, and supported by interpretation of aerial videography collected in 1994. Because of difficulties in accurately identifying wetlands with satellite data, the map incorporates wetlands mapped from aerial photographs by the U.S. Fish and Wildlife's National Wetlands Inventory. The map has approximately 40 types of habitat, half upland and half wetland. The upland habitats range from urban and residential lands, to agricultural lands including blueberry fields and row crops, to many types of upland forests.

Accuracy of the 1993 Landsat satellite land cover map of Maine

The Maine GAP Analysis Project (Krohn et al. 1998; Hepinstall et al. in prep.) produced the first seamless, digital land cover/land use map of Maine with known accuracy. The overall accuracy of the Landsat-TM derived map (agreement with thousands of randomly sampled aerial video interpretation points) for five supergroups was 88%. The

commission and omission accuracies of forest versus non-forest classes were well over 90%. Within the forest types (regeneration, hardwood, softwood, and mixed) the agreement with video interpretation was in the 60% to 80% range, except for mixed forest at 45% correct. The major proportion of misclassification for forest types was within the forest groups (e.g., softwood or hardwood misclassified as mixed wood) rather than between forest and non-forest types.

How does the satellite forest area compare with U.S. Forest Service 1995 Forest Inventory and Analysis (FIA) data?

Comparison of county-level forest area estimates between the 1995 FIA survey of Maine (Griffith and Alerich 1996) and the 1993 Landsat-TM map indicated agreement within 3% difference for 12 out of 16 counties. Of the four counties that had greater than 3% difference, three counties had high standard errors in the FIA survey (4.2%, 5.2%, and 7.3%) suggesting that lack of agreement does not necessarily equate to inaccuracy of the Landsat-TM data. The correlation coefficient for the FIA and Landsat forest area relationship was 0.985 (0.003 SE) (Figure 1).

A closer look at the county-level forest type groupings from the satellite results (Figure 2) shows the counties with the greatest land area percentage in closed upland forest (excluding recent clearcuts, heavy partial cuts, early regeneration classes, and forest wetlands), and forests of all categories (recent clearcut and partial cuts, early and late regeneration, forest wetlands, hardwood, softwood, and mixed forest). Franklin, followed by Oxford County, had the highest percentage of closed forest. Piscataquis, Franklin and Somerset were the top three counties with the highest percentage of land area in forest. For example, Piscataquis County had 97% of its land area in forest. These results agree with the 1995 U.S. Forest Service data.

How Much Forest is in Maine?

The Forest Service estimated that 89.4% of Maine's land area was in some type of forest cover in 1995. The satellite 1993 estimate is 89.2% if the shrub/scrub land cover class is included (Hepinstall

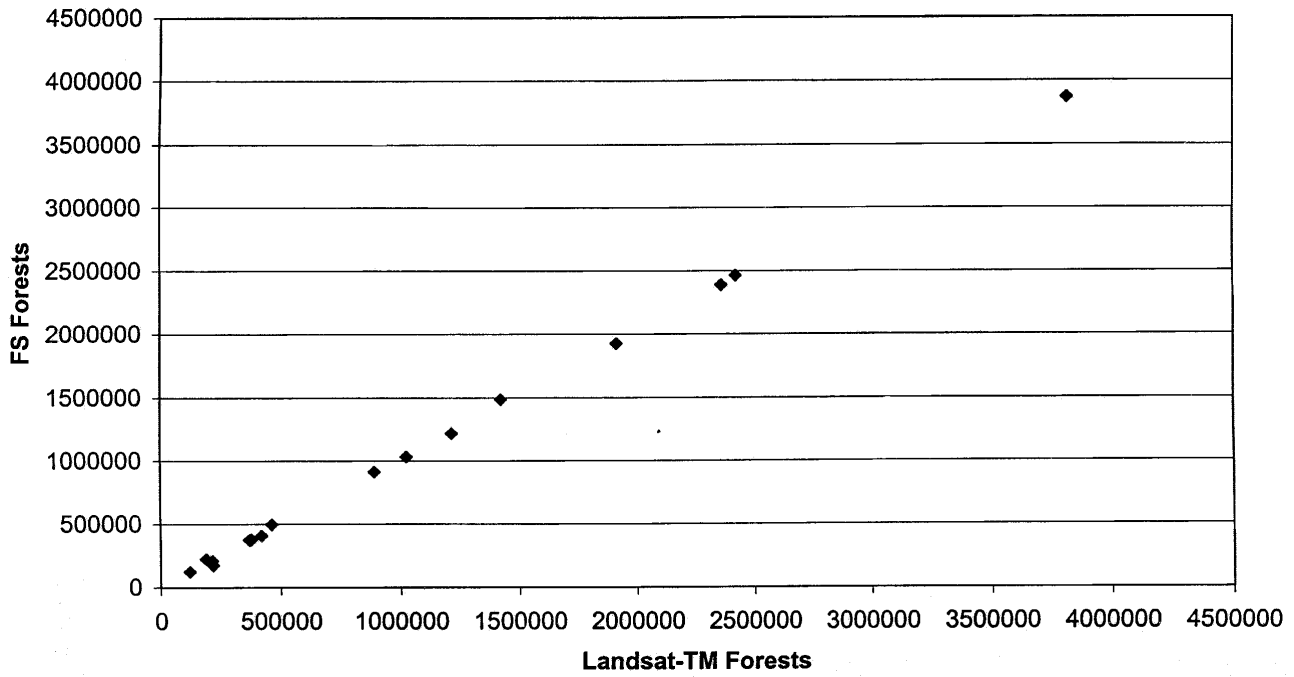


Figure 1. Comparison of 1995 Forest Service to 1993 Landsat-TM forest area for 16 Maine counties.

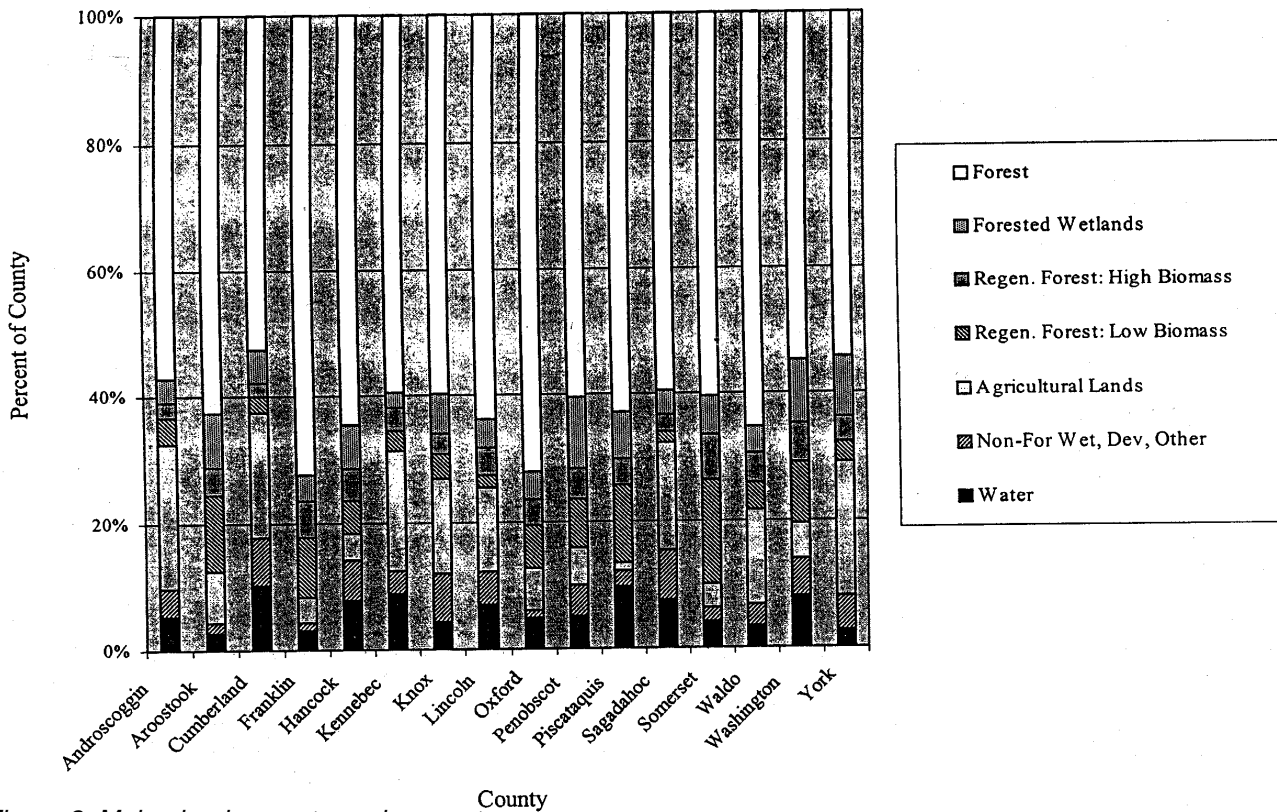


Figure 2. Maine land cover types by county.

et al., in prep.). The reason for including shrub/scrub in the estimate is related to the results of the satellite accuracy assessment. Regeneration stands are often confused or misidentified with shrub because the reflectance characteristics of young seedling and sapling trees are very similar to the shrub communities. By excluding shrub/scrub, we get a more conservative estimate of approximately 87.2% forest for 1993.

Landscape-Scale Effects of the Maine Forest Practices Act

The Maine Legislature passed the Forest Practices Act (12 MRSA Chapter 805, Subchapter III-A) in 1989. This act directed the Commissioner of the Department of Conservation to set standards for regeneration after harvests and to develop rules regarding the size and spatial distribution of clearcuts. The Forest Regeneration and Clearcutting Standards (MFS Rules Chapter 20) established three categories of clearcuts: Category I (5–35 acres), Category II (36–125 acres) and Category IIE (126–250 acres).

The Department of Forest Management, Maine Image Analysis Laboratory initiated a study to use multi-temporal (three date) satellite imagery to examine the effects of the Forest Practices Act (FPA) on forest clearcutting practices in a region of northwestern Maine. Spatial characteristics of forest harvest sites (i.e., size, shape, distribution, and other spatial metrics) before and after implementation of the FPA were compared. The study site was 29 townships north of Moosehead Lake within Piscataquis County encompassing approximately 61,651 acres in northwestern Maine. The location of the study area was chosen to represent a large forested region with multiple landowners and a minimum amount of cloud cover over the three dates of imagery.

Results from the 29-township study area indicate measurable differences between the spatial characteristics of clearcuts before and after implementation of the Forest Practice Act. In particular, a greater number of harvest sites were detected after the FPA enactment; however, there was a decrease in the mean size of individual harvest sites and total area harvested. Many of the post-FPA harvest sites tended to be clustered, which is indicative of category 1 clearcuts. The 250-foot separation zones were easily seen on the satellite images. Large clearcuts were practically eliminated after FPA enactment in 1991. We use the term “harvest site” in lieu of the term “clearcut”. Although our observations indicate that most of the harvesting we detected was indeed clearcuts, there

was also an undetermined amount of partial cutting (presumably heavy partial cuts are confused with clearcuts) that we were not able to verify. However, work is continuing in our current research program to determine how well satellite sensors can detect differences between clearcut and selective or partial harvesting activities.

The Maine Forest Service (MFS) conducted a similar evaluation of the effects of the FPA on forest management practices, with a specific focus on the size and geographic distribution of clearcuts (Maine Forest Service 1995). Data were collected from a sample of the harvest sites reported by landowners throughout the state for the period of 1991 and 1993. The MFS study obtained detailed data on regeneration rates, harvest intensity within the unharvested separation zones required by the FPA, the size distribution of clearcuts, and information on partial harvest sites. The MFS study agreed with our conclusion that the average clearcut size decreased after implementation of the FPA, although they did not have comparable data on the clearcut sites immediately prior to 1991. Comparison of Maine townships with greater than 1000 acres of clearcut harvest (Maine Forest Service, 1995) shows a close spatial agreement with the map of townships with the highest percentage of low biomass forest (recent clearcut, heavy partial cut and early regeneration) computed from the 1993 Landsat-TM map (Hepinstall et al. in prep.).

Conclusion

The U.S. Forest Service Inventory and Analysis units have been conducting forest surveys in the U.S. since the 1930s. Although the FIA has been the most reliable and comprehensive data available on forest resources in the country, the statewide survey cycle has exceeded 10 years in many states, including Maine. The federal “Farm Bill” and Maine state legislation now requires forest surveys to be conducted on an annual basis. Maine will be the first state in the Northeast region to initiate the new survey in 1999. The proposed plan is to remeasure 20% of the statewide ground plots each year for a complete remeasurement pace of five years. This new survey mandate poses new challenges for states on how to design the most efficient survey and where to collect or to allocate the sample plots each year. Many foresters involved in statewide inventories believe that remote sensing has an important role to play in documenting the location and area of forest and forest change. Some evidence has been provided in this paper to support this view. Stratification of recent forest change on disturbed plots can direct ground sampling efforts to the most appropriate locations.

The 1989 Maine Forest Practices Act and provisions of new legislation signed by the governor of Maine creates minimum standards for regeneration and buffer zones around clearcuts, requires a management plan for clearcuts greater than 35 acres, and specifies an annual inventory. The new legislative bill directs Maine Forest Service to establish a process to assess forest sustainability including the development of standards and a monitoring system. For monitoring purposes, a combination of medium- and high-resolution satellite imagery and ground-based approaches incorporated into a statewide survey design may be appropriate for monitoring harvest locations, patterns and trends as well as determining regeneration status and post-harvest site conditions.

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WHAT IS GOING ON IN SOIL AND WATER?

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Introduction

With the theme of the Fourth Annual Munsungan Conference being the *Health of Maine's Forests - Status and Outlook*, I have chosen to focus on using the criterion of Montreal Process' (Montreal Process 1995) Conservation and Maintenance of Soil and Water Resources to develop indicators for forest health in Maine. Along with the indicators of the Montreal Process, research from our Soil-Site Program at the Cooperative Forestry Research Unit (CFRU) will also be presented, where applicable. It is my hope that we will be able to expand upon past work, and integrate future work in soil and water, across disciplines to better maintain, or enhance, the health of Maine's forests. Also, I anticipate that this paper will serve as an outline for the development of indicators for forest health based on soil and water research.

The conservation of soil and water resources is fundamental to sustaining the productive capacity of forest ecosystems. The Maine Legislature (L.D. 2286) has directed the Maine Department of Conservation to establish benchmarks for water quality, wetlands, and riparian zones by January 1, 1999, and soil productivity by January 1, 2001. The Forestry Advisory Team (FORAT) for non-point source pollution is currently developing water quality benchmarks for Maine. Therefore, a discussion of criteria and indicators of forest health based on soil and water research is most appropriate at this time.

Criteria for Development of Ecological Indicators

There are a number of indicators for the criterion of Conservation and Maintenance of Soil and Water Resources. Those indicators can serve an important role in evaluating the health of Maine's forests. Indicators of forest health based on soil and water resources need to be monitored against appropriate baselines to ensure that the various components of the land base are maintained.

Indicators need to be scientifically rigorous, reliable, and meaningful in terms of forest health. Appropriate indicators should (1) be clearly related to an ecosystem process or function that is critical to the long-term sustainability of forest resources, (2) provide information relevant to societal values and be interpreted by the general public, land

managers, and policy makers, (3) be measured by inexpensive monitoring or by cost-effective automated monitoring, and (4) have a definable response when compared to measurement error or natural variability.

Indicators for the Criterion of Conservation and Maintenance of Soil and Water Resources

1. *Area and percentage of forestland with significant erosion.* This indicator measures the extent of soil erosion in forest areas that is of sufficient magnitude to lower soil fertility or cause significant sediment delivery to streams. For this indicator, the Briggs et al. (1996) report on Best Management Practices (BMPs) compliance, as well as future BMP assessments could be quite useful. Through this approach, we can define the area of forest land for which BMPs have been adopted and applied statewide. That can be used as a surrogate for the measurement of area of forestland with significant erosion.
2. *Area and percentage of forestland with significantly diminished soil organic matter and/or changes in other soil chemical properties.* This indicator provides a measure of changes in chemical properties that affect soil fertility. The level of soil organic matter should be maintained because of its links to nutrient cycling and carbon storage, effects on soil physical and hydrological properties, and role in providing substrate for soil biota. Approaches to measurements include (1) total quantity of organic matter, carbon, and selected nutrients, stratified by forest type, soil type, and forest use/harvesting system, (2) quantitative assessments based on relationships between soil organic matter, soil fertility, and ecosystem processes, and (3) extrapolation based on remote sensing.

There is a tremendous amount of variability in soil organic matter within both spruce-fir and northern hardwood forest types that needs to be accounted for when establishing benchmarks for soil organic matter or nutrients (Table 1). Table 2 shows soil organic matter contents for reference and harvested stands for two spruce forests. For one site, the Weymouth Point study site in Maine, data were collected 16 years following whole-tree harvesting for

both harvested and reference stands. For the second site, the West Branch study site in Michigan, data were collected five years following whole-tree harvesting for both harvested and reference stands. A third spruce site, the Howland study site in Maine, has forest floor and mineral soil organic matter contents of 88 and 136 Mg ha⁻¹, respectively (Fernandez et al. 1993; McLaughlin et al. 1996a). There have been no data collected relative to harvesting at the Howland site. Organic matter in the forest floor on the harvested treatments for the Weymouth Point and West Branch study sites are about 25% and 70% lower than their respective reference conditions. Organic matter in the mineral soil of the harvested stand is about 30% lower than that for the reference conditions at both sites. I must, however, emphasize that the wide range in soil organic matter contents in both northern hardwood and spruce-fir forests underscores the importance of adequately quan-

tifying reference conditions. This will greatly aid in the ability to make appropriate interpretations of soil organic matter or nutrient depletion as an indicator of forest health.

3. *Area and percentage of forestland with significant compaction or change in soil physical properties resulting from human activities.* This indicator aims to measure the extent of soil change induced by human activity that might adversely affect soil fertility, hydrology, biology, and thus ecosystem processes. Approaches to measurements include soil bulk density or characteristics of ruts, including depth and soil displacement. No widely acceptable standards exist for what constitutes significant compaction, and it varies greatly in nature. Sampling strategies should be implemented for major forest types, for which bulk densities are established. The effects of changes in soil bulk density may be determined by calibration with important processes, such as water infiltration,

Table 1. Organic matter, total nitrogen, and total phosphorus content and distribution in two forest types common to Maine.

	Organic matter Mg ha ⁻¹	N ----- kg ha ⁻¹ -----	P
Spruce-Fir			
Vegetation	100–200	332–387	51–52
Forest floor	110–130	875–1543	90–100
Mineral soil	280–448	559–8267	114–2575
Total capital	490–778	1766–10197	255–2727
Northern Hardwoods			
Vegetation	80–150	531–581	26–33
Forest floor	70–90	395–1365	26–40
Mineral soil	300–500	3890–9710	1439–2100
Total capital	450–740	4816 –11443	1491–2213

Data are from: Smith (1984), Morrison (1990), MacDonald et al. (1991a), Joslin et al. (1992), Fernandez et al. (1993), Johnson (1995), Johnson et al. (1995), McLaughlin et al (1996b).

Table 2. Soil organic matter contents for reference and whole-tree harvest conditions for two spruce forests (Weymouth Point data are 16 years following whole-tree harvesting and West Branch data are five years following whole-tree harvesting).

Soil strata	Weymouth Point		West Branch	
	Control	Harvested	Control	Harvested
	----- Mg ha ⁻¹ -----			
Forest floor	104	78	59	17
Mineral soil	484	336	104	75

Weymouth Point data are from J.W. McLaughlin, unpublished data.
West Branch data are from McLaughlin et al. (1996b).

seedling establishment, root growth, and stand growth for different forest types.

4. *Area and percentage of forestland managed primarily for protective functions (watersheds, flood protection, riparian zones).* This indicator provides a measure of both area and proportion of forestland managed primarily for protective functions. In defining measurements, consideration should be given to the level of stream protective measures applying to different stream orders. They should be subdivided by ecoregion, soil erosion risk, and land form. Geographic information system (GIS) or map overlays can be used to identify stream location and protective zone, by stream order and protective prescription.
5. *Percentage of stream kilometers in forested catchments in which stream flow and timing has been significantly deviated from the historic range of variation.* This indicator measures the effects of forest management and other factors on water flow and variation within flow. Approaches for the measurements include (1) long-term monitoring of selected representative streams, with comparisons made between adjacent natural and managed streams, (2) use of hydrological models and catchment studies to predict the effects of changed forest management on stream flow and timing, and (3) GIS.

The Soil-Site Program at the CFRU initiated a water quality study across managed forested landscapes in western Maine during June 1998. Two of the issues we are addressing are stream flow and timing using two reference watersheds and two watersheds that are currently being cut using shelterwood harvests. Streams in the harvested watersheds have intact 75 to 150 feet buffer zones, depending upon slope. However, at this time the database is too incomplete to warrant any statistical analyses or data interpretation. My hope is that this work continues for the long-term and that it is expanded to other streams within the specific ecoregion that we are studying to improve our reference conditions database. Once that is accomplished, our ability to interpret data on potential management alterations on stream flow and timing will be dramatically improved.

6. *Percentage of water bodies in forested areas with significant variation of biological diversity from the historic range in variability.* This indicator measures the diversity of in-stream flora and fauna as a reflection of the quality of habitat and water. This, in turn, can reflect the

impacts of forest management activities within a watershed, and should provide a reliable measure of the success of forest management guidelines. Approaches to measurements include diversity of aquatic macroinvertebrates, fish, and algae. Diversity measurements can be related to water flow, water quality, and stream habitat.

Our water quality study in the Soil-Site Program at CFRU is addressing diversity of macroinvertebrates for both reference streams and those that drain shelterwood harvested forests. As with the stream flow measurements, the data are too limited at this time for interpretation.

7. *Percentage of water bodies in forest areas with significant variation from historic range in chemistry, sedimentation, or temperature.* This indicator aims to assess the health of the aquatic environment and the quality of water by measuring the physicochemical parameters. Approaches to measurements for this indicator include (1) long-term catchment monitoring, (2) long-term flow-based monitoring of "representative" streams and research catchments, and (3) repeated measurement approach may be useful to improve spatial coverage.

Our stream water quality study is also addressing this indicator. We are sampling the stream chemistry and sediments on a monthly basis, and using data loggers for hourly temperature measurements.

Conclusions

Of the indicators described for the Montreal Process' Conservation and Maintenance of Soil and Water Resources, there are at least five that show promise for use as indicators of forest health in Maine. For soils, the most promising candidates are (1) BMP assessments, (2) soil organic matter depletion, and (3) soil bulk density. For streams, the most promising indicators of forest health are (1) stream temperature, dissolved oxygen, and sedimentation and (2) benthic macroinvertebrates. The benthic macroinvertebrates maybe an excellent indicator for forest health because they can be used to describe cumulative effects of forest practices within a watershed.

For all potential indicators, it is of utmost importance that natural variability be understood to most efficiently use the indicators as measurements of forest health in Maine. Reference conditions for soil productivity should, at a minimum, be established for the two major forest cover types; spruce-fir and northern hardwoods. For stream

water quality, reference conditions should, at a minimum, be established for both low-gradient and high-gradient streams, stratified by ecoregion. It is also necessary to decide what size streams should be targeted for benchmarks. Because of a large number of interacting factors (agriculture, hydro-electric, pulp and paper mills) for large streams such as the Penobscot, St. John, Androscoggin, and Kennebec, emphasis should be placed on the smaller headwater streams. Kahl (1996) suggested that small headwater streams are the ones likely needing greater protection because they are more prone to impacts from forest operations than are larger streams. Also, by focusing on small streams, potential forest management activity effects on indicators of stream water quality can be more easily evaluated as benchmarks than for large streams. Benchmark evaluation can then be conducted without having to take into consideration other complicating anthropogenic factors.

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FORESTRY AND BIODIVERSITY IN MAINE FORESTS: WHERE DO WE GO FROM HERE

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The global demand for forest products is certain to increase well into the next century. Maine's extensive forestlands will play an important role in meeting this demand. However, it is clear that the people of Maine value other benefits the forest provides as well, such as biodiversity. Although most of Maine's forestland is privately owned, the citizenry can determine how the array of economic, environmental, and recreational benefits will be balanced through forest policy and legislation. Successfully balancing these needs for the present generation, without compromising the ability of future generations to meet their needs, defines the widely popular notion of sustainable forestry. However, the technical details of just how to meet these goals on the landscape are often lacking.

One goal of forest sustainability is to maintain biodiversity. Biodiversity is defined as the variety of life in all its forms. How is the forest manager to "maintain life in all its forms"? For most species we have little or no idea whether their populations respond positively or negatively to timber harvesting. Consequently, it is difficult to design with much confidence a forest that maintains biodiversity. In addition, it would be impossible to maintain life in all its forms on every acre of timberland. Ecologists and forest managers together are faced with some challenging questions. For example, how do we manage a forest in the face of a severe shortage of biological understanding? Should all species be maintained within every 100-, 1000-, or 100,000-acre segment of Maine's landscape? What level of risk to either species, or wood flow, is acceptable to the public?

The degree of success at maintaining biodiversity over time in any landscape, whether managed for forest products or not, is a matter of probability. A landscape intensively managed for fiber production likely poses a higher risk to species loss than a landscape with light management. But until our scientific understanding of modern forestry and biodiversity becomes much better, we will be left wondering what level of risk we are in fact taking with our management strategies. It is precisely this lack of knowledge that has contributed to the forestry debate in Maine and beyond. Different people/constituencies each have a different comfort level with our current meager state of knowledge.

If we truly hope to meet the ambitious goals of sustainable forestry, not just on paper but on the landscape, ecologists, economists, and foresters need to be building systematically our knowledge base. This knowledge must be made available to the public. Our scientific knowledge of the forest, and of how to integrate economic and ecological goals, has not grown at a pace consistent with the public's interest in the forest. By prioritizing our information needs (i.e., the public's), and by working across institutional boundaries, scientists and resource professionals should be able to move us much closer, and faster, to achieving sustainability.

RELATIONSHIPS OF FOREST HEALTH TO TIMBER QUALITY IN NORTHERN HARDWOODS

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The term “forest health” has grown in definition to encompass what society now believes to be all desirable attributes of the forest. According to the Society of American Foresters, forest health is a measure of the ability of the forest to respond to both natural and human-caused stresses. Specifically, stresses can result from human activities, fire management strategies, exotic species invasions, and natural factors. Within this context, then, what can be done practically to improve the health of hardwood stands in Maine?

Of all the damaging agents in northern hardwoods, the most widespread is damage to the residual stand from mechanical injuries. As long as forests are managed for the extraction of wood products, the potential exists for trees and stands to be mechanically damaged. Residual stand damage can result in changes in stand vigor, stand composition, and productivity. Not only is the problem pervasive, but this activity is one that is under a high level of control compared with insect outbreaks, losses caused by pathogens, or natural abiotic factors such as drought or storms. Harvesting activities are therefore critical in determining whether overall stand health is maintained, improved, or reduced.

Most northern hardwood stands can be effectively managed using some form of partial cutting strategy. High-valued sawtimber and veneer usually require long rotations to achieve a financially optimum size and quality. Furthermore, and for a variety of other reasons, silvicultural strategies that favor maintaining tree cover in any given stand, and in maintaining certain individual stems for longer periods of time to serve as a “reserve tree” resource are currently gaining recognition and acceptance. Residual trees left after partial-harvesting practices such as thinnings, shelterwood harvest variations, and selection harvests are at increased risk of mechanical damage because they must exist through multiple cutting cycles. These silvicultural strategies require that care and attention is paid during the harvesting stages to be certain that residual stand damage levels are minimized. There is an obvious and direct link between tree and timber quality and forest health. Practices that result in the minimization of residual stand damage will not only protect overall forest health,

but will also result in improvements in timber quality—a win/win scenario.

Recommendations for improving forest health in hardwoods include the following. First, landowners, foresters, and contractors must not become complacent about residual stand damage at any time, or in any stand. Strong communication between silviculturists and harvesting personnel should be fostered. As a research challenge, improved methods for determining stand health prior to harvesting operation implementation, and a better understanding of how damage affects specific age and/or size cohorts is needed to more effectively predict forest response to a given treatment. All harvesting does not result in unacceptable damage levels, nor does it often result in widespread stand decline. However, constant attention must be paid to avoid those factors or conditions that can result in unacceptable levels of damage to forests by harvesting activities. Damage to the residual stand can be minimized if careful consideration and appropriate follow-through is given to the following recommendations.

1. *Plan skid trails and layout landings before harvesting operations begin:* This is a long-known and well-documented way to reduce stand damage. It also results in increased operations productivity under most stand conditions.
2. *Know the site and stand characteristics:* Soil factors (texture, drainage, rockiness), stand factors (age, density, structure), and tree factors (species, size, vigor) can all affect levels of residual stand damage and also subsequent stand response to harvesting.
3. *Assess current (pre-harvest) stand health and tree vigor:* Avoid harvesting in stands that have been recently defoliated by insects, or stressed by drought or other weather conditions. Pre-salvage operations always require exceptional care in planning and execution, yet are often conducted without consideration of the potential for increased damage in stands already impaired from some other factor.
4. *Clearly identify the crop trees and use extra caution when working near them.* Especially for hardwood stands, the value of a few high-quality stems may far outweigh the product

- value of the rest of the stand. Clearly mark trees with high value potential. If necessary, leave adjacent, low-quality stems uncut rather than risking injury to high-value stems.
5. *Use branches and slash in trails as a protective roadbed:* This practice can now be accomplished with several of the in-woods processing systems now available. In addition to protecting roots from injuries added advantages include protection of young seedlings, and better nutrient distribution for recycling.
 6. *Use bumper trees—designate them before harvesting begins—consider using “artificial” bumpers:* Bumper trees placed along primary skid trails or access corridors can be removed at the end of the operation. If cutting cycles are expected to be more frequent than every 15 years, bumper trees can be left to serve in the following harvest.
 7. *Consider season of harvest - usually there is less damage during winter months:* Frozen ground and snow cover protect roots from injuries. In addition, especially in hardwood stands, visibility is improved compared with summer months. This allows for more precise positioning and maneuvering of equipment.
 8. *Match equipment type and size to stand and site conditions:* Small equipment is more maneuverable, but is also more invasive in the stand. Equipment handling stems at the upper limit for which it was designed can result in higher damage levels than larger equipment.
 9. *Know pattern of previous harvest—multiple injuries are especially damaging:* Reuse previous skid trails and bumper trees when appropriate, but otherwise avoid damaging previously wounded trees.
 10. *Bark is easily injured during spring and summer—tight bark develops late in summer:* Given the level of force that most harvesting machinery now has, bark is just as easily damaged in the summer as in the spring. Operations need to be carefully conducted in all seasons.
 11. *Use high-flotation tires/tracks on the more fragile sites, as appropriate:* This recommendation is based on studies of softwood sites, but may apply in certain circumstances to mixed wood and hardwood sites as well.
 12. *Limit or concentrate machine activity on skid trails and access corridors:* Concentration of machinery and activities to trails will also concentrate residual damage. Plan to remove (sacrifice) severely damaged trees at the end of the operation.
 13. *Increase awareness of consequences of mechanical injuries to trees and forest stands:* Regular training sessions and active participation of the operators and foresters with post-harvest stand evaluations will improve operator performance and justify appropriate compensation.
 14. *Use silvicultural prescriptions that concentrate harvesting activity, when possible:* Small patch cutting, or group selection methods, tends to result in lower damage levels, and optimizes opportunities for volume removal. Light, area-wide harvesting with frequent entries, such as selection cuttings, need to be most carefully conducted.
 15. *Landowner, forester, logging contractor, and equipment operator share job performance responsibilities:* Communication and understanding of problem conditions or situations should be forthcoming before harvesting begins.
 16. *Agree to be more “weather sensitive” when harvesting—delay harvesting earlier and initiate harvesting later when wet conditions occur:* Recognizing that operators need as large a window of time for operating as practical, prioritize stand operations. Operate high-value stands only when conditions are optimal.
 17. *Minimize the number of stand entries:* The risk of frequent stand entries lies in the higher probability of occurrence of multiple injuries. Frequent entries should rely more heavily on using previously existing skid trails and access corridors with designated bumper trees.
 18. *Recognize that sapling/pole stages are most vulnerable to damage (size and time):* This results because the relative density of the desired residual stems is high and because trees above the sapling stage are less flexible. This may change as new equipment is adapted and designed to harvest this stand type.
 19. *Prioritize efforts to reduce injuries to roots/soil first, upper bole/crown next, then root crown:* Efforts to reduce root and soil damage and disturbance will enhance stand stability and health. Damage to individual boles will reduce value, but probably has less effect on overall stand integrity.
 20. *Extraction of larger pieces has higher potential for causing damage than that for smaller loads:* Newer short-wood forwarding systems can result in less damage than log or full-tree skidding.
 21. *Extraction of heavy loads has higher potential for causing damage than that for lighter loads:* This recommendation is made based on a trip-for-trip comparison. Optimization of load size

and number of trips requires careful operations analysis to determine the trip/size combination that will result in minimal damage.

22. *Use crop tree selection methods rather than area-wide thinning techniques when possible.* Marking individual, high-value crop trees and planning operations around them will ensure their protection from residual stand damage.
23. *Avoid harvesting "wolf" trees whenever possible—leave as "legacy," or wildlife trees.* Large trees with large crowns can result in considerable damage to residual trees during both the felling and skidding operations.
24. *Mark skid trail locations prior to harvest.* Planning the layout should be followed by on-site marking of trails. This will not only clearly establish the trails, but will allow for an additional pre-harvest assessment of site and stand conditions.
25. *Assess risk of sun scald to residual trees - consider trail/access corridor orientation:* Modify orientation of skid trails based on slope and aspect, where possible, to avoid leaving boles facing southern or southwestern exposures.

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NORTHERN HARDWOODS - DECISIONS OF MANAGEMENT AND MARKETS

Mike Dann

Seven Islands Land Company

Forest health issues in northern hardwoods rarely reach the catastrophic proportions that can occur in the spruce-fir forest. Health and quality issues are managed on a stand and individual tree basis. It has been said that when managing northern hardwood, “you make 90% of your money on 10% of your wood”. If that is true, is it possible to make 180% of your money on 20% of your wood? I think so, and believe the keys are having a forester on the ground prior to the harvest and closely controlling the harvest when it happens.

THE OAK-PINE REGION OF MAINE: AN UPDATE FROM THE HOLT RESEARCH FOREST

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A long-term, oak-pine (*Quercus rubra* L., *Pinus strobus* L.) forest ecosystem study has been underway at the Holt Research Forest in Arrowsic, Maine, since 1983. Research at the Holt Forest has two goals: monitoring long-term changes in the forest's plant and animal populations and documenting the effect of forest management on these populations. The management plan features three goals: maximizing the production of high-quality timber, enhancing wildlife diversity, and partial harvest during the winter of 1987–88. That initial entry had three objectives: removing the slow-growing and poor quality trees, creating enough gaps in the canopy to foster pine and oak regeneration, and building more vertical structure in the stands than otherwise would be found in a fairly young (60- to 80-year-old) post-agricultural forest. This talk presents our observations to date. Some of these findings will stand up to rigorous statistical testing; some are just observations that others might find helpful or worth studying themselves.

WHITE PINE AND RED OAK: MARKETS, MANAGEMENT, HEALTH ON SMALL PRIVATE LANDS

Rene D. Noel, Jr.

Southern Maine Forestry Services, Inc.

We are a small forestry consulting firm. We have a client list of something over 600 and manage about 45,000 acres for about 300 of these clients. We have been in the business of doing this since 1981. Prior to this I worked for the State of Maine as a service forester for seven years giving me almost twenty-five years of experience in managing small private woodlands. I have always been an on-the-ground managing forester and have become very familiar with the land we manage and the owners of that land. The goals of our clients are as varied as people anywhere. We deal with clients who range from those with close to a preservation orientation to those whose goal is maximum short-term income.

I do not pretend to be an entomologist or pathologist and what I am reporting to you is all based on anecdotal evidence and personal observation. Furthermore, I am a general practitioner and have to deal with forest health problems and design management strategies to achieve client goals as one of the many things a forester in private practice must do.

As an example, there is a mixed white pine/Norway pine plantation owned by a water district. It lies between a lake, which is a public water supply, and a heavily traveled numbered highway. Soils provide very good sites for white pine, but have shallow rooting depth and provide poor sites for Norway pine. The plantation is about 55 years old. At about age forty much of the Norway pine stagnated. *Fomes* root rot had infected it and windthrow and mortality increased. Early thinnings had removed weeviled and suppressed white pine, making a forest that was composed two-thirds of Norway pine. A conventional recommendation would have been to harvest all of the Norway. In this situation that was unacceptable. High public visibility, shoreland zoning and a desire to maintain a forest canopy over the watershed tipped the scales toward a gradual removal of the Norway pine in an extended shelterwood. Sanitation cuts removing dying Norway pine on a five-year cutting cycle have been utilized. Natural regeneration of white pine has been reinforced by planting white pine seedlings in any large openings or understocked areas. The overstory is now about half white pine and there is a fairly good understory of pine regen-

eration. Two more cutting cycles will likely be needed to harvest the remaining Norway pine.

A quick summary of the status of major forest health problems in southern Maine is in order. From what I see the health of the white pine/red oak forest of southern Maine has not changed notably over the last 30 years. Things come and go caused by whatever nature provides, but in the long run the healthy forest has sustained itself. Currently, the acute problems are trees damaged by last winter's ice storm, a blow down of 10 MMBF to 20 MMBF which occurred about a month ago and a decline problem of white pine for which the drought of 1995 is being blamed as the precipitating event. The activities of foresters and logging contractors in the affected areas have been heavily oriented to salvaging these damaged and dying stems. Everything else has taken the back seat.

All our other problems seem to be at endemic levels. Gypsy moth populations collapsed about eight years ago and have not been able to recover. Some stands had a fairly high number of healthy-sized egg masses this spring, but the caterpillars wilted when they were about half grown after little defoliation. I'll leave it to the specialist as to what virus or fungus attacks these caterpillars, but maybe with luck major defoliations by this insect are a thing of the past.

My opinion is that white pine weevil is the most serious deterrent to managing white pine intensively. The degrade caused by this insect is well documented. Managing for rapid growth of seedlings and saplings creates an ideal environment for the insect. If no control is applied, damage is severe. The only effective control remains treating individual leaders with Lindane or Dimilin. It is expensive, but I think a worthwhile investment for many. Using what I think are reasonable assumptions and constant dollars, returns in the 4% to 5% range are possible using a \$600 per acre land value as compared to 2% to 3% for not treating.

White pine blister rust is still around. I cannot say that I have noted any increase since *Ribes* control efforts have declined. I think I am seeing more *Ribes* plants and will be "interested" to see what will happen in the future with this disease.

Target cankers on oak can be a problem on sites with site indexes of less than 60 feet. These are sites that are much more productive for growing white

pine, but for wildlife and/or aesthetics reasons, and sometimes they are the best tree to grow in that spot. Our clients like us to hold some oak stems on these sites.

The final health problem I want to mention specifically is decay. Usually when there is a significant problem with decay in a stand there is obvious cause in the history of the stand. Some times it is of natural origin as in a past defoliation which caused dieback of major limbs, but very often it is the past management of the stand. Logging damage, high-grade cuts that left mostly suppressed stems, stands that have been left stagnant much too long. In managed stands far too often it is logging damage. Wounds to the stem are obvious, but root damage is much less obvious and is as damaging. A couple of years ago I supervised a thinning of a white pine stand on a good site. It was the third time the stand had been thinned. Much more red rot was present in this stand than I would have anticipated. In the early to mid-80s the wood had been stump cut and yarded by a small crawler tractor with a loader and a wagon. This is now called a cut-to-length system. This small equipment had woven in and around the trees and done little obvious damage to the stems. However, on looking things over more carefully it was obvious the ground had been soft during the 1980s thinning. I assume that there had been significant root damage that had allowed decay fungus to enter the trees. The loss to this owner cannot be quantified, but there was some scale deduction and some logs had to be sold as pulpwood. Logging damage is something that we as managers can do things to minimize.

Forest health does affect the returns achieved by small forest landowners. Is it a problem for these landowners? The answer is to some it is, and others are clueless.

Unfortunately a large percentage of landowners degrade the health of their forests by their choice of management. High-gradings, diameter limit cuts, harvests of high-value species, extensive soil, root and stem damage during harvests and leaving stands overstocked with stagnant stems all result in forests that are not in the peak of health and more susceptible to attack by insects or diseases. However, the negative effect of insects, diseases, and abiotic agents on the returns available from their forests is probably minor compared to the damage they do to themselves.

For those landowners who are practicing good silviculture the more intensively they manage the more they are affected by agents that damage their trees.

One inescapable conclusion I have reached over the years is that owners of small woodlots cannot make it economically by growing products with a low stumpage value. The only hope of decent returns on forestland is for landowners to grow the highest quality trees that the land is capable of producing.

To accomplish that, I point out to my clients that each stem in their forest should have a purpose in being there. A stem should be a crop tree, an insurance stem, provide training or protection to crop trees, a replacement, regeneration, a wildlife tree, provide amenity value or otherwise have a purpose. It is much more profitable to concentrate growth on 25 to 100 crop trees per acre than to grow many low-value small stems.

For example, high grading a large pole/small sawtimber size stand might yield a landowner \$500 per acre. It would likely be 20 or 25 years before that forest can yield that level of income again. The alternative would be to do a silviculturally proper thinning and nurture 25 to 100 crop trees per acre until they are economically mature. A high-quality red oak and white pine stand of trees this size has a potential stumpage value of \$2,000 to as much as \$10,000 per acre. Without figuring in income from intermediate thinnings, taxes, and management expenses, the gross rate of return would be 5% to 20% in constant dollars on the foregone income from high grading.

This return is easily possible. Over the years I have measured a number of stands with 10 MBF per acre of high-quality oak and many more pine stands with over 25 MBF per acre.

From seedling to mature crop tree of 18 to 24 inches in DBH takes a long time, at least fifty years to as much as a hundred with reasonable intensive management. During this time fungi, bacteria, and insects are all quite happy to make lunch out of some part of the tree. They are aided and abetted by mechanical injury from a number of sources. Logging damage is of particular concern. Over the life of a stand it may be treated with half a dozen or more intermediate thinnings. The more intensively landowners manage to grow large high-value trees the more they are affected by the health and vigor of each individual stem as well as overall forest health.

MAINE'S SPRUCE-FIR FOREST AFTER THE SPRUCE BUDWORM EPIDEMIC

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Maine's spruce-fir resource consists primarily of balsam fir (*Abies balsamea*) and red spruce (*Picea rubens*). Balsam fir regenerates prolifically under shade, is fast growing, and is short lived (40–70 years) (Frank 1990). Red spruce is much more inconsistent in regeneration, persists under shade, releases well, and is long lived (300+ years) (Blum 1990). The spruce-fir forest makes up 44% of the state's resource. Balsam fir and red spruce provide 46% of the softwood volume (inventory). What has had a major influence on the health and dynamics of the spruce-fir forest over the last century are spruce budworm (*Choristoneura fumiferana*) epidemics. Larvae of the moth can defoliate conifers over a period of years causing especially high mortality in balsam fir (Kucera and Orr 1981).

Spruce budworm outbreaks causing widespread mortality in Maine occurred in 1972–86, 1913–19, and possibly the early 1800s (Seymour 1992). Another outbreak in 1949–59 caused defoliation of trees, but low mortality (Irland et al. 1988). The interval between outbreaks may be decreasing because the amount of balsam fir in the forest, the

preferred host for the insect, is increasing while incidence of tolerant and non-host species are decreasing (Blais 1985). This could be due to heavy harvesting of red spruce, short rotation forestry favoring fir's ecological niche, and fire control resulting in less prevalence of hardwoods.

Prior to the 1972 outbreak, moderate to severe defoliation by spruce budworm was occurring, but generally at less than half a million acres per year (Figure 3). Beginning in 1972, the acres defoliated increased dramatically to nearly 8 million acres in 1975, possibly due to an influx of insects from the west (Blais 1985). The defoliated acres decreased slowly until 1983 after which the spruce budworm population crashed to the point where no defoliation was occurring by 1990.

During this time, stand susceptibility to budworm mortality was related to high amounts of fir, mature stands and trees experiencing additional stress from high densities, excessively wet sites, or excessively dry sites (Diamond et al. 1984; Blum and MacLean 1985). While red spruce was expected to suffer much less mortality, there was concern

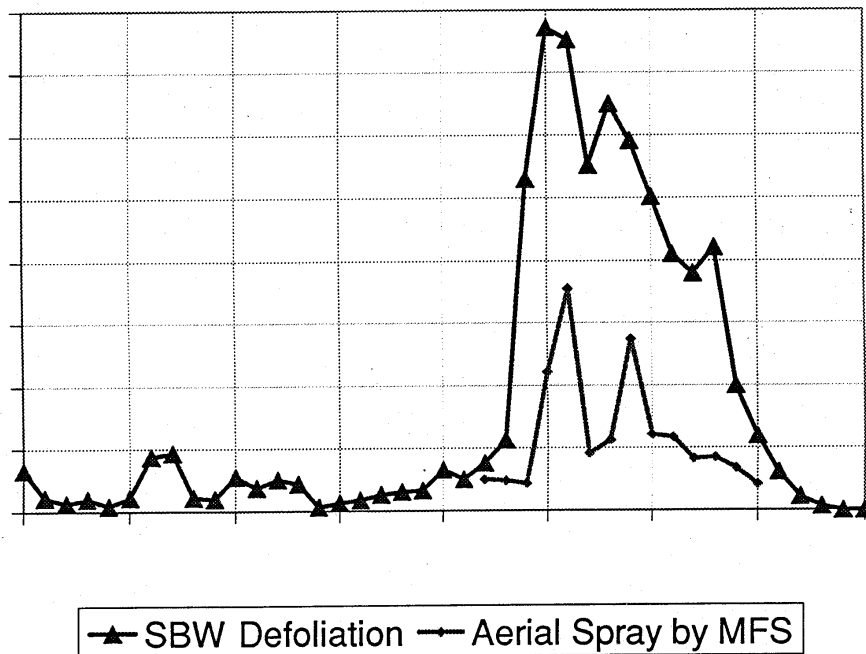


Figure 3. Spruce budworm 1972–86 epidemic.

about subsequent windthrow after the stands became more open due to the fir mortality or partial harvesting (Blum 1990).

To examine if these hypotheses and observations are consistent with what survived the last outbreak, data from the 1995 U.S. Forest Service Inventory was used (Griffith and Alerich 1995). The inventory consisted of 3001 plots located throughout the state. Of these, 2,192 were included in the 1982 inventory so that a comparison between the two inventories is possible. This was done by examining the original data set. Trees >5 in. dbh were sampled in 1/5th-acre plots, stems 1-5 in. dbh were sampled in five 6-ft radius plots and generation from 12 in. high to 1 in. dbh were measured in fir 3.7-ft radius plots. Only trees >5 in dbh were included in the 1982 inventory. The status of these trees in 1995 were recorded as living, cut, or dead. Therefore, mortality occurring between the inventories was estimated by calculating the 1982 basal area of the trees that were killed by 1995. This was then expressed as a percentage of the total 1982 basal area per acre for a plot.

The mortality data has some limitations. The budworm defoliation was widespread by 1975, but mortality prior to 1982 inventory is not included. Therefore, mortality is likely underestimated for susceptible fir. In addition, total mortality cannot be accurately estimated on harvested sites because dead or dying trees could have been removed. Also, it is not certain that mortality on non-harvested plots is an appropriate estimate of potential mortality on harvested plots because of bias. For example, harvesting may have been more likely on sites that had higher mortality, or harvesting may have been more likely on sites with more valuable trees. Finally, all mortality by natural causes was included. Therefore, it is not known how many trees died directly from defoliation, windthrow, bark beetle attack, or other causes. It is assumed in this report that much of the spruce-fir mortality in the inventory is related to the high amounts of spruce budworm defoliation that occurred between 1972 and 1986.

Results clearly show that balsam fir mortality (23%–49%) in non-harvested plots was much higher than red spruce mortality (10%–18%) in plots with fir >8 in dbh (Figure 4). About 70% of the red spruce plots had less than 10% mortality while only ca. 25% of the balsam fir plots had low mortality. On plots with smaller balsam fir (5–8 in. dbh), mortality was reduced only slightly (Figure 5). Fir mortality was lower only if fir basal area was 15% or less of the plot's total. Red spruce mortality was largely

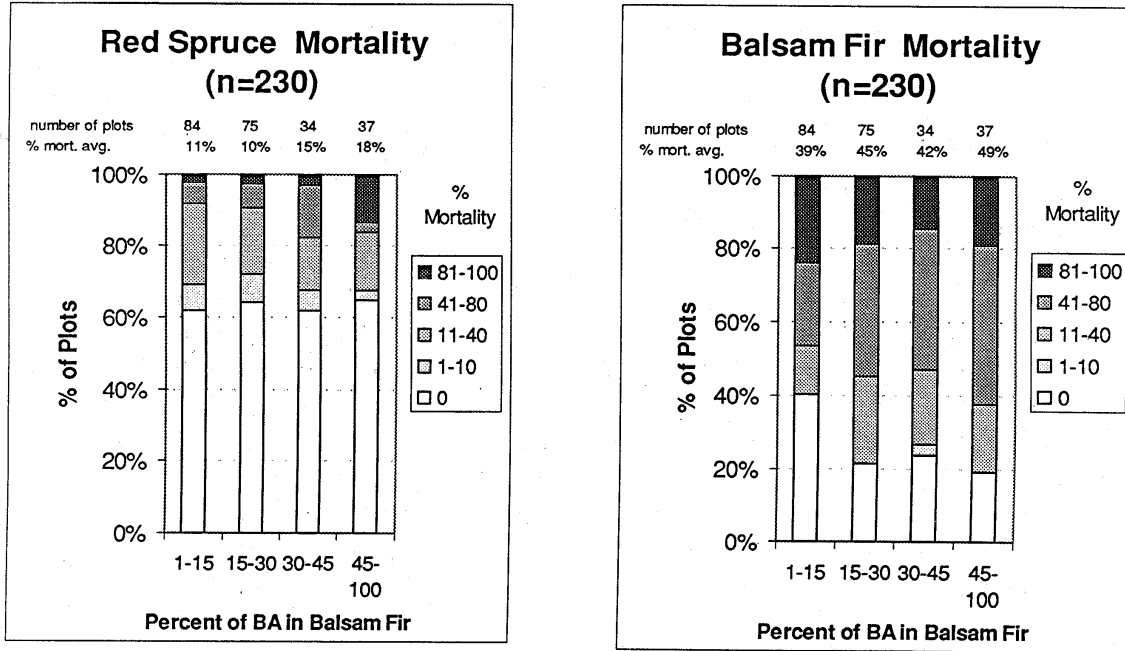
unaffected by size of balsam fir or amount of fir in the stand.

What survived the spruce budworm epidemic was estimated by selecting data from 210 plots with more than 30 sq ft basal area of red spruce in the 1982 inventory. This ensured that plots were dominated by spruce and fir. Thirty-seven percent of the plots were non-harvested, and they contained few stems of balsam fir whereas red spruce is well stocked and dominating the overstory (Figure 6). In contrast, 45% of the plots were heavily harvested (>50% of basal area), and there were essentially no large stems of either species on the plots. Both non-harvested and heavily harvested plots have a large amount of balsam fir regeneration and a much lower amount of red spruce regeneration (Figure 7). In addition to the conifer regeneration, harvested plots have a high amount of hardwood regeneration that is not present on the non-harvested sites.

Evaluating the future health of the spruce-fir forest that has survived the spruce budworm outbreak can be done in the context of a possible "Golden Rule" for forest health. The rule states that the less a tree species is adapted to site conditions (including natural disturbances), the more health problems you are likely to have. The natural composition of Maine's spruce-fir forest has been influenced by spruce budworm defoliation, and this has favored a mixed forest consisting of young fir regenerating from epidemics and an older spruce overstory that survives epidemics. This is clearly seen in the non-harvested plots, and these stands are likely to continue to develop in a healthy, predictable manner.

In contrast, the harvesting of the spruce overstory is creating a situation to which spruce is not adapted; it's continued presence in the overstory has been shortened. Because of spruce's lower regeneration capacity in comparison to balsam fir's and hardwoods (Figure 7), we should be concerned about its future capacity for regeneration. In addition, the natural spruce-fir forest presumably has not had such a high component of balsam fir as will develop on the harvested sites. One possible adverse consequence of this change is an increase in frequency and severity of spruce budworm epidemics.

Another consequence of the loss of the red spruce overstory plus increased competition by hardwoods in the heavily harvested plots is its contribution to the conifer supply "gap" or lack of conifer wood for commercial use in the near future. Stands dominated by balsam fir will likely continue to go through a "boom" and "bust" cycle. As a result,



Plots with >15% balsam fir have higher balsam fir mortality

Figure 4. Non-harvested plots with fir >8" dbh. Balsam fir mortality was higher than red spruce mortality.

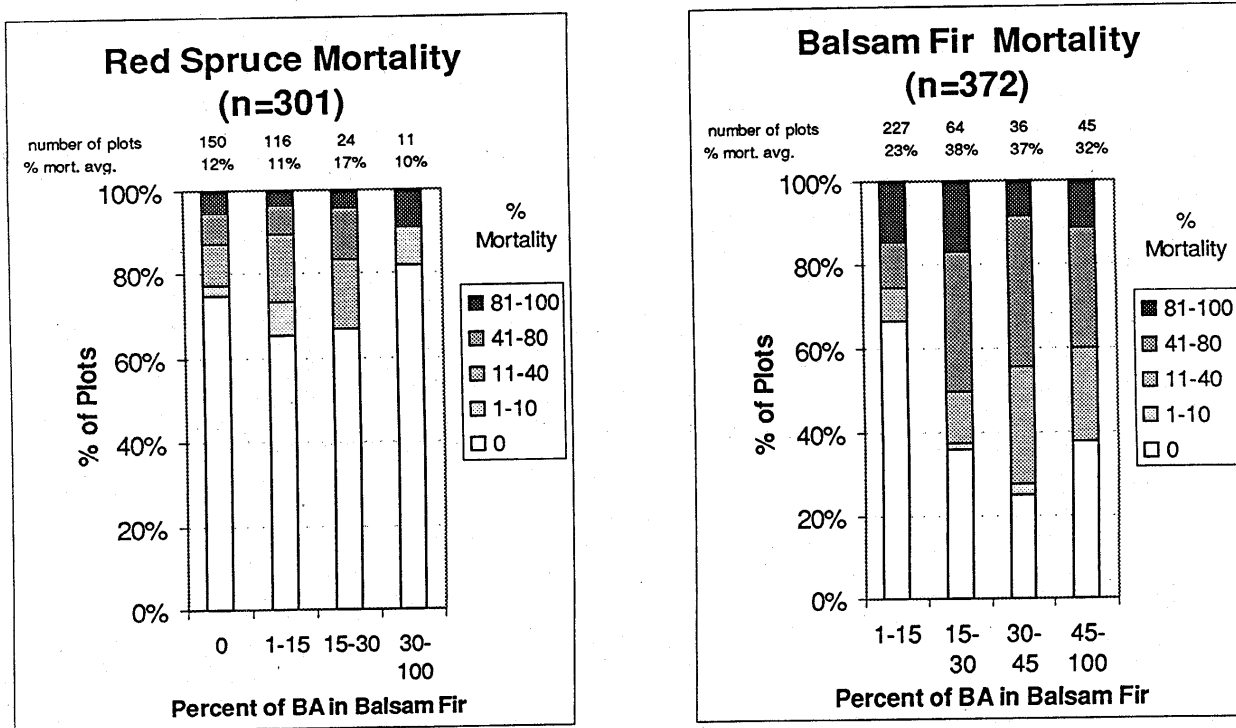


Figure 5. Non-harvested plots with smaller trees (5-8" dbh). Balsam fir mortality remained high.

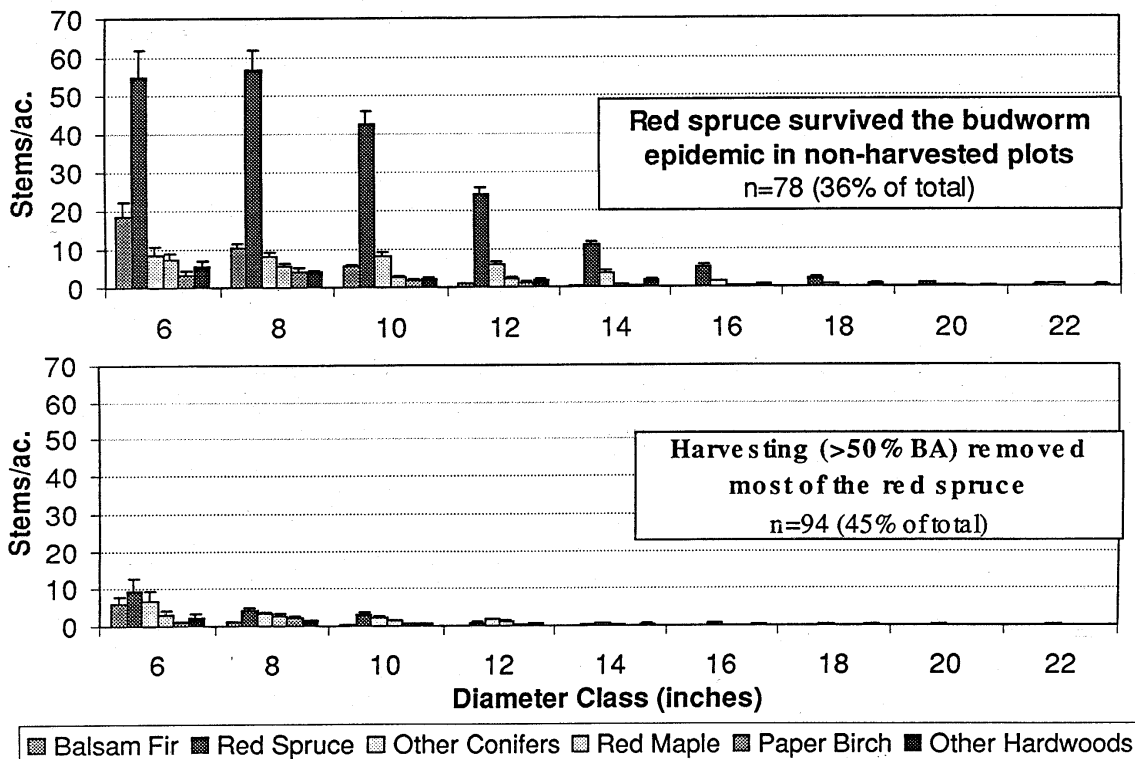


Figure 6. 1995 Average number of tree stems for plots that had >30 sq ft/ac red spruce in 1982 (210 plots total).

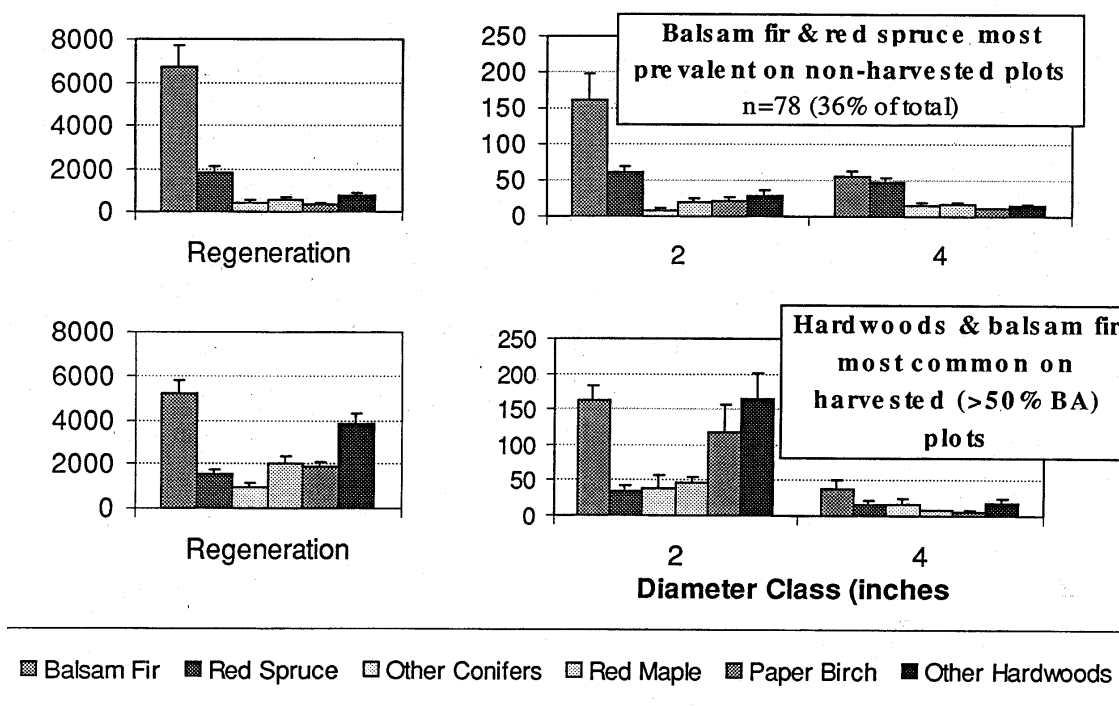


Figure 7. 1995 average number of regenerating and sapling stems in plots having >30 sq ft/ac red spruce in 1982.

we will continue to have large tracts of spruce-fir forest in a similar age class that is set by the periodicity of spruce budworm epidemics.

Susceptibility of spruce-fir forests to spruce budworm mortality could be decreased by reducing the amount of balsam fir, increasing the amount of red spruce, and maintaining stand vigor. Silvicultural practices on the Penobscot Experimental Forest have successfully met these objectives (Frank 1985). Two- and three-stage shelterwood treatments combined with thinning-out the fir has increased red spruce growing stock from 11%–25% to 41%–55% in 17 years. Red spruce regeneration has increased from 2%–7% to 40%–75% of the stems in 16–29 years.

If natural regeneration of red spruce is not available, then other non-host species can be favored such as white pine on the drier sites. On spruce-fir sites with poor conifer regeneration, plantations of black spruce (Blum and MacLean 1985), poplar, or larch (Gilmore et al. 1998) are possible alternatives. Another possibility is to take advantage of red spruce's ability to persist in the understory by planting red spruce under fast growing trees such as larch or poplar. After the fast growing trees are harvested, then red spruce is released to supply future conifer wood and to regenerate the site.

In conclusion, data from the U.S. Forest Service inventory are consistent with previous hypotheses concerning spruce budworm and the spruce-fir forest. Harvesting practices are apparently favoring an increased incidence of balsam fir and hardwoods over red spruce. However, red spruce clearly can survive spruce budworm outbreaks whereas most balsam fir cannot. It is likely that Maine's future forest will be more susceptible to mortality caused by spruce budworm defoliation because of the increasing proportion of balsam fir in the stands. Reducing the susceptibility of spruce/fir forests to mortality incited by spruce budworm will involve reducing the amount of balsam fir, increasing the amount of red spruce and maintaining stand vigor.

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IS FOREST HEALTH AN ISSUE AMONG MAINE'S LOGGERS?

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With few exceptions (e.g., Egan et al. 1997; Greene et al. 1998) the voice of the professional logging community on forestry-related issues has been overlooked. Loggers are often perceived to be relatively inaccessible and less likely to respond to surveys or interviews than other forestry-related populations such as landowners and foresters (Egan 1996). Yet loggers are indispensable players in most forest management activities and have become both increasingly knowledgeable and vocal about forestry issues. In addition, when the health of components of the forest is threatened by a biotic agent such as spruce budworm, the logging industry is often expected to adapt equipment, human resources and expertise to accommodate forestry's responses to the phenomenon. The purpose of this study was to detect the level of concern for forest health within Maine's logging community, particularly among those loggers who harvest the spruce-fir resource.

Methods

A survey was conducted of 68 of the largest and most experienced logging contractors in Maine who harvest some spruce and fir. Multiple survey mailings were used in order to mitigate bias due to non-response (Dillman 1978). Questions designed to elicit information on (a) the issues of greatest concern to the logging community and (b) factors that limit the ability of loggers to maintain or expand their businesses were posed.

Results

Approximately 69% of loggers who were mailed the survey responded. Over 22% of these responses derived from the second of two survey mailings. The average respondent was 44 years old and has been in the logging business for 22 years. All respondents harvested some spruce and fir and on average spruce-fir constituted 32% of the volume harvested by this group (Table 3).

Analysis of the survey results indicated that, although there may be general concern about the health of Maine's forest among loggers, other issues such as uncertainty about the future of logging in the state, shortage of reliable labor, mill prices, costly regulations, and equipment costs represent

Table 3. Characteristics of survey respondents and their operations.

Attribute	Average
Age (years)	44
Logging experience (years)	22
Spruce-fir harvested (%)	32
Equipment mix	
Skidders	5.5
Feller-bunchers	1.1
Cut-to-length	0.4
Forwarders	0.4

Table 4. Loggers' responses to the question, "What factors most limit your ability to maintain or expand your logging business?"

	Unimportant	Important	Very Important
	----- % -----		
Uncertainty about health of forest resource	28.3	60.9	10.9
Uncertainty about future of forest resource	17.4	47.8	34.8
Shortage of reliable labor	10.9	43.5	45.6
Equipment costs	4.3	27.7	68.1
Prices paid by mills	0.0	14.9	85.1
Too many costly regulations	12.8	27.7	59.6
Uncertainty about future of logging in Maine	6.5	73.9	19.6

more pressing concerns (Table 4). Forest health-related concerns cited by some loggers included the use of herbicides, harvesting of immature trees, and lack of forest stewardship among some of the state's landowners. In addition, over two-thirds of the respondents, including eight of the ten cut-to-length contractors who took part in the study, indicated that they were either "concerned" or "very concerned" about overcutting of the forest resource (Table 5).

Table 5. Loggers' responses to the question, "What are your major concerns about the forest resource?"

	Not Concerned	Concerned ----- % -----	Very Concerned
The health of the forest	21.7	60.9	17.4
Overcutting	30.4	41.3	28.3
Not cutting enough	66.7	24.4	8.9
Too much clearcutting	40.0	46.7	13.3
Too little clearcutting	69.6	28.3	2.2
Timber availability	13.0	58.7	28.3
Poor forest management practices	28.3	41.3	30.4

Conclusions

Maine's spruce-fir loggers identify forest health as an issue, indicating that (a) it is an "important" factor in their ability to maintain or expand their business and (b) they are "concerned" about forest health-related issues. However, other issues, such as equipment costs, regulations, and the future of logging in Maine, were identified as greater obstacles to maintaining or expanding their businesses. That overcutting, timber availability, and poor forest management—issues related to overall forest health—were also identified as "concerns" by most respondents, may indicate both a broader concern for the condition of Maine's forests, as well as a disconnect between many in the logging and forestry communities on the ways forests are managed.

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PUBLIC PERCEPTIONS OF RISK ABOUT MANAGING THE FOREST

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Introduction

To successfully manage and improve the health or condition of Maine's forests, a wide array of tools must be available to forest managers. Chemical herbicides are widely used across North America to manage forest vegetation for the purpose of improving the survival, growth, and composition of regenerating forest stands.

Stimulated by strong public opposition to herbicides, research efforts in recent years have sought to develop alternatives to herbicide use, especially aerial forms of application. Just as public opposition to herbicides has been based on a perception of unacceptable health and environmental risks relative to the perceived benefits, the acceptability of any proposed alternatives also will be linked to their perceived net risks. Efforts to develop alternatives have generally been justified under the assumption that the proposed alternatives would be perceived by the public as having lower risk and therefore be more socially acceptable.

There is, however, little information available on public perceptions of risk and acceptability for forest vegetation management alternatives. The objective of this study was (1) to quantify the perceived health and environmental risks of forest vegetation management alternatives by the general public; (2) to document public acceptability of those alternatives; and (3) to examine the relation between perceived risks and public acceptability of the alternatives.

Materials and Methods

The database for this study came from a survey of residents 18 years of age and over from the province of Ontario, Canada. Questions about the risk and acceptability of nine forest vegetation management alternatives were asked as part of a larger telephone-administered questionnaire about other forestry issues that included 140 questions and took 30 to 40 minutes to complete. All data were collected between September and November 1994 by Goldfarb Consultants, an Ontario firm specializing in survey research, using a computer-assisted telephone interviewing (CATI) system. Stratified random samples were drawn for the general public (N=1,500) and residents of timber-dependent communities (N=801). The surveyed populations were stratified by community size to ensure proportionate representation of all areas in the province.

Perceptions of risk for nine forest vegetation management alternatives were assessed using the degree of respondent agreement with statements about four dimensions of risk that have proven useful in other studies. Respondents were asked to rate whether they strongly disagreed, disagreed, agreed, or strongly agreed that the risks of each alternative are (1) difficult to control, (2) potentially catastrophic, (3) a problem for future generations, and (4) a personal worry.

Respondents rated the acceptability of each alternative as either very unacceptable, unacceptable, acceptable, or very acceptable. To examine the relation between the four dimension of risk and the acceptability of the vegetation management alternatives, a risk perception index was calculated using the sum of the percentages of respondents strongly agreeing with the four risk statements. We correlated this index with the proportion of the sample population either accepting or strongly accepting each alternative.

Results and Discussion

Based on the four dimensions of risk, public ranking of the alternatives from lowest to highest perceived risk was grazing animals < manual cutting < cover cropping < heavy equipment < prescribed fire < mulches < ground-applied herbicides < biological control < aerially applied herbicides (Figure 8). Public acceptance of the alternatives was lowest for aerially applied herbicides (18%) followed by ground-applied herbicides (37%), biological control (57%), prescribed fire (57%), mulches (65%), heavy equipment (72%), cover cropping (80%), grazing animals (82%), and manual cutting (89%) (Figure 9).

We found a strong correlation between the risk perception index and acceptability of the alternatives for the general public (Figure 10). Comparison of results obtained for the general public and those in timber-dependent communities revealed only minor differences in perceptions of risk and acceptability of vegetation management alternatives (Wagner et al. 1998a).

In addition to indicating strong support for non-herbicide alternatives, the public strongly agreed with the goal of forest vegetation management. Controlling unwanted vegetation to improve the survival of planted trees was supported by 82%

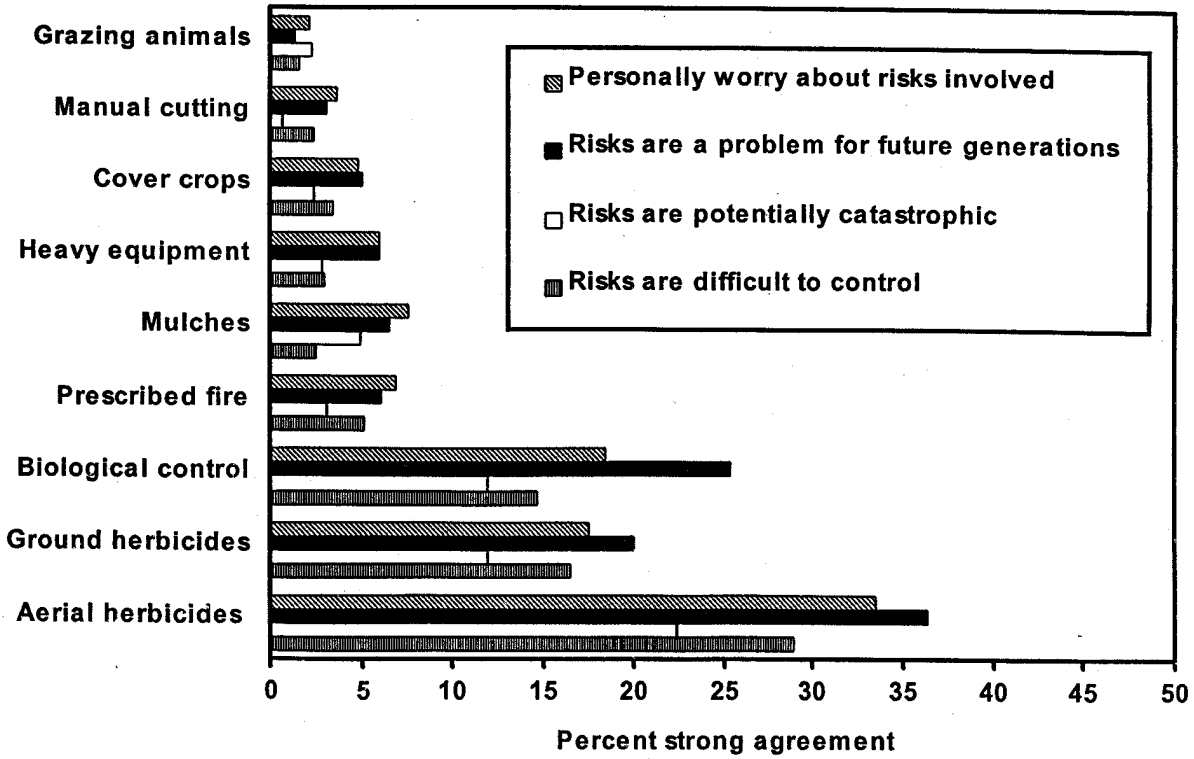


Figure 8. Proportion of the general public in Ontario strongly agreeing with four statements about the risk of nine forest vegetation management alternatives.

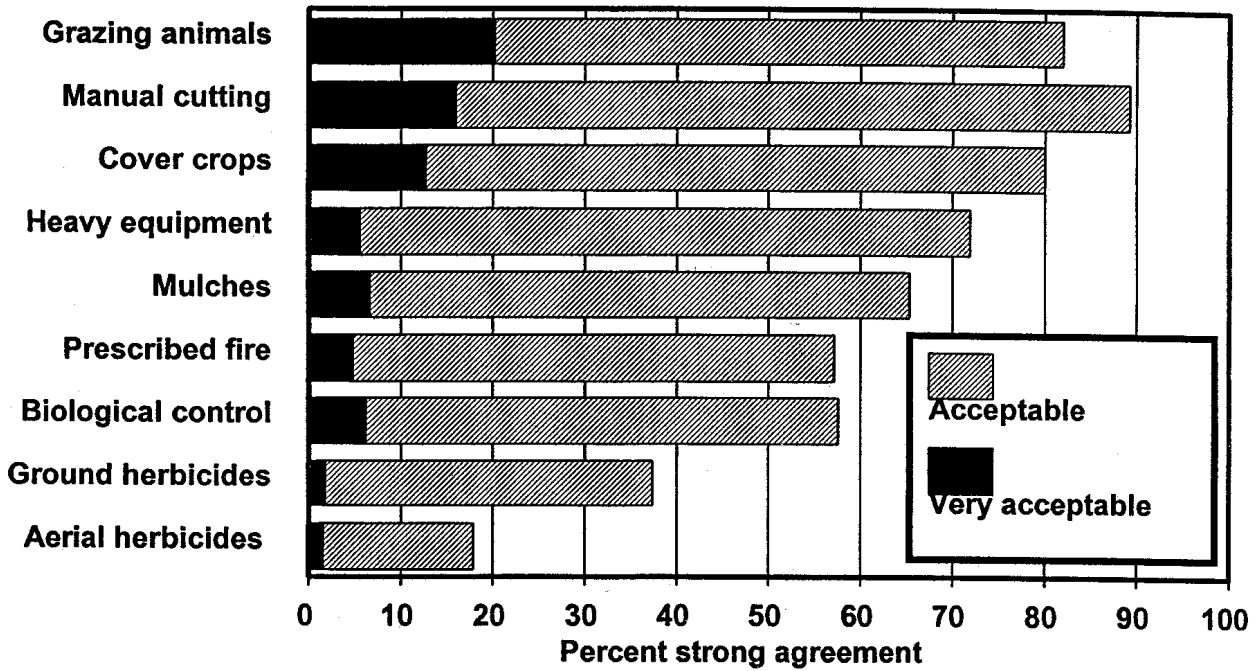


Figure 9. Proportion of the general public on Ontario finding nine forest vegetation management alternatives as acceptable or very acceptable.

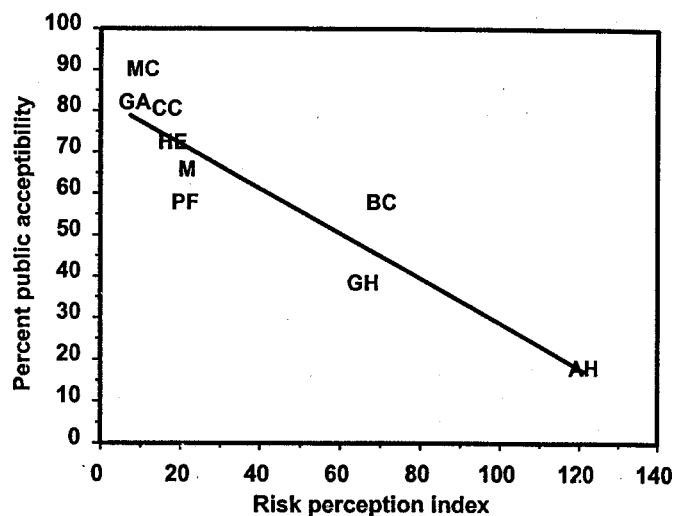


Figure 10. Relation between risk perception index (sum of percentage of those strongly agreeing with four risk statements) and the acceptability (percentage of acceptable plus very acceptable responses) of nine forest vegetation management alternatives for the general public in Ontario. Symbols are: AH = aerial herbicides, GH = ground herbicides, BC = biological control, PF = prescribed fire, M = mulches, HE = heavy equipment, CC = cover crops, MC = manual cutting, GA = grazing animals. The linear relation is: $y = 82.94 - 0.542x, r^2 = 0.84$.

of the general public and 78% of those from timber-dependent communities (Wagner et al. 1998b). The public also supported the use of science and scientific experts as a means to settle disputes about risky forestry activities. Thus, the objectives of vegetation management and the use of science for decision making represent areas of common ground between the public and forestry professionals.

The acceptability of non-herbicide alternatives by forestry professionals in Ontario was at least as great or greater than that of the public (Wagner et al. 1998b). Although the public and forestry professionals agreed on the objectives of vegetation management and the basis for decision making, we found a large difference between forestry professionals and the public in the acceptability of methods to achieve the objectives (Figure 11). The greatest difference between the public and forestry professionals was in the level of support and perceived risk of practices, like herbicide application, that the public finds risky and unacceptable. Even when faced with situations similar to those under which forest managers operate, the public differs from forestry professionals in their choice of vegetation management approaches (Gregory et al. 1997). This troublesome gap between the public and forestry professionals is an important issue for forest policy makers and underlies many communication

problems with the public in formulating and obtaining support for forest management plans.

Strong public support for forest vegetation management programs, therefore, can likely be achieved through sincere efforts to include non-herbicide alternatives and other practices perceived as environmentally sensitive and restorative. Such efforts may help improve public trust of vegetation management programs and could increase public support for herbicides if they are used judiciously as part of an integrated management effort.

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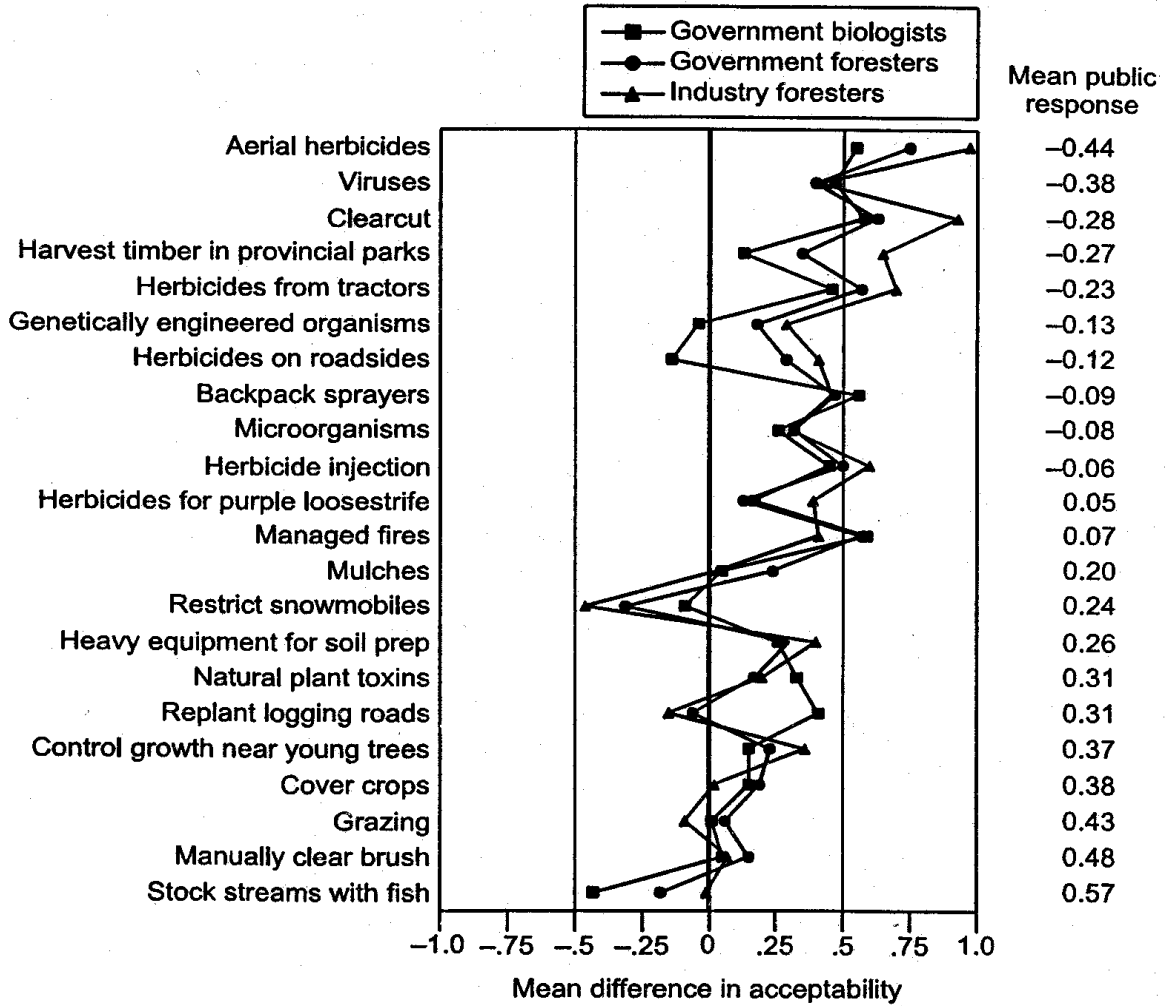


Figure 11. Difference in acceptability of vegetation management and other forestry practices between the public and forestry professionals.