2015 Vermont Forest Fragmentation Report

VERMONT DEPARTMENT OF FORESTS, PARKS AND RECREATION

AGENCY OF NATURAL RESOURCES

APRIL 2015

Submitted to House and Senate Committees on Natural Resources and Energy and the House Committee on Fish, Wildlife, and Water Resources

Report to the Vermont Legislature

Acknowledgments

Vermont Department of Forests, Parks and Recreation

Michael C. Snyder, Commissioner

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I. Authority and Scope

The Background of Act 118 of 2014

In 2014 the Vermont General Assembly enacted Act 118 (S.100), an act relating to forest integrity, with findings that:

- ⇨ The forests of Vermont are a unique resource that provides habitat for wildlife, is a renewable resource for human use, provides jobs for Vermonters in timber and other forest-related industries, and generates economic development through a productive forest products industry;

- ⇨ Large areas of contiguous forest are essential for quality wildlife habitat, preserve Vermont's scenic qualities, are needed to implement best practices in forest management, and are critical to ensuring the continued economic productivity of Vermont's diverse forest products industry; and

- ⇨ Subdividing forests into lots for house sites or other types of construction fragments Vermont's forests and reduces their value as wildlife habitat and a forest industry resource, as well as diminishes Vermont's tourist economy;

and calling for a report assessing the current and projected effects of fragmentation on Vermont's forestland and recommendations for how to best protect the integrity of Vermont's forestland from the Commissioner of the Department of Forests, Parks and Recreation to be submitted to the Vermont Legislature on or before January 15, 2015.

II. Executive Summary

Forest is the dominant land cover across Vermont. Currently at 75% forested, Vermont is the fourth most forested state in the United States. Indeed, forests have covered Vermont since well before Vermont existed as a state, though many changes in the nature and extent of our forests have occurred over the course of Vermont's history.

Native American influences to the landscape of Vermont were minimal, and early European settlers found nearly all of Vermont covered by forests. Forest clearing became widespread around 1800 as Vermont farmers became suppliers of wood products, food, and wool to a rapidly growing nation. By 1860, less than one-half of the state remained forested and Vermonter George Perkins Marsh, arguably the nation's first environmentalist, warned of the impacts of soil erosion due to forest clearing. As a result of the widespread clearing of forests and the unregulated taking of wildlife, Vermont lost many of its most iconic species by the late 1800s, including white-tailed deer, moose, beaver and fisher. Subsequently, the migration of people toward the West led to a decline in agriculture in Vermont, allowing forest succession to reclaim the state's landscape.

From the 1940s to the present, Vermont's forests have experienced another wave of wide scale transformation. On one hand, forest cover continued to expand and Vermont's forests continue to mature, as demonstrated by increases in numbers sizes and species composition. On the other, human social pressure has brought significant changes as a result of built infrastructure, and Vermont has witnessed the introduction and spread of invasive plant and insect species as well as pathogens.

Today, the vast majority of Vermont's forestland is held by private landowners (80%). Approximately 2.9 million acres, 62%, of forestland is owned by families and individuals. A relatively small proportion of Vermont's forest is public land (21%), including the Green Mountain National Forest, many state parks and state forests, and a smaller number of municipal forests.

Although Vermont's forests are still heavily owned by private landowners, the demographics of those owners is changing in important ways, with significant implications for the size and integrity of our forests: the number of landowners is increasing, the size of the parcels is decreasing, and the age of owners is increasing.

These changes bring new pressures on the forests of Vermont. The rate of development (measured in housing units and developed acres) in Vermont is increasing twice as fast as the state's population. This problem is compounded by the fact that population growth is occurring mostly in rural areas (defined as communities with fewer than 2,500 residents), where forestland and other working and undeveloped lands are concentrated. Accordingly, Vermont's forests are at risk of fragmentation.

Forest fragmentation is the breaking of large, contiguous forested areas into smaller pieces of forest, typically by roads, agriculture, utility corridors, subdivisions or other human development. It usually occurs incrementally, beginning with cleared swaths or pockets of non-forest within an otherwise unbroken expanse of tree cover. Then, over time, those non-forest pockets tend to multiply and expand and eventually the forest is fragmented and reduced to scattered, disconnected forest islands. The remnant forest islands that result from fragmentation are surrounded by non-forest lands and land uses that seriously threaten the health, function, and value of those forest islands for both animal and plant habitats and for human use.

Any land-use change can lead to forest fragmentation. The extent of actual impact depends on the type of change, the degree of fragmentation, and the species involved. It is important to distinguish between a forest fragmented by human infrastructure development and a forest of mixed ages and varied canopy closure that results from good forest management. The former is typically much more damaging to forest health and habitat quality, usually with permanent negative effects, whereas the latter may only cause temporary change in forest condition, while continuing to support multiple forest benefits.

The real effects of fragmentation are well documented in all forest regions of the planet. And, although it is related to outright loss of forestland, the impact of fragmentation is more and different than simple forest loss. It is about the negative effects on the smaller fragments of forest that do remain—the changes that occur in their configuration, condition, and connectedness. In general, fragmentation reduces overall forest health and degrades habitat quality, leading to long-term loss of biodiversity, increases in invasive plants, pests, and pathogens, and reduction in water quality. The wide range of these effects all stem from two basic problems: fragmentation increases isolation between forest communities and it increases so-called edge effects within forest fragments.

Isolation is the physical separation of fragments. It diminishes connectivity, inhibiting the movement of

plants and animals, restricting breeding and gene flow, and resulting in long-term population declines. While this may be more difficult to observe directly, we do know that connectivity of forest habitats is a key component for forest adaptation and response to climate change. Fragmentation is a clear threat to such natural resilience.

Edge effects alter growing conditions within the interior of forests through drastic changes in temperature, moisture, light, and wind on the edges. Put simply, the environment of the adjacent non-forest land use dominates and determines the environment of the forest fragment, particularly on its edges. This triggers a cascade of ill effects on the health, growth and survivability of trees, flowers, ferns, and lichens and an array of secondary effects on the animals that depend on them, including humans.

Moreover, as forest fragments become ever smaller, practicing forestry in them becomes operationally impractical, economically nonviable, and culturally unacceptable. In turn, we lose the corresponding and important contributions that forestry makes to our economy and culture. The result is a rapid acceleration of further fragmentation and then permanent loss.

Forests provide with Vermonters enormous benefits and a range of critical services. A thriving forest economy, functioning natural systems, and Vermont's quality of life rely on maintaining blocks of contiguous forests across Vermont's landscape. As we enter the 21st century, Vermont's forests have the potential to provide an abundance of economic, ecological, and social benefits into the future, and decisions and actions taken today will influence Vermont's forests and forest values for years to come.

Although Vermont remains the second least populated and second most rural state in the United, it is predicted that the population growth rate is likely to increase. By 2030, Vermont is expected to have an additional 85,000 residents compared with 2013. As we anticipate this growth, we know that the urban areas of Vermont will need to continue to plan for an accelerated population growth. In addition, many rural communities will be confronted with population increases and the pressures associated with rapid development.

Over the years, much thought has gone into how we might balance Vermont's anticipated growth with our interest in maintaining our traditional settlement patterns—with village centers surrounded by fields, farms and healthy, working forests. In order to protect the integrity of Vermont's forests, it will be important to:

1. Educate and engage Vermont landowners, schoolchildren, municipalities and land-use decision makers (e.g. realtors and developers) about the economic and ecological benefits of large forest blocks and the connectivity among smaller forest blocks;

2. Continue to invest in land conservation and strategically target investments to focus on areas that have the greatest ecological and economic values and are most at risk;

3. Support existing landowners to keep their land forested and to encourage new growth in existing settlements and near existing roadways to avoid incursions into high value forest blocks;

4. Consider additional tools for local governments and the state to discourage development that converts blocks of forest to other uses and requires mitigation when such development occurs; and

5. Ensure that forest landowners can get value from their forested land through sustainable forestry practices and develop and create markets for Vermont forest products.

Given the importance of Vermont's forests and the many, often complex, policies options available to the state, it has become clear that additional dialog is needed before we move forward down any one policy pathway. Forests impact all corners of the state, many facets of our economy and are central to our communities, as such, Vermonters should be involved in crafting a solution to the challenge of forest fragmentation. Given that several drivers of fragmentation are currently in place in Vermont—and given the significant and wide-ranging importance and value of Vermont's forests—much is realistically vulnerable to loss and much is at stake.

The final recommendation of this report is for the Commissioner of Forests, Parks and Recreation to facilitate a series of stakeholder conversations in the coming months to gather comments and feedback on the potential policy options outlined in this section, to solicit additional ideas and strategies to support forest integrity, and generate a concrete list of recommendations for lawmakers to consider during the 2015-2016 legislative session.

III. The Forests of Vermont

Definition of Forest

A forest is a biological community dominated by trees but also consisting of other plants, animals, and microorganisms, their associated physical environment (namely soils, bedrock, water, and air), and their combined interactions and processes. Forests are characterized by a more or less dense and extensive tree cover often consisting of stands varying in characteristics such as species composition, structure, age class, and associated processes; and commonly including meadows, streams, fish, and wildlife (SAF 2011).

Forests can take many forms depending on climate, soil quality, and available genetic supply for the dispersion of plant species. Forest stands range from very tall, heavily dense, and multi-structured to short, sparsely populated, and single-layered. The US Department of Agriculture (USDA) Forest Service Forest Inventory and Analysis (FIA) Program defines forestland as land that is at least 10% stocked by trees of any size or land formerly having been stocked and not currently developed for non-forest use. The treed area must be at least 1 acre in size and 120 feet wide (Morin et al 2014).

Extent of Forests in Vermont

Forest is the dominant land cover across Vermont. Currently at 75% forested, Vermont is the fourth most forested state in the United States. Forests have covered Vermont since well before Vermont existed as a state, though many changes in the nature and extent of our forests have occurred over the long course of Vermont's forest history, largely as a consequence of human use (particularly agriculture). The percentage of forest cover generally increases from west to east, mostly due to the belt of agricultural and developed land in the Champlain Valley in western Vermont (**Figure 1**). Future changes in Vermont's forestland base will depend on the pace of land development, particularly in the western and southern parts of the State (Morin et al, 2007).

Ownership of Forests in Vermont

A relatively small proportion of Vermont's forest is public land (21%) (**Figure 1**). The Federal Government holds 491,000 acres (11%) of forestland, most of which is administered by the Green Mountain National Forest (446,400 acres). The State of Vermont holds 368,000 acres of forestland (8%) in various state agencies including state parks and forests, and local governments hold another 73,000 acres of forestland (2%) (**Figure 2**).

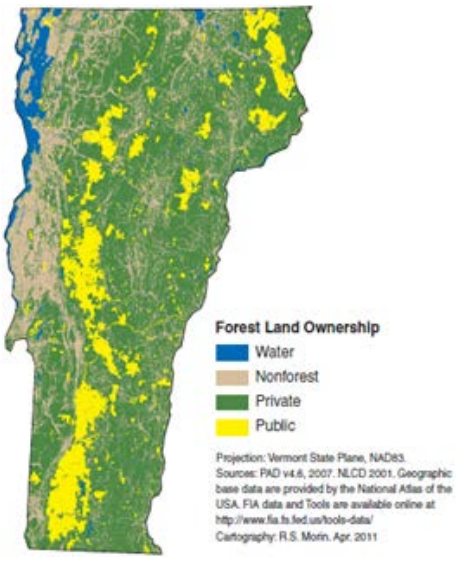

Figure 1. Distribution of forestland by owner group. Vermont, 2007.

Public land increased by about 17,000 acres between 2007 and 2013 (Morin and Pugh 2014).

The vast majority of Vermont's forestland is held by private landowners (80%). Approximately 2.9 million acres, 62%, of forestland is owned by families and individuals (Butler et al 2015). Corporate-owned forests encompass 681,000 acres, and other private forests encompass only 133,000 acres. Unlike other northeastern states with large corporate ownerships, a relatively small percentage of Vermont's forest is owned by businesses, including timberland investment management organizations (TIMOs) and Real Estate Investment Trusts (REITs).

> ***The vast majority of Vermont's forestland is held by private landowners (80%).***

Although Vermont's forests are still heavily owned by private landowners, the demographics of those owners

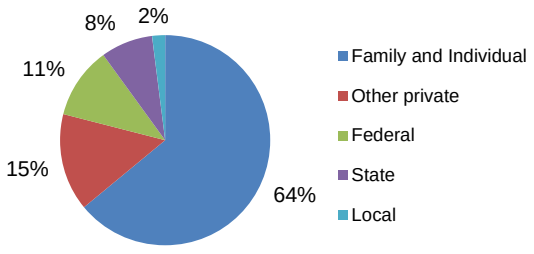

Figure 2. Ownership of forests in Vermont (Morin et al. 2014).

are changing in important ways, with significant implications for the size and integrity of our forests. The number of landowners is increasing, the size of the parcels is decreasing, and the age of owners is increasing.

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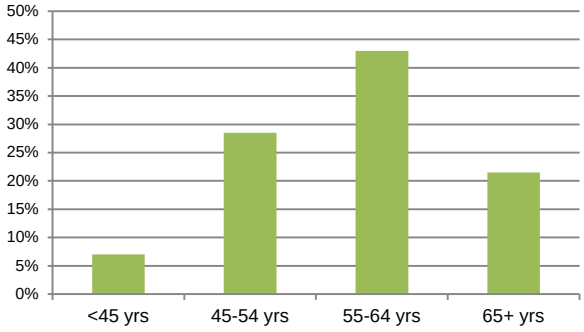
There are currently some 87,000 private forest owners. More than 40,000 of the family or individual forest owners own >10 acres, but an even higher number own <10 acres. Even among the larger ownership category (10+ acres), a majority of the family forest ownerships hold <50 acres of wooded land (Butler et al 2015). When woodlots are <50 acres, landowners' land-management objectives are limited because of the small size of the parcel. Additionally on such small acreage, a higher than usual number of land features are present, which is not desirable.

The demographic of primary forest owners in Vermont largely comprises males over the age of 55. As landowners age, the question of land transfer becomes more important. In Vermont, the owners of 7% of the family forest ownerships with 10+ acres, owning 15% of the forested land, are over the age of 75 (Butler et al 2015). Social and economic factors will likely drive a number of these older landowners to not pass on their ownership within the family and to sell their holdings. Many of these will result in smaller parcels.

Age of Forestland Owners in Vermont



Characteristics of Vermont's Forests

Vermont lies within a biological transition zone where northern and southern forests converge. At higher elevations and northern latitudes, the maple/beech/birch forests of the Northeastern United States give way to the spruce/fir forests of Northern New England (Morin et al, 2007).

On a broad scale, Vermont's forested landscape can be divided into eight biophysical regions, with each region supporting nearly 100 distinct natural community types.

The forests of Vermont are as diverse as the landowners that steward them. They hold a staggering variety of plants and animals notwithstanding the state's small geographic extent. Combined with a variety of geographic features—valleys and mountains; rivers, bogs, and lakes; and open land and forest—Vermont's forest landscape is truly varied. Describing the state's forested landscape goes beyond the trees occupying the site; foresters also consider bedrock, soil conditions, climate, and topography in classifying land.

Vermont's forests are characterized by variability and dynamism. Native American influences to the landscape of Vermont were minimal, and early European settlers found nearly all of Vermont covered by forests. Forest clearing became widespread around 1800 as Vermont farmers became suppliers of wood products, food, and wool to a rapidly growing nation. By 1860 less than one-half of the state remained forested and Vermonter George Perkins Marsh, arguably the nation's first environmentalist, warned of the impacts of soil erosion due to forest clearing. As a result of the widespread clearing of forests and the unregulated taking of wildlife, Vermont lost many of its most iconic species by the late 1800s, including white-tailed deer, moose, beaver and fisher. Subsequently, the migration of people toward the West led to a decline in agriculture in Vermont, allowing forest succession to reclaim the state's landscape.

From the 1940s to the present, there has been wide-scale transformation of Vermont's forests. In general, they are maturing as demonstrated by increases in numbers sizes and species composition. At the same time, human social pressure has resulted in forest habitat fragmentation as a result of built infrastructure, and Vermont has witnessed the introduction and spread of invasive plant and insect species as well as pathogens.

As forests mature, the volume of trees increases. Some of this increasing volume is harvested, but thus far annual net growth has exceeded the harvest, although this ratio is seeing a decline. Current inventories show that Vermont's forests add 2.4 million cords of timber growth per year whereas about 1.4 million cords is harvested. For context, Vermont's standing forest holds 80 million cords of timber (including trees 5 inches or greater in diameter).

Despite the wealth of this state's forest resources, there are indications of a future that may look quite different from today. Climate change presents a major challenge to the ecological and economic viability of forests. Although there is uncertainty about the timing and magnitude of forest impacts, it is certain that forest changes have been occurring and will continue. The capacity of Vermont's forest species to adapt to change will depend, in part, on how carefully they are managed and conserved today.

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IV. Importance and Values of Vermont's Forests

Introduction

Vermont's forests are an invaluable resource. They are natural assets, underpinning our economy and enhancing our quality of life. We depend on forests for their material and economic contributions of timber, veneer, pulpwood, firewood, chips and pellets, (for both space heating and electric generation), and maple syrup, as well as the values and services forests provide, such as water supply and water quality protection, flood control and protection, wildlife habitat and biodiversity, clean air and carbon sequestration, outdoor recreation and scenic beauty. Planning and managing forests sustainably involves a recognition of the ecological, social and economic systems necessary to maintain forest health while providing benefits for this and future generations of people.

Although Vermont's forests are vigorous and generally resilient, they are subject to a number of significant stressors related to conversion, fragmentation, climate change, invasive plants, and pests, pollution and numerous others. The manner in which these stressors can disrupt the flow of goods and ecosystem services from the forest to Vermonters can be likened to a short circuit in a wiring system or a bottleneck in an assembly line. The cause and effect relationships can be enormously complex and difficult to tease apart.

To assess the impact that changes to the forest have on Vermont, it is necessary to first acknowledge the benefits we derive from forests and their contributing processes and conditions.

Forest Products Economy

Benefit

The harvest and manufacturing of forest products contributes $1.4 billion in annual economic output to Vermont's economy (NEFA 2013).

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Discussion

Vermont's forests have provided products to sell for as long as the state has been in existence. A forest-based economy includes all of the activities involved in harvesting forest products and producing usable goods. It is estimated that the forest products industry employs 10,555 people and has $1.4 billion in economic output annually. Vermont's gross state product, the state-level equivalent of the national gross domestic product, for all forest product manufacturing is $266 million, and represents 8% of the state's manufacturing value.

Pine logs and firewood are sorted on the landing at LaPlatte Headwaters Town Forest in Hinesburg, VT.

The forest economy value chain begins with the landowners, foresters, loggers, and truckers who own, manage, harvest, and transport raw material from the forest to various markets for primary processing. Many Vermont landowners participate directly in this economy by harvesting wood from their land. Primary products include solid wood products from sawmills, veneer mills, and mills that reconstitute wood chips into oriented strand or particle board. These primary manufacturers

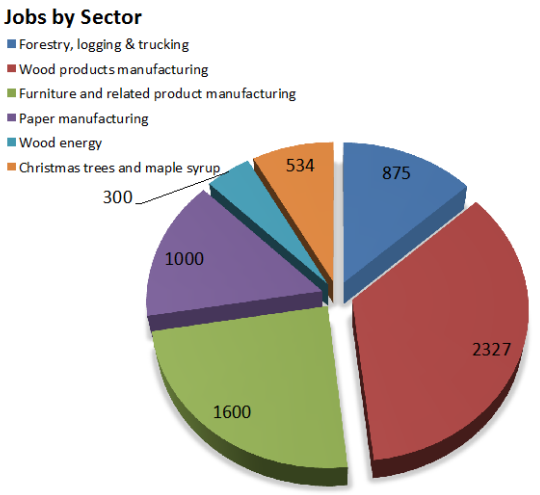
employ 2,327 workers. Payroll in the wood products sector is about $67 million annually. Today annual economic output, in terms of annual sales or value of shipments, stands at $239 million.

Secondary manufacturers transform lumber and other primary solid products into finished consumer products or components for finished products. The making of furniture, moldings, turnings, and similar products employs nearly 1,600 Vermont workers. The payroll in this sector is about $49 million annually. Annual economic output, in the form of sales or value of shipments for the secondary wood products sector, is about $143 million in Vermont.

A LOGGER RUNNING A FORWARDER UNLOADS FIREWOOD AT THE LANDING AT THE AUDUBON CENTER IN HUNTINGTON, VT.

Wood pulp mills do not exist in Vermont, but several in-state manufacturers make paper from pulp purchased from out of state. These facilities employ over 1,000 workers. Payroll in the paper sector is about $63 million annually. The annual economic output, in the form of sales or value of shipments for the pulp and paper sector, is about $317 million in Vermont.

Ninety-four percent of the wood harvested in Vermont is processed within the state. This value-added local rural economy is essential for many communities and landowners. Vermont's forest product sector, however, is also part of a larger regional economy where wood flows freely. Vermont's northern hardwood—maple, beech, yellow birch—are prized and sought after throughout the world. Although exports of raw materials exceed imports, the ratio remains almost equal: 1.2 to 1 (NEFA 2013). The impacts of forest fragmentation on the forest product sector are hard to quantify, although certainly the correlation between decreasing parcel size and the number of active sawmills is striking. Having local markets for wood products, similar to the *food-to-table* and *buy local* movements, is critical for forest landowners to retain land and reap economic benefit.



Some of the raw wood harvested in Vermont forests is turned into fuel. Vermont has a long history of using wood for heating and for electric energy generation. Many homeowners heat their homes with firewood or wood pellets. More than 75 commercial facilities use wood chips or pellets for heating, and this number is rapidly growing. Vermont is a leader in heating schools and institutional facilities with wood chips (more than one-third of all Vermont children attend schools heated by wood). Wood chips fuel two large wood-fired electric power plants, as well as a number of smaller commercial and public facilities that use forest biomass to create heat and/or electricity. There are an estimated 300 direct jobs in the wood energy sector beyond the timber harvesting and trucking sectors that are counted in another section of this report.

Vermont in 2014 was estimated to have contributed 42% of the total US maple syrup crop, producing over 1.32 million gallons of syrup (USDA Northeastern Regional Field Office 2014).

Of the total $1.4 billion contribution that forest products make to Vermont's economy, maple syrup is a small but growing sector. The syrup industry's size is not reflective of its iconic stature. It is one of the most recognized products that comes from the forest and has an outsized impact on the cultural identity of Vermont. Within the United States, Vermont plays a stand out role in syrup production. Vermont in 2014 was estimated to have contributed 42% of the total US maple syrup crop, producing over 1.32 million gallons of syrup (USDA Northeastern Regional Field Office 2014). In 2012 the economic contribution from maple syrup and related

products was $26 million, and with Christmas tree production, accounted for more than 500 full-time equivalent jobs.

Economics of Scenery, Fall Foliage, Tourism, and Recreation

Benefit

A large percentage of recreation and tourism activities are vitally linked to the forest and money flowing in to Vermont's economy can be attributed directly or indirectly to forest based recreation and tourism.

Discussion

Tourism has historically been a significant component of Vermont's economy and culture, with much of it forest-based, and dependent on a scenic forest backdrop. Indeed, Vermont continues to be associated with environmental excellence and the "green" values that have gained popularity in response to the challenges posed by rising energy costs and climate change. Vermont welcomes about 13.7 million visitors per year, and annual visitor spending is about $1.4 billion. Summer is the busiest season for number of visitors (5.1 million), however visitor spending is highest in winter ($497 million).

Vermont's largely forest-based tourism economy supports more than 37,000 jobs and accounts for about 11.5% of the state's employment (Chmura Economics and Analytics 2012). Tourism, both directly and indirectly, generates roughly 23% of the employment in the state.

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Fall foliage (**Figure 1**) as an attraction—and directly dependent on healthy intact forests—marks the largest contributing sale revenue generated, accounting for 48% of total sales. Fall foliage accounts for $460 million in tourism spending, which is a little over 25% of Vermont's overall year-round tourism revenue. Vermont enjoys about 3.57 million visitors in the fall who spend on average $128 per person. Columbus Day weekend is the busiest weekend of the year. Fall is the season that universally canvasses the state with tourism: its economic impact reaches well beyond resort areas, major attractions, or cities. Back-road and small-town touring is on most travelers to-do list.

Fall foliage accounts for $460 million in tourism spending, which is a little over 25% of Vermont's overall year-round tourism revenue.

Closely related to Vermont's tourism economy is its outdoor recreation economy which is also heavily dependent on Vermont's forests. Forest-based recreation contributes nearly as many jobs and generates even more revenue than the significant wood-based economy. Forest-based recreation supports 10,050 jobs and generates annual revenues of $1.9 million with payrolls reaching $158 million annually.

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Some activities take place primarily in the forest environment, e.g., camping, hiking, hunting, fishing, skiing, snowmobiling, and wildlife observation. These forms of recreation contribute about $1.9 million in annual sales to Vermont's economy, including retail purchases of food and beverages, gas stations, lodging, restaurants and bars, and a host of other retail-trade or service-sector providers. In total, $704.4 million were spent in 2011 on fish and wildlife-based recreational activities in Vermont (US Fish and Wildlife Service 2011). Hunting provides a major boost to Vermont's economy between leaf-peeping season and ski season. In 2011 hunting generated 4,394 jobs ($140,855,725 salary and benefits) and fishing 2,420 ($73,224,447 in salary and wages).

FIGURE 1. BRILLIANT FOLIAGE OF HOBBLEBUSH AT BRISTOL CLIFFS WILDERNESS AREA.

Flood Protection

Benefit

Healthy forests play a vital role in absorbing water and moderating its movement across the landscape. Although forests cannot prevent large floods outright, they do temper their frequency, intensity, and extent, which in turn significantly reduces the loss of life and damage to property that serious flooding causes.

> ***Healthy forests play a vital role in absorbing water and moderating its movement across the landscape.***

Contributing Processes

Water first enters the landscape in the form of precipitation (rain, snow, sleet, fog, or hail). Forests absorb (through infiltration) and reroute water—thereby diffusing its potentially damaging energy before slowly releasing the water into seeps, ponds, lakes, rills, brooks, streams, and rivers (**Figure 2**). With regard to flood protection, the net hydrologic effect of forests is to delay and reduce the size of a flood peak.

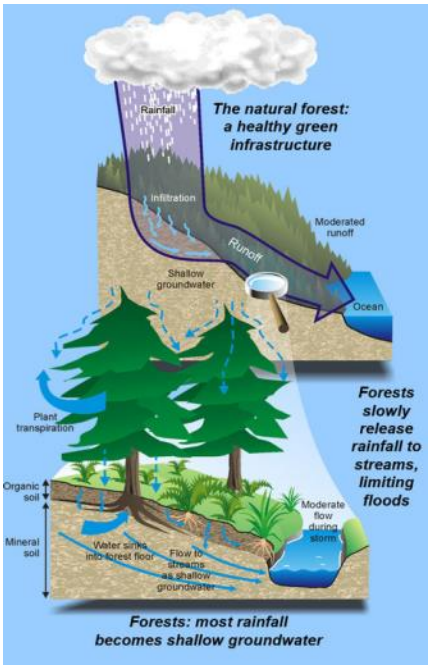
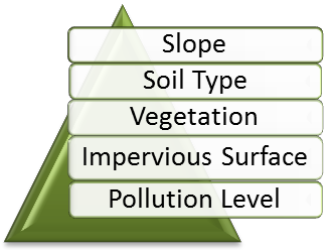


FIGURE 2. ROLE OF FORESTS IN CLEAN WATER AND FLOOD PROTECTION (SOURCE: TURNER ET AL. WATERSCAPE BOWEN ISLAND; GEOLOGICAL SURVEY OF CANADA, MISCELLANEOUS REPORT 2005:88).

Discussion

Water drains from land and feeds waterbodies. This land area is termed a *watershed*. The characteristics and condition of a watershed affect their function and impact on the receiving waterbodies. Forested watersheds have complex canopies of varied-density tree stems and branches; additional layers of non-tree vegetation; extensive root systems; deep, loose soils, and fluffy leaf litter. All these features allow a large amount of water to infiltrate the soil and be absorbed.



A rainstorm can drop millions of tons of water on land. When forest vegetation is present, leaves, stems, and downed woody debris intercept, absorb, and reduce the impact of precipitation and coursing water, allowing time for water to evaporate from plant surfaces, soak into the soil and porous spaces (animal burrows, decayed root tunnels, soil voids), or gradually run off. Soils in healthy forests are particularly porous and absorbent and can hold staggering volumes of water.

Much of the water absorbed by forest soils is drawn up by plant roots and transpired and then released back into the atmosphere as water vapor, a process known as evapotranspiration. During the growing season evapotranspiration reduces the amount of water in the soil, which in turn renews the soil's ability to absorb even more water. Forests can remove as much as 70% of incoming precipitation. Forested watersheds yield lower peak flows and smaller volumes of runoff over a longer period of time than non-forested land cover. Accordingly flood damage in forested areas—and in areas downstream—has the smallest impact among all surface conditions.

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Clean Water Supply

Benefit

Forests provide clean water for drinking, recreation and habitat. This contribution reduces, and in some cases eliminates, the need for expenditures related to man-made infrastructure designed to ensure clean water.

Contributing Processes

Forests intercept rain, meltwater and runoff and prevent impurities from entering our streams, lakes and ground water. Forests are able to have this effect on water in part by: slowing it down, spreading it out, and allowing it to sink into the soil. As forests slow the water down and spread it out, forests limit erosion and the ability of water to transport sediment, nutrients and pollutants that can cause problems for water treatment plants, recreation or functional wildlife habitat. Absorbed water permeates soil and is filtered before reaching surface waters. Tree canopies shade streams maintaining cool temperatures necessary for many aquatic species and for keeping algae in check.

BROWNS RIVER IN UNDERHILL, VT ON PRIVATE LAND.

Forests provide clean water for drinking, recreation and habitat. This contribution reduces, and in some cases eliminates, the need for expenditures related to man-made infrastructure designed to ensure clean water.

Discussion

Many of the same conditions that contribute to flood protection also function to keep a clean water supply. Tree canopies, extensive root systems, deep, loose soils, and fluffy leaf litter all intercept water, slow it down, spread it out and allow it to be absorbed into soils. Water remains largely below the soil surface, actively being filtered and kept cool (Gartner et al, 2013).

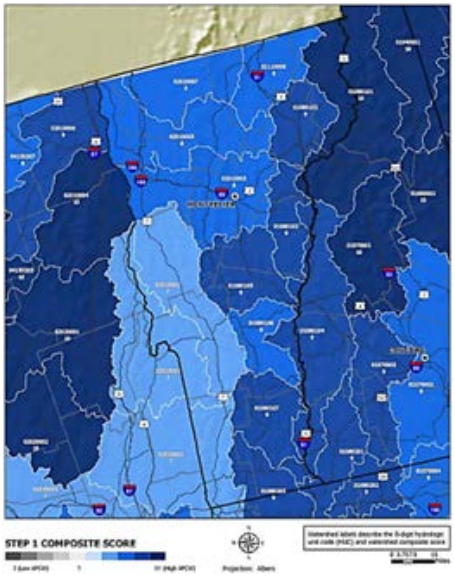

FIGURE 3. WATERSHEDS THAT ARE DARKER BLUE HAVE A HIGHER ABILITY TO PRODUCE CLEAN WATER.

Natural infrastructure combined with built infrastructure can reduce costs associated with the purification of drinking water and high-water events. In fact, recent studies suggest that for every dollar spent on natural infrastructure, $27 was saved on water-treatment costs (Winiecki 2012). This two-pronged approach, although underutilized, has been applied in several key areas, most notably the New York City watershed. The City invested $1.5 billion in its 2,000 square-mile watershed and avoided construction costs of an $8-$10 billion filtration plant (Saunders et al, 1991).

Although water demand in Vermont is not equal to that of New York City, we still depend on our forests for clean water. Areas outside of the Southern Champlain Valley have a relatively high ability to produce clean water (**Figure 3**). The Winooski River Watershed serves the

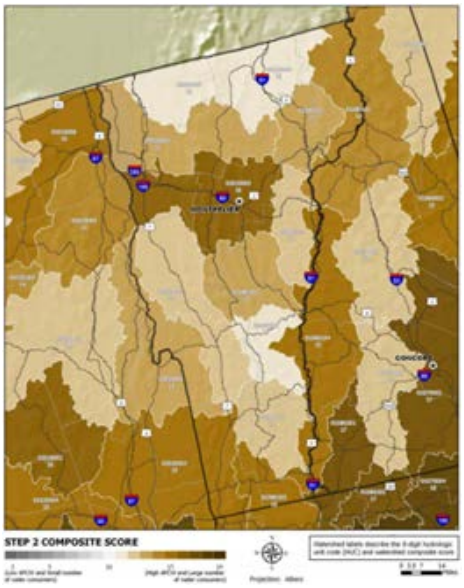

FIGURE 4. WATERSHEDS THAT ARE DARKER BROWN SERVE A HIGHER POPULATION OF PEOPLE THAT ARE DEPENDENT ON SURFACE WATER.

highest population with nearly 150,000 dependent on surface water (**Figure 4**) (USDA Forest Service 2009).

Clean Air

Benefit

Tree leaves serve as sponges for many air pollutants removing them from circulation where they do harm to humans. Fine particulate air pollution has serious human health effects, including premature mortality, pulmonary inflammation, accelerated arteriosclerosis, and altered cardiac functions. Forests intercept many air pollutants and store them temporarily on leaves and ultimately on the forest floor and within soil.

Contributing Processes

Air pollutants are varied in size, behavior, and location across the state. While some pollutants are generated locally, others are brought into the state from distant locations as air currents move pollutants. Tree species vary in leaf size, shape and abundance. Large trees with full canopies have a greater potential for capturing pollutants due to their larger leaf area. Healthy intact forests with fully foliated trees are therefore an important factor in the amount of pollution intercepted and removed by forests. Likewise, the size of forested areas also affects the amount of pollution retained by trees.

Healthy intact forests with fully foliated trees are therefore an important factor in the amount of pollution intercepted and removed by forests.

Discussion

Fine particulate matter <2.5 microns in size, known as $PM_{2.5}$, is a pollutant regulated by the Environmental Protection Agency (EPA) under the Clean Air Act and while improvements have been made over the past decade, it can still be a serious issue especially for people with respiratory illness. Studies on $PM_{2.5}$ reductions by trees show significant human health benefits (Nowak et al, 2013). Trees have been shown to remove up to 64 tons of $PM_{2.5}$ per year from cities across the country. Translated into human health benefits, deaths were reduced by up to 8 people per year per city by particulate reductions from trees. Often the association between trees and human health is not always visible until trees are lost. One example is from areas experiencing loss of ash trees due to emerald ash borer, a beetle that kills ash trees. Over the past 18 years, counties in 15 states have experienced the loss of ash trees due to this pest. Researchers found that people experienced more deaths from heart disease and respiratory disease when they lived in areas where trees had disappeared. Human deaths in counties with large tree losses compared to unaffected counties showed that an additional 15,000 deaths from cardiovascular disease and 6,000 more deaths from lower respiratory disease followed the loss of trees (Donovan et al, 2013).

Climate Change Mitigation

Benefit

Forests pull carbon from the atmosphere and store it in the soil, trees and other vegetation. This process of carbon sequestration regulates atmospheric carbon, thereby moderating the rate of climate change and its associated impacts.

Contributing Processes

For forests to effectively mitigate the rate and impacts of climate change, trees and forests must sequester and store carbon in the form of living vegetation, leaf litter and dead wood, and soil carbon. Trees do this through the process of photosynthesis where CO_2 is used to build sugars and carbohydrates for food and growth. As trees or other plants grow, carbon is incorporated into in their cells as structural compounds. Roughly half of the dry

weight of a tree is carbon. The cumulative impact of many trees removing and storing carbon from the atmosphere across large areas is significant. However, this above-ground storage is not the complete picture. In a mature forest more carbon is stored below ground than above ground. This below ground storage is the result of long term accumulation, integration and retention of carbon-rich plant tissues like roots, leaves and down trees, into the soil.

Forests pull carbon from the atmosphere and store it in the soil, trees and other vegetation. This process of carbon sequestration regulates atmospheric carbon, thereby moderating the rate of climate change and its associated impacts.

Fast-growing trees sequester carbon more quickly, whereas large, slow growing trees store more total carbon. Undisturbed soils accumulate and store vast amounts of carbon. Productive forests continue to amass carbon, but if forests become unhealthy or their soils are disturbed, the stored carbon is released back into the air. Forest management can be conducted in ways that increase forest storage of carbon, especially when trees are grown to large diameters and used as durable forest products (construction materials, furniture). These long-lived wood products reduce the amount of carbon released back into the atmosphere.

Discussion

While CO_2 in the atmosphere continues to increase as a result of fossil fuel consumption, forests continue to remove and store massive amounts of this greenhouse gas. The forests of the Northeast are one of the "largest available land-based sinks for atmospheric carbon" remaining, and offset a significant portion of heat-trapping carbon dioxide emissions that would otherwise contribute to climate change (US DOC ESA 2006). Each acre of forestland stores about 80 metric tons of carbon. The EPA estimates that forests sequester about 15% of carbon emissions per year nationwide. Vermont's forests are estimated to sequester over 8 million metric tons of CO_2 equivalents ($MMTCO_2e$) per year, almost as much as Vermont's annual emissions.

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Vermont forests annually remove an amount of CO_2 from the air equal to the annual emissions produced by 14,000 light-duty vehicles, as well as 1,610 metric tons of other pollutants—a function that would be worth about $16 million if it were paid for out of pocket (Riitters et al 2012).

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Wildlife Habitat

Benefit

Forests provide the habitat for a great number of wildlife species. Vermonters value wildlife, and recognize how wildlife uses and shapes our environment. Wildlife provides other benefits that are rarely recognized by the general public such as pest control, seed dispersal, pollination and nutrient cycling. These contributions and others are critical for proper ecosystem functioning and sustainable delivery of ecosystem services from our forests.

Critical Processes

Four habitat components are needed for wildlife to survive: food, water, cover and space. Even though all species need these habitat components the amount and type of each required differs by species.

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Food

Forests provide food resources even more diverse than the species comprising them. Some food resources are recognized as being uniquely valuable including hard mast like the nuts produced by American beech for black bears, soft mast such as the fruit of the serviceberry for birds or wetland vegetation for moose and others in the springtime. For certain species at certain times of year food may be very scarce and accessibility of food resources can be critical to survival requiring significant travel for animals.

Cover

This includes the shelter or structure that species depend on for nesting, foraging, resting, brood rearing and escape. The requirements for each species vary by species and time of year. For instance white-tailed deer depend on dense conifer for winter habitat for the thermal and snow depth regulation it provides. Certain birds will nest at certain heights off the ground. They depend on trees with branches at the appropriate height. For example black-throated blue warblers depend on understory and vegetation in the interior forest for their nests which are only few feet off the ground. For many species, available cover is a limiting factor for habitat suitability and can dictate the number of animals that the landscape can support.

Water

Animals need water. Animals get the water they need from surface waters, vegetation or food they consume. Some species are particularly sensitive to water shortages. Amphibians gain and lose water through their skin so generally require moist ground and some animals have more specialized requirements like bats which need flight-accessible surface waters. While water is generally abundant in the northeastern forests, it is projected to be less available during summer seasons as a result of climate change. The shading and cooling effects of forests are able to temper moisture fluctuations associated with dry spells.

Space

The animals that depend on Vermont's forests need enough room to meet their basic needs and this varies with species. All of them need to have enough space to access food, breeding areas and safe travel pathways for dispersal from source populations or for seasonal migration. Availability of interior forest is particularly important for some of Vermont's forest dwelling species. Interior forest is forest that shows no detectable edge influence from adjacent development. Edge influence, also known as edge effect, is the change in composition, structure, or function of the forest near its edge as a result of influences from adjacent development (Harris 1984; Harper et al, 2005). Edge effects have significant implications on habitat suitability for certain species. Birds that might nest safely in interior forest may be much more vulnerable to predation in edge habitats.

Discussion

Wildlife species rely on blocks of contiguous forest and secure linkages to other forest blocks for all or part of their habitat needs. For example, the home range of an adult male black bear can be as large as 50-100 square miles. Moose, fisher, otter, bobcats, and other species of wildlife also move great distances to find food, water, dens, refuge, and other important habitat resources.

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Finally, many songbirds require large areas of forest cover free from fragmentation and human disturbance. Species such as hermit thrush (Vermont's state bird), scarlet tanager, and ovenbird decline when forests are reduced or become fragmented. In general, a greater number and diversity of wildlife species are found in larger forest blocks. Maintaining habitat connectivity through retention of forest blocks will sustain critical habitat components needed for wildlife survival.

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Biological Diversity

Benefit

Vermont's forests provide crucial habitat for healthy and sustainable populations of native plants and animals. Biological diversity encompasses the staggering "complexity of all life at all its levels of organization, from genetic variability within species, to species interactions, to the organization of species in larger landscape units" (Thompson et al, 2000). Biological diversity is essential to resilient ecosystems and the services they provide. There are three tiers of diversity to be considered:

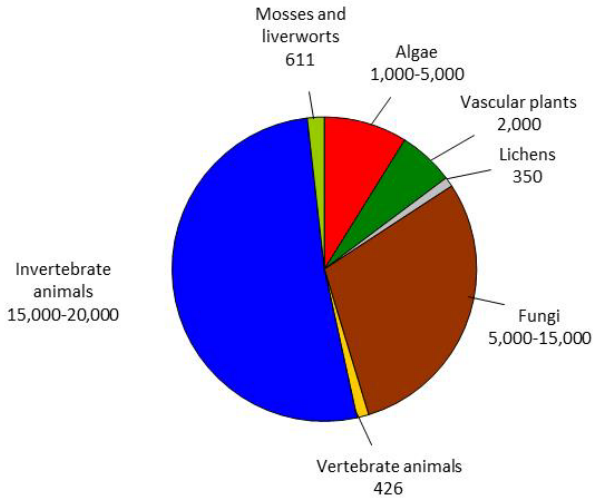
- ⇨ Enduring features are the physical features of the landscape;
- ⇨ Natural communities are assemblages of species and their physical environments; and
- ⇨ Native species (Thompson et al, 2002).

Contributing Processes

These three tiers are the building blocks of Vermont's biological diversity and ecosystem functioning on local and landscape scales. In Vermont we have a diversity of habitats that vary based on the soils, bedrock, elevation, climate, the plants that grow there, and the animals that use them. Forests create their own growing environments or micro-climates which are shaded, generally moist, and in Vermont's case, expansive. Disturbances, such as ice storms, or wind damage, create small openings and temporary changes in light, temperature and moisture that trigger growth response in vegetation followed by a return to previous forest conditions. This forested landscape provides the context and serves as the "glue" that holds together small-patch habitats.

Discussion

In Vermont we have between 24,000 and 43,000 species (of which 653 are rare), nearly 100 natural community types and 1,400 Landscape Diversity Units (LDUs) or unique combinations of elevation, bedrock, surface geology and landform (Thompson et al, 2002). A large proportion of these species and communities are associated with forested conditions, and currently, many of the LDUs tend to develop forest. Diversity of species is dependent on diversity and availability of habitats at sufficient scales and connectivity to support healthy populations and communities in the face of natural disturbance and human caused stressors. The plants and animals that comprise our forests respond to environmental conditions independently while also



SOURCE: VERMONT FISH & WILDLIFE DEPARTMENT.

interacting in very complex ways. Review of the book *Wetland, Woodland, Wildland—A Guide to the Natural Communities of Vermont* provides additional understanding of Vermont's biological diversity processes (Thompson et al, 2000).

Human Health and Quality of Life

Benefit

Forests improve human health and contribute to Vermont's unique and exceptional quality of life.

Discussion

It is clear that the ecosystem services provided by forests (air quality, flood mitigation, maintenance of water quality, soil fertility, erosion control, protection of drinking water supplies, and waste-water processing) contribute to the health and well-being of humans (Karjalainen et al 2010). However, measuring the direct benefits to human health has only recently been established.

A forest is an ecological life-support system that provides a multitude of benefits vital to human health. Visiting forests and/or areas in their proximity has been linked to human health benefits such as improved mood, lower blood pressure, slower heart rate, and decreased muscle tension. Forest visits have been shown to boost human immune response, lessen hyperactivity in children, enhance the motivation for exercise, and generally improve longevity (Anderson et al, 2014).

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Forests can provide medicinal compounds as well as organic, free-range, low-cholesterol, healthy sources of meat (deer, moose, turkey, grouse, woodcock, and waterfowl). It is not surprising that recent research also suggests that there is an increasing incidence of poor health in urban environments linked to a lack of access to forested green space.

Although more research is needed, new information suggests there is a link between incidence of Lyme disease and fragmented landscapes. Species richness declines in fragmented landscapes, potentially leading to an increase in tick densities presumably because declines in species richness favors growth of tick host populations like the white-footed mouse.

The Vermont Business Roundtable conducts a Pulse of Vermont Quality of Life Study every 5 years (1990, 1995, 2000). Respondents have been asked in every survey, 'What first comes to mind when you hear the expression "quality of life"?' In each case, "the physical environment (air, water, views, land)" was in the top three responses, along with "pace of life" and "standard of living"—well above freedom and independence, safety and crime-free, and even good health.

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In the same survey, Vermonters were asked if they were willing to pay $100 more in municipal taxes for schools, roads, police/fire, or open land. In 2 of the 3 years of the survey, more people were willing to pay more for open land than for the other three municipal needs, an indication of Vermonters' affinity for working lands and habitat conservation (Vermont Business Roundtable 2000).

Cultural Heritage

Benefit

Vermonters value the working landscape and recreational heritage.

Discussion

Vermont is a rural state. Only 38% of the population is urban compared to the US average of 79% (US DOC ESA 2006). The result is that 8 out of 10 Vermonters live in a rural setting as opposed to the national standard of 3 out of 10. This characteristic is what contributes to the uniqueness of Vermont. Vermont is only one of four states that is <50% urban. This influences Vermonters' connection to the land and their support of land-conservation initiatives.

Historically, many Vermont landowners aligned themselves with a "no-posting" (i.e., open for public use) cultural imperative and for much of the state's history, the public had free access to many undeveloped lands for hunting, fishing, trapping, hiking, and other outdoor pursuits. This mindset began to change in the 1960s and continues to this day. In the Northeastern United States, 29% of privately owned land was available for public recreation in 1967. By 1986 this had decreased to <20% (Dennis 1993).

Support for the traditional use of wildlife (hunting, fishing, trapping) seems to decline drastically in states that are >70% urban (J. Organ, personal communication, 2014). In fact, researchers have found that "the greater the proportion of state residents who live in urban areas, the lower the proportion who hunt" (Decker et al 2001). This is supported by the fact that in 2011 Vermonters ranked second only to Alaskans in enjoying fish and wildlife resources. Sixty-two percent of Vermonters fish, hunt, engage in wildlife watching, or enjoy a combination of these activities, versus 64% of Alaskans. Vermont ranks first in the nation in the number of participants that engage in wildlife-watching activities (53%).

This land-based cultural heritage is reflected in the way Vermonters view the landscape. The Center for Rural Studies polled Vermonters and found support (*strongly agree* and *agree* combined; see below box) for working landscapes and the cultural heritage associated with them (Center for Rural Studies 2008):

Statement	Percent
I value the working landscape and its heritage	97.2
I am proud of being from or living in Vermont	93.6
I value Vermont's spirit of independence	93.1
I value the privacy I get in Vermont	91.0
I believe Vermont's creative communities are valuable to the state	89.2
I believe there is a strong sense of community where I live	85.4
I value the participatory government in Vermont	82.9
I believe that private property rights are well respected in Vermont	69.9

N = 699. Source: Center for Rural Studies 2008.

In addition, Vermont has established a successful economic niche by building on the advantage of having smaller cities and towns and their proximity to rural and forested natural landscapes. Furthermore, in Vermont there is strong emphasis on preserving small, local businesses (Aref 2012). Small towns surrounded by undeveloped forests and fields seem to exemplify the Vermont brand and have both economic and intrinsic value for Vermonters: the intangible significance of enjoying forests, the natural surroundings, and the quality of life associated with this working landscape.

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Particular Importance of Forest Blocks

Much of the benefit Vermonters derive from forests can be attributed to forest blocks. Forest blocks are areas of contiguous forest and other natural habitats, often spanning multiple ownerships and frequently unfragmented by roads, development, or agriculture. Vermont's forest blocks are primarily forests, but can also include wetlands, rivers and streams, lakes and ponds, cliffs, and rock outcrops.

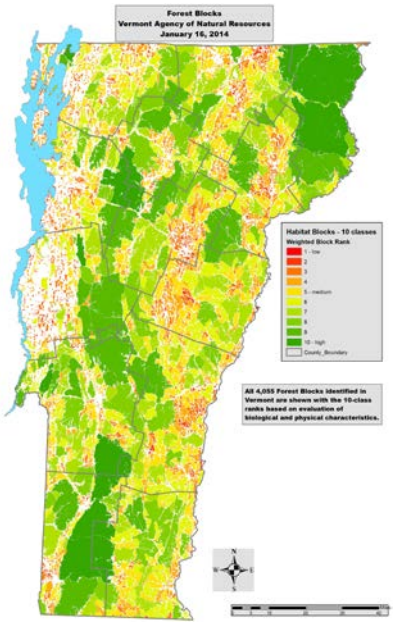

FIGURE 4. VERMONT'S FOREST HABITAT BLOCKS. SOURCE: VERMONT FISH & WILDLIFE DEPARTMENT.

Forest blocks provide many ecological and biological values critical for protecting native species and the integrity of natural systems. These values include (Austin et al, 2004):

- supporting natural ecological processes such as predator-prey interactions and natural disturbance regimes;
- helping to maintain air and water quality;
- supporting the biological requirements of many plant and animal species, especially those that require interior forest habitat or require large areas to survive;
- supporting viable populations of wide-ranging animals by allowing access to important feeding habitat, reproduction, and genetic exchange;
- serving as habitat for source populations of dispersing animals for recolonization of nearby habitats that increase the resiliency of wildlife populations to climate change and other environmental stressors;
- minimizing wildlife mortality from disturbance, conflicts with humans, and roads;

- ⇨ minimizing/reducing the encroachment of invasive exotic plant and animal species;
- ⇨ helping to maintain traditional rural cultural values; and
- ⇨ providing the scale of forest and access to land necessary to support working lands.

Mapping by the Vermont Agency of Natural Resources demonstrates that there are 4,055 intact habitat blocks in Vermont. The largest of these blocks is 154,564 acres surrounding the Nuhlhegan Basin (**Figure 4**), but the average size is only 1,131 acres, reflecting the large number of much smaller blocks. While significant benefits should be attributed to forest blocks, it must be recognized that all forests are valuable and provide benefits to Vermonters.

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V. Forest Fragmentation

Forest Health

Healthy forests are highly resilient and capable of self-renewal. They maintain forest processes and are structurally complex, ecologically productive, and composed of diverse native plants and animals. Although it is unrealistic to revert to pre-settlement forest conditions, striving toward healthy forests can be compared to creating and maintaining the characteristics of relatively undisturbed forests of the region.

Forest integrity is a measure of forest condition relative to its natural or historic range of variation. It measures the ability to support and maintain biological communities (species assemblages), to support physical elements of the ecosystem (soils, air, water), and to support ecological processes (nutrient cycling). Maintaining forest integrity requires connected forests to facilitate mobility of organisms and grow capacity to maintain forest health.

Forest Fragmentation

Forest fragmentation is the breaking of large, contiguous, forested areas into smaller pieces of forest. Typically these pieces are separated by roads, agriculture, utility corridors, subdivisions, or other human infrastructure development.

> ***Forest fragmentation is the breaking of large, contiguous, forested areas into smaller pieces of forest.***

When referring to natural communities, wildlife habitat, and natural landscapes, fragmentation means dividing land with naturally occurring vegetation and ecological processes into smaller and smaller areas as a result of land uses that remove vegetation and create physical barriers that limit species' movement and interrupt ecological processes between previously connected natural vegetation.

Any large-scale canopy disturbance affects a forest, but it is important to distinguish between a forest fragmented by development from human-built infrastructure and a forest of mixed ages and varied canopy closure that results from proper forest management. The former is typically much more damaging to forest health and habitat quality, usually with permanent, negative effects, whereas the latter may cause only a temporary change in the forest, supporting dynamic characteristics across the forested landscape.

Forest Parcelization

Closely related to, but different from fragmentation, is the process of forest parcelization. Parcelization is the legal process whereby large tracts of land are divided into smaller ownerships or land holdings. Parcelization results in an increased number of people who own a given tract of land. When larger parcels are divided and sold or transformed into multiple parcels (often through subdivision), the result can be disjointed land ownership patterns that promote new human-built infrastructure development (roads, septic units, utilities, residential and commercial buildings, etc.) (VNRC 2013). When this development occurs in forested landscapes, it leads to forest fragmentation.

Left: intact; center: parcelized; and right: fragmented (Center for Land Use Education and Research, University of Connecticut).

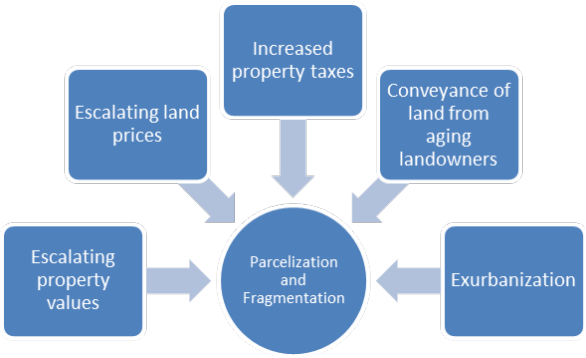
Causes and Drivers of Parcelization and Fragmentation

There are many causes of parcelization and fragmentation in Vermont, including:

- Escalating land prices;
- Increased property taxes;
- Conveyance of land from aging landowners; and
- Exurbanization.

Escalating Land Prices

As land values and demand for development opportunities increase, landowners have greater incentive to subdivide and develop their properties. Within Vermont, the average value of land rose at a higher rate than the national average from 1990 to 2007, and according to assessment records, the value of forestland in parcels 50 acres or larger appreciated significantly in recent years, increasing from an average



value of $930 per acre in 2003 to $1,615 in 2009. These higher market values make it more difficult to own forestland for non-development purposes, and it also influences the rate of subdivision of larger parcels (VNRC 2013).

Increasing land and property valuations, along with higher school and municipal spending, have led to rising property taxes. This puts additional pressure on landowners to divide and sell all or portions of their land. The National Woodland Owner Survey conducted by the USDA Forest Service lists property taxes as the number one concern among landowners (US Fish and Wildlife Service 2011).

Conveyance of Land from Aging Landowners

In addition to escalating land values, the aging population of forestland owners indirectly contributes to parcelization. In the United States, as much as 25% of all privately owned forestland is owned by people who are 65 years of age or older (US DOC ESA 2006). Although estate and succession planning can provide ways to keep forestland intact among successive generations of forest owners, the will of a deceased landowner often divides the ownership of land into smaller parcels for purposes of bequeathing the land to multiple heirs. This generally leads to forestland parcelization unless the landowner has provided direction to keep the land intact (Dennis 1993; VNRC 2013).

Exurbanization

Another driver of forest fragmentation is people's desire to either relocate to or purchase second homes in rural settings where land is relatively inexpensive compared with urban real estate markets. This trend, known as "exurbanization," is defined as the migration of urban residents to rural environments (Decker et al 2001). Rather than buying rural land for traditional uses such as forest management and agriculture, more people are developing private residences far from towns and services in order to maximize privacy and scenic views. The demand for high-end homes in Vermont is contributing to increasing parcelization of forestland (VNRC 2013).

Vermont Context

The rate of development (measured in housing units and developed acres) in Vermont is increasing twice as fast as the state's population (Center for Rural Studies 2008). This problem is compounded by the fact that population growth is occurring mostly in rural areas (defined as communities with fewer than 2,500 residents), where forestland and other working and undeveloped lands are concentrated and at risk of parcelization (Aref 2012; VNRC 2013). In Chittenden County, structure density was about four structures per square mile in 1950 and increased to about 28 structures per square mile in 2005. Between 1950 and 2005, more structures (10,857 in total) were added to the Rural Planning Area than to any other single Planning Area (CCRPC 2012, pp. 14-15).

PHASE 1: SMALL PATCHES WITHIN A LARGE FOREST MATRIX.

PHASE 2: INCREASED PARCELIZATION RESULTING IN THE EXPANSION OF PATCHES.

PHASE 3: CONVERSION FROM FOREST TO HUMAN LAND USE.

Part of the problem is that although many municipalities value local forests, towns have limited regulatory strategies for addressing the maintenance of forestland. For example, despite the fact that 87% of town municipal plans identify forests as a valuable habitat type, a small percentage of municipalities that have zoning bylaws include a specific district that is geared toward the maintenance of forestland, such as a forest reserve district (NEFA 2013). Furthermore, only about half of all municipalities in Vermont have subdivision regulations (USDA Northeastern Regional Field Office 2014).

Although many municipalities value local forests, towns have limited regulatory strategies for addressing the maintenance of forestland.

These deficiencies highlight land-use trends that contribute to the parcelization of forestland resources (VNRC 2013). As a real-life example, in Chittenden county recent housing development trends show that only 17% of new housing units consumed nearly 72% of all housing development land. This is because the 17% were on large lots (>3 acres)—development permitted under current regulations that, according to the Regional Planning Commission's scenario-planning exercise, runs counter to the public's aspirations (based on data from 1990 to 2008) (CCRPC 2012, p. 42).

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VI. Status and Projected Trends of Forest Fragmentation in Vermont

The US Forest Service's National Forest Inventory and Analysis Program (FIA) publishes periodic reports on the characteristics of the forests of Vermont. The most recent FIA figures from 2013 show a continuing, though gradual, loss of about 75,000 acres of forestland since 2007. It is clear from the FIA data that our forestland is no longer expanding and in the long term is vulnerable to land-use conversion and fragmentation as slow but steady development growth resumes. These trends are verified by satellite imagery analyses.

> ***The most recent FIA figures from 2013 show a continuing, though gradual, loss of about 75,000 acres of forestland since 2007.***

Developed land in Vermont, excluding land in rural transportation uses, has increased from 180,000 acres in 1982 to about 302,000 acres in 2010—a significant increase of 67% over three decades and far outpacing Vermont's population growth (NRCS). Vermont parcelization is largely associated with residential development. Housing development on previously undeveloped forestland has increased and parcels of 50 acres or larger have decreased (VNRC 2010). This is significant because the majority of these lands were developed with at least one or more new homes, roads, driveways, and utilities, thus reducing the intact and unfragmented nature of forestland in Vermont.

The number of forestland owners is increasing and parcel size is decreasing. The majority of forests are owned by private non-industrial individuals or what FIA calls *family forest ownerships*. As of 2012, in Vermont there were an estimated 43,000 family forest ownerships with at least 10 acres, up from 40,000 in 2006. Ownership of 1-19 acre forested parcels is increasing at a rate of just over 1,000 new parcels per year since 1983. Over a similar time period, the total acres in private ownership have declined from 3,992,600 acres in 1983 to 3,564,000 in 2013 (USDA Forest Service 2008; USDA Forest Service 2012; USDA Forest Service 2013).

> ***The number of landowners is increasing, the size of the parcels is decreasing, and the age of owners is increasing.***

Though complex and somewhat difficult to measure directly, forest fragmentation can be quantified by the amount of forest edge versus interior forest, proximity to roads, forest patch size, local human population density, and inter-mixed house densities. The following text is based on FIA's 2012 report highlighting some such Vermont data.

Vermont Fragmentation Data

In Vermont, 74% of forestland is greater than 295 feet from an agriculture use or developed edge. Put differently, nearly a quarter of Vermont's forestland is within <300 feet of a non-forest edge. This ranges from 60% in more fragmented Grand Isle County to just 8% in Essex County (**Table 1**) (data from National Land Cover Data Base which uses satellite imaging and may be slightly different from FIA estimates).

> ***Nearly a quarter of Vermont's forestland is within <300 feet of a non-forest edge.***

Figures 1 and **2** show where and to what extent forestland is affected by roads. As both Forman (2000) and Riitters and Wickham (2003) reported, this effect can be quite extensive, even in areas that appear to be continuous forestland from the air. In Vermont, for example, 22% of forestland is within 330 feet of some form of road and 48% within 980 feet (Riitters and Wickham, 2003; Riitters et al 2000; Chen et al, 1992; Flaspohler et al 2001; Barlow et al, 1998; Munn et al 2002; Theobald 2005; Hammer et al, 2004). Forestland in Vermont occurs primarily as a relatively contiguous forest matrix within which urban development, agriculture,

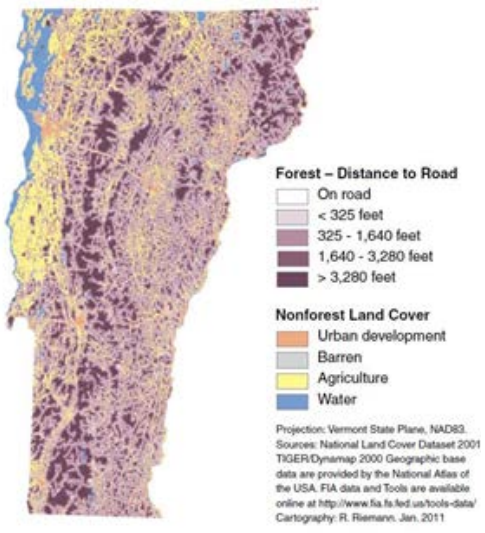

Figure 1. Distribution of forestland in distance to the nearest road classes (includes all roads) in Vermont (2000 and 2001).

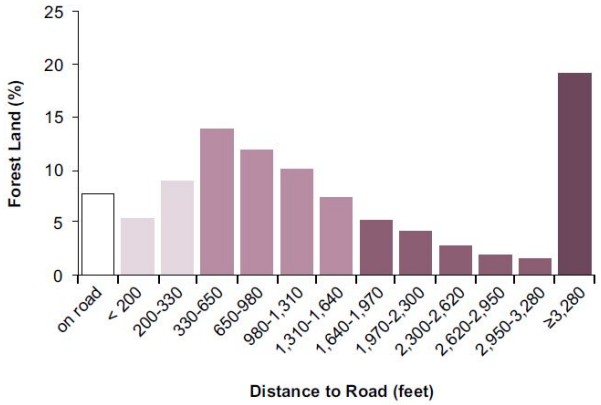

FIGURE 2. DISTRIBUTION OF FORESTLAND IN DISTANCE TO THE NEAREST ROAD CLASSES (INCLUDES ALL ROADS) IN VERMONT (2000 AND 2001).

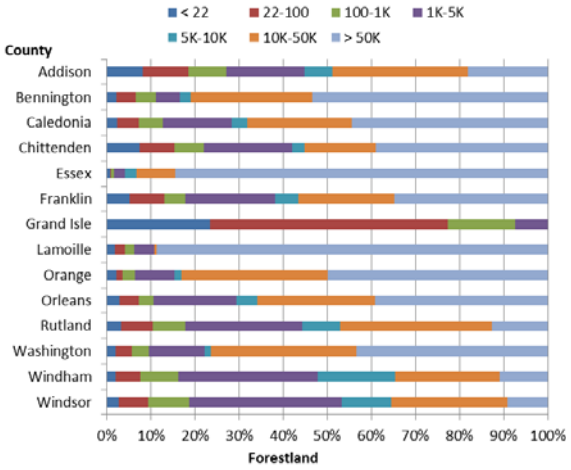

FIGURE 3. DISTRIBUTION OF FORESTLAND BY PATCH SIZE BY COUNTY. VERMONT, 2012.

roads, and other non-forest areas occur (Riitters et al, 2000). Forested areas containing higher proportions of small forest patches (<100 acres) occur along the river valleys in northwestern Vermont. Most counties have a very low proportion of forestland in small patches (**Figure 3**).

The Wildland-Urban Interface (WUI) is commonly defined as the zone of transition between unoccupied land and human development. Here a house density above 15.5 houses per square mile is used as the threshold for WUI.

Figures 4 and **5** illustrate how much forestland is affected by house densities >15.5 houses per square mile. Counties range from 6% (Essex) to 53% (Chittenden) of forest intermixed with house densities of >15.5 per square mile, except for Grand Isle County, which is 87% (**Figure 5**). **Table 1** shows the extent to which the current forestland base is influenced by one or more urbanization and fragmentation factors. For example, in Essex County, which is 90% forested, 8% of the forestland is potentially affected by house densities >15.5 per square mile, and 92% of the forestland is far enough from an edge to be

TABLE 1. PERCENT DISTRIBUTION OF FORESTLAND, VERMONT 2015

County	In the county[a]	House density >15.5 per square mile[b]	>295 feet from an Ag or developed edge[c]	Located in patches >100 acres in size[d]	Located in a block with population densities >150 per square mile[e]	>1,310 feet from a road[f]
Addison	56	36	72	82	3	48
Bennington	86	32	82	93	3	50
Caledonia	79	34	72	93	2	31
Chittenden	64	72	68	85	13	36
Essex	90	8	92	99	1	51
Franklin	62	39	65	87	4	41
Grand Isle	38	90	40	23	10	28
Lamoille	83	41	78	96	3	45
Orange	80	42	70	96	2	24
Orleans	74	34	70	93	1	38
Rutland	79	35	75	90	3	43
Washington	83	48	75	94	5	34
Windham	87	51	73	92	3	30
Windsor	83	52	70	91	3	27
State total	**77**	**40**	**74**	**92**	**3**	**38**

Percent is with respect to several urbanization and fragmentation factors, expressed as a percent of the forestland in each county in Vermont, 2015.

[a] Percent forest estimate based on the National Land Cover Database (NLCD) 2011 data. Values are generally higher than estimates from FIA plot data.

[b] Approximating forestland potentially affected by underlying development (2010 Census).

[c] Approximating forestland undisturbed by edge conditions (NLCD 2006).

[d] Approximating forestland with potentially enough core area for sustainable interior species populations (NLCD 2006).

[e] Approximating forestland not available for commercial forestry (2010 Census).

[f] Approximating forestland outside of the effect of roads.

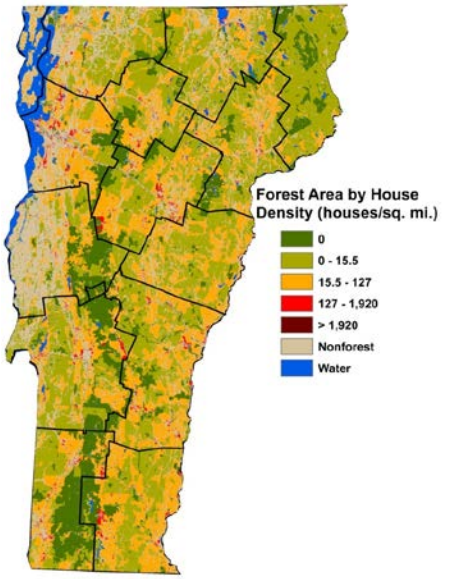

FIGURE 4. DISTRIBUTION OF FORESTLAND BY HOUSE-DENSITY CLASSES. VERMONT, 2010.

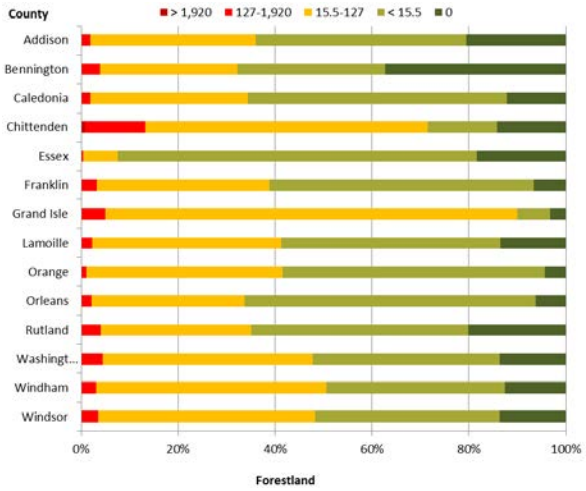

FIGURE 5. DISTRIBUTION OF FORESTLAND BY COUNTY AND HOUSE-DENSITY CLASS. VERMONT. 2010.

considered interior forest. Nearly all of the forestland is in large patches (>100 acres), but only 51% is >1,310 feet from a road. In Windham County, which is 87% forested, 51% of the forestland is potentially affected by house densities >15.5 per square mile, and 73% of the forestland is far enough from an edge to be considered interior forest. Nearly all of that forestland is in large patches (>100 acres), but only 30% is >1,310 feet from a road. On the other end of the spectrum are the forests in Grand Isle County which occupy 38% of the land area and occur largely mixed with housing densities >15.5 per square mile (90% of the forestland). The forests tend to occur in smaller patches (23% of the forest is in patches >100 acres), and the county has correspondingly much less interior forestland than other areas (40%).

What This Means

Edge effects vary with distance from forest edge, and species of vegetation or wildlife, (e.g., Chen et al, 2002, Flaspohler et al, 2001; Rosenberg et al, 1999a), but 300 feet is frequently used as the *vanishing distance*, beyond which the edge effect disappears and interior forest conditions begin.

Figures 1 and **2** depict the pervasiveness of roads in the Vermont landscape. Road effects diminish when distance from road to forest reaches about 330 feet for secondary roads, 1,000 feet for primary roads (10,000 vehicles per day), and 2,650 feet for roads in urban areas (50,000 vehicles per day) (Forman 2000). Roads have a variety of effects including hydrologic changes, chemical changes (salt, lead, and nutrients), sediment load changes, noise level changes, introduction of invasive species, habitat fragmentation, increases in human access, impacts on forest ecosystem processes, and wildlife movement and mortality. With 62% of Vermont's forestland within 1,310 feet of a road statewide, potential cumulative ecological impact from roads is significant. Actual ecological impacts of roads will vary by the width of the road and its maintained right-of-way, number of cars, level of maintenance (salting, etc.), hydrologic changes made, imperviousness of road surfaces, location with respect to important habitat, and other factors. (Forman 2000; Forman et al, 2003; Maine Audubon 2007).

Roads have a variety of effects including hydrologic changes, chemical changes (salt, lead, and nutrients), sediment load changes, noise level changes, introduction of invasive species, habitat fragmentation, increases in human access, impacts on forest ecosystem processes, and wildlife movement and mortality.

Dense human population is generally recognized as having a negative effect on the viability and practice of commercial forestry (Barlow et al, 1998; Kline et al, 2004; Munn et al, 2002; Wear et al, 1999). Working in Virginia, Wear et al, (1999) identified a threshold of 150 people per square mile as the population density at which the probability of commercial forestry drops to practically zero. Only 3% of forestland in Vermont is near population centers that exceed the threshold of 150 people per square mile, but this proportion is higher in northwestern Vermont in the counties of Chittenden (13%) and Grand Isle (10%) (**Table 1**).

Forest intermixed with houses represents areas of forest cover most likely to be in non-forestland use and more likely to be experiencing pressures from recreation, invasive plant species, and other local human effects. This intermix area also represents a challenge to managing forest fires. Although the other pressures from high housing densities are likely to be more of an issue than forest fires in Vermont, thresholds for those issues are less developed at this point. Therefore, **Figure 5** should be interpreted as identifying where areas of increased pressure from intermixed residential development are likely to occur. Nationwide, increases in lower-density, ex-urban development have been forecast by both Theobald (2005) and Hammer et al, (2004), particularly at the urban fringe and in amenity-rich rural areas.

Forest health, sustainability, management opportunities, and the ability of forestland to provide needed products and ecosystem services and suitable habitat are affected to varying degrees, and in different ways, by changes in the fragmentation of forests and urbanization.

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VII. Impacts and Effects of Forest Fragmentation

Introduction

Fragmentation has been characterized as the dominant regional stressor on our forests (Anderson et al, 2014). Erosion of the health of Vermont's forests through fragmentation has serious ecologic, economic, and cultural implications for landowners and communities. As the impacts and effects of forest fragmentation are considered, it is important to recognize the intersection of forest stressors like forest pests, invasive plants and climate change with fragmentation. These stressors do not play out on a pristine landscape. Climate change, discussed at the end of this section, is of particular concern because it will likely compound the impacts of fragmentation on our forests and vice versa.

Fragmentation has serious ecologic, economic, and cultural implications for landowners and communities.

Mechanisms of Impact

To understand the effects of fragmentation it is first important to understand the physical changes associated with built infrastructure development in forests. These changes include:

- ⇨ new roads;
- ⇨ new ditches and right-of-way maintenance;
- ⇨ new structures and attendant uses; and
- ⇨ conversion of forest to non-forest uses.

These changes disrupt ecosystem processes. The location and pattern of these changes in the forest can play a major role in the degree to which they are disruptive for forest processes. The following section is a discussion of how physical changes associated with fragmentation impact the benefits and value that accrue from Vermont forests.

Overview of Fragmentation Effects

In most of Vermont, forest fragmentation has primarily resulted from road construction and associated residential and commercial development. In the Champlain Valley and some other areas of the state with highly productive soils, conversion to agricultural use has also been an important factor leading to forest fragmentation.

Isolation Effects

Such forms of fragmentation increase isolation among separated forest communities and increase deleterious edges along non-forest areas. These changes erode forest health and degrade habitat quality. Fragmentation leads to loss of biodiversity; increases the incidence of invasive plants, pests, and pathogens; and reduces water quality.

Once fragmented, a forest patch becomes isolated from other forested lands and movement of plants and animals is inhibited. This restricts breeding and gene flow and results in long-term population decline. Connected forest habitats are a key component of forest adaptation and response to climate change, and fragmentation is a threat to this natural resilience.

Once fragmented, a forest becomes isolated and the movement of plants and animals is inhibited. This restricts breeding and gene flow and results in long-term population decline. Connected forest habitats are a key component of forest adaptation and response to climate change, and fragmentation is a threat to this natural resilience.

Edge Effects

One of the most important reasons that forest blocks provide such necessary values is that they include areas of interior forest conditions. Interior forest is forest that shows no detectable edge influence from adjacent development. Edge influence or edge effect is the change in composition, structure, or function of the forest near its edge, as a result of influences from the adjacent development or land use (Harris 1984; Harper et al 2005). Edge effects alter growing conditions within the interior

forest through drastic changes in temperature, moisture, light, and wind. In short, edge effect is when the environment of the adjacent non-forestland determines the environment of the forest fragment, particularly the edges.

> ***Edge effects alter growing conditions within the interior forest through drastic changes in temperature, moisture, light, and wind. In short, edge effect is when the environment of the adjacent non-forestland determines the environment of the forest fragment, particularly the edges.***

Ecologists suggest that true interior forest conditions only occur at least 200-300 feet inside the non-forest edge. And so a circular forest island in a sea of non-forest would have to be >14 acres in size to include just 1 acre of true interior forest condition. Put differently, the negative habitat effects of each residential building pocket within a forest radiate outward, affecting up to 30 additional acres with increased disturbance, predation, and competition from edge-dwellers. This may not matter to generalist species like deer, raccoons, and blue jays, which may actually benefit from fragmentation, but this effect is detrimental to interior-dependent species like salamanders, goshawks, bats, and flying squirrels. The smaller the remnant, the greater the influence of external factors and edge effects.

> ***A circular forest island in a sea of non-forest would have to be >14 acres in size to include just 1 acre of true interior forest condition.***

Small patches of forest, or those portions of land that are largely fragmented, run a higher risk of shifting toward edge-adapted and invasive species (Riitters et al, 2012). This triggers a cascade of ill effects on the health, growth, and survivability of trees, flowers, ferns, and lichens and an array of secondary effects on the animals that depend on them.

Fragmentation Impacts on the Forest Products Economy

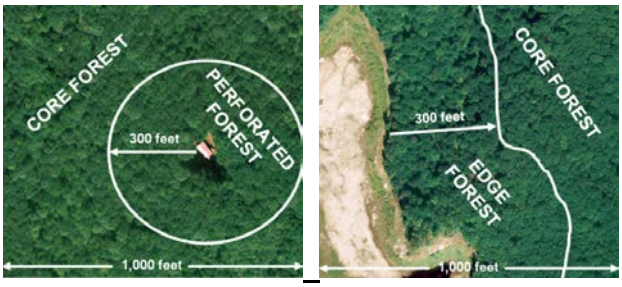
Vermont's forest landowners are diverse and dynamic and their reasons for owning land are varied. Although many forest landowners are interested in amenity values such as beauty, scenery, protection, or privacy, the role and importance of economic return should not be overlooked. In Vermont, 30% of forest landowners have harvested or removed trees from some or all of their land. The size of the holding does matter and is a determinant of management activities. As parcel size continues to decline, the impact on harvesting and the forest product economy will also decline (FFO 2006, p. 21).

Fragmentation of Vermont forests presents a significant threat to the operability and economic viability of the forest products economy. As forest fragments become ever smaller, practicing forestry within them becomes operationally impractical, economically non-viable, and culturally unacceptable. An important barrier to sustainable forestry is the fragmentation of forests which limits access to the woods for harvesting (Kittredge et al, 1996) and smaller patches of forest or those in more populated areas are less likely to be managed for forest products (e.g., Kline et al, 2004; Wear et al, 1999).

> ***As forest fragments become ever smaller, practicing forestry within them becomes operationally impractical, economically non-viable, and culturally unacceptable.***

A continued flow of forest goods and services depends on maintaining healthy, intact forests. Maintaining healthy forests, productive capacity of the soil and water, diversity of flora and fauna, and the interaction and relationship between all forest systems can sustain Vermont's forests and the goods and services they provide. Local sourcing of wood increases connections between community sustainability and forest sustainability.

The forest products economy is primarily dependent on private forestland for wood supply. A constantly changing and aging landowner population and increasing subdivision of forested lands are current issues that affect wood availability. As woodlot parcels are subdivided, the



SOURCE: CENTER FOR LAND USE EDUCATION AND RESEARCH, UNIVERSITY OF CONNECTICUT.

resulting smaller parcels are less profitable because timber has to be harvested on a parcel-by-parcel basis. Yet, as the landowner population changes, there is an increasing number of owners who are not aware of the role that timber harvesting plays in forest stewardship.

> ***Fragmentation has the potential to destablize income for forest landowners who provide a variety of resources that contribute to the collective economic prosperity and health of communities.***

With over 80% of Vermont's forest privately owned, forest landowners provide the underpinning of benefits and values that all citizens appreciate and enjoy. Privately owned forestland contributes to the state and local economy as well as tourism and outdoor recreation, while providing much-needed forest products. If significant acreage of forestland is unavailable for forest management as as result of fragmentation and parcelization, the impacts will be felt in all facets of the economy. Fragmentation has the potential to destablize income for forest landowners who provide a variety of resources that contribute to the collective economic prosperity and health of communities. Without these economic incentives, forest landowners may be faced with property values and land-holding costs that force alternative land-use decisions. In turn, Vermont loses the associated, critical contributions that forestry makes to its economy and culture. The result is a rapid acceleration of further fragmentation and then permanent loss.

Inter-generational transfer of forestland presents a particular challenge to forest landowners and forest managers and planners. Without estate planning, properties transferred after the death of an owner are often taxed at high rates. Many leave property to more than one heir, which distributes the tax burden but often forces the sale or subdivision of said assets to achieve equity in transfer and pay the taxes. Even in cases where an elderly forest landowner wishes to pass on an intact forest, such a wish can be impeded by an heir who is pressed for time or otherwise has no interest in or does not live near the managed property. Most attorneys practicing estate law do not present clients with options regarding land protection unless it specifically requested by the client. A 2008 study found that forest landowners aged 65 years or older controlled 46% of the nation's forests, and that 20% were controlled by an owner 75 or older. Only 12% of private woodland owners were under 45 (USDA Forest Service Forest 2008). Figures for Vermont are expected to mirror national statistics. Given the amount of forestland that may turn over in the next decade, lands controlled by older forest landowners are at the highest risk for development and potential fragmentation unless legal planning for transfer has undertaken beforehand.

> ***Inter-generational transfer of forestland presents a particular challenge to forest landowners and forest managers and planners.***

Fragmentation Impacts on Scenery, Fall Foliage, Tourism, and Recreation

Vermont's appeal is based in part on a working landscape with the interpertion of forests and fields. Tourists come to Vermont to see a landscape that is different from those seen in urban areas.

Changes in scenic quality and recreational opportunities—owing to loss of open space, decreased parcel size, and fragmentation—degrades the recreational experience and lead to increased likelihood of land-use conflicts.

> ***Forest fragmentation results in a decline in public access to private lands for forest-based recreation, including hunting, fishing, hiking, biking, and skiing.***

Forest fragmentation results in a decline in public access to private lands for forest-based recreation, including hunting, fishing, hiking, biking, and skiing. Access to recreational lands is particularly at risk in the Eastern United States where 80% of the nation's population resides but <10% of the land base is in public ownership (Anderson et al, 2014). Dennis, a researcher from the Northeast Forest Experiment Station, found that "all else being equal, the probability that a non-industrial land parcel will be posted, increased as parcel size decreased." In addition, the closer the land was to a residence, the greater the chance it would be posted. Therefore, if subdivision and/or parcelization of a large forested parcel is accompanied by residential development, the risks of posting increases. This is supported by researchers Widmann and Birch who found that 34% of forestland owners who posted their land, did so for safety reasons (Widmann and Birch 1988).

In many counties larger parcels are being sold to people from out of state who are less likely to have been exposed to the hunting culture of Vermont, including the tradition of keeping private lands open to public access. Increasing exurbanization in Vermont and elsewhere

VAST FOREST ASSOCIATE WITH CAMEL'S HUMP.

means fewer people are exposed to hunting. In addition, people who own larger parcels in Vermont tend to be older in age, thus increasing the chances for parcelization and fragmentation as these parcels get sold or passed on to future generations.

The Vermont Fish & Wildlife Department recently conducted a survey through the research firm Responsive Management. In that survey, Vermont residents were asked how important it was that people have a place to hunt. When the same question was asked in 2003, 66% of respondents said it was very important (Duda 2013). In 2013 that number had jumped to 80%, one indication seen as a decline in access for hunting. The continued fragmentation and parcelization of the Vermont countryside will continue to exacerbate a growing problem in the state. For example, land clearing and home construction on ridgelines and hilltops can impair scenic resources. Old logging roads formerly used by the public for recreational pursuits may be converted to private driveways.

The result is that water draining from developed areas is generally lower quality, and moves faster and in higher volumes than water draining from forests. This in turn limits the ability of our landscape to provide clean water and flood protection.

Fragmentation Impacts on Clean Water and Flood Protection

The existence of forestland is a significant component of surface- and ground-water protection, and fragmentation and development of forestland have been observed to affect both water quality and quantity (Hunsaker et al, 1992; McMachon and Cuffney 2000; Riva-Murray et al, 2010).

Impact of Fragmentation	Effects on Water and Hydrology
Increased impervious surface (road surfaces, buildings)	• Less infiltration in to soils faster downslope movement of water • Increased concentration of water resulting in higher erosive power
Interception and concentration of water in ditches	• Faster downslope movement of water • Increased erosive power • Transportation of sediments and pollutants • Warming of water and discharge in to streams • Reduced opportunity for filtration by forest soils • Reduced opportunity for flow regulation by forest soils and structure • Reduced groundwater recharge • Deprivation of water for some areas by ditch interception
Increased air movement and temperatures caused by permanent clearing	• Increased evaporation • Increased surface water temperatures

When forests give way to development, the amount of impervious surface increases. It is well-documented that various forms of development affect water quality and hydrologic processes. According to a Massachusetts report, if 7% of the forest in a watershed is converted to pavement, "the abundance of river fish declines by about 25%". Shockingly, the results of a Connecticut study showed that those areas where the impervious cover reached 12%, "failed to meet water quality standards for aquatic life" (Thompson 2014). The mechanisms by which development affects water quality and hydrologic processes are varied and include increased area of impervious surfaces (buildings, pavement, and gravel roads), altered drainage pathways (ditches), introduction of pollutants (salts), and often increased air movement and sunlight. These changes can reduce water infiltration, increase overland flow, and change water chemistry and temperature. The result is that water draining from developed areas is generally lower quality, and moves faster and in higher volumes than water draining from forests. This in turn limits the ability of our landscape to provide clean water and flood protection.

Clean Air and Climate Change Mitigation

Fragmentation reduces the ability of forests to provide clean air and sequester carbon in multiple ways. Clearing

of forest results in release of carbon stored in soils and vegetation. Furthermore, areas that are converted from forest have reduced capacity to sequester carbon and soak up fine particulate matter in the atmosphere. Where fragmentation contributes to declines in tree vigor or productivity it will also reduce carbon sequestration and the capacity of the forest to contribute to clean air.

Fragmentation reduces the ability of forests to provide clean air and sequester carbon in multiple ways.

Climate Change as Context for Fragmentation

As the impacts of forest fragmentation are considered it is important to acknowledge climate change and the context within which these impacts will be experienced, "The effects of climate change will not play out on pristine landforms. They will interact with existing conditions and generally increase the severity and extent of existing problems such as species extirpation, water pollution, and water scarcity" (Furniss et al 2010).

The implications of climate change are significant and will likely serve to compound the impacts of fragmentation. In the Northeastern United States we can expect winter temperatures to rise by 5°-12° F by the end of the century and summer temperatures to exceed 90° F for 30 to 60 days. The likelihood and severity of heavy rainfall events will increase particularly in winter where a 20-30% increase is possible with more precipitation falling as rain as winter temperatures rise. In summer and fall, droughts will become more common with extended periods of low stream flow, and a longer growing season (NECIA 2006). In addition, large temperature shifts are likely to result in the redistribution and/or extinction of native species throughout the Northeast.

Climate change disrupts normal forest functions and is expected to increase forest habitat fragmentation. Maintaining continuous forest cover may become more challenging, and maintaining forest connectivity for animal migrations will require extra effort. Reducing forest fragmentation where possible now will create more resilient, adaptable forests for the future. Sustaining blocks of high-quality forest habitat is particularly important in the face of climate change. It is expected that large intact forests will help plants and animals adapt to changing conditions or migrate to areas with a more suitable climate (Travis 2003).

When forests are replaced by suburban development, the land shifts from a net sink to a net source of heat-trapping carbon dioxide (Thompson et al, 2014).

When forests are cleared for development, most of the stored carbon is released into the atmosphere; though some remains stored in long-lived wood products such as furniture and homes. When forests are replaced by suburban development, the land shifts from a net sink to a net source of heat-trapping carbon dioxide (Thompson et al, 2014).

Maintaining healthy, intact forests ensures that Vermont's forests continue to serve as a valuable contribution to greenhouse gas mitigation. Maintaining or improving forested landscape connectivity is recognized as a primary strategy for conserving fish, wildlife, and plant diversity as changes to the region's climate unfold in the face of a rapidly changing climate (Opdam and Wascher 2004; Krosby et al 2010; Heller and Zavaleta 2009; Kart et al 2005). Species are most likely to be able to shift their geographic ranges in landscapes with the least amount of habitat fragmentation and the greatest landscape connectivity.

Impacts on Wildlife and Biological Diversity

Habitat loss and fragmentation are two of the major factors driving loss of biological diversity and degradation of ecosystem services (such as air quality and climate regulation) both in the United States and worldwide (Anderson et al, 2014; Hansen et al, 2005; Millennium Ecosystem Assessment, 2005; Hoekstra et al, 2005; Saunders et al, 1991). Whereas loss of sensitive, critical, and rare habitats receives considerable conservation attention, particularly in Vermont, fragmentation of Vermont's predominately forested landscape continues with much less attention.

There has been considerable scientific research on the biological and ecological effects of ecosystem fragmentation. Two review articles are especially helpful in summarizing this well-studied field (Saunders et al, 1991; Trombulak and Frissell, 2000). Trombulak and Frissell (2000) focus on the effects of permanent roads (the primary source of habitat fragmentation) and breaks these ecological effects into the following seven categories:

- ⇨ mortality from road construction;
- ⇨ mortality from vehicle collisions;
- ⇨ modification of animal behavior;
- ⇨ disruption of the physical environment;
- ⇨ alteration of the chemical environment;

- ⇨ spread of exotic species; and
- ⇨ changes in human use of land and water

These categories are discussed below.

Mortality from Road Construction

Road construction kills all plants and other sessile organisms as well as slow-moving animals in the roadway.

Mortality from Vehicle Collisions

Mortality of wildlife from collisions with vehicles is well-known by most Vermonters and has been well studied. The majority of data collected on road kill on Vermont highways is for larger mammals, especially deer, moose, bear, fox, coyote, and bobcat. However, many smaller mammals (mice, voles, moles, shrews, squirrels, skunks, muskrats, raccoon, weasels, mink, otter), amphibians (frogs and salamanders), reptiles (snakes and turtles), and birds are also killed by vehicle collisions. The number of insects killed along roads must be very high, and although there is likely little reason for concern over the mortality of very common species, the effects on populations of rarer species of butterflies, dragonflies, and bees are unknown.

Modification of Animal Behavior

Modification of animal behavior is possibly the most recognized effect of habitat fragmentation on wildlife: Many species avoid roads, especially roads that are wide, paved, and have high traffic volumes. In addition, studies in the Adirondacks of New York found that the impacts of one home in the forest can extend up to 31 acres beyond the footprint of the house (Glennon and Kretser, 2012). Animal behavior is modified through at least five mechanisms: home range shifts, altered movement patterns, altered reproductive success, altered escape response, and altered physiological state (Trombulak and Frissell, 2000). In North Carolina, black bears shifted their home ranges away from high road density areas (Brody and Pelton 1989). In a Vermont study, black bears selected areas away from roads [mean distance of 2,211 feet (674 meters) for adult males] and many animals used roads as their home range boundaries, but seldom crossed these roads during daily and seasonal movement, especially in years with natural food availability (Hammond, 2002).

Studies in the Adirondacks of New York found that the impacts of one home in the forest can extend up to 31 acres beyond the footprint of the house (Glennon and Kretser, 2012).

Roads and other forms of habitat fragmentation create edge effect, reduce the area of interior forest habitat, and result in more forest fragments of smaller size. Forests in fragmented landscapes have been shown to support fewer forest interior nesting migratory birds (Donovan and Flather, 2002). There is also increased nest predation by raccoons and other species and nest parasitism by brown-headed cowbirds in smaller forested patches of fragmented landscapes (Robinson et al, 1995; Keyser et al, 1998; Trine 1998). These examples show modification of behavior by nesting birds, predators, and bird nest-parasites in response partly to habitat fragmentation.

Disruption of the Physical Environment

Road construction results in transformation of the physical environment under the road but also has significant effects on the physical environment adjacent to the road. At least eight characteristics of the physical environment of forests are altered by roads: soil compaction; increased soil temperature; decreased water content in soil; increased light; increased dust; altered surface and ground water flow; altered patterns of surface water runoff; and increased sedimentation of adjacent streams, ponds, and wetlands (Trombulak and Frissell, 2000). An additional physical alteration is the change in local wind patterns adjacent to roads and other permanent openings.

These physical alterations adjacent to roads or other permanent opening are what result in edge effects, which are most commonly observed as changes in species composition or structure of the adjacent forests. Changes in light, wind, and moisture alter canopy cover, plant recruitment, herbaceous plant density and richness, decomposition rates, tree blow-down from increased wind, and many other factors (Riitters et al, 2012; Burke and Nol, 1998). Edge effects on plant species composition have been shown to penetrate up to 60 meters (197 feet) on south-facing edges and 20 meters (66 feet) on north-facing edges in North Carolina mixed hardwood forests (Fraver 1994).

Edge effects on plant species composition have been shown to penetrate up to 60 meters (197 feet) on south-facing edges.

For example, land clearing and road construction can result in the loss of evergreen/conifer trees used by deer for cover and protection during winter cold and snow. Land clearing and road construction can also disrupt

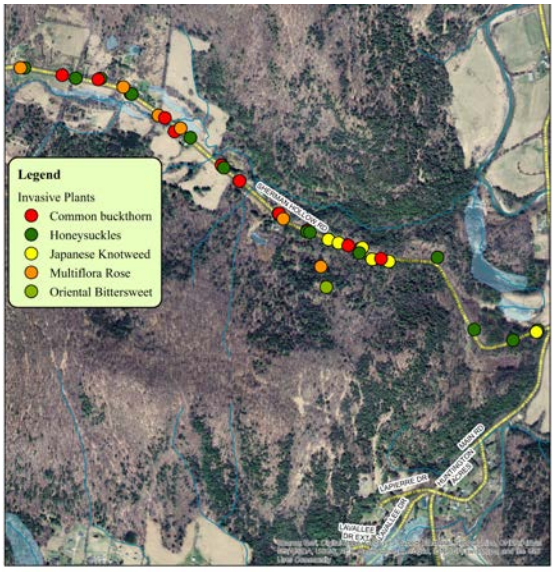
wildlife travel corridors, which negatively affects species such as black bear (VNRC Report).

Alteration of the Chemical Environment

There has been extensive study of the effects of roads on the chemical environment of forests. At least five classes of chemicals associated with road maintenance and use are introduced into the adjacent forest environment: heavy metals, salts, organic molecules, O_3, and nutrients (Trombulak and Frissell, 2000). In Vermont, primarily as a result of road salt application and runoff, chloride concentrations have been steadily increasing in Lake Champlain and most of its major tributaries since the early 1990s, and there is growing concern about the effects on aquatic ecosystems (Shambaugh 2008). Phosphorus and sediments are also associated with road runoff in Vermont. In the Winooski River watershed, estimates indicate that over 40,000 metric tons of sediments are eroded from unpaved roads and over 15,000 kg of total phosphorus (Wemble 2013).

Spread of Exotic Species

Invasive, exotic species are recognized as one of the primary threats to biological diversity because they commonly out-compete native species (Allendorf and Lundquist 2003). Roads and other forms of fragmentation facilitate dispersal of invasive, exotic species through a landscape. Altered physical site conditions along roads make invasion more likely by removing native species and providing easier movement by wild or human vectors (Trombulak and Frissell, 2000). Disturbed soil, increased light levels, and increased soil nutrient levels are all features associated with road margins and disturbed forest edges as conditions that contribute to invasive plant species spread into forests (Saunders et al, 1991; Hutchinson and Vankat 1997).



INVASIVE PLANTS MAPPED IN HUNTINGTON, VT.

HONEYSUCKLE GROWS VIGOROUSLY IN RESPONSE TO AN OPENING CREATED BY STRONG WINDS IN WESTFORD, VT.

> ***Roads and other forms of fragmentation facilitate dispersal of invasive, exotic species through a landscape.***

American robin nests in invasive, exotic honeysuckle and buckthorn have been shown to experience higher nest predation than nests in comparable native shrubs in an Illinois forest fragment (Schmidt and Whelan 1999).

Changes in Human Use of Land and Water

Roads that fragment forests provide additional access for human use and development. Although human uses such as hiking may have relatively minor ecological effects, residential or other development along roads significantly increases the level and impact of fragmentation.

For example, housing development may result in road construction, conversion of forest resources, the planting of non-native species, and *woodscaping*—the practice of removing forest understory (vegetation <8-10 feet in height) to create a park-like aesthetic. This results in a loss of the protective native habitat for ground-nesting birds and introduces potentially invasive (i.e., non-native) species of plants, insects, and diseases (VNRC Report) and eliminates seedlings and saplings that would otherwise grow to become the future forest, i.e., regeneration.

Other examples of development influences are water runoff from roofs, paved driveways, fertilized lawns, and

new roads that channels through culverts and new ditches potentially altering natural flow patterns and the composition of soil and water.

Fragmentation Impacts on Wildlife Corridors and Landscape Connectivity

There is general agreement among conservation biologists that landscape connectivity and wildlife habitat corridors can mitigate some of the adverse effects of habitat fragmentation on wildlife populations and biological diversity (Beier and Noss 1998; Noss and Cooperrider 1994; Haddad et al, 2003; Damschen et al 2006). Landscape connectivity is the opposite of fragmentation—it refers to the degree to which blocks of suitable habitat are connected to each other (Noss and Cooperrider 1994).

Wildlife corridors (also referred to as *wildlife-connecting habitat* or *linkage habitat*; Meiklejohn et al, 2009)[1] are lands and waters that connect larger patches of habitat together within a landscape and allow the movement, migration, and dispersal of animals and plants (USDA Northeastern Regional Field Office 2014). *Corridors* describe specific paths along which animals and plants move and migrate, usually providing connections between blocks of suitable habitat across a dissimilar landscape matrix (Beier and Noss 1998). Although individual species may vary in the rate and extent to which they use corridors, the majority of mobile species rely on wildlife corridors for a variety of purposes (Gilbert-Norton et al 2010).

Maintaining functional landscape connectivity as development continues to fragment forest habitat is a critically important conservation goal. Identifying potential corridors and structural landscape connectivity using available GIS data and least-cost path models is a common approach (Beier and Noss 1998; Watts et al 2010; Jantz and Goetz 2008).

The amount and quality of future forest habitat will be determined by the amount and configuration of land-use change. Of particular importance is interior forest habitat that is far from a forest's edge. These lands are resistant to invasive species, allow movement of wildlife, and permit a range of ecosystem processes to occur unfettered by human influence. Unfortunately, interior forests are extremely vulnerable to changes in land use (Forman and Deblinger 2000). Over time, forest conversion to developed uses fragments and perforates forest blocks, which both reduces the total habitat area and degrades the quality of what remains. Small isolated forest fragments of <5 acres, although better than pavement, provide the lowest quality forest habitat (Thompson et al, 2014).

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Fragmentation Impacts on Human Health, Quality of Life, and Cultural Heritage

Human Health

Although it may be difficult to directly measure the effects of forest fragmentation on the health of Vermonters, it is clear that the ecosystem services (air quality, soil fertility, erosion control, flood mitigation, maintenance of water quality, protection of drinking water supplies, and processing waste water) provided by intact, healthy forests contribute to the health and well-being of humans (Karjalainen et al 2010). Loss and fragmentation of forests significantly reduces these human health benefits.

Fragmentation of forests may be linked to decreased mood and higher blood pressure, faster heart rate, elevated muscle tension, decreased immune response, increased hyperactivity in children, decreased motivation for exercise, and a general decrease in longevity (Anderson et al, 2014).

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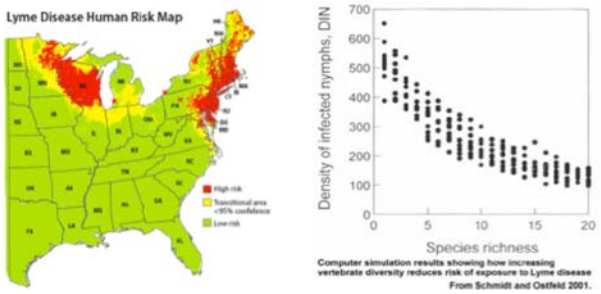
Although more research is needed, new information suggests that there is a complex link between the

[1] These terms are sometimes used interchangeably, but do have distinct meanings that can be useful in distinguishing between closely related concepts of animal and plant movement and propagation of ecological processes. *Corridor* generally refers to a swath of land that allows movement of particular species between two or more areas of disjunct but suitable habitat. Corridors are often thought of as narrow strips of land, but may also be wider areas of suitable habitat used for animal or plant movement and migration. *Linkage* generally refers to broader regions of connectivity that allow the movement of multiple species and that maintain ecological processes (Meiklejohn et al. 2009).

incidence of Lyme disease and fragmented landscapes. In fragmented landscapes, species richness declines as invasive plants expand from forest edges to the interior. Tick survival improves on invasive plants, leading to an increase in tick densities.



LEFT: MAP OF LYME DISEASE RISK IN THE EASTERN UNITED STATES. RIGHT: RRLATIONSHIP BETWEEN SPECIES RICHNESS (OR NUMBER OF WILD SPECIES) AND DENSITY OF TICKS (NYMPHS) INFECTED WITH LYME DISEASE (SCHMIDT AND OSTFELD 2001).

"Prior to 2005, a small number of cases of Lyme disease were reported to VDH. Since 2005, the number of cases has steadily increased. The number of cases reported climbed from 105 cases in 2006 to 522 cases in 2012. In 2013, the number of cases increased to 893 cases" (Vermont Department of Health, 2013).

"Evidence shows that the incidence of Lyme disease continues to be high in Vermont. An increase in infected tick populations, better recognition and reporting by health care providers, and habitat and environmental changes may account for the high number of cases reported in the Green Mountain State" (**Figure 2**) (Vermont Department of Health 2012).

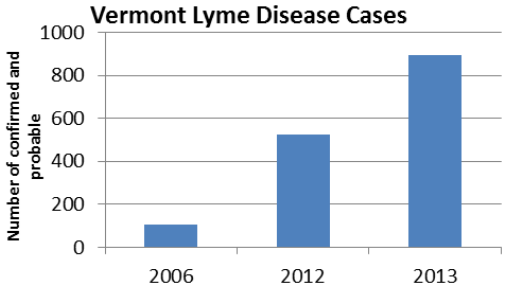


FIGURE 2. INCIDENCE OF LYME DISEASE IN VERMONT.

Quality of Life

Numerous, repeated public surveys suggest that the protection of working forests and wildlife habitat are extremely important to Vermonters. In a 1997 survey, 93% of Vermonters felt it was very important or somewhat important to support state ownership of land for biological diversity and 94.5% for wildlife habitat protection (VT ANR 1997). When asked whether it was important for people in Vermont to have the opportunity to participate in wildlife-related outdoor recreation (such as hunting, fishing, and wildlife watching) 97% said it was somewhat or very important (Responsive Management 1996). These responses were underscored by the results of a smaller survey conducted by the Vermont Fish & Wildlife Department in 2001 in advance of a Wildlife Congress workshop. About 100 attendees representing various social, economic, and ethnic groups were asked, "What makes you want to live in this state"? Attendees responded in many ways but in brief, it was the quality of life: the small number of people and accessibility to government, a sense of place, Vermont's rural nature, a healthy environment, and Vermonter's connection to the land. Clearly, Vermont's forests, the habitats they support, and the state's rural nature are valued by Vermonters and contribute to their quality of life.

Numerous, repeated public surveys suggest that the protection of working forests and wildlife habitat are extremely important to Vermonters.

Fragmentation and conversion of forests limits public access, degrades wildlife habitat, reduces the viability of working lands, decreases resiliency to floods and climate change, and forever alters what is Vermont: "the small villages surrounded by a working landscape." Vermont is an exceptional place to live. Many Vermonters understand this and choose to live here because of the forested landscape and the quality of life this landscape encourages.

Cultural Heritage

Fragmentation of the forested landscape threatens the cultural underpinnings of what makes Vermont indeed Vermont. It leads to the urbanization and/or suburbanization of the landscape and a subsequent change in public attitudes and values toward the state's traditional rural-based cultural heritage. For example, smaller patches of forest or those in more populated

Smaller patches of forest or those in more populated areas are more likely to be posted against access (Butler et al. 2004), potentially affecting forest industries as well as outdoor recreation opportunities and local culture.

areas are more likely to be posted against access (Butler et al, 2004), potentially affecting forest industries as well as outdoor recreation opportunities and local culture.

Support for the traditional use of wildlife (hunting, fishing, trapping) seems to decline drastically in states that are >70% urban (J. Organ, personal communication, 2014). In fact, researchers found that "the greater the proportion of state residents who live in urban areas, the lower the proportion who hunt" (Decker et al 2001).

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VIII. Policy Options to Promote Forest Integrity

Introduction

Forests provide with Vermonters enormous benefits and a range of critical services. A thriving forest economy, functioning natural systems, and Vermont's quality of life rely on maintaining blocks of contiguous forests across Vermont's landscape. As we enter the 21st century, Vermont's forests have the potential to provide an abundance of economic, ecological, and social benefits into the future, and decisions and actions taken today will influence Vermont's forests and forest values for years to come (Thompson et al, 2011).

Although Vermont remains the second least populated and second most rural state in the United States (U.S. Census Bureau, 2010), it is predicted that the population growth rate is likely to increase. By 2030, Vermont will have an additional 85,000 residents compared with 2013. This growth might even be greater, depending upon whether there is a migration from areas experiencing the adverse effects of climate change. As we anticipate this growth, we know that the urban areas of Vermont will need to continue to plan for an accelerated population growth. In addition, many rural communities will be confronted with population increases and the pressures associated with rapid development.

We have some experience with this already. Grand Isle County has been experiencing such population growth. The county's population as of 2013 increased over 31% since 1990 with significant implications. Other rural areas of Vermont face similar population growth rates with similar risks. Lamoille County experienced an increase of 27% from 1990 to 2013 and the population continues to grow at a steady rate.

Over the last fifteen years, Vermont has added 1,400 new households annually or an average annual growth rate of 0.6% (Vermont Housing Finance Agency, 2009). The proportion of developed land also continues to increase as a result of increased residential and commercial development, as well as construction of second homes, mostly related to the ski industry.

Over the years, much thought has gone into how we might balance Vermont's anticipated growth with our interest in maintaining our traditional settlement patterns—with village centers surrounded by fields, farms and healthy, working forests. In order to protect the integrity of Vermont's forests, it will be important to:

1. Educate and engage Vermont landowners, schoolchildren, municipalities and land-use decision makers (e.g. realtors and developers) about the economic and ecological benefits of forest blocks and the connectivity among smaller forest blocks;

2. Continue to invest in land conservation and strategically target investments to focus on areas that have the greatest ecological and economic values and are most at risk;

3. Support existing landowners to keep their land forested and to encourage new growth in existing settlements and near existing roadways to avoid incursions into high value forest blocks;

4. Consider additional tools for local governments and the state to discourage development that converts blocks of forest to other uses and requires mitigation when such development occurs; and

5. Ensure that forest landowners can get value from their forested land through sustainable forestry practices and develop and create markets for Vermont forest products.

These general concepts have been discussed previously in a variety of forums and are outlined in further detail in the following sections of this report.

The final recommendation of this report is for the Commissioner of Forests, Parks and Recreation to facilitate a series of stakeholder conversations in the coming months to gather comments and feedback on the potential policy options outlined in this section, to solicit additional ideas and strategies to support forest integrity, and generate a concrete list of recommendations for lawmakers to consider during the 2015-2016 legislative session.

Education and Outreach

Engagement with Forest Landowners

As a first step to protecting our forests, we must increase our education and outreach to Vermont's forest landowners. Although 86% of Vermont's forestland is in private ownership, Vermonters are largely unaware of the connection between good forest stewardship, a working landscape, and the benefits provided by healthy forests. A few past efforts have had some success, and some strategies have been developed but not adopted.

Engagement with Schoolchildren

Vermont's agricultural community has been highly successful in incorporating an agricultural curriculum into Vermont schools, as evidenced by how effective the "farm to school" program has been in teaching students about the origins of their food. A similar effort should be made for forest products, so that Vermont school children can understand why forests are important, and how many products the forest provides. This type of educational focus would foster an interest in working in the forest products industry and help to identify and encourage students who show an interest and aptitude for this type of work. In addition, schools should be encouraged to take advantage of school-specific opportunities to teach students about forests and forest products. A few examples include:

- ⇨ When a school is installing a wood pellet or chip heating unit, students could be taught about how pellets and chips are and by talking with foresters and loggers about from the sources of the wood.

- ⇨ If a school is using locally made wood products, students could tour where the products were made and talk to the manufacturers, as well as foresters and loggers to learn about different kinds of wood and how it is sourced from forests and how it gets made into furniture and other products.

Fortunately, the state has a network of existing outreach and service providers that already deliver this message of the importance of forests and forestry, which can be deployed more extensively in the future.

County Foresters

These forest professionals from the Department of Forests, Parks and Recreation are stationed throughout the state, providing technical assistance, promoting forest stewardship and supporting landowners enrolled in the Use Value Appraisal program ("current use"). The County Foresters have existing relationships with forestland owners, understand the economic and market forces of the forest products economy, and have technical expertise related to natural resource protection, water quality and the other habitat and ecological values of large forested parcels. **The role of County Foresters could be expanded as strategy to support forest integrity**. In this expanded role the county foresters could work with multiple landowners at a landscape scale. Many forest values and functions are spread out across multiple ownerships, and a strategic approach of building connections between landowners with shared interests and resource concerns could help maintain forest integrity at a greater scale than an individual parcel. County foresters currently play a role in this, but cold expand their involvement at the local and regional planning level by providing forest resource planning advice.

Enhanced Tools for Technical Assistance to Landowners

Many landowners have little knowledge about harvesting operations. As a result, they risk making uninformed decisions that can lead to negative consequences for their finances and their forest. Landowners may accept the first offer from a logging contractor for a harvest without having an estimate of their forest's potential value or its ecological attributes. Without understanding options for management, they may also unintentionally allow "high grading," which removes high-quality trees and leaves only poorer quality trees, severely reducing future options and potential. In 2013 the General Assembly passed Act 24, requiring the Commissioner of Forests, Parks and Recreation to develop voluntary harvesting guidelines for forest landowners that help ensure long-term forest health and sustainability. These guidelines were adopted on January 15, 2015. The recommendations outlined in the Voluntary Harvesting Guidelines address planning for a harvest, conducting a harvest, and considerations related to water quality, biodiversity and wildlife habitats, and soil productivity. **These guidelines should serve as the basis for an expanded toolkit of technical assistance and guidance for landowners.**

Vermont Farm and Forest Viability Program

In 2013, forestry interests were added to Vermont's successful farm viability program administered by the Vermont Housing and Conservation Board (VHCB) (see http://www.vhcb.org/Farm-Forest-Viability/). The Vermont Farm and Forest Viability Program's (VFFVP) relatively new forestry program provides forestland owners and forestry related businesses a suite of business planning and technical assistance services that help maintain a viable forest product industry. Maintaining and growing a strong wood products industry is a key strategy to make long term ownership of blocks of unfragmented forestland a profitable enterprise. **The services of VFFVP could be expanded to reach a wider network of landowners and forest products sectors, as well as to provide increased implementation grants or financing to help business ownership put business plans and system**

upgrades to practice. To further promote forest integrity, technical assistance and grant programs should be targeted to lands that have the highest impact on regional integrity, such as forestland that ranks high in the Vermont Department of Fish and Wildlife Habitat Block Assessment or that is within or adjacent to blocks of conserved forestland.

Staying Connected

Staying Connected is a regional partnership of state fish and wildlife departments, transportation agencies and conservation groups seeking to retain, restore and enhance landscape connectivity for wildlife across the Northeastern United States and Canada (see http://stayingconnectedinitiative.org/). The protection of intact blocks of forest is an important strategy to maintain connectivity, so Staying Connected's work not only promotes wildlife habitat, but prioritizes forest integrity. Staying Connected supports local governing bodies, planning commissions and conservation groups in designing development and transportation projects that maintain and enhance wildlife connectivity at the local and regional scale. Staying Connected representatives also support the development of town plans and local bylaws that enhance these wildlife functions. **These outreach efforts should be supported and could be expanded to further prioritize forest integrity**.

Forest Roundtable

Convened by the Vermont Natural Resources Council (VNRC), the Forest Roundtable provides an opportunity for a variety of forestry and conservation organizations to meet periodically to discuss issues of concern, set legislative priorities, and collaboratively develop policies related to forest integrity. As a result of the Roundtable work, VNRC was successful in securing several US Forest Service competitive grants to support their analysis of forest fragmentation.

Tools for Tracking Forest Land Use and Change

ANR and our partner organizations have made significant investments in information and GIS mapping tools to provide municipalities, landowners, conservation organizations and others with the best information possible about our forests, the location of our high value forest blocks, areas of significant biodiversity and the critical habitat corridors that connect them. These tools include the Vermont Department of Fish and Wildlife's Habitat Block Assessment, the BioFinder and Natural Resource Atlas mapping tools, the FPR-supported Vermont Association of Planning and Development Agencies Forest Stewardship Mapping Tool, and the Vermont Land Trust's Conservation Lands Atlas.

As the accuracy and richness of data improves, these mapping tools become ever more effective to plan for growth, conservation and enable resource protection. To that end, the Vermont Center for Geographic Information is working with ANR and other public and private partners to fund full LIDAR coverage for the state. LIDAR is cutting edge remote-sensing technology that provides a spectrum of incredibly granular data including topography, land cover type and other data valuable for natural resource planning.

Although used in other regions, systematic landscape-scale assessments of forest loss and fragmentation have not been available to inform policy and management decisions in the state of Vermont. Because existing parcel-based methods are time consuming and do not capture the fine-scale patterns of change associated with forest loss and conversion, a complementary and more comprehensive method is necessary. A systematic remote sensing approach would provide more accurate estimates of forest fragmentation, in terms of its location, extent, timing, and cumulative impacts on forest ecosystem services. Investing in a statewide forest fragmentation monitoring program would serve many stakeholders in addition to forest managers and policy makers. Yearly forest cover maps could be used to inform other activities such as wildlife management, development planning, and water quality protection efforts.

A statewide remote sensing approach should be developed to monitor forest fragmentation, leveraging the latest mapping tools and techniques in a nested framework to maximize accuracy and minimize long-term costs. By integrating readily available geospatial datasets across multiple scales in space and time, this program would provide yearly, unbiased, and consistent estimates of the rates and impacts of forest fragmentation across the state of Vermont in a timely manner.

Land Conservation

After education and outreach, the next strategy to promote forest integrity is to enhance the economic benefits that flow to landowners who maintain forestland in continuous blocks. Economic pressure on families and individuals often drives the subdivision and parcelization of forest blocks, so targeting land conservation incentives to help maintain the most critical blocks can be an effective investment in integrity. Incentives could be offered for both landowners interested in managing their

land for wood products and for those interested in protecting the other ecological and recreational values forestland provides. Vermont has a long history of public and private investment in conservation that has been successful in protecting critical resource areas while supporting growth and development in existing settlements, downtowns and village centers; this historic development pattern and existing conservation infrastructure could be re-purposed and prioritized around forest integrity. Potential strategies to promote forest integrity through conservation incentives are included in the subsections here below.

Enhanced Forestland Conservation

The targeted protection of forestland through permanent land conservation is central to maintaining and enhancing the multiple benefits and integrity of Vermont's forests. Supporting private landowners who choose to conserve their land can help protect these benefits while also supporting rural economies, maintaining lower per-acre public service costs, and enhancing the climate protection functions of the land. Compensating private landowners through the purchase and sale of conservation easements also provides economic security that may offset the need for landowners to subdivide and parcelize blocks of forestland, a key driver of fragmentation.

In addition to the protection of privately owned land, conservation efforts that place forestland in public ownership, such as state forest, park and wildlife management areas, also support multiple forestland values and are an integral part of Vermont's overall forestland protection strategy.

Vermont has invested heavily in the conservation of forestland. Since 1987, the state (through the Vermont Housing and Conservation Board (VHCB)) has permanently protected 213,511 acres of working forestland representing an investment of $16,039,432, and 37,606 acres of forestland that supports unique natural communities, wildlife habitat, and important recreational uses such as the Long Trail, which represents another $17,696,77 of investment. The Vermont Department of Forests, Parks and Recreation has been successful in accessing $45,000,000 in competitive federal forest legacy funding to conserve 88,000 acres of working forestland. Statewide and regional land trusts like The Nature Conservancy, Vermont Land Trust, Trust for Public Lands, and The Conservation Fund and local groups such as Stowe Land Trust, Pinnacle Hill Association, and numerous others have leveraged this public investment with millions of dollars in private donations.

This private/public partnership has made remarkable progress in consolidating areas of conserved forestland and protecting in part many of the largest forest blocks in the state. Successful examples include:

- ⇨ Kingdom Heritage Lands;
- ⇨ Atlas Timber Lands;
- ⇨ Chittenden County Uplands;
- ⇨ Pinnacle Hill; and
- ⇨ Route 4/155 Bear Corridor.

However this investment could be undermined by the development of lands within or nearby these conserved blocks, fragmenting forest integrity and compromising conservation values. A key strategy to prevent the further fragmentation of these areas is continued investment in strategic conservation projects, targeting parcels that pose a risk to these previous efforts. **To maximize the impact on forest integrity, an enhanced forestland conservation strategy would target parcels that possess key values**, such as parcels

- ⇨ located within or adjacent to existing blocks conserved of forestland;
- ⇨ ranking high in the Vermont Fish & Wildlife Department's Forest Block Assessment;
- ⇨ meeting US Forest Service Legacy goals and supported the 2010 Vermont Forest Resource Plan;
- ⇨ providing important climate adaptation and regional connectivity functions;
- ⇨ having long-term contracts to provide sustainably harvested wood projects or fuel for in-state processing and consumption; and
- ⇨ providing a high level of ecosystem services or conservation values.

Another important goal for an enhanced forestland conservation strategy is to make investments that facilitate the intergenerational transfer of blocks of forestland without parcelization or that shift large tracks into alternative ownership models, such as cooperatives, where the land is owned by a group, but managed as one large track to prevent further fragmentation.

Land trusts in Vermont have had great success using the purchase of development rights to help farmers pass land from one generation to next, lowering the cost of entry for young farmers looking to own their first farm. While the economics of forestry and farming are different, the

premise of lowering costs at the time of transfer by infusing capital from an easement purchase would still be an important and applicable strategy for forestland. Land trusts have also traditionally provided landowners guidance and limited assistance with estate and tax planning around transfers of land. **The expansion of these services paired with a focus on conservation investments that facilitate the intergenerational transfers of blocks is another enhanced forestland conservation strategy.**

Landowner Incentives

The annual carrying cost of land is a significant factor in whether private forestland can be owned, managed, and maintained in large blocks into the future. Unlike the annual return from an agricultural operation, working forestland is typically managed on longer rotations where income generating harvests are spread out over years and often decades. If economic pressures befall forest landowners, they may have limited options to generate equity and may turn to subdivision and parcelization of portions of their land.

One key economic variable for land owners is property tax. Vermont's Use Value Appraisal ("Current Use") program is intended to stabilize property tax rates and assess working lands at their value for either agricultural or forestry use. This program has been instrumental in keeping annual property taxes affordable and allowing forestland owners to hold and steward parcels of 25 acres or larger. Maintaining and strengthening current use is a key strategy to support forest integrity.

In recent years UVA was amended to allow for the enrollment of forestlands that provide unique ecological services. This has allowed landowners who might not manage land as actively for timber products to participate in the UVA program. The further expansion of UVA to allow enrollment of large forested parcels for values other than timber management—such as for their ecological services, clean water value, or flood resilience functions—may be another strategy to promote forest integrity. Other potential revisions to UVA that support forest integrity include:

- ⇨ Increased benefit levels for parcels that comprise high ranking forest blocks according to the Vermont Fish & Wildlife Department's Forest Block Assessment; and
- ⇨ Established tiers of commitment, where tax benefits would increase the longer a landowner commits to keep a parcel in the program, with the highest benefits awarded to parcels under conservation easement.

Estate Taxes and Monetizing Ecosystem Services

Estate taxes may also hinder the intergenerational transfer of intact blocks of forestland. Heirs sometimes must subdivide and sell off portions of large forested parcels when land is passed as part of an estate settlement. **Opportunities to lessen the impact of estate taxes or to provide enhanced estate succession planning for forestland owners is another strategy worthy of exploration.**

Another means to incentivize ownerships patterns that support forest integrity may be through tracking and *monetizing the ecological services* blocks of forestland provide. As discussed elsewhere in this report, forests provide a range of critical services to Vermonters—from flood resilience and improved air and water quality to recreational uses. The Gund Institute at the University of Vermont is exploring ways to quantify, track, and monetize these ecological services, and as these services become more critical as a result of climate change, it may be appropriate to socialize the cost of these services and provide some modest income stream or additional tax benefit to forestland owners in recognition of the public benefits intact blocks of forest provide. Current opportunities on carbon trading, notably through the California Cap-and-Trade Program are focused on a larger scale than Vermont's typical parcel size. An approach of aggregating forest parcels to take advantage of carbon trading opportunities is worth pursuing.

Land-Use Planning Tools and Strategies

Vermonters, through the decisions of private landowners or collectively as communities, have a remarkable capacity for and history of acting in the best interest of the state and our natural environment. Indeed, that Vermont's forests are still intact and vital, especially as compared to our neighbors to the south, is testament to Vermonter's shared environmental ethic. But as the state's population increases, it may be important to further support Vermont's historic settlement pattern of compact communities surrounded by working farms and forest blocks with modernized land-use regulations that include a focus on forest integrity. There are myriad strategies to address land use, but it is critical that any recommended strategy provide for economic growth, anticipate a growing population, and accommodate expanded commercial, residential and energy uses in appropriate locations across the landscape. While the Agency of Natural Resources is not specifically

recommending any policy or regulatory changes, examples of well-balanced strategies for forest integrity are detailed below.

Local Land-use Planning

The vast majority of land-use decisions in Vermont are made at the community level. Less than 5% of subdivisions trigger statewide review through Act 250, so adequate local planning and regulations are critical to maintain Vermont's forest integrity. Fortunately, many communities already have a number of tools at their disposal to limit the fragmenting effect of development on their forests.

These planning and zoning tools will, in many cases accommodate a landowner's desired development goals, but may involve alternate configurations that minimize the impacts to forest integrity. The Vermont Natural Resource Council's 2013 *Community Strategies for Vermont's Forest and Wildlife* publication includes an extensive discussion of some of the most effective means of addressing forest integrity at the municipal scale, including:

- ⇨ Conservation planning;
- ⇨ Written standards for development review;
- ⇨ Conservation, forest and overlay districts;
- ⇨ Subdivision regulations;
- ⇨ Planned unit development; and
- ⇨ Road and trail policies.

The Vermont Fish & Wildlife Department's 2013 guide to community-based planning, *Conserving Vermont's Natural Heritage*, is another excellent resource with planning recommendations that, if broadly implemented at the local level, will have profound, positive impacts on forest integrity.

These municipal planning tools, in combination with modernization of Vermont's local planning and zoning laws, Chapter 117 of Title 24, would make it possible for communities to better protect Vermont's forests. Vermont statute (24 VSA Chapter 117 §4414) specifically enables communities to enact "Forest Districts permitting commercial forestry and related uses and prohibiting all other land development." In addition to this section, Chapter 117 could be strengthened by specifically calling out the value of forest blocks and by empowering municipalities to develop bylaws specific to forest fragmentation. Examples of possible changes to Title 24 include

- ⇨ Defining forest blocks and landscape and habitat connectivity in 24 VSA §4303;
- ⇨ Permitting or requiring municipalities to adopt by-laws to address forest blocks and connectivity under 24 VSA §4412 and/or 4414; and
- ⇨ Adding protecting forest blocks from fragmentation to planning and development goals. See section 6302 Title 24.

In its report entitled *Informing Land Use Planning and Forestland Conservation Through Subdivision and Parcelization Trend Information,* VNRC made a series of recommendations about steps that could be taken by communities to better protect their forest assets. VNRC noted that "it is common practice in Vermont for communities to delineate special purpose districts (e.g., village, commercial, mixed use, natural resource conservation) with boundaries that coincide with recognized physical landscape features, and to designate the area outside of those districts as rural residential or comparable designations. Communities that designate forest districts most often do so by delineating areas that are predominantly forested and sparsely developed or undeveloped, in many instances defined by elevation, public land ownership, or distance from accessible roads or other infrastructure." This report made some specific recommendations about ways in which local zoning by-laws could better protect forest integrity; for example, as indicated in the subsections that follow below.

Section 248 and the Consideration of Forest Fragmentation

The integrity of forest blocks and the impacts of forest fragmentation are already considered by the Public Service Board in the permitting of large-scale energy facilities in Vermont, under Title 30 Section 248. To date, the PSB has issued Certificates of Public Good for large-scale facilities located in or nearby large forest blocks, but has, in certain cases, required revisions to the layout of the project and/or required mitigation to minimize or offset impacts to forest integrity.

The PSB has greater authority to address forest fragmentation than the decision makers (District Commissions and the Environmental Court) under Vermont's Act 250 law. This is because, while the PSB gives *due consideration* to certain Act 250 criteria, they apply a broader environmental standard to their review of energy projects: whether a project poses an undue adverse impact to the natural environment. It is under

this broad consideration that the PSB has addressed forest integrity and the impacts of fragmentation.

Act 250 Updates for Forest Integrity

Whereas most land-use decisions are made locally, large-scale commercial development and residential subdivisions typically require a land-use permit from a regional Act 250 District Commission. However, Act 250 is largely silent on the issue of forest fragmentation.

There are a number of ways that Act 250 could be modernized to protect forest integrity. These changes run along a spectrum from substantive changes to the review criteria to jurisdictional changes that impact when Act 250 review is triggered. The enhanced consideration of forest integrity through Act 250 would not necessarily prevent development within forested blocks, but could minimize the fragmenting effect of proposed development by modifying the location or layout of the development within the block, and/or by requiring mitigation of adverse impacts.

To provide the appropriate tools and clear authority for Act 250 to protect forest blocks, there are a number of amendments to Act 250 to consider, including the following:

- ⇨ Adding definitions to 10 V.S.A. § 6001 for "significant forest" blocks and "significant connecting habitat" so that those features of forest integrity can be addressed specifically in Act 250. By limiting consideration to only *significant* areas, such as the higher ranking blocks in the Vermont Fish & Wildlife Department's Forest Block Assessment, the Act 250 review would focus only on parcels critical to forest integrity and not create more process for projects in other locations.

- ⇨ Criterion 8A (wildlife habitat and endangered species) could be enhanced to include explicit consideration of significant forest blocks and connecting habitat. Currently, Act 250 does not specifically consider these elements of forest integrity and given the nexus between significant forest blocks and the Department of Fish and Wildlife's assessment of high ranking forest blocks, criterion 8A appears the most appropriate place to add this consideration. This change would give the Act 250 district commissions the necessary tools to moderate the impacts from development on the most critical forest blocks across the state.

- ⇨ Authorization of off-site mitigation for impacts under Criterion 9C (forest soils), and amend Criterion 9C to focus on forest blocks instead of soils.

- ⇨ The Act 250 jurisdictional trigger for the subdivision of parcels could be changed for parcels situated in high ranking forest blocks. Lowering the jurisdictional threshold for projects in the most critical areas for forest integrity would allow Act 250 review of projects with the most potential to do harm, while not unnecessarily regulating development in lower raking blocks and non-forested parts of the state.

- ⇨ Act 250 originally included a jurisdictional trigger based on new road construction that extends a specified distance into a high ranking forest block. This was taken out of the law in 2001. Since that time research shows that residential units developed along the edge of a forest will have far less impact on forest integrity than if that development extends deep into the center of the block. Indeed, fragmentation through development of long roads into the interior forest is one of the biggest threats to forest integrity. Act 250 could be modernized by a rule that triggered jurisdiction based on the proposed depth of intrusion into high ranking blocks. This would encourage landowners to locate those lots on the periphery of the block, rather than the interior, to avoid Act 250.

Promote Sustainable Forestry and the Vermont Forest Economy

The economic importance of Vermont's working forests has seen considerable attention of late. This recognition has seen a renaissance in the "Buy Local" movement extending from food to forests. From firewood to lumber, biomass to fine furniture, carbon sequestration to clean water, our forests have value. Forest-based manufacturing and forest-related recreation and tourism are significant economic drivers for Vermont, resulting in a substantial contribution to our state's economy.

Well-managed forests provide tremendous economic and environmental benefits to society. Currently, <2% of the forestland in Vermont is harvested each year and a significant proportion of our paper and wood products originate from beyond our border. As a result we are diverting economic benefits away from rural towns, transferring impacts to ecosystems elsewhere, and fueling

the disconnect between natural resource use and production.

There is a less transparent interconnectedness between local markets for low-grade wood and improvement in residual timber quality. An increased demand for low-grade wood creates a market incentive for landowners to indirectly improve the residual timber that can serve as higher-quality curable wood products.

Space heating represents one-third of Vermont's total energy demand and 80% of that is met by fossil fuels (one-half of that is oil). Despite a long and continuing tradition of heating with wood, only 15% of Vermont's heating demand is currently met with wood. This represents an enormous opportunity to increase forestry to supply heating needs with efficient, clean-burning technologies, while improving timber quality and value-added prospects for durable wood products, yet keeping forests forest. An additional potential consideration is promoting combined heat and power at scales suitable for small-scale commercial or residential use.

The most important point to make about our forest products sector is that the full value it provides to Vermont cannot be measured by the sum of private balance sheets alone. Of course, there are the ecological and social benefits generated by responsible forestry. And those benefits are, in turn, enabled by a diverse forest products industry which provides an outlet for trees of different species, ages, and quality.

Moreover, a significant percentage of the dollars that come into Vermont via tourism and recreation are generated thanks to the attraction people have to our working landscape. And yet, because the economic value that our forests generate for tourism and recreation is often not captured by the very forest and wood products businesses that sustain that working landscape people come to see, these businesses often struggle to survive.

Indeed, the forest sector of our economy faces unique challenges. Starting near the beginning of the supply chain, we know that for loggers the high cost of workers' compensation insurance often precludes additional hiring. Not surprisingly, more than half of all forest and wood products businesses in Vermont are either sole proprietors or have less than one full-time employee. This makes it difficult for new and younger loggers to enter the profession unless they have a family connection. Consequently, we have seen the average age of loggers continue to rise.

Logging is also incredibly capital intensive. With modest profit margins at best, securing loans for modern, high-cost equipment is very difficult. While this is also true for our farming sector, there are fewer sources of patient, risk tolerant capital for the forest sector to access. For instance, Slow Money Vermont—an intentionally patient, risk-tolerant capital provider—has a goal of "mobilizing additional and complementary capital for Vermont's food system entrepreneurs and innovators," yet it does not include forest-based businesses in its eligibility. For secondary wood products manufacturers, the common challenges are similar to the broader manufacturing sector: relatively high energy costs compared to other parts of the country; difficulty attracting and retaining skilled talent; and trucking and shipping costs, especially for those who serve primarily out of state markets. In surveys of the Vermont forest and wood products sector, the most commonly identified gap in our supply chain is sufficient infrastructure—specifically saw mills and dry kilns. These businesses report that state regulations, especially Act 250, make the building of new mills extremely difficult.

One of the best resources we have had to address these interrelated issues in recent years has been the Working Lands Enterprise Initiative. With the ability to make meaningful impact investments in key working lands enterprises, capital and infrastructure that benefits the whole supply chain, and statewide services (including business planning and workforce development), the Working Lands Initiative has given the forest industry a shot in the arm. Today, for instance, thanks to the Working Lands Enterprise Initiative, the Farm Viability Program of the Vermont Housing and Conservation Board has become the Farm *and Forest* Viability Program, providing business planning and technical assistance to an array of forest products businesses that had never before had access to their resources.

Vermont's workforce is aging and this trend is visible in the forest product sector. In order to sustain a working landscape, we need to sustain a viable workforce through supporting workforce development and training for loggers by investing in programs that support youth developing loan programs for equipment purchase, creating a worker's compensation pool (or other), and providing better access to health insurance.

Additional forms of support would include workforce development and training for loggers. At minimum such support should include Investment in programs that support youth, develop loan programs, a worker's compensation pool (or other), and better access to health insurance;

Develop Local Markets

Although Vermont has a relatively small population, opportunities do exist to develop local markets for forest and wood products. The state and the industry should foster these markets and encourage consumers to purchase local products, just as they have been encouraged to buy local food. In addition to full time Vermont residents, other potential in-state markets include second home owners and tourists.

Opportunities to promote sustainable forestry and the forest economy include:

- ⇨ Supporting efforts that promote the use of local wood through outreach and education to designers and architects on the viability of Vermont wood in the design and construction of residential, commercial, and institutional buildings.

- ⇨ Promoting a *branding* of Vermont wood products that recognizes the consumers' interest and value of forest sustainability and health which are an integral part of forestry in the state. Increase forest product's exposure in global markets through promotion of forest certification.

- ⇨ Promoting investment opportunities through Vermont Economic Development Authority (VEDA) in primary and secondary manufacturing capacity so that Vermont logs are processed into lumber and other products, for all the value-added benefits provided.

- ⇨ And increasing outreach to forest landowners that encourage sustainable forest management and harvests that will ensure a consistent flow of raw material such as that the Voluntary Harvesting Guidelines created by the Department (see http://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Your_Woods/Voluntary_Harvesting_Guidelines/VHG_FINAL.pdf).

Create New Markets Within the Industry and Beyond Vermont

Wood is a commodity product in a global marketplace, making it exceptionally difficult for Vermont forest products enterprises to compete in this global commodity market because of the high costs of production here in relation to other parts of the world. At the same time, like other commodities, wood has great potential for having value added to it. The key is to add the value to the wood here in Vermont, rather than shipping the raw product to other places to add the value. Developing key value-added markets could allow Vermont forest enterprises to create products for those markets and reap the benefits of adding the value here in Vermont.

Another key area that should be explored is *new markets development*. There is growing recognition of the potential of the Northeast and key population centers (e.g., Boston and New York), as well as potential global markets where consumers are looking for experiential, sustainable, or high-quality custom products (e.g., China). Development of "mass customization" should be pursued as a way to reach these customers and the industry may need to adopt new technologies and production methods to take advantage of these markets.

Working Lands Enterprise Initiative

Initially launched in 2012, the mission of the Working Lands Enterprise initiative (WLEI) is to grow the economies, cultures, and communities of Vermont's working landscapes by investing in critical leverage points across Vermont's farm and forest sectors.

The Working Lands Enterprise initiative, Act 142, (http://www.leg.state.vt.us/docs/2012/Acts/ACT142.pdf) created the Working Lands Enterprise Fund (WLEF) and the Working Lands Enterprise Board (WLEB). The WLEB is made up of private sector members throughout the supply chains of agriculture and forestry, the Vermont Agency of Agriculture, Vermont Department of Forests, Parks & Recreation, Vermont Agency of Commerce and Community Development, Vermont Housing Conservation Board, Vermont Economic Development Authority, and Vermont Sustainable Jobs Fund.

Some of the goals of the Working Lands Initiative, as outlined in the Findings section of Act 142 (see http://www.leg.state.vt.us/docs/2012/Acts/ACT142.pdf), are as follows:

1. Stimulate a concerted economic development effort on behalf of Vermont's agriculture and forest product sectors by systematically **advancing entrepreneurism, business development, and job creation**;

2. Recognize and build on the **similarities and unique qualities** of Vermont's agriculture and forest product sectors;

3. **Increase the value** of Vermont's raw and value-added products through the development of in-state and export markets;

4. **Attract a new generation of entrepreneurs** to Vermont's farm, food system, forest, and value-added chain by facilitating more **affordable access** to the working landscape;

5. **Provide assistance** to agricultural and forest product businesses in navigating the regulatory process;

6. Use Vermont's brand recognition and reputation as a **national leader** in food systems development, innovative entrepreneurism, and as a "green" state to leverage economic development and opportunity in the agriculture and forest product sectors;

7. **Promote the benefits of Vermont's working lands,** from the economic value of raw and value-added products to the public value of ecological stability, land stewardship, recreational opportunities, and quality of life;

8. Increase the amount of state investment in working lands enterprises, particularly when it **leverages private and philanthropic** funds; and

9. Support the people and businesses that depend on Vermont's renewable land-based productive use of the land by coordinating and supporting financial products and programs.

To date, the Working Lands Enterprise Board has invested in 74 agriculture and forestry projects in all fourteen Vermont counties, distributing $2.1 million dollars in Working Lands funds, and leveraging an additional $3.1 million dollars in matching funds.

The Working Lands Enterprise Initiative, including the fund and board, should be supported and expanded.

Vermont's forests provide significant contributions to our economy, environment and well-being. When we invest in support services and infrastructure for working forests and forest products enterprises, this pillar of the economy grows stronger and we bolster both Vermont's character and integrity.

Conclusion

Given the importance of Vermont's forests and the many, often complex, policies options available to the state, it has become clear that additional dialog is needed before we move forward down any one policy pathway. Forests impact all corners of the state, many facets of our economy and are central to our communities, as such, Vermonters should be involved in crafting a solution to the challenge of forest fragmentation. Given that several drivers of fragmentation are currently in place in Vermont—and given the significant and wide-ranging importance and value of Vermont's forests—much is realistically vulnerable to loss and much is at stake.

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