Forest Biomass as an Alternative Energy Source in Washington State: Potential Environmental and Ecological Impacts.

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Introduction

The implementation of Washington's Renewable Energy Portfolio resulting from the Energy Independence Act of 2007 (I-937) has driven an increase in demand for the use of forest woody biomass for renewable energy generation. This increase is exemplified by the Washington state legislature's recent adoption of House Bill 2481 in 2010 which directs the Department of Natural Resources (department) to "facilitate and support the emerging forest biomass market and clean energy economy, and enable the department to encourage biomass energy development on state trust lands for the trust land's potential long-term trust beneficiaries. The legislature finds that biomass utilization on state forest lands must be accomplished in a manner that retains organic components of the forest necessary to restore or sustain forest ecological functions" (Section 1., SSHB 2481, 2010 Regular Session).

Most recently (4/13/11) the legislature passed a bill authorizing the Washington Department of Natural Resources (DNR) to conduct a forest biomass to aviation fuel demonstration project (House Bill Report SHB 1422, 2011 regular session). In 2009 the legislature authorized the DNR to implement biomass energy pilot projects in eastern and western Washington. The purpose of the pilot projects is to demonstrate "that removing biomass feedstock in ecologically sustainable ways to produce energy (liquid fuels or heat and electricity) may provide income for forest landowners while improving forest health; create rural jobs; reduce wildfires and greenhouse gas emissions; and aid in the production of renewable energy".

Prior to conducting these pilot projects, and entering long-term forest biomass contracts, the DNR must first assess the available supply of biomass in forests that serve as potential source areas. In 2010 the DNR received a grant from the U.S. Forest Service to perform a statewide forest biomass supply assessment (DNR 2010). The DNR selected the University of Washington's School for Forestry to conduct the assessment. According to the House Bill Report (SHB 1422), the Forest Biomass Supply Assessment will assess forest biomass availability and sustainability throughout Washington on all forestland ownerships, including state-owned lands. The assessment will further evaluate operational and economic factors for biomass availability, and environmental sustainability. The first draft Report of The Forest Biomass Supply Assessment (FPSA) was completed in September 2011 and is currently in the process of review by DNR and interested stakeholder groups.

Several prominent Washington environmental organizations have expressed concerns that the University of Washington's FBSA report, by virtue of being a "supply assessment" study, will be narrowly focused on biomass supply to the extent that it will not be comprehensive enough to address substantial environmental and ecological impacts (Forests and Fish Conservation Caucus 2011). Pending final completion of the University of Washington's FBSA report, this paper provides a brief review of relevant literature examining the potential for environmental and ecological impacts of increased woody biomass harvest from forestlands of the Pacific Northwest. More specifically, this report examines the physical watershed processes, water quality and ecological functions required to maintain fish and wildlife habitat potentially affected by the removal of large quantities of forest biomass (i.e., beyond what's required under existing forest practices rules). This report will hopefully augment the University of Washington's FBSA study and will further assist informing DNR policy makers and forest managers that seek to "restore or sustain ecological functions" in accordance with the Washington state legislature's directive. This report also identifies information gaps that still exist in better understanding the potential impacts of forest biomass removal on ecological processes, and makes recommendations where appropriate on mitigating the potential effects of woody biomass removal from forests.

Background

The Pacific Northwest and interior coniferous forests contain the largest amounts of woody biomass in the United States (Woodall 2008). Woodall (2008) estimates large woody debris at 10.1 tons per acre, far surpassing that of other regions in the United States (Table 2, Figure 1 below). Due to the potentially large supply of woody biomass, many biomass projects are planned or are currently underway in Washington and other Pacific Northwest states (Evans and Finkral 2009).

Table 2 Estimates of LDW by region from Woodall et al. (2008), and LDW as a percentage of total forest carbon (EPA 2010 Table A-216)

Region	Tons of LDW biomass per acre	MT of CO_2eq per acre	LDW as a percentage of total forest carbon
Northeast	3.8	6.3	2.3%
Northern Lake States	4.1	6.8	1.9%
Northern Prairie States	3.3	5.5	2.4%
Pacific Southwest	5.1	8.5	2.9%
Pacific Northwest	10.1	16.9	4.4%
Rocky Mtns. (North)	6.4	10.6	4.6%
Rocky Mtns. (South)	2.4	4.1	2.7%
South Central	1.9	3.2	1.9%
Southeast	2.4	4.1	1.7%

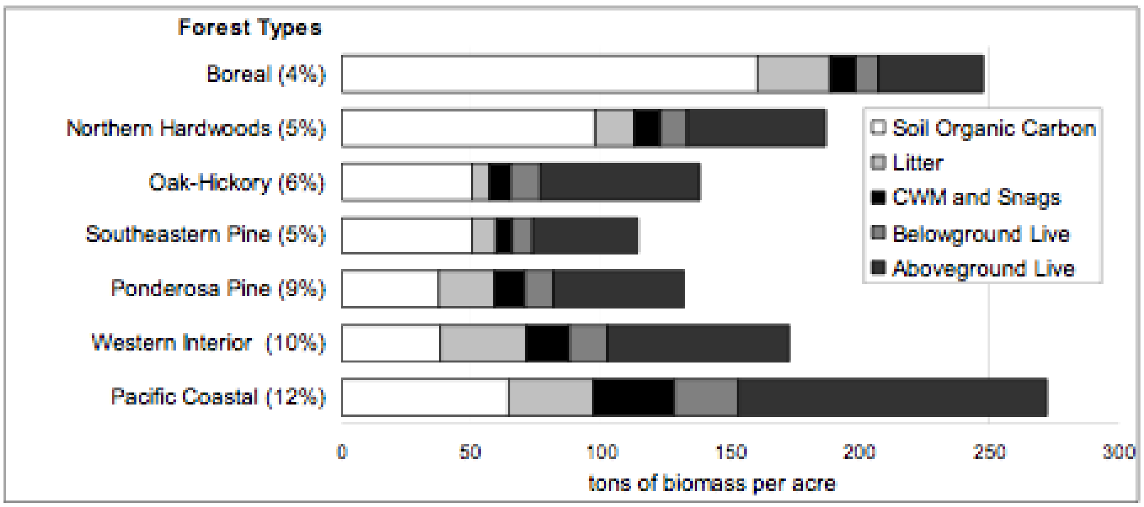
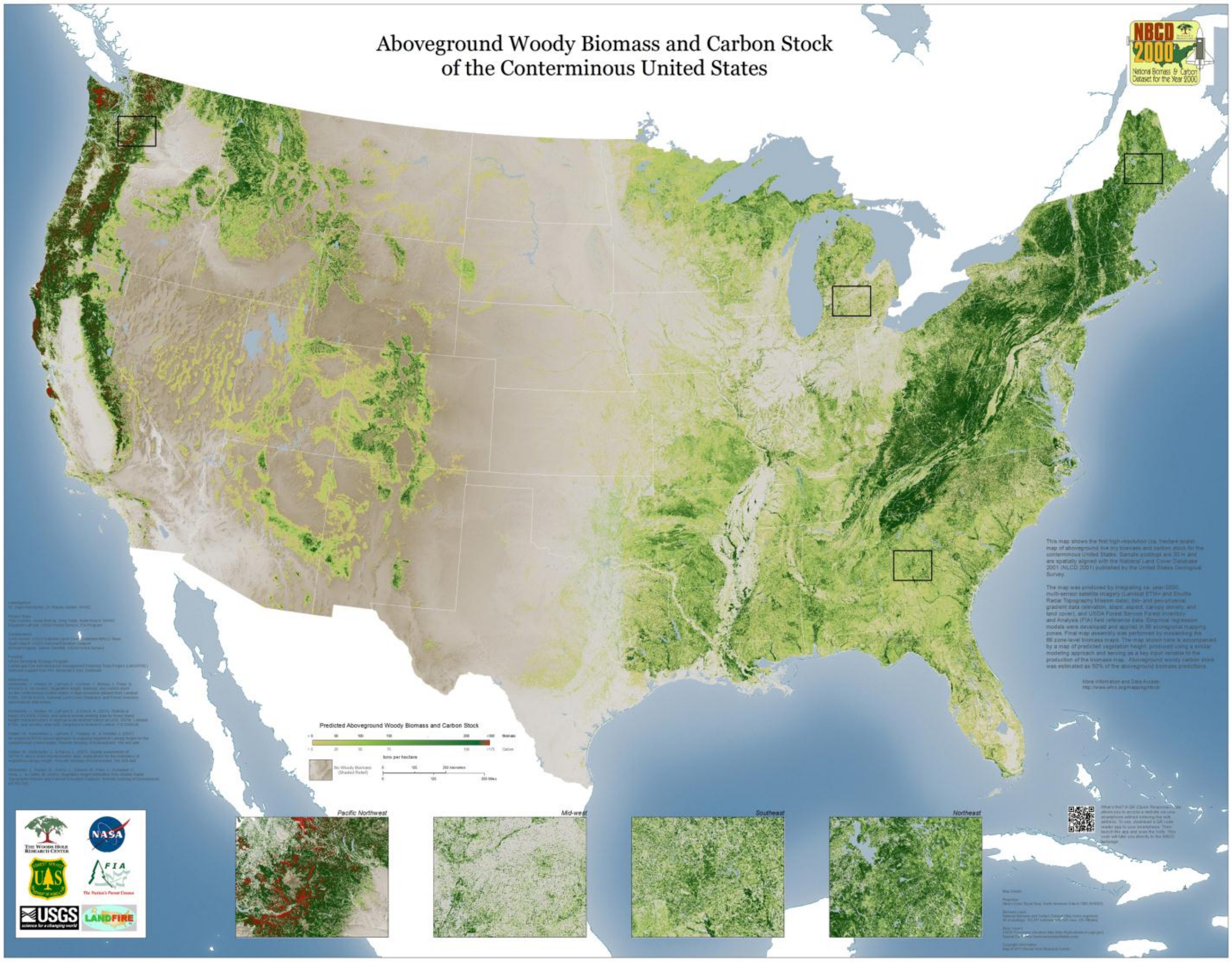


Figure 1 Estimates of biomass by forest type per acre, with percentage made up by CWM and snags in parentheses (EPA 2010 Table A-211)

The Woods Hole Research Center recently released a high resolution "National Biomass and Carbon Dataset for the year 2000" (NBCD2000), the first ever spatially explicit inventory of its kind. The project has generated a high resolution (30 m), year 2000 baseline estimate of basal area weighted canopy height, aboveground live dry biomass, and standing carbon stock for the conterminous United States. While the resolution is poor at the scale of this 8.5 x 11 inch paper, the Pacific Northwest region clearly stands out (darker greens and red) as containing the most aboveground woody biomass and carbon stock in the United States (www.whrc.org).



The removal of biomass material from forests to achieve management objectives such as forest stand manipulation and restoration to maintain and restore fish and wildlife, and hazardous fuel reductions have recently been pushed to the forefront of policy makers as western states attempt to meet renewable energy portfolio standards adopted by state and federal governments.   Woody biomass has long been a useful, and some would argue underutilized byproduct of forest management activities. Rising energy costs, concerns about carbon emission from fossil fuels, and the threat of catastrophic wildfires have greatly increased interest in removing and using woody biomass from forests.

Use of wood as a replacement for fossil fuels has the potential to reduce greenhouse gas emissions and therefore, contribute to climate change mitigation. Much of the biomass that will potentially be used to replace fossil fuels will likely come from coniferous forests of the Pacific Northwest. Many of these interior forests have undergone fire suppression over the past century resulting in the increased risks of catastrophic wildfires (Noss et al. 2006). Large fires, like the Biscuit fire in Oregon, release massive amounts of greenhouse gasses to the atmosphere (Wiedinmyer and Neff, 2007).

Washington State Forest Practices Rules and Biomass

In Washington there are approximately 22 million acres of forestland. Approximately 55% of this forestland is owned and managed by private forest landowners and the DNR under two separate Habitat Conservation Plans (DNR State Lands HCP 1996, National Marine Fisheries Service EIS 2005). Both HCPs have a suite of forest practices rules and regulations designed to protect, conserve and maintain a variety of upland and aquatic species. However, at the time these HCPs were approved by the U.S. Fish and Wildlife Service (USFWS), the U.S. Environmental Projection Agency (EPA), and the National Oceanic and Atmospheric Association (NOAA), they were done so without consideration of the potential impacts on "listed" species caused by woody biomass removal for the purpose of supplying and generating alternative energy sources. Both the Washington State forestland HCP (1996) and the WA Forest Practices programmatic private forestlands HCPs (2005) that were negotiated and approved by the federal services were premised on the assumption that only *live* trees would be removed for commercial timber value, with the exception of forest thinning associated with forest health, restoration and wildfire prevention. The potential effects of non-merchantable, woody biomass removal on environmental and ecological processes affecting listed species under both HCPs was not considered prior to their approval, but will be further explored in this paper.

What Exactly is Woody Biomass?

Generally, the term woody biomass includes all trees and woody plants in forest, woodlands, and rangelands. This biomass includes limbs, tops, needles, leaves, and other woody parts (Washington Forest Practices Board 2011). Under current law in Washington "forest biomass" means the by-products of prescribed and permitted forest management practices; forest protection treatments; or forest health treatments (House Bill Report SHB 1422, 2011). From a commercial perspective, woody biomass usually refers to material that has low economic value and cannot be sold as saw timber or pulpwood. In this paper, the term woody biomass refers to vegetation removed from forests, usually logging slash, small diameter stems, tops, limbs, trees and snags, and other dead and downed wood that otherwise cannot be sold as higher-value products such saw timber.

Although interest in and implementing woody biomass removal projects in the Pacific Northwest and U.S has increased recently, little research is available to document and characterize these harvests or their potential effects on ecological processes. On a national and local scale, little is known about the objectives behind biomass removal, how these projects are implemented, or the characteristics of successful projects (Evans and Finkral 2009).

Potential Environmental Impacts from Woody Biomass Removal

<u>Watershed processes</u>

In describing the effects of forest biomass use on watershed processes in the Western United States, as shown below in Figure 2. Elliot (2010) lists several key forest watershed processes and the impacts of biomass use on those processes including: Forest hydrology, soil compaction, duff integrity, infiltration, surface erosion, roads, and water yield. Hydrologic processes in forested ecosystems of the Pacific Northwest are complex - climate, topography, geology, soils and vegetation all interact to affect runoff and erosion rates (DNR, Washington Watershed Analysis Manual 1995).

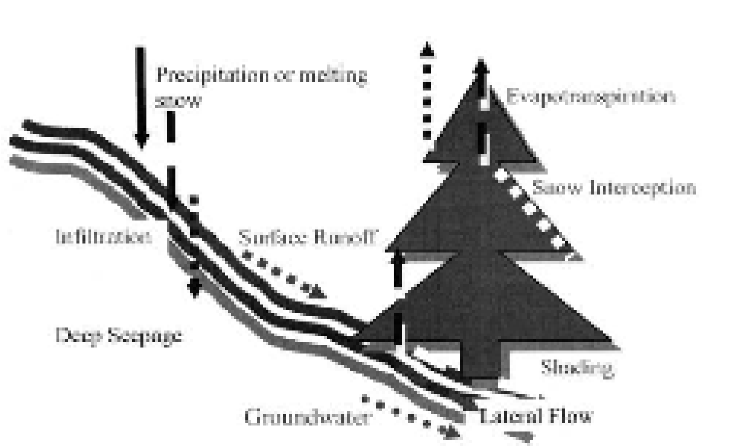


Figure 2. Dominant hydrologic processes on a forest hillslope.

The removal of forest vegetation can play a significant role in forest hydrology, and biomass removal can cause considerable disturbance within a watershed. Logging traffic can cause soil compaction, particularly if soils are wet, and duff disturbance exposing mineral soils (Elliot 2010, DNR 1995). These disturbances contribute to reduced infiltration and increased surface erosion. Harvesting additional non-merchantable trees and woody biomass (e.g., limbs, tops, leaves and bark) has the potential for greater onsite impacts than would otherwise be experienced with standard forest practices. For example, mechanical harvesting of additional woody biomass after commercial harvest has already taken place would require additional machine traffic over much of the same area increasing soil compaction and road use.

Soil Compaction

If woody biomass is removed using wheeled or tracked equipment when soils are wet and soil strength is low, soil compaction is likely to occur (Johnson and Beschta 1980). Compacted soils may take many decades to recover to undisturbed conditions (Froehlich et al. 1985). Processes that reduce soil compaction include wetting and drying in soils that are high in clay, and freezing and thawing in climates where temperatures drop below freezing before there is snow cover. Growth of plant roots can open up passages that become macropores when the root dies, but compacted soils tend to resist root penetration, slowing this form of recovery. In most forest environments, none of these processes occur quickly, and it is not uncommon to observe compaction many decades after the forest operation that created the compaction (Alexander and Poff 1985). Compaction reduces infiltration rates, and in all but sandy soils, it reduces the amount of soil water available for plant growth (Jonson and Beschta 1980).

Duff Integrity and Infiltration

Forest duff is a layer that is constantly decomposing and being replenished by needles, leaves, and branches from forest vegetation. As woody biomass is removed from the duff layer and there are fewer trees to generate organic material to replenish material that is lost through decomposition and biomass harvest, compaction will likely increase. In addition, the physical process of removing biomass can displace the duff layer, leaving bare mineral soil exposed to the erosive forces of wind, rain, and overland flow (Elliot et al. 2010).

Compaction and loss (or large-scale displacement) of duff will reduce soil infiltration rates leading to increased surface runoff and potential hillslope erosion (Elliot et al. 2010). In some climates, frozen soils can also significantly decrease infiltration rates, particularly if the insulating duff layer has been disturbed by mechanical operations. Where surface runoff does occur, it is usually associated with areas that are heavily disturbed, such as roads and skid trails. Small changes in infiltration are unlikely to cause any major changes in surface runoff rates. These changes in infiltration can however, change lag times and increase instantaneous peak discharges for small storms in small watersheds (Sendek 1985, DNR 1995).

Surface Erosion

Compaction, loss of surface cover, and a small increase in surface runoff can lead to significant increases in surface erosion (Elliot et al. 2010, DNR 1995). Splash erosion and runoff are minimal when surface cover protects mineral soils from raindrop impacts. Raindrop splash erosion, rill erosion, and gully erosion are all directly affected by surface runoff rates which may increase with woody biomass removal when tracked and rubber tired machinery further compacts soils and/or displaces the duff layer.

Roads

One of the greatest sources of sediment in most forested watersheds is from the road network (Elliot et al. 2010, DNR 1995). A road network is necessary to remove biomass. Many "legacy" forest roads were built to lower standards in the last century and are now covered with grass and shrubs. Forest roads are highly compacted by design, and they retain this compaction for decades (Foltz et al. 2009). The impact of overgrown legacy roads on erosion may be minimal or significant, depending on site-specific conditions. In northern California and the Pacific Northwest, legacy roads subjected to large storm events can produce substantial sediment delivery to stream channels from mass wasting failures associated with poorly constructed road fills, as well as catastrophic failures of unmaintained stream crossings (Elliot et al. 1994, DNR 1995, Dube 2011).

Natural Wildfire Regimes

Historically, a natural fire regime describes the type of wildfires that typically occurred in a forest prior to modern human mechanical intervention. Natural fire regimes have been described for different forest types based on a combination of fire *frequency* and fire *severity*, i.e., the percentage of overstory trees killed. Interior conifer forests fire regimes experienced frequent (as often as every 4-20 years), low severity fires. By contrast, coastal Washington and Oregon forests historically had very infrequent (100-400 years), high severity fires (Brown et al. 2004).

These departures from historical fire frequency or disparity can result in alterations of key ecosystem components, e.g., species composition, forest structural state, forest stand age, and forest canopy closure and fuel loadings (ODF 2008). In many forested watersheds, the greatest source of sediment is associated with erosion following wildfire (Elliot 2006). Peak runoff rates and erosion rates following wildfire are 10 to 1,000 times greater than from undisturbed watersheds. One of the benefits to harvesting biomass in fire-prone forested landscapes is the severity or frequency of wildfire may be reduced with a reduction in fuel loads (Elliot 2006).

Woody Biomass Removal Effects on Wildlife

There are only a few recent reports have been completed in the Pacific Northwest that provide a comprehensive overview of the effects of woody biomass removal on wildlife. Two of these reports were recently completed by the Oregon Department of Forestry (ODF 2008) and by the University of California Berkeley's Center for Forestry and College of Natural Resources (Stewart et al. 2010). Both reports draw on a multitude of literature, research and monitoring reports. These studies examine thinning techniques used on interior coniferous forests by reducing fuel loads (woody biomass) to lower the risk of wildfires, and to a lesser extent on coastal and inland temperate forests that historically burned less frequently, but more severely. Even with low wildfire risk, coastal and temperate coniferous forests west of the Cascade Crest have been targeted for woody biomass removal, largely due to the relatively high amount of woody biomass they contain post commercial harvest ("residues") and a higher rate of harvest by state and private industry than interior forests (ODF 2008).

Similar to Washington, the Oregon State legislature passed a bill (SB 1072) requiring the ODF to investigate and report on the effects of biomass removal on plant and wildlife resources stating "…utilizing, to the greatest extent practicable, data collected from the state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and on the air and water quality of this state." California is under a similar mandate in response to implementation of their very progressive Renewable Energy Portfolio Standard (Stewart et al. 2010). California's report (2010) states that, "The implementation of California's Renewable Portfolio Standard may drive an increase in the use of woody biomass for renewable energy generation." And, their goal is to "identify critical information gaps regarding the potential environmental impacts of increased utilization of woody biomass for energy generation..."and "Assess both the negative and positive environmental impacts of the increased utilization of woody biomass…".

The most recent DRAFT of University of Washington's Forest Biomass Supply Assessment study (2011) does not specifically address individual species, and instead narrows its scope of defining "ecological functions" through "ecological stoichiometry" which is limited to describing and predicting nutrient flow paths over time with implications of forest biomass removal. The DRAFT Report (WFBSA 2011) also has a brief section on "woody biomass removal as a wildfire risk management tool" and "woody debris and biodiversity and habitat values". However, the latest version of the WFBSA DRAFT Report (2011) falls well short of providing a comprehensive overview of the potential affects of woody biomass removal on individual species (federal and state "listed" and non listed), to the same extent that the Oregon and California Reports do as directed by their state legislatures.

Since Washington State has yet to generate such a report, the following summarizes some of the more relevant literature from the Oregon and California's reports related to forest biomass removal for similar species found in Washington State.

Effects on Forest Carnivores

The California report (Stewart et al. 2010) states that mammals found in California include the mountain lion (*Felis concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), black bear (*Ursus americanus*), fisher (*Martes pennanti*), and American martin (*Martes americana*). Important habitat elements of these large mammals include dead and downed wood and understory shrub and tree cover both within and adjacent to mature forest stands. Large diameter logs and snags with cavities are often used for denning and resting. Common feeding habitats for bears and martens include foraging within dead and downed wood for invertebrates and vertebrate prey. Because these mammals have such large home ranges the impacts associated with a single biomass harvest would be negligible. However, the cumulative impacts to carnivorous mammals from biomass harvests may be serious if dead and downed wood and understory vegetation (i.e., reduction in prey populations, forage, and denning habitat) is significantly reduced across the landscape.

The Oregon report (ODF 2008) lists the same carnivorous mammal species as the California report (Stewart et al. 2010), with the addition of grizzly bear (*Urus arctos*), and wolf (*Canis* *lupus*). The ODF report also states that carnivorous mammals could be affected by loss of denning habitat and changes in prey populations due to the cumulative effects of biomass harvests and larger scale projects (Pilliod et al. 2006). And, that both marten and fisher are sensitive to loss of canopy cover and are strongly associated with downed wood cover.

Washington State public forestlands also have carnivorous mammals "listed" under their Habitat Conservation Plan (DNR 1996). The grizzly bear is federally listed as "threatened" and the gray wolf is federally listed as "endangered" under the Endangered Species Act (ESA) and cover over half of their harvest planning units. Additional carnivorous mammals listed under the Washington state forestlands include the Pacific fisher (*Martes pennant pacifica*), California wolverine (*Gulo gulo luteus*), and the North American lynx (*Felix lynx canadensis*).

It is likely that the potential effects of biomass removal on the carnivorous mammals in California and Oregon will be similar for the same species, and sub-species, that occur in Washington State concerning their habitat requirements.

Effects on Small Mammals

The California report (2010) states that logs and course woody debris provide perching platforms and escape runways for small mammals. Loose bark provides cavities for hiding and thermal cover. Food availability for small mammals increases as invertebrates and fungi colonize the dead wood material and aid in decay. A given species may use dead and downed wood to meet all, several, or one of its life history requirements (feed, cover, reproduction, etc.). The abundance of small mammals using dead wood is directly related to the quantity and quality of logs, limbs, stumps, and snags in the forest ecosystem. Biomass harvests that remove or disturb dead and downed wood and understory vegetation layers will result in lower habitat quality and smaller small mammal populations (Carey and Harrington 2001).

The Oregon Department of Forestry report (2008) states that small mammals that prefer high canopy closure may be adversely affected by thinning. Thinning will likely have a drying effect on high-canopy, high-density stands of grand fir, potentially having a negative effect on northern flying squirrel populations. Northern flying squirrel abundance in dry Douglas fir-ponderosa pine-western larch forests in northeastern Oregon degreased 1-2 years after a thinning treatment, possibly due to habitat changes and decreases in truffles, the primary food of northern flying squirrels and other small mammals (Lehmkuhl et al. 2006). Lehmkuhl and others (2006) concluded that thinned and burned stands would likely be poor bushy-tailed woodrat habitat in eastern Washington dry forests due to the woodrat's association with abundant large snags, mistletoe brooms and soft log cover.

Effects on Bats

The California report (2010) states that many species of bats locate roosting sites within large, moderately decayed snags with cavities and under the bark of large trees. Bats use different structures for roosting throughout the day that may help with thermo-regulation. Roost structures are often tall and occur in gaps, opening or areas of small low canopy closure. Biomass harvests that reduce the quantity and quality of snags will likely impact bat species. Several species of bats are known to use large stumps with cracks and crevices within clearcuts, especially when preferred roosting sites (snags) have been removed. Bats often use open habitats for feeding more intensively than dense forests. The type of vegetation within a forest stand will influence the insect population present and therefore, the food supply for bats. Biomass harvests that remove the majority of herb and shrub cover within a stand could be detrimental to insect populations and bats. If biomass harvest results in homogeneous forest structures across the landscape lacking in understory vegetation and dead wood (mainly snags) bat populations will likely decline.

The ODF report (2008) is less clear about the potential impacts of biomass removal on bats. The report states that little data exists on direct effects of fuel treatments on bats, but some inferences can be made based on their known habitat. Similar to the California report (2010) bats, specifically Long-legged myotis, silver-haired bats, and other bat species roost under the bark of tall, large-diameter trees or in cavities of large snags. In the Oregon Coast Range, bat activity in Douglas fir stands was highest in old-growth forests, lowest in un-thinned second growth (50-100 years old), and intermediate in thinned second growth stands. Bat activity was higher in old-growth stands of Douglas fir than in mature and young stands in the southern Washington Cascades and Oregon Coast Range.

The Washington State lands HCP (1996) lists several bats as federal “candidate” species including the long-legged myotis, fringed myotis, small-footed myotis, long-eared myotis, and Yuma myotis. The effects of removal of woody biomass on these species habitat requirements will need to be further explored to ensure their long-term viability is not jeopardized.

Effects on Other Species

Both the ODF Report (2008) and the California report (Stewart et al. 2010) continue to list and report on a suite of other forest species potentially impacted by woody biomass removal. The list includes: Ungulates (Elk, deer bighorn sheep, and mountain goats), birds (owls, hawks, falcons, woodpeckers, and song birds), reptiles and amphibians (snakes, lizards, salamanders, and frogs), forest invertebrates and plants.

The majority of potential effects of woody biomass removal on the above forest species are directly linked to the degree to which their habitat requirements, at various life stages, are met by the presence and consistent accumulation of dead and downed woody debris (slash, snags, branches, tops, stumps, understory trees, etc.). Presently, most of this biomass comes in the form of non-merchantable residuals left over from timber harvest and forest restoration and thinning projects attempting to lower the risk of wildfire (frequency and severity).

Conclusions and Recommendations

Washington, Oregon and California have some of the most progressive renewable energy portfolios in the western U.S. (ODF 2008, Stewart et al. 2010, DNR 2010). Meeting portfolio standards will likely increase demand for woody biomass that in turn will lead to increased economic value given to woody material that was previously non-merchantable. This new emerging market will likely result in more intensive, forest management in Pacific Northwest states. If harvest rotations continue to shorten, and forest biomass harvests occur more often (at both intermediate pre-commercial thinning and regeneration clearcut harvests), the accumulation of dead and downed wood will likely be substantially reduced.

This reduction in woody biomass may contribute to the continued deterioration of watershed processes including soil compaction, loss of duff integrity, alterations if forest hydrology, loss of infiltration, increased surface erosion, increased runoff for forest roads, and a potential decrease in wildfire frequency and severity by removing forest "fuels" in fire prone forests. Developing and complying with well established management practices designed to minimize such risks resulting from commercial timber harvest should also be rigorously applied and enforced for biomass removal.

Because of the importance of woody biomass structures for maintaining wildlife populations and biodiversity, woody biomass harvesting guidelines requiring retention of dead and downed wood will likely be necessary. Providing for the replacement of snags and decomposing downed wood may also become necessary. Large snags particularly, are very valuable structural components of wildlife habitat as they provide different habitat functions for many species over their long duration in the forested landscape (ODF 2008, Stewart et al. 2010). More intensive forest management may lead to fewer trees reaching the large diameter classes necessary for the production of valuable habitat in the form of snags and logs.

Few studies have attempted the difficult task of quantifying the specific amounts of dead and downed wood necessary to maintain viable wildlife populations, and more work is needed to accurately identify critical threshold levels. It may also be challenging to interpret and more broadly apply the results recent studies, as they tend to be more site specific and focus on a single species or subset of the entire forest ecosystem. However, given what we know, and more importantly what we don't know about the potential affects of woody biomass removal on wildlife and their life history and habitat requirements, a precautionary approach to forest management is warranted. And, maintaining viable wildlife populations and biodiversity over a highly variable landscape in the face of what is likely to become increased woody biomass removal will require a much broader approach to forest management in the Pacific Northwest.

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