NATURAL CAPITAL INITIATIVE AT MANOMET REPORT

Biomass Sustainability and Carbon Policy Study

Chapter 4

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CHAPTER 4
FOREST SUSTAINABILITY AND BIOMASS HARVESTING IN MASSACHUSETTS

4.1 INTRODUCTION

The objective of this task of the Biomass Sustainability and Carbon Policy study is to evaluate the potential impacts posed by increased biomass harvesting in the forests of Massachusetts and offer recommendations for mitigating any negative outcomes that are identified. Although biomass harvesting offers opportunities to enhance silvicultural treatments and produce greater quantities and quality of traditional forest products such as sawlogs these economic impacts are not the focus of this chapter. This chapter reviews indicators of forest sustainability for Massachusetts forests and gauges the impact of increased biomass harvesting on forest ecosystem sustainability. It also suggests options for policies, guidelines, or regulations that might be needed to protect ecological values while producing a forest based energy supply and realizing the economic benefits from increased silvicultural productivity.

The concept of forest sustainability requires consideration of what is being sustained, over what time period, and at what landscape scale. Section 2 addresses these issues at the stand-level, focusing on the localized ecological impacts of biomass harvesting. These stand-level considerations are most readily observed and quantifiable. The stand-level analysis discusses the potential impacts to ecological systems and processes and then reviews the biomass harvesting guidelines used by other states and political entities to minimize any impacts at the stand level. Then the adequacy of Massachusetts' current forest management regulations and guidelines are evaluated. Section 3 considers a broader set of sustainability factors at the landscape rather than the stand level. This discussion includes socio-economic indicators that go beyond stand-level ecological effects and have the potential to alter the provision of forest ecosystem services at a regional scale. The chapter concludes with a discussion of policy options that the state may want to consider for addressing these potential stand- and landscape-scale impacts.

To help answer questions about the potential impact of increased biomass harvests on forest sustainability at both stand and landscape scales, this report draws heavily on information from three separate but related reports that were developed or updated for this study by the Forest Guild. These documents are included as appendices to this report. *Ecology of Dead Wood in the Northeast* consists of a literature review of important topics relevant to biomass harvesting in forest types common to Massachusetts. Excerpts from this report and implications for Massachusetts policies are included in Section 2. *An Assessment of Biomass Harvesting Guidelines* (2009) was revised for this study, and the unpublished revised version is included. Finally, *Forest Biomass Retention and Harvesting Guidelines for the Northeast* is a complete set of recommendations to protect Massachusetts forest types that was developed in a parallel process by Forest Guild members and staff.[4] These guidelines provide a useful starting point for the development of state-specific guidelines for Massachusetts.

These reports provide more detailed background information and a richer exploration of the underlying science and issues. Overviews of each of these reports and their implications for policies addressing increased biomass harvests in Massachusetts are included in Section 2 with the stand-level discussion.

4.2 STAND-LEVEL IMPACTS TO FOREST HEALTH RESULTING FROM INCREASED BIOMASS DEMAND

As we learned from the analysis in Chapter 3, woody biomass generated solely from logging debris (tops and branches) will contribute minimally to commercial-scale biomass facilities. This implies that the only way to meet higher demand would be to increase the annual forest harvest, i.e., cut more trees per acre or harvest additional acreage. Increasing harvest levels does not automatically mean an unsustainable forest ecosystem. As noted in Chapter 3, timber inventories have been increasing in Massachusetts for many decades and harvests can potentially be increased without reducing future wood supplies. The challenge with increased harvests is to provide assurances that forest ecosystem health would be preserved. There are three main areas where forest ecosystem sustainability might be affected. These issues are relevant to any harvesting operation, but become of greater concern if additional wood is removed for biomass:

- Impact on hydrology and water quality
- Impact on soils and site productivity
- Impact on habitat and biodiversity

4.2.1. INTRODUCTION

Hydrology and water quality are already covered with existing Best Management Practices (BMPs) in Massachusetts (reference to BMPs). Increasing the harvest levels to meet biomass demands should therefore not compromise water resources because of the protections already in place. It is not clear that protections are in place for soils and productivity, or biodiversity, and therefore we focus on these issues in this Task.

Many of the possible impacts related to biomass harvesting relate to the removal and retention of woody material. This is true for soil protection as well as wildlife and biodiversity. Although dead wood and declining trees have traditionally had little commercial value, they do have substantial ecological value. For this reason, we focus our analysis on the ecology and benchmarks for retention of this material.

4 The three Forest Guild reports mentioned here are included in the Appendices.

Ecology of Dead Wood in the Northeast was prepared to provide background information for this study as well as to policymakers and foresters involved in biomass harvest issues elsewhere.

The paper reviews the scientific literature to provide information about the amount of dead wood retention necessary for forest health in the forest types of the northeastern U.S. Establishing the ecological requirements for dead wood and other previously low-value material is important because expanded biomass markets may cause more of this material to be removed, potentially reducing the forest's ability to support wildlife, provide clean water, and regenerate a diverse suite of vegetation. The paper covers the topics of dead wood, soil compaction, nutrient conservation, and wildlife habitat in temperate forests generally as well as in specific forest types of the Northeast. The sections that follow include excerpts from the report that cover the relevant major research findings and then summarize the implications for policies in Massachusetts.

4.2.2. IMPACTS ON SOILS AND PRODUCTIVITY

Biomass harvesting can affect chemical, physical, and biological attributes of soils. The silvicultural choices of what to harvest, the amount of material harvested, and the way the material is harvested are all factors that need to be considered, and sometimes mitigated, to protect soils. This section covers issues related to soil nutrients and productivity.

4.2.2.1 Definition of Downed Woody Material

Woody material is sometimes divided into coarse woody material (CWM), fine woody material (FWM), and large woody material. The U.S. Forest Service defines CWM as down dead wood with a small-end diameter of at least 3 inches and a length of at least 3 feet and FWM as having a diameter of less than 3 inches (Woodall and Monleon 2008). FWM tends to have a higher concentration of nutrients than CWM. Large downed woody material, such as logs greater than 12 inches in diameter, are particularly important for wildlife. Fine woody material is critical to nutrient cycles. In this report, we use the term **downed woody material (DWM)** to encompass all three of these size classes, but in some circumstances we discuss a specific size of material where the piece size is particularly important.

Implications for Massachusetts Policies: In order to avoid confusion, it will be important for Massachusetts to settle on definitions and terminology that are most helpful to discussions of native forest types and associated concerns.

4.2.2.2 DWM: Stand Development and Harvesting

The process of dead wood accumulation in a forest stand consists of the shift from live tree to snag to DWM, unless a disturbance has felled live trees, shifting them directly to DWM. During stand development following a clear cut, there is a large amount of DWM. The DWM remaining from the initial harvest decomposes rapidly in the first 25 years and continues to decline to age 40. The young stand produces large numbers of trees, and the intense competition produces an increasing number of snags. As the trees grow larger, more snags of larger sizes begin to appear. From age 40 to 100 years, DWM increases as small snags fall. Then larger snags begin to contribute to DWM. Very few large pieces of DWM are produced. Large DWM often results from wind or other disturbances that topple large trees in the old-growth stage. Thus, large dead wood tends to accumulate periodically from these disturbance pulses, whereas small pieces of DWM accumulate in a more predictable pattern throughout all stages of stand development.

Implications for Massachusetts Policies: The patterns of DWM development indicate the importance of retaining large live trees and large snags at the time of harvest. As the stand moves through the younger stages of development, it creates minor amounts of DWM of larger sizes. Retaining larger-diameter trees in all stages can provide larger size classes of DWM.

The concern at the stand level is that increased biomass harvests in Massachusetts might alter natural patterns of DWM accumulation and cause ecological damage. This can occur in stands that have not previously been harvested or by adding the additional removal of biomass to any kind of previous harvest. With new biomass markets becoming available, all sizes of woody material might be removed. Harvests that include taking material for biomass energy could lead to the removal of most or all of the dead or dying standing material, as well as low-quality trees that would eventually enter this class. Regeneration harvests, cuttings that are intended to establish new seedlings, might be helped by the ability to remove cull material that hinders new regeneration, but if the biomass removals are too heavy and too consistent, the amount of DWM could be reduced to insufficient levels. In some cases, increased prices for biomass, coupled with under-utilized equipment and logging contractors looking for work, might persuade a landowner to do a more intensive harvest than under a pre-biomass market scenario. Without guidelines for DWM retention, these heavier harvests might, in some cases, pose a greater risk for soils by depleting the structures—FWM, and to a lesser extent CWM and large woody material—that store and release nutrients back into the mineral soil.

4.2.2.3 DWM: Soil Productivity

DWM plays an important physical role in forests and riparian systems. DWM adds to erosion protection by reducing overland flow (McIver and Starr 2001, Jia-bing et al. 2005). DWM also has substantial water-holding capacity (Fraver et al. 2002).

In many ecosystems, DWM decomposes much more slowly than foliage and fine twigs, making it a long-term source of nutrients (Harmon et al. 1986, Greenberg 2002) (Johnson and Curtis 2001, Mahendrappa et al. 2006). While there is great variation across ecosystems and individual pieces of DWM, log fragmentation generally appears to occur over 25 to 85 years in the U.S. (Harmon et al. 1986, Ganjegunte et al. 2004, Campbell and Laroque 2007).

In some ecosystems, CWM represents a large pool of nutrients and is an important contributor to soil organic material (Graham and Cromack Jr. 1982, Harvey et al. 1987). However, a review of CWM in Northern coniferous forests suggested that it may play a small role in nutrient cycling in those forests (Laiho and Prescott 2004).

A review of scientific data suggests that nutrient capital can be protected when both sensitive sites (including low-nutrient) and clearcutting with whole-tree removal are avoided (see also Hacker 2005). However, there is no scientific consensus on this point because of the range of treatments and experimental sites (Grigal 2000). A study of an aspen/mixed-hardwood forest showed that even with a clear-cut system, calcium (Ca) stocks would be replenished in 54 years (Boyle et al. 1973). Minnesota's biomass guidelines present data that showed soil nutrient capital to be replenished in less than 50 years even under a whole-tree harvesting scenario (Grigal 2004, MFRC 2007). Whole-tree clearcutting and whole-tree thinning (Nord-Larsen 2002) did not greatly reduce amounts of soil carbon or nitrogen (N) in some studies (Hendrickson 1988, Huntington and Ryan 1990, Olsson et al. 1996, Johnson and Todd 1998). Lack of significant reduction in carbon and N may be due to soil mixing by harvesting equipment (Huntington and Ryan 1990). However, intensive cutting, such as clear-cutting with whole-tree removal, can result in significant nutrient losses (Hendrickson 1988, Federer et al. 1989, Hornbeck et al. 1990, Martin et al. 2000, Watmough and Dillon 2003)—in one case, an initial 13% loss of Ca site capital (Tritton et al. 1987).

Overall, the impact of biomass harvesting on soil nutrients is site dependent. Low-nutrient sites are much more likely to be damaged by intensive biomass removal than sites with greater nutrient capital or more rapid nutrient inputs, which is one reason scientific studies on the nutrient effects of whole-tree harvesting may yield different results.

Low-impact logging techniques that reduce soil disturbance can help protect nutrient capital (Hallett and Hornbeck 2000). Harvesting during the winter after leaf fall can reduce nutrient loss from 10 to 20% (Boyle et al. 1973, Hallett and Hornbeck 2000). Alternatively, if logging occurs during spring or summer, leaving tree tops on site would aid in nutrient conservation. Nordic countries have demonstrated that leaving cut trees on the ground in the harvest area until their needles have dropped (one growing season) can also reduce nutrient loss (Nord-Larsen 2002, Richardson et al. 2002).

Implications for Massachusetts Policies: The scientific literature makes clear that DWM plays a critical role in ensuring continued soil health and productivity. Modeling indicates that biomass harvests have the potential to reduce soil nutrient capital and cause long-term productivity declines (Janowiak 2010) at some sites; but other studies identify cases where soil nutrient capital is replaced in reasonable time periods even under whole-tree harvesting scenarios.

A recent report, *Silvicultural and Ecological Considerations of Forest Biomass Harvesting In Massachusetts*, suggested that with partial removals (i.e., a combination of crown thinning and low thinning that removes all small trees for biomass and generates from 9 to 25 dry t/ac or 20 to 56 Mg/ha) stocks of Ca, the nutrient of greatest concern, could be replenished in 71 years (Kelty et al. 2008). The Massachusetts study was based on previous research with similar results from Connecticut (Tritton et al. 1987, Hornbeck et al. 1990).

During the Forest Guild's working group discussions of soil productivity, the Kelty study was investigated thoroughly as it raised serious questions of long-term sustainability. As general cautionary context for soil productivity, it should be noted that leaching, particularly of Ca due to acidic precipitation, can reduce the nutrients available to forests even without harvests (Pierce et al. 1993). In the case of Ca and the Connecticut research there are important questions as to whether the input rates from natural weathering were accurate. Other researchers believe the weathering rates are much higher and the Ca-phosphorus mineral apatite may provide more sustainable supplies of Ca to forests growing in young soils formed in granitoid parent materials (Yanai et al. 2005). For example, a recent study using long-term data from Hubbard Brook Ecosystem Study indicated that "the whole-tree harvest had little effect on the total pool of exchangeable calcium" after 15 years (Campbell et al. 2007).

Consequently, the analysis provided in the Kelty study does not provide sufficient scientific justification to generalize about Ca depletion. The bottom line is that even while some available studies suggest that soil capital should be protected by avoiding sensitive sites and prohibiting clearcutting with whole-tree removals, there is no scientific basis for concluding that avoiding clearcutting or whole-tree harvesting are necessary at all sites to maintain productivity. Sensitive soil types should be determined and appropriate guidelines applied. We recommend a conservative approach that includes the retention of some DWM in all harvests. The Forest Guild Biomass Retention and Harvesting Guidelines deal directly with these issues and are summarized in this report.

4.2.2.4 Quantities of Dead Wood

Site productivity and the rate of decomposition help determine the amount of dead wood in a given stand (Campbell and Laroque 2007, Brin et al. 2008). As mentioned above, DWM decomposition varies greatly but generally occurs over 25–85 years in the U.S. (Harmon et al. 1986, Ganjegunte et al. 2004, Campbell and Laroque 2007). All mortality agents including wind, ice, fire, drought, disease, insects, competition, and senescence create dead wood (Jia-bing et al. 2005). These mortality agents often act synergistically.

A review of 21 reports of quantitative measures of DWM in Eastern forest types shows great variability across forest types and stand-development stages (Roskoski 1980, Gore and Patterson 1986, Mattson et al. 1987, McCarthy and Bailey 1994, Duvall and Grigal 1999, Idol et al. 2001, Currie and Nadelhoffer 2002). The reports ranged from 3 to 61 t/ac (7 to 137 Mg/ha) with a median of 11 t/ac (24 Mg/ha) and a mean of 15 t/ac (33 Mg/ha). Measurements of old forests (>80 years old), had a median of 11 t/ac (24 Mg/ha) and a mean of 13 t/ac (29 Mg/ha) in DWM.

In contrast, a study of U.S. Forest Service inventory plots found a mean of 3.7 t/ac (8.3 Mg/ha) and a median of 2.9 t/ac (6.5 Mg/ha) of DWM across 229 plots in the Northeast (Chojnacky et al. 2004 see Figure 2). This low level of DWM across the landscape may be due to widespread clearcutting in the 1880-1930 periods.

Implications for Massachusetts Policies: The amount of dead wood varies across forest types and stand ages. In order to determine appropriate benchmarks that correlate with forest health, more data by stand and age is required than current research provides. However, we find there is sufficient data to construct some initial, but likely conservative, guidelines. These are detailed in the Forest Guild's Biomass Retention and Harvesting Guidelines and summarized in Section 4.5.2 of this report.

4.2.2.5 Soils and Productivity Issues by Forest Type

Northern Hardwood Forests: In general, the amount of DWM in Northern hardwood forests follows the 'U' pattern mentioned above. Young stands have large quantities of DWM (usually due to a harvest); mature stands have less; older or uncut stands have more. For example, a study in New Hampshire measured 38 t/ac (86 Mg/ha) of DWM in a young stand, 14 t/ac (32 Mg/ha) in mature stands, 20 t/ac (54 Mg/ha) in old stand, and 19 t/ac (42 Mg/ha) in an uncut stand (Gore and Patterson 1986). Gore and Patterson (1986) also note that stands under a selection system had lower quantities of DWM, i.e., 16 t/ac (35 Mg/ha). A review of other studies identified similar temporal patterns and quantities of DWM (Roskoski 1977, Gore and Patterson 1986, McCarthy and Bailey 1994, McGee et al. 1999, Bradford et al. 2009).

Estimates of the volume of down dead wood in Maine's northern hardwood forests are 598 ft^3/ac (42 m^3/ha) or 9 t/ac (20.5 Mg/ha) (Heath and Chojnacky 2001). Keeton (2006) estimates a volume of 600 ft^3/ac (42 m^3/ha) of DWM in a multi-aged northern hardwood forest.

Transitional Hardwoods: As with the other forest types discussed, DWM density tends to follow a 'U' shape in oak-hickory forests. For example, Idol and colleagues (2001) found 61 t/ac (137 Mg/ha) in a one-year post-harvest stand, 18 t/ac (40 Mg/ha) in a 31–year-old stand, and 26 t/ac (59 Mg/ha) in a 100-year-old stand. Tritton and colleagues (1987) measured 5.8 t/ac (13 Mg/ha) in an 80-year-old stand in Connecticut.

Estimates of the volume of down dead wood in Maine's oak-hickory forests are 244 ft^3/ac (17 m^3/ha) or 0.7 (1.5 Mg/ha) (Heath and Chojnacky 2001). Wilson and McComb (2005) estimated the volume of downed logs in a western Massachusetts forest at 143 ft3/ac (10 m3/ha).

A study in Appalachian oak-hickory forests showed that the decomposing residues left after a saw log harvest increased concentration of Ca, potassium (K), and magnesium in foliage and soils after 15 years in comparison to a whole-tree harvest (Johnson and Todd 1998). However, the study found no impacts on soil carbon, vegetation biomass, species composition, vegetation N or P concentration, soil bulk density, or soil N because of the whole-tree harvest (Johnson and Todd 1998).'

White Pine and Red Pine Forests: Estimates of the volume of down dead wood in Maine's pine forests are 255 ft3/ac (18 m^3/ha) or 1.6 t/ac (3.5 Mg/ha) (Heath and Chojnacky 2001). A review of research on DWM in the red pine forests of the Great Lakes area showed that there were 50 t/ac (113 Mg/ha) of DWM in an unmanaged forest at stand initiation and 4.5 t/ac (10 Mg/ha) in a 90-year-old stand (Duvall and Grigal 1999). In comparison, the managed stand Duvall and Grigal (1999) studied had less DWM at both initiation 8.9 t/ac (20 Mg/ha) and at 90 years 2.9 t/ac (6.6 Mg/ha). The same review showed the unmanaged stand had 30 snags per ac (74 per ha) while the managed forest had 6.9 per ac (17 per ha) (Duvall and Grigal 1999). Red and white pine that fall to the ground at time of death will become substantially decayed (decay class IV of V) within 60 years (Vanderwel et al. 2006).

While not a recognized forest type, stands with a mix of oak, other hardwoods, white pine, and hemlock are common. Many of the red oak and white pine stands on sandy outwash sites are susceptible to nutrient losses because of a combination of low-nutrient capital and past nutrient depletion (Hallett and Hornbeck 2000).

Implications for Massachusetts Policies: The amount of DWM and natural patterns of decay and soil replenishment vary by forest type in unmanaged stands. Ideally, DWM retention targets would also vary by forest type; but presently there are not enough data across forest types and ages to set specific targets. The Forest Guild Retention and Harvesting Guidelines for the Northeast include examples of DWM ranges by forest types.

Exhibit 4.1: DWM Ranges by Forest Type

	Northern HW	Spruce-Fir	Oak-Hickory	White and Red Pine
Tons of DWM per acre*	8—16	5—20	6—18	2—50

**Includes existing DWM and additional material left during harvesting to meet this target measured in dry tons per acre.*

The Forest Guild's guidelines also include general targets for retaining logging residues to protect soil nutrient capital. Over time, Massachusetts and other state guidelines may be able to hone in on specific targets by forest type.

4.2.2.6 Impacts from Changing Harvesting Technology Caused by Increased Biomass Harvesting

All harvesting practices disturb forest sites, but the overall impact on soil structure and nutrients depends on the site, operator skill, and conditions of operation. A comprehensive study of site impacts in Maine (Benjamin 2010) reviewed the literature regarding soil compaction and erosion from logging. A comparison of nine related studies (Martin, 1988) concluded "the percentage of disturbance per area has increased over time with changes in equipment (tracked to wheeled machines, chain saws to harvesters) and harvest methods (partial cuts to clearcuts to whole-tree clearcuts)." However, the research also suggests that biomass harvesting will not contribute to or create additional physical impacts on the soil productivity as compared to conventional harvesting as long as BMPs are followed (Shepard 2006)

The supply scenarios developed in the Chapter 3 Forest Biomass Supply analysis indicate that 'if biomass demand increases due to the expansion of electric power plants, it will almost certainly be accompanied by increases in whole-tree harvesting due to the limited supply of other forest biomass and the cost advantages of whole-tree methods.' The concerns for physical soil structure and erosion revolve around the equipment that will likely be introduced on harvesting operations. Whole-tree harvesting systems come in a variety of designs that rely on different pieces of equipment. In Massachusetts, the most common whole-tree logging systems employ a feller/buncher, one or more grapple skidders, and some kind of loader at the landing. This equipment can be larger and heavier than traditional harvesting equipment and has the potential to magnify adverse effects on soil. Also, many biomass harvests use a two-pass system in which one piece of equipment cuts trees and stacks them and another piece eventually picks them up for transportation to the landing. Repeated equipment passes can cause greater degrees of soil compaction, resulting in increased soil strength, which can (1) slow root penetration and reduce the regeneration and tree growth (Greacen and Sands, 1980; Miller et al., 1996); and (2) reduce soil infiltration rates, thereby increasing the potential for erosion through changes in landscape hydrology (Harr et al.1979).

The extent of impacts on soil properties and site productivity will depend on the degree current best management practices (BMPs) and new guidelines are followed. Current BMPs include fundamental approaches that apply to biomass harvests as well as traditional harvests. They include anticipating site conditions, controlling water flow and minimizing and stabilizing exposed mineral soil. These guidelines should be re-emphasized and implemented in biomass harvests. Additional guidelines related to the retention and use of woody biomass will be helpful especially on skid trails and stream approaches. For example, research shows that spreading tops and limbs along skid trails and other operating areas and driving the equipment on this buffer can reduce soil impacts. In order to have this material available for these purposes it must be retained in place or brought back to the operating area. There are competing values of biomass that pit the desire to remove the material as a renewable fuel and to mitigate the global effects of climate change on forest ecology versus its onsite ecological benefits.

4.2.3 IMPACTS ON HABITAT AND BIODIVERSITY

Increasing harvests to include greater biomass removal will have two primary effects on habitat and biodiversity. First, a greater volume of wood will be removed from many harvest operations to meet the biomass demand. This will initially result in a more open residual stand than would have occurred otherwise and can range from stands with slightly lower residual stocking all the way to clearcuts. Habitat will change on individual parcels providing opportunities for new species and eliminating them for others. The other potential impact is on dead wood. Both standing snags and fallen logs (DWM) are important habitat features for many forest species. Dead wood is a part of a healthy forest. Forests that are intensively managed for forest products may eliminate important dead and dying structural components which could result in a lack of habitat and species on those managed landscapes. To ensure forest health for biodiversity, safeguards will be needed to ensure that dead wood remains a component of the forest ecosystem.

4.2.3.1 DWM: Wildlife and Biodiversity

Dead wood is a central element of wildlife habitat in forests (Freedman et al. 1996). Many forest floor vertebrates have benefited or depended on DWM (Butts and McComb 2000). In New England, De Graaf and colleagues (1992) catalogued at least 40 species that rely on DWM.

Some examples from the Northeast of relationships between animals and DWM include a study showing that low densities of highly decayed logs (less than one highly decayed log/ha) had a negative impact on red-back voles (*Clethrionomys gapperi*) in a northern hardwoods forest in New Brunswick, Canada (Bowman et al. 2000). DWM retention increased spotted salamander (*Ambystoma maculatum*) populations in a Maine study (Patrick et al. 2006).

In aquatic environments, DWM provides a crucial refuge from predation (Angermeier and Karr 1984, Everett and Ruiz 1993). Logs that fall in the water formed a critical component of aquatic habitat by ponding water, aerating streams, and storing sediments (Gurnell et al. 1995, Sass 2009). In fact, removal of large woody material from streams and rivers had an overwhelming and detrimental effect on salmonids (Mellina and Hinch 2009).

DWM is a key element in maintaining habitat for saproxylic (live and feed on dead wood) insects (Grove 2002). For example, some specialist litter-dwelling fauna that depend on DWM appear to have been extirpated from some managed forests (Kappes et al. 2009). Extensive removal of DWM could reduce species richness of ground-active beetles at a local scale (Gunnarsson et al. 2004). More generally, a minimum of 286 ft^3/ac (20 m3/ha) of DWM has been suggested to protect litter-dwelling fauna in Europe (Kappes et al. 2009).

Dead logs serve as a seedbed for tree and plant species (McGee 2001, Weaver et al. 2009). Slash could be beneficial to seedling regeneration after harvest (Grisez, McInnis and Roberts 1994). Fungi, mosses, and liverworts depend on dead wood for nutrients and moisture, and in turn, many trees are reliant on mutualistic relationships with ectomycorrhizal fungi (Hagan and Grove 1999, Åström et al. 2005). In general, small trees and branches host more species of fungus-per-volume unit than larger trees and logs; however, larger dead logs may be necessary to ensure the survival of specialized fungus species such as heart-rot agents (Kruys and Jonsson 1999, Bate et al. 2004).

Implications for Massachusetts Policies: It is clear that dead wood is a central contributor to biodiversity in our forests and that many species are dependent on sufficient quantities and sizes. This requires retention of DWM, standing cull trees and live trees that will eventually create these structures.

4.2.3.2 Habitat and Biodiversity Issues by Forest Type

Northern Hardwood Forests: The number of dead trees in five hemlock-yellow birch forests range from 16 to 45 per ac (40 to 112 per ha) or from 3 to14% of the basal area (Tritton and Siccama 1990). The 14 sugar maple-beech-yellow birch stands survey ranged from 14 to 99 dead trees per ac (35 to 245 per ha) or 5 to 34% of basal area (Tritton and Siccama 1990). Other estimates of snag densities in northern hardwood forests include 5 per ac (11 per ha) (Kenefic and Nyland 2007), 15 per ac (38 per ha) (Goodburn and Lorimer 1998), and 17 per ac (43 per ha) (McGee et al. 1999).

The number of cavity trees is another important habitat element in northern hardwood forests that is reduced by harvest. For example, studies in northern hardwood forests have shown a reduction from 25 cavity tree per acre (62 per ha) before harvest and to 11 (27 per ha) afterward (Kenefic and Nyland 2007). Another study measured 7 cavity trees per ac (18 per ha) in old growth, 4 per ac (11 per ha) in even-aged stand, and 5 per ac (13 per ha) in a stand in selection system (Goodburn and Lorimer 1998).

Transitional Hardwoods: Out of seven oak stands in Connecticut, the number of dead trees ranged from 19 to 44 per ac (46 to 109 per ha) or 5 to 15% of basal area (Tritton and Siccama 1990). The decadal fall rates of snags in a Massachusetts study varied from 52 to 82% (Wilson and McComb 2005). Snags, particularly large-diameter snags, provide important nesting and foraging sites for birds (Brawn et al. 1982, Gunn and Hagan 2000). In general, wildlife habitat requirements for dead wood are poorly documented, but it is clear that some wildlife species rely on dead wood in oak-hickory forests (Kluyver 1961, DeGraaf et al. 1992).

Implications for Massachusetts Policies: The number of standing dead trees varies by forest type in unmanaged stands. Ideally, biomass retention targets would also vary by forest type; but presently there are not enough data across forest types and ages to set specific targets for standing dead trees by forest type. The Forest Guild Retention and Harvesting Guidelines for the Northeast include guidelines with targets for retaining standing live and dead trees that are general for all forest types in Massachusetts. Over time Massachusetts and other state guidelines may be able to hone in on specific targets by forest type.

4.3 LESSONS FROM OTHER INITIATIVES: PROTECTING STAND LEVEL ECOLOGICAL VALUES THROUGH BIOMASS HARVEST GUIDELINES

States from Maine to Missouri, Canada, and some European countries have addressed or are addressing stand-level ecological concerns by developing guidelines for harvesting woody biomass from forests. To inform the Massachusetts process, we have expanded on the Forest Guild's report *An Assessment of Biomass Harvesting Guidelines* to provide updates, include additional states in New England, and give a thorough assessment of northern European initiatives. This section begins with an overview of the Guild report highlighting key points relevant to Massachusetts. It concludes with a brief review of the harvesting regulations and BMPs in Massachusetts and the gaps in those directives that indicate that a new set of guidelines is needed.

4.3.1 OVERVIEW OF REGULATORY FRAMEWORKS

In the U.S., forestry on private and state lands is regulated primarily at the state level. At least 276 state agencies across the country have some oversight of forestry activities, including agencies focused on forestry and others concerned with wildlife or environment protection policies (Ellefson et al. 2006). All 50 states have BMPs. In general, BMPs originally focused on water quality and did not anticipate the increased removal of biomass. Consequently, BMPs historically have offered little or no specific guidance on the amount of removal that is healthy for ecosystems or how much biomass should be retained. However, this situation is changing. Pennsylvania's old BMPs encouraged operators "to use as much of the harvested wood as possible to minimize debris," while more recent guidelines recommend leaving "15 to 30% of harvestable biomass as coarse woody debris."

Woody biomass is usually considered to be logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-value products. Depending upon prevailing market conditions, however, material meeting pulp or pallet specifications may also be used in biomass energy facilities. Reasons for biomass harvesting guidelines are likely to mirror the reasons forestry is regulated in general, which include (Ellefson and Cheng 1994):

- general public anxiety over environmental protection,
- the obligation to correct misapplied forestry practices,
- the need for greater accountability,
- growth of local ordinances,
- landscape-level concerns, and
- following the lead of others.

Biomass harvesting guidelines are designed to fill the gaps where existing BMPs may not be sufficient to protect forest resources under new biomass harvesting regimes. In other words, BMPs were developed to address forest management issues at a particular point in time; as new issues emerge, new guidelines may be necessary. State BMP manuals usually include sections on timber harvesting, site preparation, reforestation, stream crossings, riparian management zones, prescribed burning and fire lines, road construction and maintenance, pesticides and fertilizers, and wetlands. These programs are routinely monitored, and literature suggests that when these BMPs are properly implemented they do protect water quality (Shepard, 2006).

U.S. federal law requires states to address non-point source pollution of waterways. State programs vary with some states prescribing mandatory practices while others rely on voluntary BMPs and education and outreach programs. These programs can be categorized in three ways: non-regulatory with enforcement, regulatory, and combination of regulatory and non-regulatory. In the Northeast, Massachusetts and Connecticut are considered regulated; Vermont and New Hampshire are non-regulated with enforcement; and Rhode Island, New York, and Maine use a combination of approaches.

Over time BMPs for water quality have expanded to include aesthetics, wildlife, and other resources. A survey in 2000 noted that nine states had extended their BMPs in such fashion, three of those from the Northeast (NASF Edwards and Stuart). This indicates a precedent for expanding BMPs to include issues such as increased biomass harvesting. In fact, some of the BMPs developed for water quality and conventional forestry already contain guidelines that would serve to protect water quality during increased biomass harvests. When these guidelines were developed, however, they were designed to specifically and solely address the issue of water pollution. Full implementation of these guidelines is necessary for protection of water quality. As harvests become more intense, other ecological issues, such as soil nutrient protection and wildlife habitat, come into play; previous BMPs likely do not account for them.

Although in many cases BMPs are voluntary, water pollution control requirements are not, and therefore landowners are compelled by law to adopt water quality BMPs to avoid legal penalties. This may explain the relatively high rates reported for national compliance (86%) and in the Northeast (82%) (Edwards 2002). Biomass harvesting standards must address several management criteria such as protection and maintenance of forest structure for wildlife habitat, soil nutrient protection, and forest-stand productivity. These criteria, unlike those for water quality, typically have no legal foundation to compel compliance.

The recently updated Forest Guild report, *An Assessment of Biomass Harvesting Guidelines*, reviews the biomass harvesting or retention guidelines from New York and New England, other states with specific biomass guidance, parts of Canada, northern European counties, and other organizations including the U.S. federal government and certification groups. We have grouped New York and the New England states together to offer a snapshot of the current situation in states geographically near Massachusetts. Maryland, Minnesota, Missouri, Michigan, Pennsylvania, Wisconsin, and California are also covered because of their forest practices guidance on biomass harvest and retention.

Entities interested in addressing concerns about biomass removal have taken at least three different approaches. One is to verify that existing forest practice regulations cover the issues raised by biomass harvests, obviating the need for new guidelines. Second, in instances where existing rules or recommendations are found to be insufficient, some entities—including Minnesota, Missouri, Pennsylvania, Wisconsin, and Maine—have taken a different approach and chosen to craft separate biomass guidelines that augment existing forest practice guidance. In the third case, standards-setting entities, such as the Forest Stewardship Council (FSC), have chosen to address concerns particular to biomass harvests in a revision of existing rules or recommendations. The examples in this report detail the status of rules and recommendations for removing biomass from forests.

The existing guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and disturbance. *An Assessment of Biomass Harvesting Guidelines* lists the commonly used subtopics for each and identifies which are covered in a given set of guidelines. In some cases, a subtopic is noted as covered because it appears in another set of forestry practice rules or recommendations instead of that state's biomass guidelines. The list of subtopics was developed from section headings of the existing guidelines and is similar to other criteria for sustainable production and harvest of forest biomass for energy (Lattimore et al. 2009).

4.3.2 KEY FINDINGS FROM *AN ASSESSMENT OF BIOMASS HARVESTING GUIDELINES (REVISED)*

An Assessment of Biomass Harvesting Guidelines reveals a number of approaches to the development of biomass guidelines that provide useful insights for Massachusetts. While not necessarily directly applicable to the ecological conditions in Massachusetts, these approaches illustrate the general types of measures that have been adopted by other states and government entities. Three important questions are addressed:

Do other guidelines offer specific targets backed by scientific research, or are they more general and open to further interpretation?

The ability to assure the public that sustainable forestry is being practiced is often confounded by vagueness and generalities in forestry BMPs or guidelines. Foresters are leery of prescribing targets that are expected to be carried out on every acre of forestland. Each forest stand is subject to different ecological factors, historical trends, disturbance patterns, landscape context, and management intent and should be treated as unique. Despite these difficulties, it is important for the profession to define targets and a system of monitoring to win public confidence and retain what has been called a "social contract" to practice forestry. The struggle between the need to set specific measurable targets and the realities of on-the-ground forestry is now being played out as states and others entities attempt to set biomass harvesting guidelines.

In Maine, the earlier drafts of voluntary guidelines provided specific numeric targets, but the final version is more general (Benjamin 2010). Although background materials refer to specific targets recommended in an important multi-stakeholder report on biodiversity in Maine, targets were not incorporated in the final draft. The final guidelines call for leaving "some wildlife trees" without incorporating the numbers of trees per acre suggested in the report. Also, these guidelines call for leaving "as much fine woody material as possible" without specific requirements for top retention found in other states. Similarly, the Forest Stewardship Council's standards for the U.S. require the maintenance of habitat structure and well-distributed DWM, but are not specific about the amount that should be left on site.

How do other guidelines address the concern over the depletion of soil nutrients?

As noted above, some biomass harvest guidelines call for sufficient material to be retained to protect ecological functions such as soil nutrient cycles but offer no targets. A number of guideline documents, however, do offer targets in this category. The following is a sampling of the various ways retention of DWM has been approached.

- **Alabama**: Enough logging slash should be left and scattered across the area to maintain site productivity.
- **Maine**: Where possible and practical retain and scatter tops and branches across the harvest area.
- **Michigan**: retention of 17% to 33% of the residue less than four inches in diameter.
- **Minnesota**: tops and limbs from 20% of trees harvested.
- **Missouri**: 33% of harvest residue.
- **New Hampshire**: "Use bole-only harvesting (leaving branches and limbs in the woods) on low-fertility soils, or where fertility is unknown."
- **Pennsylvania**: 15 to 30% of "harvestable biomass."
- **Wisconsin**: tops and limbs from 10% of the trees in the general harvest area with a goal of at least 5 tons of FWM per acre.
- **Sweden**: 20% of all slash must be left on site.
- **Finland**: 30% of residues should remain and be distributed evenly over the site.

How do other guidelines address the concern over retention of forest structure and wildlife habitat?

The literature confirms that forest structure is important for wildlife habitat. Existing BMPs and new biomass harvesting guidelines use both general and specific approaches to address this issue. The following samples provide a snapshot of the range of approaches.

- **Maine**: leave some wildlife trees; retain live cavity trees on site; vary the amount of snags, down logs and wildlife trees; and leave as much FWM as possible.
- **New Hampshire**: Under uneven-aged management, retain a minimum of 6 secure cavity and/or cavity trees per acre with one exceeding 18 inches diameter at breast height (DBH) and 3 exceeding 12 inches DBH.
- **California**: retain all snags except where specific safety, fire hazard, or disease conditions require they be felled.
- **Minnesota**: on non-clear cut sites, leave a minimum of 6 cavity trees, potential cavity trees, and/or snags per acre. Create at least 2-5 bark-on down logs greater than 12 inches in diameter per acre.

4.3.3 ADEQUACY OF MASSACHUSETTS BMPS FOR INCREASED BIOMASS HARVESTS

The situation in Massachusetts is very similar to that in other states: current regulations and guidelines were developed for protection of water quality and did not anticipate the intensification of biomass harvesting. In Massachusetts, current regulations require a cutting plan that describes the harvest and the approaches to mitigate water-quality problems such as erosion and sedimentation.

Current regulations and BMPs, however, do not direct silvicultural or harvesting activities to sustain all the ecological values that might be negatively affected by increased biomass harvesting. There are no retention rules or guidelines that would prevent the harvest of every cull tree or den tree on a property, a situation that could take place with or without an expanded biomass market. Similarly, there are no harvesting guidelines that would prevent the scouring of DWM. Our literature review reveals these activities have the potential to degrade wildlife habitat, biodiversity, and soil nutrient levels. In addition, the current cutting plan process does not require sound silvicultural practice and the ecological safeguards that these proven practices offer in comparison to undisciplined harvesting. Finally, the introduction of larger, heavier whole-tree harvesting equipment presents new challenges and opportunities. Larger equipment can damage forest soils through soil compaction and increase residual stem damage because of their size. However, in some cases, new forest equipment can reduce soil impacts because they can provide less pressure per inch and reduce stand damage because of their longer harvesting reach. In practice, some of these impacts are and will be mitigated through good decisions by landowners, foresters and loggers, and the influence of supervising foresters through the cutting plan process. In most situations, however, there are no regulatory or voluntary guidelines in place that compel compliance.

The assessment of guidelines in other states and countries reveals a number of additional approaches that can be tailored to state forest types and conditions to prevent ecological damage from biomass harvesting. We recommend that a similar set of guidelines be developed in Massachusetts and integrated into the cutting plan process. The newly developed *Forest Guild Biomass Retention and Harvesting Guidelines* for the Northeast utilize the best thinking and approaches from other states to develop a set of guidelines for northeastern forest types. These should be directly applicable to Massachusetts and provide a starting point for developing guidelines tailored to the regional ecology and forest types of the Commonwealth.

4.4 FOREST SUSTAINABILITY INDICATORS AND LANDSCAPE LEVEL EFFECTS OF BIOMASS HARVESTING

4.4.1 INTRODUCTION

Beyond stand-level impacts, biomass harvesting has the potential to affect the provision of a broad suite of ecosystem services at larger regional or statewide scales. In this context, we are adopting the ecosystem services definitions used in the recent Forest Futures Visioning Process conducted by the Massachusetts Department of Conservation and Recreation (DCR). These include ecological, socio-economic and cultural values provided by forests—essentially the term ecosystem services refers to all the public and private values provided by our forests. The sustainability of this broad suite of ecosystem services across the landscape is not primarily a scientific problem; instead it involves balancing a complex set of public values that go far beyond simply ensuring that biomass harvests leave a well-functioning ecosystem in place on harvested sites.

Landscape ecological processes operate at varying spatial scales (e.g., across multiple stands, within a watershed, or an entire ecoregion). In the case of forests, the spatial arrangement and relative amounts of cover types and age classes become the ecological drivers on the landscape. The two most relevant ecological processes of interest in Massachusetts' forests include facilitating or blocking movement of organisms and loss of "interior" habitat because of smaller patch sizes. Pure habitat loss is not necessarily a landscape ecological issue until it reaches a threshold where it influences the spatial pattern of habitats. At that time, which will vary by species, the spatial pattern can drive impacts beyond the effects of pure habitat loss. For most species (including plants, invertebrates, and vertebrates), we do not know where this threshold exists (Andren 1994, Fahrig 2003, Lindenmeyer & Fischer 2006). In the discussion below, effects at the "landscape scale" generally refer to loss of habitat at different scales (e.g., watershed, statewide) and we do not attempt to address ecological processes that are influenced by the spatial arrangement of habitats.

The wood supply analysis in Chapter 3 suggests that absent very significant changes in energy prices, we do not expect dramatic increases over the next 15 years in harvest acreage across the state. But that analysis is really focused on overall supplies, and has not attempted to define more localized spatial impacts of these harvests. Moreover, although we do not foresee major changes in electricity pricing that would provide incentives for much heavier harvests, we cannot rule out such an occurrence in the event of a major energy price shock or a change in energy policies that significantly raises long-term prices. Consequently, for any specific bioenergy facility, we cannot rule out that forest impacts are potentially more dramatic within the 'wood basket' of the facility than would occur on average across forests in the state.

Such localized, wood basket effects could take the form of rapid reduction or change in the quality of forest cover if many landowners respond to the demand from a new biomass facility by cutting more heavily on acres they would have harvested for timber anyway or by increasing the acreage they decide to harvest. From the ecosystem services perspective, such an increase in cutting could have a variety of effects. First, if enough landowners decide to conduct relatively heavy biomass harvests, we might see a reduction in older forest habitat and a shift to plant and animal species that prefer younger forests. Second, heavier or geographically concentrated cutting by private landowners could have broad aesthetic impacts that might be unacceptable to the public, potentially having negative impacts on other ecosystem services like forest-based recreation or tourism. Third, at a regional scale, increased harvest area or intensity may have long-term implications for the local timber and wood products economy if stands are harvested in a manner that results in a reduction in long-term supplies of high-quality timber. These various effects are discussed below in greater detail.

4.4.2 POTENTIAL ECOLOGICAL IMPACTS OF BIOMASS HARVESTS

The ecological impacts from differing harvest scenarios can be considered at different scales. At the broadest scale—the forested land base of Massachusetts—a total harvest of 32,500 acres per year is approximately 1% of the total land base. This rate of harvest is unlikely to cause statewide ecological changes. The state's forestland is on a trajectory to be comprised of older age classes, and harvests on 32,500 acres will not alter that trajectory significantly other than to provide the opportunity to make small shifts toward younger successional forests. The harvest intensities predicted at the stand level are close to historical ranges, and the total volume of removal is far below growth rates. Other factors such as climate change, rapid land conversion, large-scale disturbance from insect, disease, or hurricanes could all play a cumulative role to cause landscape-wide ecological disturbance, but the harvest scenarios are not widespread enough to have this broad effect alone.

However, landowner response to increased demand from bioenergy facilities could create more significant changes at smaller landscape scales. It is possible that several adjacent landowners or a significant number of landowners in a watershed or viewshed independent of each other could all respond to biomass markets with regeneration cuts over a short time period. Although this cannot be ruled out, the historical trends and landowner attitudes predict otherwise. Historically, rising prices at local sawmills do not appear to have stimulated widespread harvests of sawtimber for parcels nearby. Varying landowner attitudes and goals for their properties apparently work at even the smaller scale to mitigate a mass movement in any one direction of harvest or management, and we expect this to hold for biomass markets as well.

The public's major landscape ecological concern focuses on wildlife habitat and the potential risks to individual or groups of species. The fact is, the abundance of any given species will wax and wane as forest age classes change and as those age classes shift across the landscape. The challenge, whether biomass harvesting becomes prevalent or not, is to make sure that no species declines to a level where it is at risk of being extirpated from the landscape as a result of forest harvesting. Once again, the number of different private landowners and varying nature of private landowner attitudes and behaviors serves to insulate forest landscapes from trends in harvesting strong enough to cause anything other than slight landscape scale changes in habitat or species composition.

Wildlife habitat could potentially be affected at smaller landscape scales (such as a watershed) if many landowners in the wood basket of a power plant suddenly change their historical cutting patterns. If clearcutting or acceleration of regeneration harvests in even-aged stands are used, this could create a loss of mature, interior habitat (depending on the spatial level of harvesting) and species associated with that habitat. Although these species would likely shift elsewhere and still maintain viable populations across broader landscape scales, they might not exist in certain sub-regions for periods of time. Our scenarios do not predict broad-scale clear cutting, and it is more likely that habitat could be affected by practices that are more acceptable to landowners such as more intensive thinnings. One possible scenario for landowners would be to use the new markets for biomass to combine a partial thinning of the dominant trees with a low thinning to remove understory vegetation. If poorly managed, these practices could eliminate certain structural layers from the forest or deplete the forest of the dead and dying material necessary for certain species. The importance of dead wood has been covered elsewhere in the report. The lower forest structure provides important habitat as well. For example birds, particularly long-distance migrants prefer stands with an understory component (Nemi and Hanowski 1984, DeGraaf et al 1998).

In order to gauge the effect that increased biomass harvesting could have on the amount of habitat at the landscape scale, it is instructive to consider neighboring regions. Maine and New Hampshire have a longer history with markets for low-grade material and the introduction of whole tree harvesting and clearcutting for pulp and biomass. How well these landscapes have fared in an ecological sense depends on perspective. If one compares these landscapes to an old growth ideal, they fall resoundingly short. However, a recent review of the ecological literature (Jenkins 2008) for the Northern Forest region indicates the difficulty in quantifying landscape-wide ecological damage.

Jerry Jenkins, a scientist with the Wildlife Conservation Society, reviewed the scientific literature on ecological factors in the intensively managed Northern Forest region for the Open Space Institute. The subsequent report, *Conservation Easements and Biodiversity in the Northern Forest Region*, includes sections on Northern Forest biodiversity and the effects of logging on biodiversity. Although the conclusions of this review are debated in the Northern Forest region, his introduction is helpful in understanding the different perspectives in evaluating landscape ecology. The 'pragmatic' approach is to maintain the biodiversity that exists at present. The 'idealistic' approach is to restore the forest to a more natural state. Jenkins notes that the pragmatists point to the literature which suggests "there have been almost no losses of vertebrates or higher plants from the working forests and that overall levels of biodiversity in clearcuts and managed forests often exceed those of old, undisturbed forests." The idealists "see the working forest as a conservation failure, and while they grudgingly accept it has considerable biodiversity, they argue that it is the wrong kind." They draw on 'the general literature of biodiversity and landscape ecology to suggest that our current forests are fragile and impoverished or will become so when the "extinction debt" induced by dissection and fragmentation is finally "paid." These proponents however, have not able to come up with good lists of the species that have actually been lost from managed forests.

The history of the intensively managed industrial landscape of northern New England and New York is far different than Massachusetts. The low harvest rates of the last century have allowed the Massachusetts forests to mature. The current forest landscape of the state offers management possibilities for the pragmatist and the creation of old growth for the idealists. The lessons from the Northern Forest indicate that even in regions with much heavier harvesting the debate over the impacts of changing habitat patterns across the landscape continues unresolved. We can certainly expect this debate to continue in Massachusetts as we try to understand a dynamic and shifting land cover that is resilient but faces a number of pressures. While the number of landowners and their attitudes and behaviors seem to ameliorate the possibility of widespread harvests, there still remains the possibility of localized habitat loss within a watershed as well as stand-level effects. For this reason, in a concluding section we suggest a number of policy options that Massachusetts officials could consider if they wish to assure a greater degree of protection for these ecological values.

4.4.3 POTENTIAL IMPACTS OF BIOMASS HARVESTS ON LANDSCAPE AESTHETICS

The forests of Massachusetts play a number of supporting roles in the socio-economic framework. They are the predominant natural land type and form the backdrop for most communities and many economic enterprises, including tourism and recreation. The forest landscape is integral to the way of life of Massachusetts residents and shapes the image of Massachusetts for visitors and employers locating businesses there. Although historically these forests have been heavily cut, and at one time reduced to 20% of the landscape, the current perception is one of dense unmanaged forests covering most of the landscape. At the more localized or regional scale, biomass harvesting could potentially alter this forest landscape. The heavily harvested forest landscape of northern Maine is one extreme example of what a forested landscape can look like when subject to available markets for low-grade material and landowners willing to harvest using clearcutting and short rotations. From the level of public reaction and media attention paid to clearcutting on public lands in the past, it is expected that broad scale clearcutting on private lands would likely have severe socio-economic impacts for Massachusetts.

While the harvest scenarios do not anticipate broad scale clearcutting, reactions to aesthetic landscape changes are difficult to quantify. The view-shed of most forested areas of Massachusetts now consists of rolling acres of consistent overstory. Even a small amount of clearcutting, consistently repeated across the landscape would dramatically alter these views and probably create a different and negative reaction from tourists or residents. Therefore, any significant increase in clearcutting methods as a form of forest management could have potentially dramatic impacts on recreation and tourism and face significant challenges from residents accustomed to a maturing forest. The quantification of these effects is beyond the scope of this study.

Fortunately, alternative forms of forest management are available including uneven-aged management that maintains a continuous overstory, and forms of even-aged management that delay final harvests until sizable regeneration has occurred. These alternative methods would mitigate the landscape-scale aesthetic effects on tourism and recreation and likely be more acceptable to residents.

4.4.4 POTENTIAL IMPACTS OF BIOMASS HARVESTING ON ECONOMIC PRODUCTIVITY OF FORESTS

Massachusetts forests have historically supported a vibrant forest products industry that has declined dramatically in the last two decades. Although harvest rates of sawtimber remain steady, the number of Massachusetts sawmills and wood product businesses has declined. More of the current harvest leaves the state for processing. The future of this industry is directly connected to a continuing availability of high-quality forest products. The growth and harvest of these higher-quality forest products could be either enhanced or diminished by increased biomass harvesting.

As demand and price for biomass rises, the number and choice of trees removed in harvests change. Trees that previously had no value and were left behind can now be removed profitably or at no cost. We expect that increased demand for biomass will lead to the introduction of whole-tree harvesting equipment on a wider scale, which will enable smaller trees to be harvested more economically. One positive effect of these new markets is to make it possible for foresters to remove portions of the stand that have little future economic value and thus provide growing space for trees with better potential. Without a biomass market, such improvement operations cost money and are typically not possible to perform.

However, new biomass markets may cause the harvest of trees that would eventually develop into valuable crop trees if left to grow. A straight, healthy 10" oak tree that would someday grow to be an 18" high-value veneer log might be removed too early in order to capture its much lower biomass value today. The misuse of low thinnings to remove biomass could also remove the future sawtimber crop as well as the forest structure referred to earlier. Whole tree harvesting equipment may make such removals more profitable, but these trees can also be added to the harvest in conventional operations that use skidders and chain saws. Whether these negative scenarios play out depends on whether the stand is managed with a silvicultural prescription, and that in turn depends on landowner intentions and state regulations for forest management.

4.4.5 EXISTING APPROACHES TO MANAGING LANDSCAPE LEVEL IMPACTS IN MASSACHUSETTS

Historically, Massachusetts has not had programs to manage silviculture and forest harvesting at the landscape (i.e., multi-owner) level. This may be a function of the historical fact that over the last century Massachusetts forests have been recovering from heavy harvesting and deforestation from a prior period when much of the landscape was in agricultural use. In addition, the statewide harvest has been limited in number of acres and intensity. The advent of increased biomass harvesting, the continued loss of forestland to development and the effects of climate change may change the perception of an expanding healthy forest and need for greater oversight of harvesting at the landscape level. While the state does limit the size of individual clearcuts and requires adequate regeneration from harvests and in some cases regulates harvesting in concern for endangered species, nothing in current regulations or guidance limits the ability of private landowners to independently decide to harvest their forests, even if this results in very heavy and rapid cutting in a relatively small area. Furthermore, under the existing regulations, it is theoretically possible for an individual landowner to legally harvest an entire standing forest within a relatively short timeframe (5–10 years) by using a combination of clearcutting and shelterwood harvests.[5]

There are many historical reasons why forest regulatory policy has been implemented at the stand level rather than the landscape level. The focus of existing regulations has generally been aimed at protecting *public* rather than *private* ecosystem services values. For example, BMPs came into existence to protect water quality, which is clearly an ecosystem service that affects the public good—either through off-site contamination of drinking water supplies or damage to public recreational resources. Proposed policies that assert control over ecosystem services that are viewed as purely private in nature have been much more controversial. The recent proposed changes to introduce better silviculture into the Forest Cutting Practices regulations are a case in point where the State Forestry Committee wrestled with these issues and ultimately agreed on an approach that would require sound silviculture practices across all harvests. The practice of silviculture was determined to be a public value and worthy of addressing in the cutting plans. But again, the only controls on forest harvesting now are at the stand level and focused on protecting values that are traditionally considered in the greater public's interest, such as clean water, rare species, adequate forest regeneration, and fire protection. Landscape aesthetics, for example, are not captured by any existing regulation. Voluntary programs, such as land

5 Shelterwood harvest are heavier cuttings that are intended to regenerate the forest with seedlings but leave a sheltering mix of larger trees that are removed shortly after the regeneration is established.

purchases for conservation through land trusts and the state, have been the mechanism to achieve landscape objectives.

A second hypothesis for the lack of landscape-level forest management policies is a purely practical one. How such controls might be implemented is a difficult question. For example, what type of system would be put in place to decide who can harvest their land and when? Suppose a landowner needs short-term income for a medical emergency or college tuition. It will be difficult for the state to assume too much control over an individual's rights when a widely held public value is not being obviously compromised.

Finally, in the past 50 to 75 years, we generally have not had a forest landscape 'problem' caused by over-cutting that the public believed needed to be addressed. Forests have been increasing in both area and wood volume for many years as abandoned farmland has returned to woodland. However, that trend may be changing as urbanization and other land-use changes begin to reduce the amount of forestland in the Eastern U.S. (Drummond and Loveland 2010).

From this discussion, it should be clear that the sustainability of ecosystem services at the landscape level raises a wide array of complex issues involving public values. Forest ecology and science can help inform decisions about the need for an approach to ensuring biomass harvests do not compromise ecosystem services at a landscape scale. But ultimately, public policy on this issue will be a value-based exercise. As a result, our recommendations on this issue, included in the final section of this chapter, focus on options that could be considered as part of a broader process of assessing public perceptions about what would be unacceptable impacts at the landscape level.

4.5 RECOMMENDATIONS FOR ADDRESSING STAND AND LANDSCAPE LEVEL IMPACTS OF INCREASED BIOMASS HARVESTING

4.5.1 STAND LEVEL RECOMMENDATIONS

The science underlying our understanding of the potential impacts posed by increased biomass harvests and the efficacy of policies to minimize these impacts is currently far from providing definitive guidance. While it is clear that DWM is fundamental to nutrient cycling and soil properties, there appears to be little or no consensus on the amount of woody debris that should be maintained. In fact, the literature generally suggests that minimum retention levels will differ based both on underlying site productivity as well as with the volume of material harvested and the anticipated amount of time the stand will have to recover before the next harvest. DWM is also essential for maintaining habitat and biodiversity; but again the scientific studies do not provide a definitive answer to the question of how much DWM should be left after a harvest. The impacts of logging equipment on soils are also likely to depend on site-specific conditions.

Fundamentally, in the face of imperfect scientific information, the choice of policies for protecting ecosystem functions at the stand level must factor in public values regarding how conservative biomass retention policies should be. In addition, it may be important to understand the public's views on the extent to which biomass standards should rely on voluntary or mandatory standards. This likely will depend on the extent to which the public believes the proposed harvest practices are needed to protect public versus private values.

In light of these considerations, Massachusetts may find it useful to utilize the State Forestry Committee to convene an appropriate public process to establish biomass harvesting retention and harvesting guidelines for Massachusetts. The scientific data we reviewed in Section 3 provide a starting point for these public discussions. One approach other states have used is to create a panel of experts from across the spectrum of forestry interests to come up with recommendations which are then reviewed and commented on by stakeholders. The revision of Chapter 132 regulations could easily fit this format by using the State Forestry Committee as the expert panel.

Embedded within our process recommendation is a second broad recommendation that the State Forestry Committee use the *Forest Guild's Forest Biomass Retention and Harvesting Guidelines* for the Northeast as a starting point for the substantive discussion of the options for ensuring biomass harvesting does not result in diminished ecosystem function at the stand level. The Forest Guild's proposed guidelines are readily adaptable to the Commonwealth and cover the major Massachusetts forest types. The Forest Guild Biomass working group consisted of 23 Forest Guild members representing field foresters, academic researchers, and members of the region's and country's major environmental organizations. The process was led by Forest Guild staff and was supported by the previously referenced reports *Ecology of Dead Wood* in the Northeast (Evans and Kelty 2010) and *An Assessment of Biomass Harvesting Guidelines* (Evans and Perschel 2009a).

Wherever possible the Forest Guild based its recommendations on peer-reviewed science. As noted above, however, in many cases available research was inadequate to connect practices, stand level outcomes, and ecological goals. Where this was the case, the Forest Guild relied on field observation and professional experience. The guidelines are meant to provide general guidance and where possible offer specific targets that are indicators of forest health and can be measured and monitored. They are not intended to be applied on every acre. Forests vary across the landscape due to site differences, natural disturbances, forest management, and landowner's goals. All of these elements need to be taken into consideration when applying the guidelines. These guidelines should be revisited frequently, perhaps on a three-year cycle, and altered as new scientific information and results of field implementation of the guidelines becomes available.

In the following section, the Forest Guild's stand-level recommendations for ensuring biomass harvests do not damage ecosystems are examined in. six major categories.

4.5.1.1 Forest Guild Biomass Harvest Guidelines

Site Considerations to Protect Rare Forests and Species

Biomass harvests should be avoided in critically imperiled or imperiled forest types that can be determined through the State National Heritage Program. Biomass harvesting on sensitive sites may be appropriate to control invasive species, but they should only be done for restorative purposes and not to provide a long-term wood supply. Old-growth forest should be protected from harvesting. In Massachusetts, old growth exists exclusively on public lands.

Retention of Coarse Woody Material

A review of scientific literature reveals a limited number of studies that address the biomass and nutrient retention issue. Some studies suggest that biomass harvesting is unlikely to cause nutrient problems when both sensitive sites (including low-nutrient sites) and clearcutting and whole-tree harvesting are avoided. However, there is no scientific consensus on this point because of the wide array of treatments and types of sites that have not yet been studied. Given this lack of consensus, the Guild's recommendations adopt a conservative approach on this issue. They direct harvesting away from nutrient-limited sites. On sites with operable soils, we recommend that between 25% and 33% of tops and limbs be retained in harvests where 1/3 of the basal area is being removed on 15 to 20 year cycles. When harvests remove more trees or harvests are more frequent, greater retention of tops and limbs may be necessary. Similarly, where the nutrient capital is less rich or the nutrient status is unknown, greater retention of tops, branches, needles, and leaves is recommended. Conversely, if the harvest removes a lower percentage of basal area, if entries are less frequent, or if the site is known to have high nutrient levels, then fewer tops and limbs need to be left on site.

In Massachusetts it will be important to identify the soils where there are concerns regarding current nutrient status as well as those soils that could be degraded with repeated biomass harvests. Much of the current harvesting activity falls into the low-frequency and low-removal categories and will require lower levels of retention. It is difficult in most operations to remove all the tops and limbs even if the operator is attempting to do so. In these cases, the retention guidelines may not call for a significant change in operations. If whole-tree harvesting becomes more commonplace, the guidelines would become more important and the balance of acceptable retention and the frequency of harvests and removal intensities a greater issue. Whole-tree operations in some jurisdictions have dealt with retention targets for tops and limbs by cutting and leaving some whole trees that would otherwise have been designated for removal or transporting and scattering a certain percentage of the material back to the woodlot from the landing during return trips to remove additional material.

Retention of Forest Structures for Wildlife and Biodiversity

The Forest Guild recommends a number of approaches for retaining forest structure. All live decaying trees and dead standing trees greater than 10 inches should be left. In areas under even-aged management, we suggest leaving an uncut patch for every 10 acres of regeneration harvest, with patches totaling 5% to 15% of the area. These guidelines also call for maintaining vegetation layers (from the over-story canopy to the mid-story), shrub, and ground vegetation layers to benefit wildlife and plant species diversity. There are targets for retention of downed woody material by weight and forest type. In addition, there are specific targets by forest types for snags, cavity trees, and large downed logs.

In Massachusetts, there has been an awareness of the importance of forest structure for wildlife but no specific guidelines that broadly influence the retention of this material. The targets recommended here can be readily integrated into forest inventories, tree selection, and forest cutting plans.

Water Quality and Riparian Zones

In general, water quality and riparian concerns do not change with the addition of biomass removals. Massachusetts State BMPs currently cover these issues, and habitat management guidelines are available for additional protections for streams, vernal, pools, and other water bodies. These can be integrated into a set of guidelines tailored to Massachusetts.

Silviculture and Harvesting Operations

Most concerns about the operational aspects of biomass harvesting are very similar to all forestry operations. However, some key points are worth mentioning for Massachusetts forestlands:

- Integrate biomass harvesting with other forest operations to avoid re-entering a site and increasing site impacts such as soil compaction.
- Use low-impact logging techniques such as piling slash to protect soil from rutting and compaction.
- Use appropriate equipment matched to the silvicultural intention and the site.

Forest Types

Different forest types naturally develop different densities of snags, DWM, and large downed logs. Currently, available science leaves uncertainty around the exact retention targets for specific forest type and does not provide enough data to provide detailed guidance on each structure for every forest type. The Forest Guild guidelines, however, do discuss the relevant science that is available by forest type. Massachusetts can take that information and augment it with more localized research or prompt new research on specific topics. This information can be used to establish minimum retention targets for Massachusetts forest types. Wherever possible, targets should be exceeded as a buffer against the limitations of current research.

4.5.1.2 Improved Silvicultural Requirements for Forest Ecosystem Management

Finally, we would like to note that Massachusetts has for a number of years been considering changes to the forest cutting plan regulations. In our view, putting these improved silvicultural guidelines in place, while not directly aimed at biomass harvests, will provide greater assurance that Massachusetts forests are managed to maintain ecosystem functions at the stand level. The remainder of this section discusses the current regulatory context and the changes that have been proposed.

Existing Regulatory Framework

Regulations for harvesting forest growth in Massachusetts are guided by intent to promote sound forestry practices and the maintenance of the health and productivity of the forest base. The licensing of foresters in Massachusetts is a recognition of their unique professional education, skills, and experience to practice forestry. One of the keystones of forestry is the practice of silviculture, the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis. Therefore, the argument has been made that all harvesting in the state should adhere to an acceptable form of silviculture and be performed by a licensed professional forester.

The state requires an approved harvesting plan for any harvest over 25,000 board feet. Any harvest is subject to oversight by Natural Heritage and Endangered Speices Program which imposes "life zones" around vernal pools and limits harvesting to certain months of the year in turtle habitat. But most harvested acres are ultimately subject only to requirements indicated in the state approved cutting plan for the property. Unfortunately, the current harvesting plan does not need to be filled out by a licensed forester, nor does it need to follow any accepted form of silvicultural practice.

On the cutting plan, landowners are offered a choice of long-term management and short-term management. A long-term management choice 'employs the science and art of forestry.' However, the short-term option does not and is characterized as follows:

> *Harvest of trees with the main intention of producing short-term income with minimum consideration given to improving the future forest condition ... [and] the selection of trees for cutting based on the economic value of individual trees which commonly results in a residual forest stand dominated by poor-quality trees and low-value species. While this strategy produces immediate income and meets the minimum standards of the act, it does little to improve the future condition of the forest.*

DCR takes the position that long-term management is the preferred option and warns that the short-term harvests retain slower-growing and poor-quality trees which can limit management options. Still, the short-term option is acceptable and used by 20% of current harvests. This means that aside from restrictions on some harvest areas through the Natural Heritage and Endangered Species Program the door remains open for virtually any kind of harvest as long as it protects water quality and assures adequate regeneration of some kind of tree species- a near certainty in Massachusetts forest conditions. The current system is not designed to assure protection and oversight of a number of ecological and socio-economic sustainability indicators that could be affected by increased biomass harvesting.

Proposed Changes to the Cutting Plan Process

In 2006 the Massachusetts Forestry Committee ended a three-year process where regular public committee meetings were held to completely revise the Chapter 132 Forest Cutting Regulations. By statute, the Committee involves representatives from the key stakeholder interests, and each meeting included a number of public members from various stakeholder groups. The process also involved work in several sub-committees and data analysis from the DCR. The process ended in the spring of 2006 with the Committee completing its voting on a complete package of revisions to the Regulations. The result, supported by the majority of members, was forwarded to DCR in anticipation of public hearings on the Regulations.

Two of the proposed changes are directly related to ensuring that biomass harvesting protects ecological and socio economic values.

- A requirement that all forest cutting be based in silviculture, regardless of the owner's intent, and allowing state foresters to require that trees of high-timber quality be left distributed across the stand after thinning or intermediate cuttings.
- A requirement for marking all trees either to be cut or to be left, regardless of value or cost.

The committee was considering using the silvicultural requirement as a way of getting around opposition to a third suggestion that would mandate that only licensed foresters could fill out a harvesting plan. We recommend that when the Chapter 132 review process begins again, these proposed changes be resurrected in light of the interest in increasing the biomass harvest.

The requirement that all cutting plans be based on silviculture would help assure that biomass harvesting would be ecologically sound and aligned with the long-term economic productivity of the stand. In our view, the requirement for marking trees will also promote good silviculture and ecological practices. However, it may not be necessary in every case, and some flexibility should be considered. These changes would ensure the engagement of professional foresters, require that the harvest be silviculturally sound, and refine the decision making process for selecting trees for harvest by requiring the marking of trees in most cases.

4.5.2 LANDSCAPE LEVEL RECOMMENDATIONS

To determine the need for and nature of approaches to minimizing ecosystem service losses at the landscape-scale as a result of forest biomass harvests, we recommend a public process-based approach. A broad-based and legitimate public process is necessary for addressing landscape-scale impacts of biomass harvesting, particularly because the scientific literature has much less to offer at the landscape scale than it does at the stand level. A key driver of public concerns about diminished ecosystem services at the landscape level is uncertainty about the local and regional impacts of specific bioenergy facilities. Resolving these uncertainties requires gaining a better understanding of the spatial dimensions of harvests for specific proposed facilities. These uncertainties depend on facility size, wood demand, and the extent to which the facility relies on forest versus other biomass. Another uncertainty relates to future energy prices. While landowner reaction to price trends is difficult to predict with accuracy, the likelihood of increased harvests and the concern over landscape-scale impacts increases if policies result in greater use of bioenergy technologies that can afford to pay more for wood (e.g., thermal, CHP, cellulosic ethanol).

Uncertainty, however, will not be the only driver of public preferences. Equally important is how the public perceives and values possible impacts to competing ecosystem services (e.g., renewable energy production versus biodiversity across the landscape), and how risk averse the public is to potential negative impacts of biomass harvesting. Only through a legitimate public process will it be possible to gauge the public's desire for some landscape-level controls on biomass.

With these issues in mind, we have developed some options that could form the basis for a public dialogue on the need for and desirability of policies addressing landscape-scale impacts of biomass harvesting. These range from non-regulatory, information-based approaches to more stringent and enforceable regulatory processes. In general, it may be easier for an individual bioenergy facility to implement voluntary sustainable guidelines for the procurement of their biomass than for a state to implement the same sort of policies. Four possible options are discussed briefly below.

Option 1: Establish a transparent self-monitoring, self-reporting process for bioenergy facilities that includes a commitment towards continual improvement.

Bioenergy facilities could report their procurement status on a year-to-year basis. The report could include a report card that indicated where the supply came from according to a number of assurance criteria. Examples of these criteria can be found in the Forest Guild's A*ssurance of Sustainability in Working Forest Conservation Easements* and the Biomass Energy Resource Center's *Wood Fuel Procurement Strategies for the Harwood Union High School* report. Using a licensed forester or a management plan would be at one end of the assurance of sustainability spectrum. Compliance with the Forest Guild's biomass harvesting and retention guidelines might be in the middle of the spectrum and receiving supply from forest certified by FSC could be one of the highest assurances. Each year the facility would be expected to show improvement.

Option 2: Require bioenergy facilities to purchase wood from forests with approved management plans

If bioenergy facilities were allowed to purchase wood only from landowners with approved forest management plans approved by licensed foresters, there would exist a base level of assurance that biomass energy supplies would be harvested in a manner that would not result in damage, at least at the stand level. Vermont and New York require their biomass power producers to obtain their supply from forests with approved forest management plans. Such a requirement would be a start for Massachusetts facilities, but the harvests should also be certified as having been conducted under an acceptable set of biomass harvesting and retention guidelines. The Forest Guild guidelines or other state guidelines could be used where deemed sufficient, or enrollment in one of the existing forest certification programs that incorporate biomass retention guidelines could work as well.

One wood pellet manufacturer in New York State is supplied by 100% FSC-certified lands. Historically, certification has not been a practical option for a diverse, small forest-ownership land base such as Massachusetts. To the extent that aggregation of land ownerships into certification systems becomes more common, this may become feasible. In addition, the state has recently developed a new program that will allow small owners who seek Chapter 61 property tax exemption for their forest land to prepare 'stewardship plans' that will automatically confer third-party certification status on their lands. The biomass facility would periodically report and be evaluated on the ecological and socioeconomic sustainability of the supply. This kind of transparent reporting has proven effective in the toxic waste sector and is applicable to biomass supply.

Another level of assurance is to require the biomass facilities that receive subsidies or incentives to monitor, verify, and report on the sustainability of their supply, including an annual geographic analysis of the facility's geographic wood basket. Some of the supply may come from other states; so the biomass facilities will need to account for supply not produced under the various safeguards that may be instituted in Massachusetts.

Overall, while these approaches improve the likelihood that bioenergy facilities are supporting good forestry practices, they may not be sufficient to fully protect against over harvesting at the local or regional scales.

Option 3: Require bioenergy facilities to submit wood supply impact assessments

This option would require that a facility submit information on its anticipated wood supply impacts as part of the facility siting and permitting process. The facility would identify the area from which it anticipates sourcing most of its forest biomass and would present information on the level of the cut across this region over the life of the facility. As conceived here, this is purely an informational requirement and would not be used as the basis for a positive or negative determination on a permit. But requiring information from a developer on the long-term impacts of their operation on wood supplies within the wood basket of the facility, may result in greater public accountability for the facility and a better understanding of the likely impact on forests. Similar informational programs, such as requiring manufacturing companies to submit information on toxic chemical use, have created positive incentives for improved environmental outcomes.

Option 4: Establish formal criteria for approval of wood supply impact assessments

This option differs from Option 3 in that the state would establish criteria that would have to be met in order for a facility to receive approval for its wood supply impact assessment. For example, possible approval criteria might be based on limits on the amount of harvests relative to anticipated forest growth in the wood basket zone. These could take a variety of forms. For example, the state could require a demonstration that biomass harvests could be conducted without reducing future harvest levels in the wood basket zone (i.e., a non-declining even flow) or other types of limits on how much forest inventories in the wood basket could be reduced over the life of the facility. Once approved, the facility might also be required to submit annual comparisons of actual wood supplies with those included in the approved wood supply impact assessment. Measures could also be put in place requiring corrective actions to be taken by a facility if impacts exceed those anticipated in the impact assessment. Such an approach is more regulatory in nature and likely will be more expensive for facilities but it would give added assurance to the public that local and regional harvests would not diminish broader forest-based ecosystem services.

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