STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION

and

STATE OF MAINE
LAND USE PLANNING COMMISSION
IN THE MATTER OF
CENTRAL MAINE POWER COMPANY

Application for Site Location of Development Act permit and Natural Resources Protection Act permit for the New England Clean Energy Connect ("NECEC")

L-27625-26- A-N
L-27625-TB-B-N
L-27625-2C-C-N
L-27625-VP-D-N
L-27625-IW-E-N

SITE LAW CERTIFICATION SLC-9

Testimony of Janet S. McMahon

<u>Testimony of Janet S. McMahon</u>

Intro/Qualification Questions

Q. Please state your name and business address.

Janet McMahon, PO Box 302, Waldoboro, Maine 04572

Q. Please describe your current employment.

I am a consulting ecologist. I conduct natural resource inventories and prepare management plans and regional conservation plans for conservation groups, government agencies, and private landowners. I am also on the faculty of Watershed School, an independent high school in Camden, Maine, where I teach a course on Global Climate Change.

Q. Please describe your education and professional background and experience.

I have a B.S. in biology and geology from Colby College and an M.S. in plant ecology from the University of Maine. My masters thesis, The Biophysical Regions of Maine, and my professional career have focused on conservation at the landscape scale. I helped develop Maine's Ecological Reserves system, worked at The Nature Conservancy as a conservation planner, and more recently have worked with land trusts to identify conservation focus areas and wildlife corridors that are most likely to be resilient to the impacts of climate change and to prepare management plans that take these and other considerations into account. My resume is attached (Group 1 Exhibit 2)

Q. Please describe any publications you have authored or co-authored (papers, chapters of books, etc.).

A list of publications is attached (Group 1 Exhibit 3). Two that are particularly relevant to this topic include:

McMahon, J. 2016. Diversity, Continuity and Resilience: The Ecological Values of the Western Maine Mountains. Occasional Paper No. 1. Maine Mountains Collaborative, Phillips, Maine.

McMahon, J. 2018. The Environmental Consequences of Forest Fragmentation in the Western Maine Mountains. Occasional Paper No. 2. Maine Mountains Collaborative, Phillips, Maine.

Summary of Testimony

Q. What is the purpose of your direct testimony in this proceeding?

To describe the adverse impacts of habitat fragmentation that would be caused by the New England Clean Energy Connect Project.

Q. On whose behalf are you offering testimony in this proceeding?

Friends of the Boundary Mountains

Q. Please summarize your testimony.

The proposed NECEC Project transmission corridor would be the largest fragmenting feature in the Western Maine Mountains region. This region is significant at a continental scale for a variety of reasons. It includes more than half of the United States' largest globally important bird area, which provides crucial habitat for 34 northern woodland songbird species. It provides core habitat for marten, lynx, loon, moose and a host of other iconic Maine animals. Its cold headwater streams and lakes comprise the last stronghold for wild brook trout in the eastern United States. Its unfragmented forests and complex topography make it a highly resilient landscape in the face of climate change. It lies at the heart of the Northern Appalachian/ Acadian Forest, which is the largest and most intact area of temperate forest in North America, and perhaps the world (Haselton et al. 2014; Riitters et al. 2000). Most importantly, the Western Maine Mountains region is the critical ecological link between the forests of the Adirondacks, Vermont and New Hampshire and northern Maine, New Brunswick and the Gaspé.

My comments focus on the negative impacts of the 53.5 mile stretch of the transmission corridor that would cross the Western Maine Mountains region. The impacts associated with a project of this scale are huge. The 150-foot wide 53.5 mile long NECEC proposed transmission corridor would directly impact approximately 973 acres of the region through forest and wetland species mortality and habitat alteration and destruction associated with the corridor footprint. It would negatively impact between 20,000+ and 40,000+ of additional acres due to edge effects and hydrologic changes that would extend from 0.5 to 1 km (1640 to 3280 feet) from the high contrast edges of the corridor into adjacent forest land. In addition, the corridor would have significant negative regional and long term impacts because it would reduce connectivity in a critical ecological linkage, fragment large habitat blocks into smaller ones, and compromise headwater stream water quality and function. The applicant does not address any of these negative regional and long term impacts in their application.

It is also worth noting that fragmentation almost always leads to more fragmentation. As access roads are built and corridors are widened over time (as is happening in other parts of the NECEC corridor), these typically create new nodes of development.

Q. Are you including exhibits as part of this filing?

Yes, the following four exhibits are attached:

Group 1 Exhibit 2 Resume of Janet S. McMahon (JSM)

Group 1 Exhibit 3 List of Publications, JSM testimony

Group 1 Exhibit 4 for JSM testimony

McMahon, J. 2016. Diversity, Continuity and Resilience: The Ecological Values of the Western Maine Mountains. Occasional Paper No. 1. Maine Mountains Collaborative, Phillips, Maine.

Group 1 Exhibit 5 for JSM testimony

McMahon, J. 2018. The Environmental Consequences of Forest Fragmentation in the Western Maine Mountains. Occasional Paper No. 2. Maine Mountains Collaborative, Phillips, Maine.

Q. Upon what materials did you rely in reaching the opinions set forth in your direct testimony?

See literature cited and analyses summarized in the two exhibits listed above and the citation below:

Smith, M.P., R. Schiff, A. Olivero, and J. MacBroom. 2008. The Active River Area: A Conservation Framework for Protecting Rivers and Streams. The Nature Conservancy, Boston, Massachusetts.

Also, I've drawn from first-hand on the ground experience as an ecologist working in all corners of the state for the past 40 years, and I reviewed the relevant parts of CMP's application.

Detailed Information

Q. Please describe the significance of the region through which the proposed transmission line would pass.

The Western Maine Mountains region, which would be bisected by Segment 1 of the NECEC transmission corridor, is exceptional because it remains a largely unfragmented, lightly settled and connected landscape. The region is significant at a continental scale for many reasons. It lies at the heart of the Northern Appalachian-Acadian Forest Ecoregion, which is the largest and most continuous area of temperate forest in North America, and perhaps the world (Haselton et al. 2014; Riitters et al. 2000). This high degree of connectivity, combined with large elevation gradients and a diversity of physical landscapes, makes the Western Maine Mountains a highly resilient landscape in the face of climate change and a critical ecological link between undeveloped lands to the north, south, east and west.

Resilient sites are those that are projected to continue to support biological diversity, productivity and ecological function even as they change in response to climate change. In The Nature Conservancy's Conservation Gateway climate resilience map of the eastern United States, the Western Maine Mountains stand out in terms of biodiversity, climate flow and climate resilient sites. Eighty percent of the region is of above-average resilience, based on geophysical setting and local connectedness. This compares to 60% for the state as a whole and an average of 39% in southern Maine. A review of The Nature Conservancy's Conservation Gateway maps for the rest of New England and the eastern United States indicates that resiliency is even lower outside of Maine, making the Western Maine Mountains one of the most resilient and connected landscapes east of the Mississippi. Most importantly, the Western Maine Mountains region is the critical ecological link between the forests of the Adirondacks, Vermont and New Hampshire and northern Maine, New Brunswick and the Gaspé.

The Western Maine Mountain region includes more than half of the United States' largest globally important bird area, which provides crucial habitat for 34 northern woodland songbird species. The region provides core habitat for umbrella species such as American marten and Canada lynx, loon, moose and a host of other iconic Maine animals. Its cold headwater streams and lakes comprise the last stronghold for wild brook trout in the eastern United States (Whitman et al. 2013; DeGraaf 2014).

Q. Please explain the concept of forest fragmentation.

Habitat fragmentation occurs when habitats are broken apart into smaller and more isolated fragments by permanent roads, utility corridors, buildings, clearings or changes in habitat conditions that create discontinuities in the landscape. These features not only reduce the total amount of forest in a landscape, but they alter the environment in adjacent habitat because of edge effects. Fragmenting a forest landscape by a transmission corridor creates an abrupt edge between the corridor and adjacent forest edge which greatly increases the total amount of land impacted. Different species are affected by fragmentation in different ways, depending on biological attributes such as habitat specialization, niche specialization, home range size, dispersal ability, mobility and a host of other factors (Lindenmayer and Fischer 2006). Some effects are temporary and local in extent, such as clearings created by timber harvests, while others such as permanent roads and utility corridors occur at a landscape scale and are cumulative, playing out over decades or more. Research in Maine, the Northeast and around the world demonstrates unequivocally that fragmentation degrades native terrestrial and aquatic ecosystems and reduces biodiversity and regional connectivity over time.

Q. Would the proposed NECEC transmission line cause forest fragmentation?

Yes. The 53.5 miles of new transmission corridor between Beattie Twp and Wyman station (Segment 1) would be the largest fragmenting feature in the Western Maine Mountains region. To put this in context, a 150-foot wide cleared corridor is about two times as wide as Route 201 or Route 1, and about as wide as the I-95 Turnpike (including pavement and cleared verges). The transmission corridor would permanently remove ~973 acres of forest habitat, it would divide large forest habitat blocks into smaller ones, and it would create 107 miles of high contrast edge between the cleared corridor and adjacent forest. Associated edge effects would impact thousands of additional acres of forest land. The impacts of forest fragmentation at this scale are regional in scope. The corridor would have a profound negative impact on forest connectivity of the region.

Q. What would be the negative impacts of forest fragmentation caused by the NECEC transmission line?

The proposed corridor would negatively impact both terrestrial and aquatic ecosystems processes, habitats and species on a regional scale. Regional and long term impacts of the proposed corridor such as forest fragmentation are not addressed in the application. The most severe effects are summarized below:

1) *Direct forest habitat loss and species mortality from corridor construction.*

Approximately 973 acres of upland and wetland forest will be cleared and then maintained in an early-successional (scrub shrub or meadow) condition, through regular cutting of capable trees and herbicide application. Forest plant and animals in the corridor will be destroyed during construction. Forest and undisturbed wetland ecosystems support a completely different suite of species than artificially maintained meadow and scrub shrub habitat.

2) Direct impacts on headwater stream and catchment areas associated with infrastructure during and after construction.

Segment 1 crosses or includes portions of approximately 89 perennial streams, 215 intermittent streams and 480 wetlands (from application). Almost all of these are located in the uppermost reaches of their watersheds. It is within these small watersheds that 1st order streams are formed from overland flows, intermittent and zero order streams and gullies, and from springs (Smith et al. 2008). The catchments and riparian areas along these streams contribute inorganic and organic material and large woody debris which serve as the basic building blocks for the food web of the entire stream system. Large woody debris originating from trees within 50 meters of the channel influences local channel structure and habitat (Smith et al.). In addition, in headwater wetlands, the accumulation, processing, and eventual downstream transport of organic material is an important energy transfer process that influences the entire watershed. A transmission line that converts forest to scrub or meadow vegetation in material contribution areas of this many headwater streams will negatively impact downstream water quality and habitat conditions for brook trout and other cold water species, as well as downstream aquatic biodiversity and processes in general. The overall impact of clearing and maintaining shrubby vegetation in narrow stream buffer areas, as opposed to closed canopy forest in the catchment area, is not addressed in the application. Also not addressed are the impacts of herbicide application on overall water quality. In addition, many wetlands, streams, and vernal pool boundaries extend beyond the corridor boundary. Because habitat alteration within the corridor would impact portions of these features that extend outside of the corridor, the total acreage of wetlands and stream catchment areas impacted by the project would be significantly greater than indicated in the application.

3) Increased mortality and other direct impacts to wildlife associated with infrastructure after construction is complete.

Negative impacts such as avian and bat collisions with transmission poles and wires over a new corridor of this length are likely to be substantial. There is a growing body of research suggesting that electromagnetic radiation from transmission lines can affect behavior, reproduction and development of bird and other species groups. This is not addressed in the application.

4) Changes in species composition and reduced habitat quality from edge effects.

The transmission corridor will create ~107 miles of high contrast edge where the maintained corridor meets adjacent forest. Forest abutting the corridor will be windier, warmer and drier than the forest interior. Increased sunlight, changes in air temperature and humidity, altered plant, animal and microbial species composition, and species invasions are typical edge effects. Penetration distances range from 20-50 meters to more than a kilometer, depending on the edge effect. For example, the decline of many ground-nesting, forest-interior species in the Northeast, such as the oven bird and wood thrush, have been attributed to increased predation pressure from raccoons and other generalist species that thrive along forest edges (Ortega and Capen 1999; De Camargo et al. 2018). Increased nest predation and reduced reproductive success can extend more than 2,000 feet into adjacent forest. The habitat lost or altered by edge effects will be many times greater than the footprint of the transmission corridor itself. This is not addressed in the application. The application states that generalist species diversity can increase in the early-successional habitat that will be maintained in the corridor. This is at the expense of forest plant species which typically have low dispersal capacities compared to disturbance-adapted "weedy" plants (Harper et al. 2005). There is no shortage of early successional habitat in the Western Maine Mountains. In fact, 2017 U.S. Forest Inventory and Analysis data indicates that 98.6% of the forest is in an early to mid-successional condition and that total forest acreage in the region declined by approximately 12,000 acres.

5) Changes in species composition and behavior as habitat patch size decreases.

A habitat patch is a relatively homogeneous habitat area that differs from its surroundings. Large habitat patches have more species than small ones for several reasons. First, a large patch will almost always have a greater variety of environments than a small fragment, and each will provide niches for different species. Second, a large patch is likely to have both common and uncommon species, but small fragments are likely to have only common species. For instance, species with larger home ranges, such as black bear or bobcat, are unlikely to survive in smaller fragments. Finally, small fragments will, on average, have smaller populations that are more susceptible to being extirpated than a large population. In Maine, patch size appears to be particularly critical for species associated with mature forest conditions, larger patch sizes and forest interiors. Many Maine birds, such as red-shouldered hawk, black-throated blue warbler, Canada warbler, ovenbird and wood thrush, require hundreds of acres of continuous, relatively closed-canopy forest to reproduce successfully, as do mammals with large home ranges, such as moose, bobcat, black bear and American marten (Charry 1996; Askins 2002). For example, Chapin et al. (1998) found that resident American martens established home ranges in areas where median intact forest patch size ranged from 375 to 518 acres, for males and females respectively. These area-sensitive and habitat specialist species will start disappearing when the size of habitat blocks falls below a certain threshold (Askins 2002; Blake and Karr 1984; Whitcomb et al. 1981). The proposed transmission corridor will fragment some of the largest remaining habitat blocks in the region, with unknown impacts on area-sensitive species. The application does not provide a habitat block map with the corridor overlay, which makes it impossible to determine the exact number and extent of intact habitat blocks affected. Animals from Maine's populations are currently replenishing "sink" populations in New Hampshire. The corridor could compromise the Western Maine Mountain region function as a source area for marten and lynx.

6) Introduction and spread of exotic species.

Invasion by exotic plant species is a common and widespread negative impact of fragmentation that can result in displacement of native species. In general, non-native invasive plant species thrive in disturbed and early successional habitats and frequently become established in utility corridors. Common traits of invasives include rapid growth, light and drought tolerance, bird-disseminated seeds, and the ability to outcompete native plants (Webster et al. 2006). In addition, invasive woody and herbaceous plants rapidly colonize forest edges and may penetrate more than 330 feet into the forest interior, altering or eliminating habitat for native plants (Charry 1996). Wetland and aquatic invasives pose a similar threat in wetland and aquatic ecosystems. Other impacts include changes in soil chemistry and biota—which may suppress native tree regeneration—and reduced or eliminated foods used by pollinators, fruit and seed eaters and herbivores (Silander and Klepeis 1999; Charry 1996; Webster et al. 2006; Burnham and Lee 2010; Ehrenfield et al. 2001; Heneghan et al. 2006; Hunter and Mattice 2002). Large forest blocks appear to resist woody plant invasions better than small blocks due to the deep shade created by mature trees and the buffering effect of large block size, which serves to isolate interior portions of the forest from invasive seeds.

Many terrestrial invasive plant species and wetland invasives, such as glossy buckthorn, oriental bittersweet, purple loosestrife and phragmites, are already well established in southern Maine and have expanded to the edges of the Western Maine Mountains. These disturbance-adapted species thrive in utility corridors and roadside ditches, where they out-compete native species. With roughly one third of Maine's flora comprised of non-native plant species (and most of these already established in the southern part of the state), the cause-and-effect relationship between fragmentation and the establishment of non-native plant species poses a significant threat to native species and habitats in northern Maine (Mosher et al. 2009; Charry 1996).

The applicant proposes controlling invasives that become established in the transmission corridor through manual removal and herbicide application. The negative impacts of herbicides on other species are not addressed, nor is the fact that the corridor would increase suitable habitat for invasives outside of the corridor ROW in areas impacted by edge effects.

Q. What would be the long-term consequences of forest fragmentation caused by the NECEC transmission line?

The magnitude and permanence of the land-use changes associated with this project would have negative long-term consequences on connectivity in the Western Maine Mountain region. Fragmentation, by definition, is a continuous and cumulative process that leads to degraded habitats and loss of species over time. There is a growing body of research that suggests that the ecological dynamics in fragmented landscapes are a stark contrast to the dynamics in intact landscapes (Haddad et al. 2015). Research shows strong and consistent responses of organisms and ecosystem processes to fragmentation arising from decreased habitat patch size, decreased connectivity and the creation of habitat edges (Haddad et al. 2015; Lindenmayer and Fischer 2006). In general, the greater the difference between forested patches and their surrounding environment and the smaller and more isolated patches become, the greater the adverse impact on biodiversity and ecosystem function.

In the Western Maine Mountains, changing land use patterns resulting from fragmentation have already caused changes in species composition and will likely cause changes in plant and animal abundance over time. Two of these changes include the increased proportion of early successional species and the large-scale reduction in the structural complexity of forest stands on which other forest organisms and ecological processes may depend (Rowland et al. 2005; Hagan and Whitman 2004). The transmission corridor would significantly exacerbate both of these trends.

Large tracts of forest are important because they are relatively free from the variety of plant and animal population dynamics that might take place near new edges, including the encroachment of individuals displaced by habitat loss. This immigration lag may also mask the risk of invasion by exotic species since there may be a long lag between introduction, colonization, and rapid range expansion of some invasive species (Webster et al. 2006).

Ecosystem functions, such as nutrient cycling and decomposition rates, can also be reduced or lost over time—a process called ecosystem function debt. Evidence suggests that during forest succession, this delayed loss of function is greater in smaller, more isolated fragments (Cook et al. 2005; Billings and Gaydess 2008). The mechanisms for this are complex. Functional debt can result when fragmentation causes food webs to be simplified as species are lost, or when altered forest succession patterns resulting from permanent fragmentation cause changes in tree density, light and moisture, which impair ecosystem function (Haddad et al. 2015).

Increased fragmentation is expected to exacerbate the negative impacts of climate change on biodiversity and connectivity in the region. Forest fragmentation increases the vulnerability of Maine's native flora and fauna to climate change (Fernandez et al. 2015; Rustad et al. 2012). For example, declines in the diversity of native flora in New England's mixed northern hardwood forests are attributed to a high degree of habitat specialization, a highly fragmented range, depauperate understories and barriers to dispersal (New England Wildflower Society 2015). Three of the top four stressors are caused or aggravated by forest fragmentation, including habitat conversion, invasives and succession. All of these stressors are expected to become more pronounced as the climate changes. The resiliency of the Western Maine Mountains in the face of climate change is largely due to the extent and connectivity of its forests. These would be adversely affected by the proposed NECEC transmission corridor.

The application focuses on direct and immediate impacts and fails to address long-term and regional impacts of the corridor on connectivity and biodiversity.

Conclusion

Q. Please summarize your testimony.

The proposed NECEC Project transmission corridor would be the largest fragmenting feature in the Western Maine Mountains region. This region is significant at a continental scale for a variety of reasons. It includes more than half of the United States' largest globally important bird area, which provides crucial habitat for 34 northern woodland songbird species. It provides core habitat for marten, lynx, loon, moose and a host of other iconic Maine animals. Its cold headwater streams and lakes comprise the last stronghold for wild brook trout in the eastern United States. Its unfragmented forests and complex topography make it a highly resilient landscape in the face of climate change. It lies at the heart of the Northern Appalachian/ Acadian Forest, which is the largest and most intact area of temperate forest in North America, and perhaps the world (Haselton et al. 2014; Riitters et al. 2000). Most importantly, the Western Maine Mountains region is the critical ecological link between the forests of the Adirondacks, Vermont and New Hampshire and northern Maine, New Brunswick and the Gaspé.

The negative impacts of a 53.5 mile stretch of the transmission corridor crossing the Western Maine Mountains (Segment 1) would be regional in scale and would have long term negative ecological implications. The 150-foot wide transmission corridor would directly impact approximately 973 acres through forest and wetland species mortality and habitat alteration and destruction associated with the corridor footprint. It would negatively impact between 20,000+ and 40,000+ of additional acres due to edge effects and hydrologic changes that would extend from 0.5 to 1 km (1640 to 3280 feet) from the high contrast edges of the corridor into adjacent forest land. In addition, the corridor would have significant negative regional and long term impacts because it would reduce connectivity in a critical ecological linkage, fragment large habitat blocks into smaller ones, and compromise headwater stream water quality and function. The applicant does not address any of these negative regional and long term impacts in their application.

It is also worth noting that fragmentation almost always leads to more fragmentation. As access roads are built and corridors are widened over time (as is happening in other parts of the NECEC corridor), they typically create new nodes of development.

Q. In your opinion:

1. Would this project have an unreasonable adverse effect on the existing natural resources of the Western Mountain region of Maine? If so, how?

Yes. The NECEC transmission corridor would be the largest infrastructure project in the history of the WMM. It would have direct negative impacts on upland forest, wetlands, vernal pools, streams and stream catchment areas. Forest conversion and maintenance of land within the corridor in an early-successional condition would permanently fragment this forested region. This would contribute to the simplification of forest structure and negatively impact native biodiversity (particularly cold water aquatic species) in the region. Forest simplification would, in turn, reduce the current high climate resiliency of the region. The proposed transmission corridor would compromise the region's value as the key ecological linkage between forests in New Hampshire and the Adirondacks and those of Northern Maine and the Gaspe. The application does not address these regional and long-term impacts.

2. Would this project fit harmoniously into the existing natural environment? If not, why not?

No, this transmission corridor would require habitat conversion, and then vegetation maintenance in an early successional condition through herbicides and regular removal of "capable" trees[1]. It would create a permanent high contrast edge on either side of the 53.5 mile corridor, an artificial feature that would impact thousands of additional acres of adjacent forest land due to edge effects. It would fragment large forest blocks into smaller more isolated ones. It would cross large wetland complexes such as those along Gold Stream and Moxie Stream, and would impede movement of some wildlife species. There is no way new energy infrastructure at this scale can fit harmoniously into one of the more remote and environmentally intact areas of the state.

3. Would this project have an unreasonable adverse effect on water quality in the townships where it is located or in neighboring townships? If so, please explain.

Yes. See page 5, bullet 2.

4. Would this project have an unreasonable adverse effect on any undeveloped land or water area which is undeveloped and which contains natural features of unusual geological, botanical, zoological, ecological, hydrological, or other

[1] Applicant describes capable trees as "those plant species and individual specimens that are capable of growing tall enough to violate the required clearance between the conductors and vegetation established by NERC" (North American Electric Reliability Transmission Vegetation Management, Standard FAC 003-3). Follow-up maintenance when the line is operating will require the removal of capable species, dead trees as well as hazard trees along the edge of the corridor.

scientific, educational, scenic or recreational significance? If so, please explain.

Yes. Many species and discrete ecological features, such as jack pine stands, vernal pools, and deer yards would be negatively impacted. My testimony focuses primarily on the adverse regional and long term impacts of fragmentation that would be caused by the transmission corridor.

5. Will this project provide buffer strips with adequate space for movement of wildlife between important habitats? If not, why not?

No. Proposed buffer strips along streams and around wetlands are insufficient to maintain functioning catchments around these important headwater systems.

6. Will this project maintain suitable and sufficient habitat to provide wildlife with travel lanes between areas of available habitat? If not, why not?

No. By definition, transmission corridors are major fragmenting features on any landscape. The large extent of this corridor means it will reduce connectivity on a regional scale, especially because it of its east-west orientation. As the climate warms, species are expected to move from south to north and upslope.

7. Will this project unreasonably harm any significant wildlife habitat, freshwater wetland plant habitat, threatened or endangered plant habitat, aquatic or adjacent upland habitat, travel corridor, freshwater, estuarine or marine fisheries or other aquatic life?

Yes. A project of this scale will have a direct negative impact on hundreds of individual vernal pools, headwater streams, wetlands and other habitats, including the portions of these that lie outside of the corridor footprint. Reducing canopy height and closure, altering vegetation structure and composition, and application of herbicides will harm terrestrial and aquatic habitat within and adjacent to the corridor. In addition, because the corridor will impact the catchment areas of headwater streams and wetlands, it will impact the watersheds that these feed. Looking at discrete impacts on only state significant features masks the regional and cumulative impacts of the corridor as a whole.

Notarization

I, Janet McMahon being first duly sworn, affirm that the above testimony is true and accurate to the best of my knowledge.

Date: February 28, 2019 Name: Janet S McMahon

Personally appeared the above-named Janet S McMahon and made affirmation that the above testimony is true and accurate to the best of her knowledge.

Date: February 28, 2019 Name: Colleen G Jones
Notary Public

My Commission Expires: Dec 16, 2019

COLLEEN G. JONES
Notary Public • State Of Maine
My Commission Expires Dec. 16, 2019

Janet S. McMahon

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EDUCATION

M.S. in plant ecology, University of Maine, 1990. Thesis title: The Biophysical Regions of Maine: Patterns in the Landscape and Vegetation. Phi Kappa Phi.

B.A. in biology and geology, Colby College, 1979. SEA Semester W-38 (Woods Hole, Massachusetts to the Gulf of Mexico and back). Graduated from Colby with distinction in the majors.

PROFESSIONAL EXPERIENCE

Ecologist - self-employed consultant, various locations in Maine. 1991 to present.

Examples of completed projects include: (1) evaluation of ecological significance of the Western Maine Mountains region, (2) development of a regional conservation plan for 800,000 acres in midcoast Maine for the 12 Rivers Conservation Initiative, (3) landscape-scale conservation plans for the Medomak River, St. George River, and Sheepscot River watersheds and the Blue Hill peninsula that identified, mapped, and described priority conservation areas for the land trusts that serve these areas; (4) strategic plan on alewife enhancement and alewife habitat survey for the town of Waldoboro; (5) ecological assessment and conservation site design for 250,000 acres along the Allagash River for Clayton Lake Woodlands, (6) SmartWood Green Certification evaluation for the Baxter State Park Scientific Forest Management Area, (7) natural resource inventory of the 90,000 acre Medomak River watershed for the Medomak Valley Land Trust, and (8) ecological assessment and design of Fourth Machias Lake Reserve for Downeast Lakes Land Trust.

Conservation Biologist, The Nature Conservancy – Brunswick, Maine. January 1993 to 1998.

Evaluated tracts of land and designed potential reserves using conservation biology principles. From 1994 to 1998, I coordinated an inventory of Maine’s public and private conservation lands for the Maine Forest Biodiversity Project to determine which sites had ecological reserve potential.

Senior Planner, Ecological Reserves Study, Maine State Planning Office - Augusta, Maine. January 1990 to February 1991.

Developed a blueprint for a statewide ecological reserves system in Maine. Responsibilities included developing a Maine ecosystem classification, coordinating an inventory of Maine's public and private conservation lands to determine which natural ecosystem types were represented and adequately protected, developing guidelines for reserve design and management, outlining protection strategies, and identifying ways to integrate the reserve system with other land conservation efforts. Worked closely with the state's natural resource agencies, private conservation organizations, and university scientists to develop ecological reserve legislation, which passed in 2000.

Land Stewardship Director, Maine Audubon Society - Falmouth, Maine. March 1985 to July 1987.

Managed Maine Audubon's sanctuary program. Responsibilities included administration, raising all program funds, developing management plans for ten sanctuaries, working with prospective donors, overseeing trail crews and stewardship committees, conducting natural resource inventories, and developing educational programs in the Bath and Bangor areas.

Educational Consultant, The Atlantic Center for the Environment and The Foundation for PRIDE - Turks and Caicos Islands, British West Indies. January to June 1984.

Worked on a natural resource curriculum for the Turks and Caicos Islands' school system and evaluated the effectiveness of island-wide education programs developed by PRIDE Foundation.

Biologist/Geologist, Maine Critical Areas Program - Augusta, Maine. 1979 to 1982.

Designed and conducted an inventory (aerial and ground surveys) of whitewater rapids in Maine and wrote a report recommending exceptional areas for protection. The results provided a building block for a statewide river protection plan - The Maine Rivers Study. Also worked closely with major landowners toward the voluntary protection of recommended areas.

Program Director, Ocean Horizons, The Atlantic Center for the Environment - Fogo Island, Newfoundland. Summers 1981 and 1982.

Directed a marine education program on Fogo Island, Newfoundland that offered instruction and first-hand experience in ecology, natural history, and resource management to children and adults of the province. Responsibilities included working closely with local residents, educators, and resource managers on overall program design, supervising a staff of five, and designing a curriculum.

Coordinator, Saint John River Expedition, The Atlantic Center for the Environment - Maine and New Brunswick. May through August 1979.

Coordinated a seven week canoe trip down the Saint John River from Baker Lake, Maine to Saint John, New Brunswick. Natural history, resource and social issues, and the feasibility of running similar trips for valley residents were studied. Co-authored a report describing the expedition and its results.

OTHER PROFESSIONAL ACTIVITIES

Faculty, Watershed School – Camden Maine. 2008 to present.
I teach courses in Global Climate Change and World Geography at Watershed School, an independent high school that serves students from Belfast to Damariscotta. Highlights have included working with students to develop a blueprint for a carbon neutral Maine, a street light inventory of Rockland, Maine, and a survey of midcoast high school students views on the issue of global warming.

Allagash Wilderness Waterway Advisory Council – Appointed by Governor John Baldacci to a 7-member council charged with advising the Bureau of Parks and Lands on long-term governance, management and oversight of the Waterway. 2007 to 2015.

Ecological Reserves Scientific Advisory Board – Appointed by Governor Baldacci to a 12-member board that advises the Maine Natural Areas Program on selection and monitoring of ecological reserves in Maine and is developing guidelines for recreational use on reserves. 2008 to present.

Maine Forest Biodiversity Project - Participant in a 100-member consortium of forest landowners, conservationists, scientists, sportsman and public agency representatives that developed strategies to protect the biodiversity of Maine's forests through a combination of reserves, sustainable forest management, and education. 1994 to 1999.

Maine Council on Sustainable Forest Management – Appointed by Governor Angus King to a 10-member council that was charged with assessing the sustainability of Maine's forest resources. 1995 through 1996.

Medomak Valley Land Trust - Helped found a land trust centered around the Medomak River watershed in 1991 and served on the board and as chair of its lands committee until 2007. I currently serve on the lands working group of Midcoast Conservancy which merged with Medomak Valley Land Trust in 2019.

Recipient of the following:

- New England Wildflower Society's 2001 Maine State Award
- Natural Resources Council of Maine's 1998 Environmental Activist Award for work on ecological reserves
- Maine Association of Planners Special Recognition Award for the 1994 report: The Medomak River Watershed - A Natural Resource Inventory.

Janet McMahon

REPORTS AND PUBLICATIONS

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DIVERSITY, CONTINUITY AND RESILIENCE – THE ECOLOGICAL VALUES OF THE WESTERN MAINE MOUNTAINS

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DIVERSITY, CONTINUITY AND RESILIENCE –
THE ECOLOGICAL VALUES OF THE
WESTERN MAINE MOUNTAINS

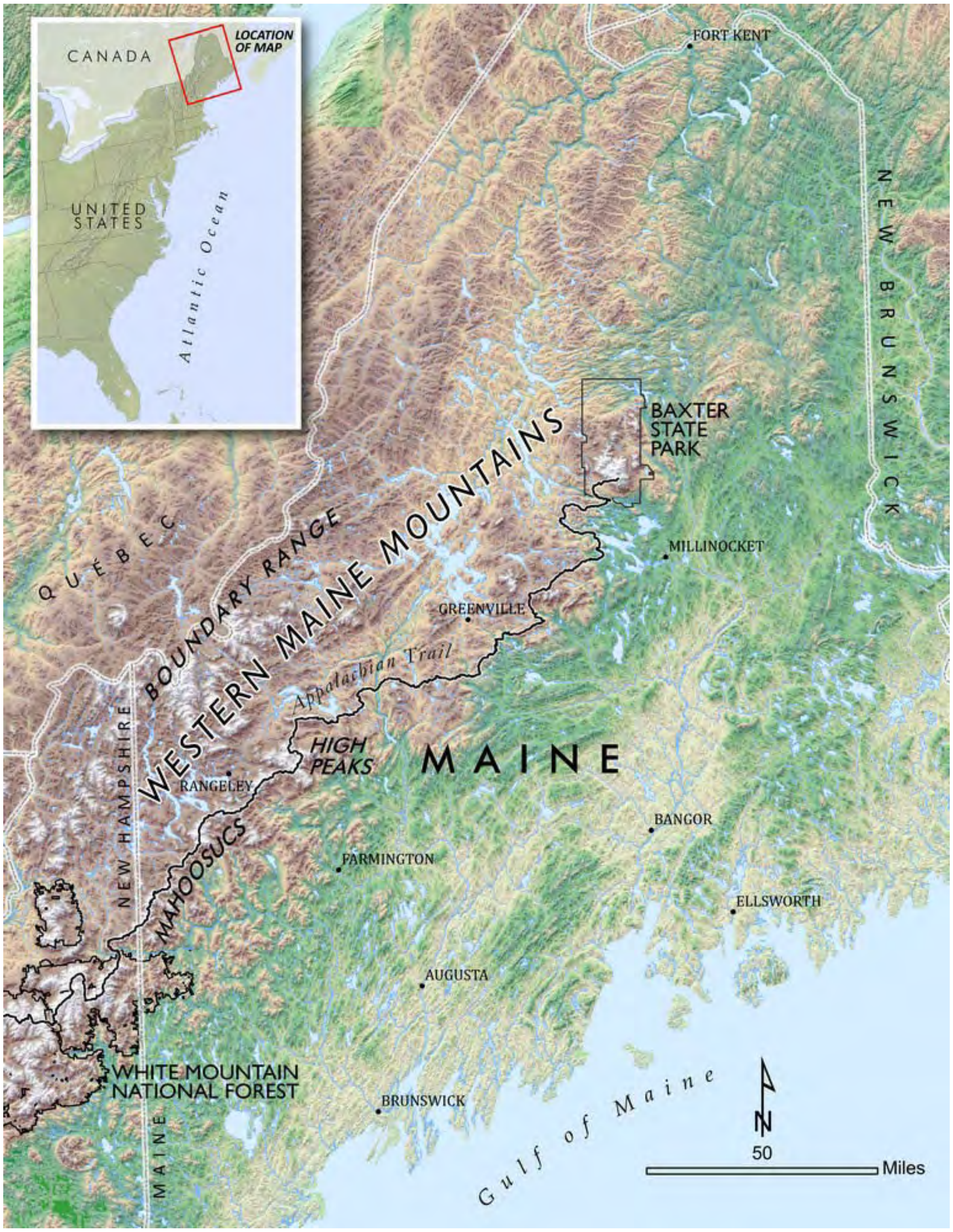
Dawn over Crocker and Redington Mountains *Photo courtesy of The Trust for Public Land, Jerry Monkman, EcoPhotography.com*

Abstract

The five million acre Western Maine Mountains region is a landscape of superlatives. It includes all of Maine's high peaks and contains a rich diversity of ecosystems, from alpine tundra and boreal forests to ribbed fens and floodplain hardwood forests. It is home to more than 139 rare plants and animals, including 21 globally rare species and many others that are found only in the northern Appalachians. It includes more than half of the United States' largest globally important bird area, which provides crucial habitat for 34 northern woodland songbird species. It provides core habitat for marten, lynx, loon, moose and a host of other iconic Maine animals. Its cold headwater streams and lakes comprise the last stronghold for wild brook trout in the eastern United States. Its unfragmented forests and complex topography make it a highly resilient landscape in the face of climate change. It lies at the heart of the Northern Appalachian/Acadian Forest, which is the largest and most intact area of temperate forest in North America, and perhaps the world. Most importantly, the Western Maine Mountains region is the critical ecological link between the forests of the Adironcaks, Vermont and New Hampshire and northern Maine, New Brunswick and the Gaspé.

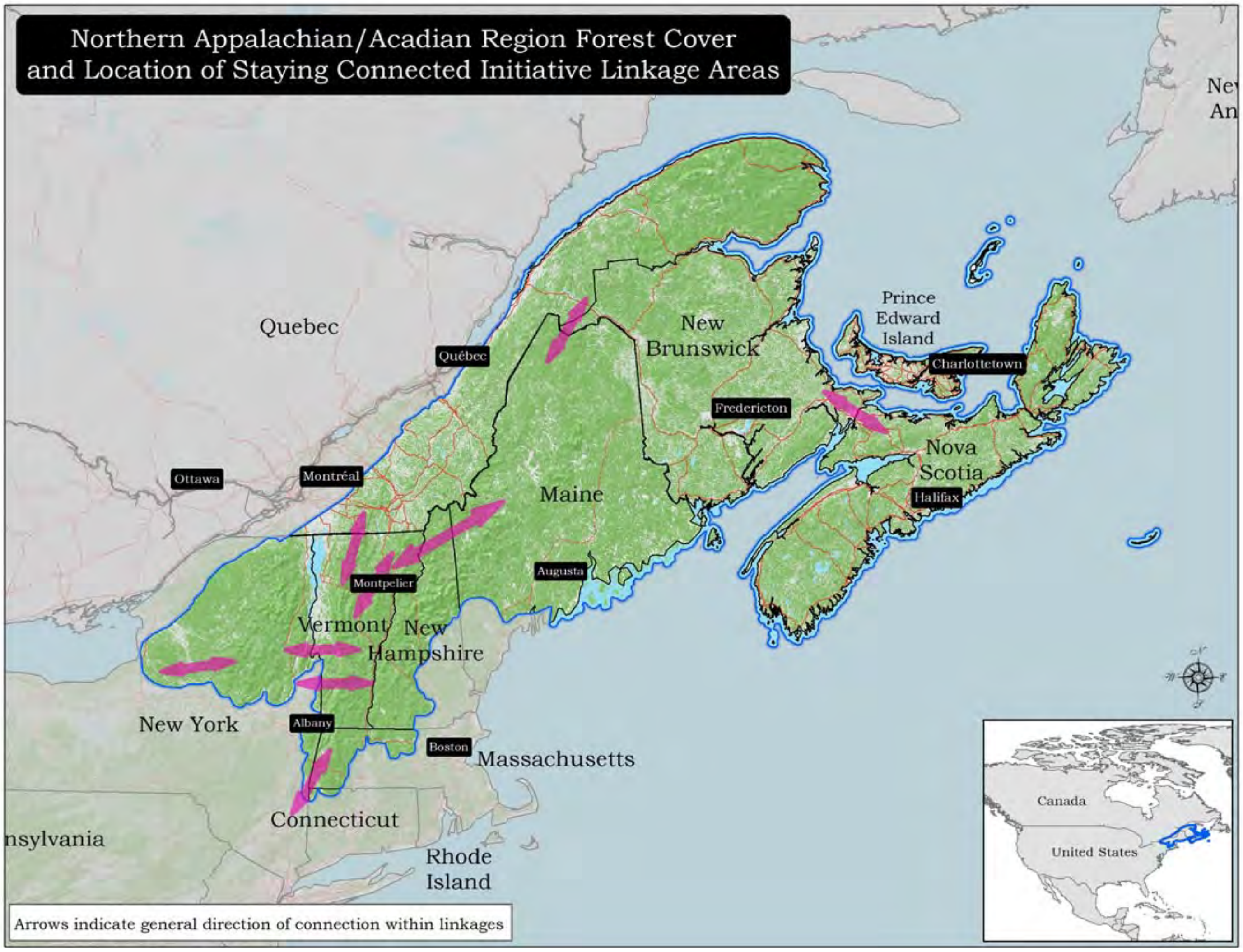
Introduction

In 1884, when Thoreau ascended Ktaadn, the Penobscot Nation's sacred "highest land," he was struck by the *"continuousness of the forest"* with *"no clearing, no house,"* uninterrupted except for *"the narrow intervals on the rivers, the bare tops of the high mountains, and the lakes and streams"* (Thoreau 1984). More than a century later, the view south and west from Mount Katahdin is much the same and, remarkably, with the exception of the wolf, cougar, and caribou which have been driven north and west, all of the animals Thoreau might have encountered more than a century ago still thrive in the Western Maine Mountains.



The Western Maine Mountains stretch in a broad band from the summits of the Katahdin group, southwesterly one hundred and sixty miles to Boundary Bald Mountain and the Mahoosuc Range on Maine's western border. In all, the region encompasses over five million acres. It is a landscape of superlatives. It includes all of Maine's high peaks. It contains a rich diversity of ecosystems, from alpine tundra and boreal forests to ribbed fens and floodplain hardwood forests. It is home to more than 139 rare plants and animals, including 21 globally rare species and many others that are found only in the northern Appalachians.

It includes more than half of the United States' largest globally significant bird area, which provides crucial habitat for 34 northern woodland songbird species. It provides core habitat for marten, lynx, loon, moose and a host of other iconic Maine animals. The region's abundant snowfall and cool summer rains feed hundreds of miles of cold clear headwater streams that are essential habitat for wild brook trout and other cold water species. Its unfragmented forests and complex topography make it a highly resilient landscape in



Credit: The Nature Conservancy

The Staying Connected Initiative, http://stayingconnectedinitiative.org, has identified critical linkages to maintain connectivity in the Northern Appalachian/Acadian Forest Ecoregion.

the face of climate change.[1] It lies at the heart of the Northern Appalachian/Acadian Forest Ecoregion,[2] which is the largest and most intact area of temperate forest in North America, and perhaps the world.[3] Within this vast forest, the Western Maine Mountains region is the critical ecological link between undeveloped lands to the north, south, east and west.

Northern Maine is the only place in the eastern United States where such a large area of contiguous land has remained continuously forested since pre-

The Western Maine Mountains region is a critical linkage in the Northern Appalachian/Acadian Forest Ecoregion, which is the largest and most intact area of temperate forest in North America, and perhaps the world.

1 Resilience is the capacity of an ecosystem to maintain or return to its essential composition, structure, and ecosystem function after disturbance (Holling 1973).

2 Ecoregions are large units of land with similar environmental conditions, especially landforms, geology and soils, which share a distinct assemblage of natural communities and species. The Northern Appalachian-Acadian Forest Ecoregion includes the mountainous regions and boreal hills and lowlands in Northern New England and Maritime Canada. The ecoregion includes the Adirondack Mountains, Tug Hill, the northern Green Mountains, the White Mountains, the Aroostook Hills, New Brunswick Hills, the Fundy coastal section, the Gaspé peninsula and all of New Brunswick, Nova Scotia and Prince Edward Island (Anderson et al. 2006).

3 Based on Riitters et al. (2000) and the author's analysis of Google Earth imagery. Other northern temperate forests at the same latitude have lower species diversity (Scandinavia) and are more fragmented (Europe, eastern Asia) than the forests of the Northern Appalachian/Acadian Forest Ecoregion.

settlement times (Barton et al. 2012). This is in large part because of the timber value and resilience of its vast forests, most of which have been in private ownership and actively managed for more than two centuries. Many of the ecological values of the Western Maine Mountains region remain because of this fact.

The following pages summarize the region's key ecological values, which include:

- High landscape diversity
- A high diversity of northern species and ecosystems
- More than five million acres of contiguous forest that lie at the heart of the largest intact temperate forest in the United States
- Some of the country's least disturbed forests
- A globally important bird area
- A U.S. stronghold for wild populations of brook trout
- Vital habitat for focal carnivore species such as lynx and marten
- An exceptionally resilient landscape today and predicted high resilience in the face of climate change
- A critical ecological link between the boreal and temperate forest biomes
- An important role in buffering and regulating global, regional and local climates

The region's latitudinal position, mountain topography, forest contiguity, and Atlantic influence are unique at a continental scale.

The Western Maine Mountains lie near the northern terminus of the Appalachian Mountains and include some of the chain's most rugged terrain. The western part of the region includes the Boundary Mountains to the north and the Longfellow Mountains to the south. These two mountain ranges are separated by a series of large lakes, including Umbagog, Upper and Lower Richardson, Rangeley and Flagstaff. To the north and east are the mountains and foothills of the Katahdin group as well as the highlands surrounding Moosehead and Chesuncook Lakes. The region has the greatest topographic relief in the state. Its eastern boundary roughly follows the 1,000 foot contour, but elevations range from 600 to 5,270 feet. The region includes Maine's fourteen peaks taller than 4,000 feet as well as all of the state's high elevation habitat.[4]

The region's climate is influenced by its latitude and weather systems that originate in both the Atlantic and the Arctic. It is characterized by cool summers, harsh winters, a short growing season and the highest snowfalls in Maine, which average 120 inches in a typical winter. Annual precipitation is about 40 inches, although some of the higher mountains produce a rain shadow effect, with precipitation as high as 50 inches on windward slopes and less than 35 inches to leeward (McMahon 1990; Lautzenheiser 1978). Thoreau called the land above tree line a *"cloud-factory–these were the cloud works, and the wind turned them off done from the cool, bare rocks"* (Thoreau 1884). The mountainous landscape is dissected by hundreds of cold, fast-flowing streams, which form the headwaters of four of Maine's major rivers, the Penobscot, Kennebec, Androscoggin and Allagash.

> Because of their latitude, mountainous topography, continuous forest and Atlantic influence, Maine's Western Mountains are unique at a continental scale and are home to a diversity of rare species and ecosystems.

The region's latitudinal position, mountain topography, forest contiguity, and Atlantic influence are unique at a continental scale (McKinley 2007). And because species diversity is highly correlated with geophysical diversity in the eastern United States (Anderson and Ferree 2010), the Western Maine Mountains are home to a surprising diversity of both widespread and rare species and ecosystems.

4 The high elevation threshold in Maine is 2,700 feet. Subalpine and alpine habitats are typical above this point. About three percent or 139,222 acres of the region is classified as high elevation (Publicover and Kimball 2012).

The ecological diversity of the Western Maine Mountains is significant at multiple scales, ranging from state to continental.

On a summer day, the view from any mountain in the region is of seemingly endless forest, darker greens of spruce and fir on upper and northerly slopes, lighter greens of northern hardwoods on lower and southerly slopes. A closer look reveals a much more complicated picture. In fact, the Western Maine Mountains harbor the largest concentrations of high value ecosystems and natural features in the state (McKinley 2007; McCollough et al. 2003). The region's rich animal diversity ranges from large mammals, such as lynx and moose, to the rare Bicknell's thrush to bog lemmings and endemic[5] mayflies. This diversity is due to a combination of the region's location within the transition zone between the boreal forest biome to the north and the eastern deciduous forest biome to the south (Delcourt and Delcourt 2000), its complex topography, the continuity of the landscape, and the inherent diversity of forests, with their complex vertical structure, which provides habitat for a multitude of plants and animals. For example, of the 55 mammal species documented in Maine, at least 51 occur in the Western Maine Mountains (DeGraaf and Yamasaki 2001). Only the New England cottontail, the woodland vole, the Virginia opossum, a relative newcomer to Maine, and possibly the southern flying squirrel are absent. The region also retains all of the tree species that were here during presettlement times, including the thirty commercial species that are harvested today, as well as at least 41 of the 48 forest community types that occur in Maine.[6]

> The rich ecological diversity of the Western Maine Mountains ranges from large mammals, such as lynx and moose, to the rare Bicknell's thrush to bog lemmings and endemic mayflies. This diversity is due to the region's location within the transition zone between the boreal forest biome to the north and the eastern deciduous forest biome to the south, its complex topography, the continuity of the landscape, and the inherent diversity of forests, with their complex vertical structure, which provides habitat for a multitude of plants and animals.

The most distinctive suite of species in the Western Maine Mountains occurs at high elevations—above tree line and in the subalpine fir forests just below. The globally rare boreal and tundra communities that occur here are among the most pristine areas in the Northern Appalachian-Acadian Forest and are classified as rare in all four northeastern states (Publicover and Kimball 2012). They cover about three percent of the Western Maine Mountains region, but contain a disproportionate number of rare species. Maine's alpine communities are remnant biogeographic islands from the last glacial period (Seidel et al. 2009), and as a result contain many local and regional endemics. The species names tell the story: Aleutian maidenhair fern, tundra dwarf birch, alpine azalea, Alaskan clubmoss, Arctic red fescue, Lapland rosebay, northern bog lemming, White Mountain tiger beetle, Katahdin Arctic butterfly. Maine's mountains include some of the lowest elevation alpine areas at similar or more northern latitudes anywhere in the world (Seidel et al. 2009). Mount Katahdin alone has nineteen rare alpine plant species that are found nowhere else in Maine (Maine Beginning with Habitat Program).

Between tree line and an elevation of about 2,700 feet are extensive subalpine fir forests. This rare forest type provides nesting habitat for high elevation and coniferous forest specialist birds, such as spruce grouse, dark-eyed junco, bay-breasted warbler, blackbacked woodpecker, white-throated sparrow, blackpoll warbler, and the elusive Bicknell's thrush, a state endangered species that breeds only in subalpine forests and krummholz in the northern Appalachians (Maine Beginning with Habitat Program). In all, more than 52 upland rare plant species and 9 rare animals species have been documented on Maine's mountain tops.[7]

> The globally rare boreal and tundra communities that occur here are among the most pristine areas in the Northern Appalachian-Acadian Forest.

5 Endemic species are those that are found only in a defined geographic area, such as the Katahdin Arctic butterfly, which is found only on Mount Katahdin.

6 Determined from distribution maps in Gawler and Cutko (2010).

7 Estimated from descriptions and maps of the Ecological Focus Areas that occur in the Maine Mountain Collaborative study area.

The natural diversity of the Western Maine Mountains goes far beyond the species and communities found at higher elevations. The Maine Natural Areas Program and Department of Inland Fisheries and Wildlife have identified 20 landscape-scale focus areas of statewide ecological significance in the region. These focus areas encompass nearly 762,000 acres or about 13% of the region's land area. The relatively intact unfragmented landscapes of these focus areas have a high concentration of rare species and high quality natural communities, ecosystems, and wildlife habitats. These are the 'biodiversity hot spots' of the region. A small sample of some of the biological gems in these focus areas showcases the rich diversity of the Western Maine Mountains.

- Between the Moose River and Attean Pond is No. 5 Bog, a 1400+ acre peatland that is one of the largest, most diverse, and least disturbed peatlands in the eastern United States. It contains the southernmost example of a ribbed fen in North America and is considered nationally significant.

- Wild brook trout populations, which have never been genetically modified by stocking, thrive in the cold high elevation streams and lakes of the Western Maine Mountains, where entire watersheds are unimpeded by dams and culverts. Cold Stream in West Forks Plantation, Orbeton Stream in Redington Township, and Wassataquoik Stream, which flows out of Baxter State Park are just a few of the many pristine examples in the region.

- An outstanding 3,000+ acre Appalachian–Acadian Rivershore ecosystem along the lower Wassataquoik and the East Branch of the Penobscot River contains one of the least disturbed and most extensive hardwood floodplains in the state.

- The Klondike, located in the basin just west of the Tablelands on Mount Katahdin, is Maine's largest and most intact example of a black spruce bog.

- The highest concentration of pristine, remote ponds in New England occurs in the Nahmakanta area. Among its dozens of lakes and ponds, Third Debsconeag Lake, Rainbow Lake and Nahmakanta Lake are the largest and most well-known.

- The beech-birch-maple forest southwest of Speckled Mountain is one of the largest and best examples known in the White Mountains, with trees over 150 years old.

- Millinocket Lake Wetlands and West Branch Flowage chain of lakes and wetlands provide habitat for wild brook trout, the state's northernmost populations of the globally rare tidewater mucket and yellow lampmussel, and breeding habitat for the rusty blackbird, a special concern species that breeds in northernmost New England, Canada, and Alaska.

- The calcium-rich soils of the Twin Peaks area support enriched hardwood cove forests and some of Maine's rarest plant species, including Goldies fern, male fern silvery spleenwort, squirrel corn, and a host of others.

- The region's many cold, clear streams and ponds provide some of the state's best habitat for spring salamanders, wood turtles, freshwater mussels, and dozens of rare aquatic insect species, including at least three globally rare boreal species—the Katahdin Arctic butterfly, the Roaring Brook mayfly and the White Mountains tiger beetle.

- Big and Little Moose Mountains boast two exemplary spruce-fir-northern hardwoods ecosystems, one surrounding Big and Little Moose Ponds, and the other on the northern peak of Big Moose Mountain. Both examples are intact, mature forests that include a variety of hardwood and softwood community types.

- Six of Maine's twelve arctic charr populations occur in the Western Maine Mountains. This species thrives in Bald Mountain Pond and other cold clear ponds in the region. Maine and Alaska are the only states in the country with native populations of this species.
- The Lake Umbagog Wetlands focus area supports breeding pairs of peregrine falcons and bald eagles, and historically provided habitat for nesting golden eagles. Peregrines and golden eagles prefer to nest on rugged cliff faces. The majority of documented peregrine nest sites in Maine are in the Western Mountains, and this is the only region in the eastern United States with year round activity by golden eagles, Maine's rarest breeding bird (Morneau et al. 2015; Charlie Todd, personal communication).

The region lies within the largest and most contiguous forested landscape in the eastern United States.

On satellite images taken of North America at night, northern Maine stands out because of its darkness. The Western Maine Mountains lie at the heart of the 26 million acre Northern Appalachian/Acadian Forest, which spans four states and five Canadian provinces. This ecoregion contains the broadest extent of nearly contiguous natural forest east of the Rockies (Anderson et al. 2012; Anderson 2006) and is the only extensive region of interior temperate forest at middle latitudes worldwide (Riitters et al. 2000). Western and northern Maine are the least developed portions of the ecoregion—with few settlements, no large areas of cleared lands, few paved roads, and some of the region's largest unfragmented forested blocks. Less than two percent (~100,000 acres) of the Western Maine Mountains has been converted to date, compared to 28% of the Northeast as a whole (Publicover, personal communication 2016; Anderson and Sheldon 2011). Baldwin, et al. (2007) described Maine's forests as the ecological core of the Northern Appalachian-Acadian forest, important because of their extent, relatively light human footprint, and because they link the forests of the Northeast to those of the Canadian Maritimes. Within the Northern Appalachian-Acadian Forest, the Western Maine Mountains region provides the key link between the unfragmented forests to the west in northern New Hampshire and Vermont and the vast north woods of Maine.

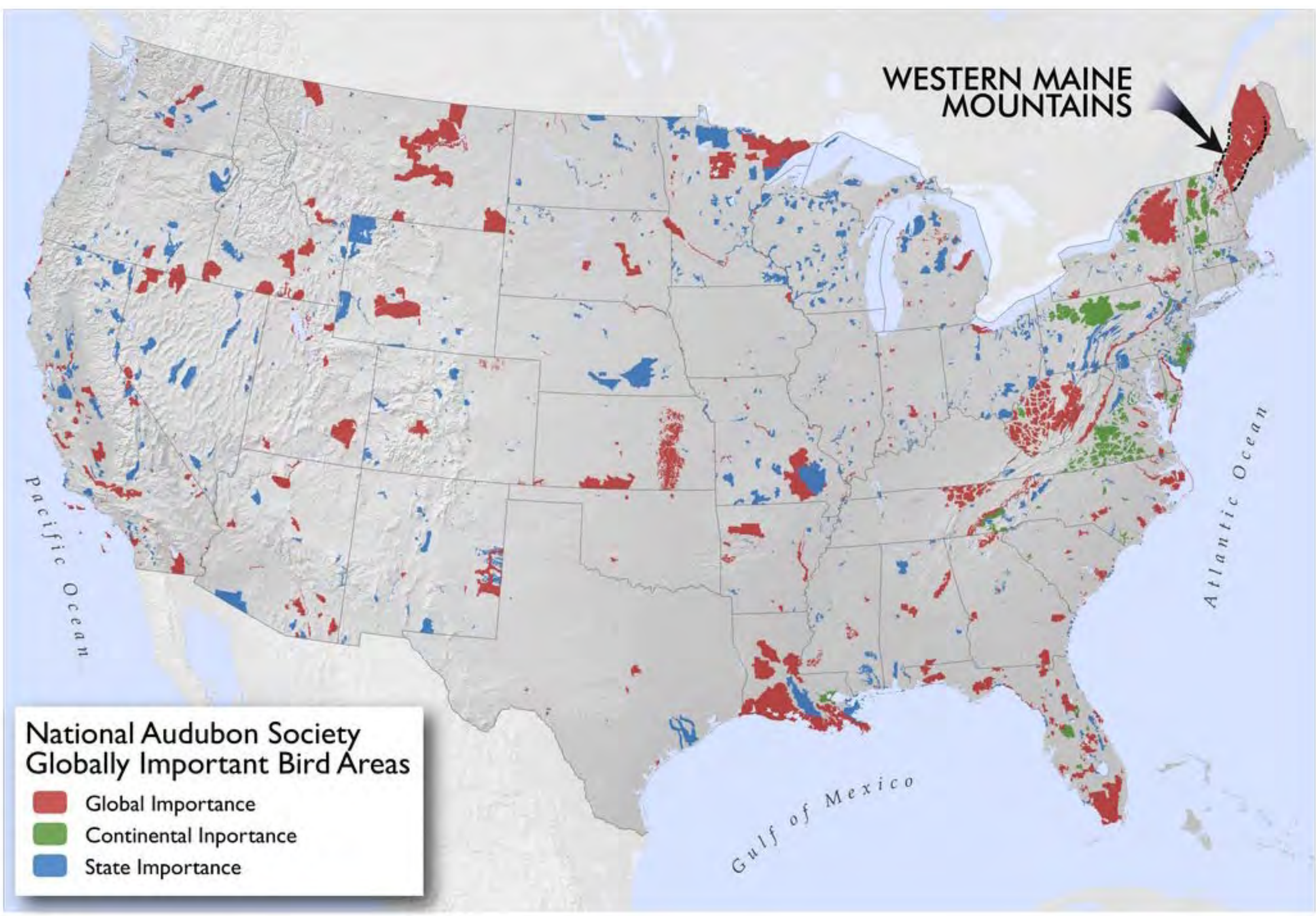
> The Western Maine Mountains lie at the heart of the Northern Appalachian/Acadian Forest, which is the only extensive region of interior temperate forest at middle latitudes worldwide.

The Western Maine Mountains region includes some of the least disturbed forest landscapes east of the Mississippi.

As noted above, the Northern Appalachian-Acadian Forest is the most intact unfragmented ecoregion east of the Mississippi. In addition, the forests, wetlands and riverine ecosystems of the Western Maine Mountains have experienced less human disturbance than lands to the south, northwest and east. Although the region has a long harvest history, because of its mountainous terrain and short growing season, settlements are few, most of the land was never cleared, plowed or drained for farming, and there are many large blocks of land that have not been fragmented by roads or development. Unlike most of New England, soils here have never been plowed and, as a result, are more likely to have an intact organic soil horizon with native fauna and flora, including native rather than introduced earthworms. Earthworms can have a dramatic effect on nutrient cycling, particularly in northern hardwood forests, where the species composition and richness of the herbaceous layer change markedly after nonnative earthworm invasions (Hopfensperger et al. 2011; Frelich et al. 2006; Burtelow et al. 1998). Invasive plants, which thrive on disturbed soils, have not gained a foothold in the region. In the U.S. Forest Service's 2008 inventory of Maine's forests, the Western Maine Mountains, upper Saint John Valley and Washington County were the only places where invasive plant populations were not documented (McCaskell et al. 2008). In addition, the region's forests have not experienced overbrowsing by white-tailed deer, which are beginning to impact the ecology of forests to the south (Russell et al. 2001). Finally, compared to New Brunswick, there has been less stand conversion from one forest type to another and plantation forestry is rare (McCaskell et al. 2008). While forest practices have led to a forest that is more homogeneous and has a simpler structure than in presettlement times, all of the region's tree taxa still remain (Thompson et al. 2013). In short, the forests of the region demonstrate a huge natural capacity for renewal.

The Western Maine Mountains region includes more than half of the country's largest Globally Important Bird Area.

Intact forests are critical to the future of most forest birds (National Audubon Society 2015). Maine includes the largest forest blocks in the entire Eastern Atlantic Flyway, which is the major migratory route for hundreds of neotropical bird species, including most of the songbirds familiar to New Englanders. In 2012, National Audubon set out to identify a network of forest blocks that collectively include the best 10 to 25% of forest in the flyway. The "northern Maine forest block" was identified as a Globally Important Bird Area by National Audubon Society and Birdlife International (National Audubon Society 2012). The Western Maine Mountains region makes up more than half of this block and bridges the two avifaunal biomes of the flyway—the Eastern Deciduous Forest Biome and the Northern Forest Biome. The global designation was given because of the area's high bird richness and abundance as well as the extent and intactness of its forest, and is grounded in research that shows that breeding birds are more successful on larger blocks

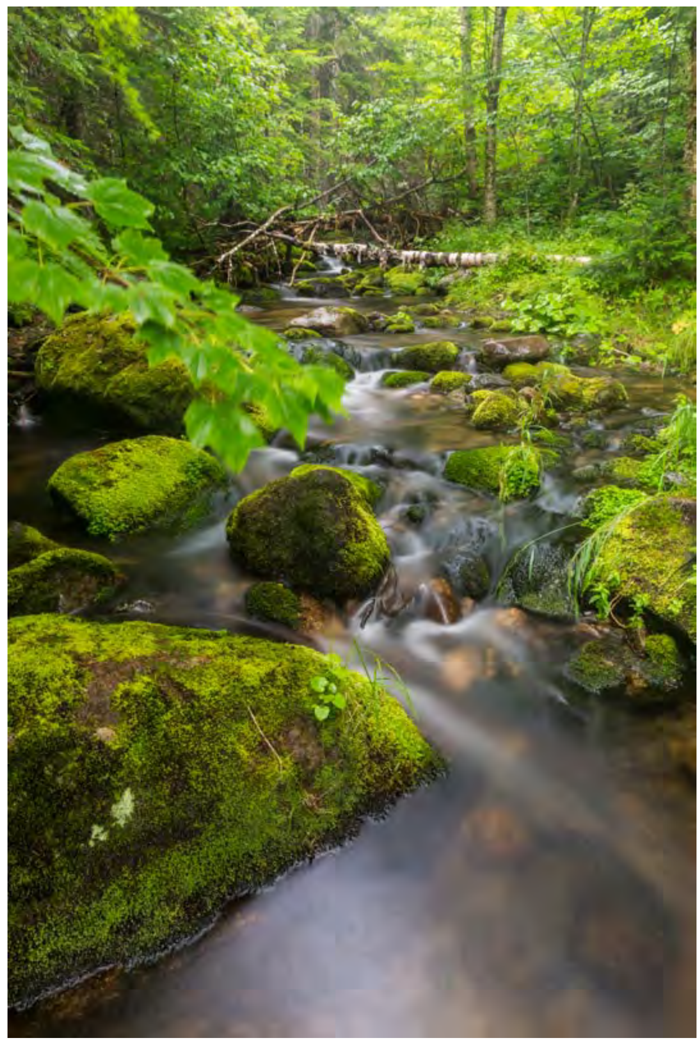


Maine includes the largest Globally Important Bird Area in the US, because if its large intact forests within in the Eastern Atlantic Flyway, the major migratory route for hundreds of neotropical bird species.

(John Guarnaccia, personal communication 2016; Nieme et al. 1998). It is the largest globally important bird area in the United States and is considered vital habitat for 34 priority songbird species whose global breeding distribution is restricted to the northern forest biome[8] (National Audubon Society 2012). The Western Maine Mountains region is a key part of what Maine Audubon biologist Sally Stockwell calls a *"baby bird factory."* Stockwell considers conservation of the forests of the region essential to the future of many of our most cherished bird species.

Northern Maine is the last stronghold for wild brook trout in the eastern United States. Nearly three quarters of the state's wild brook trout waters occur in the Western Maine Mountains.

Northwestern Maine is the last stronghold for wild brook trout[9] in the eastern United States (Whitman et al. 2013a; DeGraaf 2014), supporting 97% of its intact lake and pond wild trout populations. The highest concentration (about 73%) of wild brook trout lakes occurs in the Western Maine Mountains and many more lakes are dependent on the region's snowpack, which provides the clean, cool, well-oxygenated water and the narrow range of water temperatures trout and other cold water species need to survive (Bonney 2009; The Nature Conservancy 2008). In addition, the region's high elevation streams have more intact riparian habitat and are less fragmented by dams and other barriers than elsewhere in New England (Whitman et al. 2013; Anderson and Sheldon 2011). Five of these: the Magalloway, Kennebago, Moose, and East and West Branches of the Penobscot have been identified as particularly important for conservation by The Nature Conservancy because they are long connected stream networks with unaltered water flow and intact forested riparian areas (Anderson and Sheldon 2011).



Perham Stream

Photo courtesy of The Trust for Public Land, Jerry Monkman, EcoPhotography.com

The region's mountainous landscape is critically important to cold water stream and lake ecosystems, playing a particularly important role in maintaining the flow and high water quality required by brook trout, lake trout, whitefish, spring salamanders, and a variety of aquatic insects.

8 Biome-restricted species are those with at least 80% of their population concentrated within one avifaunal biome (US IBA Committee).
9 This number includes heritage brook trout ponds which have never been stocked and wild brook trout ponds, which were historically stocked but are now self-sustaining.

Mountainous landscapes play a particularly important role in maintaining the flow regimes and high water quality required by brook trout, lake trout, whitefish, spring salamanders, and a variety of aquatic insects. On average, the mountains of western and central Maine receive twice the annual snowfall of southern and midcoastal regions (Fernandez et al. 2015; Lautzenheiser, R.E. 1978). These mountains capture, store, purify and gradually release water stored in ice, snow, soils and vegetation into the headwater streams of the Penobscot, Kennebec, Androscoggin, and Allagash Rivers and into groundwater aquifers downstream. Three of the state's prized fish species—lake trout, brook trout, and whitefish—and many other cold water fish and invertebrates depend on this influx of cold water to survive. As the climate warms, snowfall in the mountains is expected to decline at a much lower rate than along the coast (less than 20% versus more than 40% along the coast) and will be all the more important in regulating river flow and maintaining water temperature and supplies in the state (Fernandez et al. 2015). Maine's mountains are and will continue to be critically important to cold water stream and lake ecosystems.

The Western Mountains Region and lands to the north provide the greatest remaining opportunity in eastern North America for maintaining lynx and marten populations, and reestablishing viable populations of the eastern gray wolf.

Nearly one quarter of all designated critical habitat for lynx, a federally threatened species in the United States (Simmons-Legaard et al. 2013) occurs in Maine. The Western Maine Mountains include more than half of this core habitat as well as core habitat for marten. Both lynx and marten are wide-ranging species that reach their southern range limits in the region (Laliberte and Ripple 2004) and, along with the eastern gray wolf, are considered important focal species for biodiversity conservation in the greater Northern Appalachians (Reining et al. 2006). Focal species play a critical ecological role that is of greater importance than we would predict from their abundance. They are wide ranging, so conserving their habitat would provide a protection umbrella for other species with similar requirements; they are sensitive to habitat quality, such as changes in climate; and they are charismatic (Trombulak et al. 2008). In short, if enough habitat is maintained to

Maintaining habitat requirements for lynx and marten will also maintain the requirements of more than 85% of 110 other vertebrate species.

Canada lynx

support viable populations of these species, many other species will also be conserved (Trombulak et al. 2008). Hepinstall and Harrison (in preparation) found that the habitat requirements for lynx and marten encompass the requirements of more than 85% of the 111 forest generalist, deciduous forest specialist, and coniferous forest specialist vertebrate species that occur in northern Maine.

Marten

Lynx and marten are also important because their populations represent "peninsular extensions" of their boreal ranges (Carroll 2005). As a result, they are likely to be particularly sensitive to climate change—especially to changes in snowfall—and they represent unique ecotypes at the southern limit of their range (Carroll 2005; Reining et al. 2006). Models developed by Carroll (2007) and others indicate that the Western Maine Mountains region is likely to be of critical importance to the future of northeastern lynx and marten populations, since their ranges are expected to contract to the north and to higher elevations as the climate warms. The Western Maine Mountains region already serves as a north-south and east-west link between peripheral populations in the White Mountains and those in northeastern Maine and the Gaspé (Carroll 2007). Both species have used this link to recolonize New Hampshire (Daniel Harrison, personal communication). While the forests of the region currently support lynx and marten, recent research suggests that harvest practices on two thirds of Maine's commercial forestland are creating habitat that no longer serves the needs of these umbrella species, and many others, which may lead to population declines in the future (Simmons-Legaard et al. 2013; Fuller and Harrison 2005; Homyack et al. 2010). Lynx thrive in the young dense spruce-fir forests that regenerate after clearcutting, which provide ideal habitat for snowshoe hare, the lynx's principle prey. Over the past several decades, there has been a broad-scale decline of early-successional habitat and in the spruce-fir forest type overall (Simons-Legard et al. 2016).

Although breeding populations of a third focal species—the grey wolf—have not yet been documented in Maine, there are many reports of wolves along the region's western border. The Western Maine Mountains, along with much of northern and central Maine, is considered potential habitat for this wide-ranging carnivore (Laliberte and Ripple 2004). A number of organizations in Maine and elsewhere are working on recovery efforts for this federally endangered species.

The Western Maine Mountains region is poised to serve as a critical ecological linkage between the temperate and boreal forest biomes.

According to Whitman and others (2013b), the composition of nearly every plant community and wildlife habitat in Maine is likely to be affected by climate change (Jacobson et al. 2009). Although there is uncertainty about how individual species' ranges will respond to various climate change scenarios, most species will likely shift north and/or upwards in elevation. Maintaining a connected landscape is the most widely cited strategy in the scientific literature for building resilience in the face of climate change (Anderson et al. 2012; Heller and Zavaleta 2009). The Western Maine Mountains region is the critical ecological link between the forests of northern Maine, New Brunswick and the Gaspé and the forests of New Hampshire, Vermont and the Adirondacks, as well as smaller forested areas to the south.

Within the northeastern United States, the Western Maine Mountains region is already considered a priority linkage for species such as lynx, marten and moose, because it contains a "highly concentrated east-west regional flow pattern" which connects resilient landscapes to the west and south to those in northern Maine (Anderson et al. 2012). This large-scale directional flow occurs here because the Western Maine Mountains region is sandwiched between the agricultural lands of the St. Lawrence Valley and developed lands in Vermont, New Hampshire and southern and coastal Maine.

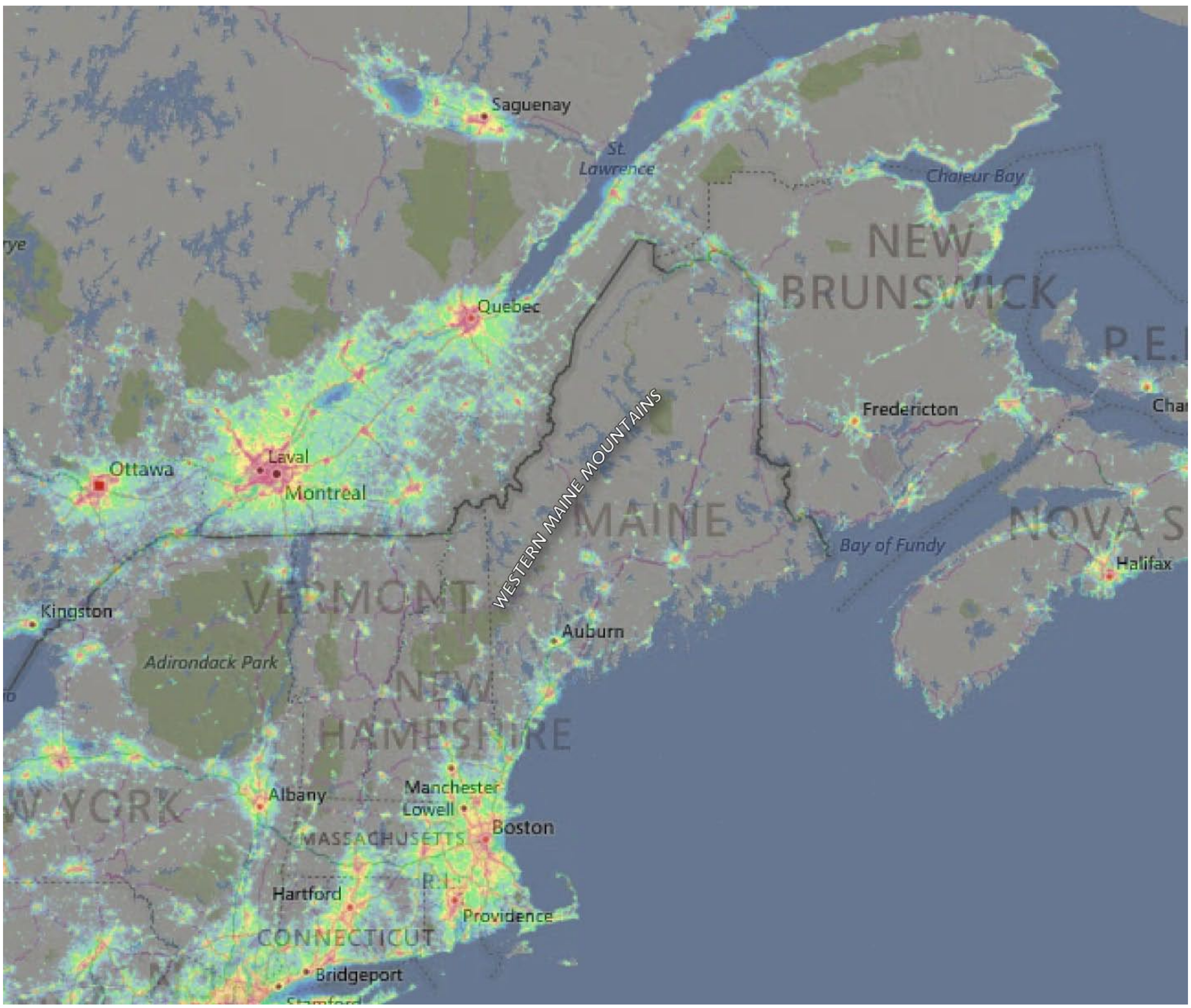


Image from Jurij Stare, www.lightpollutionmap.info, based on original data sourced from Earth Observation Group, NOAA National Geophysical Data Center. Western Maine Mountain text added.

This satellite image of the night sky illustrates the critical position of the Western Maine Mountains region as a link connecting the unfragmented forests in the Adirondacks, Vermont and New Hampshire to Maine's north woods and the forests of Canada, a connection critical to the entire Northern Appalachian-Acadian Forest Ecoregion.

The Wildlands Project has identified four 'megalinkages' that, if implemented, would tie North American ecosystems together to conserve and benefit native species in their current and projected natural patterns of range and abundance (Reining et al. 2006). The Western Mountains Region is a key part of the Atlantic Megalinkage, which extends from Florida to New Brunswick, mostly along the Appalachians. The megalink includes two core areas in Maine, both of which occur in the region—one centered around the Baxter region, the other around the Boundary Mountains and upper Androscoggin watershed. The Wildlands network highlights the great importance of northern Maine and the Gaspé Peninsula for long-term conservation in the Northern Appalachian region, not only for focal species like lynx, marten and (potentially) wolf, but also as the remaining places where large new wildlands could be established (Reining et al 2006).

The region's value as an ecological link would be greatly enhanced by connecting it to the boreal forest north of the St. Lawrence River through the remaining intact forest blocks in adjacent Quebec. Creating a more permeable and connected landscape would be an extremely ambitious project that would require regeneration of existing farmland to forestland and identifying potential corridors across major highways. Many studies have identified the Western Maine Mountains region as a key part of such a linkage (One Country Two Forests, National Audubon Society, Wildlands Project, The Nature Conservancy, Adirondack to Acadia, Boreal Songbird Initiative, Staying Connected). Over time, such a link could potentially enhance some of the other key ecological values of the Western Maine Mountains, for example, by connecting and expanding potential habitat for wide-ranging carnivores and breeding songbirds.

Maine's most extensive older forests are found in the Western Maine Mountains.

Next to conversion of forest to some other land use, the loss of older forest age classes is a major threat to forest biodiversity worldwide (Hagan and Whitman 2004). Older forests of the temperate and boreal zones contain exceptional forest structure including large trees, large snags, large logs, large volumes of dead wood, and vertical structural diversity not found in younger forests (Whitman and Hagan 2007)[10]. In the United States, late-successional stands (those older than 100 years) now constitute less than 4% of forested areas (Ryan et al. 2010). In Maine, late successional forests cover somewhere between 3 and 6% of the state, and their extent continues to decline (Maine Department of Inland Fisheries and Wildlife 2015; Hagan and Whitman 2004). In Finland, where old forests comprise less than 0.5% of all forested areas, extinction-vulnerable old forest species now number more than 1,000 (Hanski 2000), and an estimated 5% of Finland's forest species are predicted to go extinct in the next 50 years (Hagan and Whitman 2004). Much of Maine's older forest is in the Western Maine Mountains at high elevations, in the Baxter area, in the White Mountains and in other ecological focus areas in the region. These areas are important for species such as marten, many woodland raptors and songbirds, mosses, lichens and other species that depend on mature interior forest, large cavity trees, downed wood, and the large number of forest niches present. Hagan and Whitman (2004) suggest that we may be accruing 'extinction debt' in Maine's forests. They describe the process as follows:

> *"Once old forest elements such as large trees or logs are lost from a stand (e.g., as a result of a clearcut, or even a selection cut), it can take centuries for the species to return to that location. A species first has to wait for these structural features to redevelop, and then the species has to find them. Scientists are beginning to understand that forest continuity is key to many forest species. Continuity refers to the persistence of big trees and big logs in a forest stand over a very long period of time (centuries), even though the stand might be subjected to many different disturbances, such as fire, wind, disease, or even selection logging. Species that move or disperse slowly through the landscape, and prefer large old trees or logs, are the species most at risk to the loss older forests."*[11]

10 Most forests in Maine are under 75 years in age. Pathological maturity—the age at which trees begin to suffer serious decay—is 150 years or older, depending on the species (Thompson et al. 2013).

11 These tend to be small and uncharismatic, such as insects, lichens, fungi, and mosses.

Although forest cover has remained relatively stable in Maine, the loss of older forest age classes from the vast Northern Appalachian-Acadian forest could be leading us down a biodiversity path that has already begun to unfold in Scandinavia (Hagan and Whitman 2004). The late successional forests that remain in the Western Maine Mountains are critically important, especially those that are large enough to protect source populations of plants and animals that may disperse to surrounding forests as they mature (Baldwin et al 2007).

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The Western Maine Mountains region is expected to be a highly resilient landscape in the face of climate change.

Ecologist Aldo Leopold captured the concept of ecological resilience in two elegant statements (Anderson et al. 2012): *"Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity"* (Leopold 1949). Climate change is expected to alter the distribution of Maine's flora and fauna. The process is well underway—we are already experiencing the northward migration of northern cardinals, Virginia opossums, deer ticks, northern shrimp, and a host of other species. Conservationists are urgently working on strategies that will conserve the maximum amount of biological diversity as species ranges shift.

The Nature Conservancy is at the forefront of developing the science to guide these efforts. Their approach is based on three observations. First, that species diversity is highly correlated with landscape diversity in the Northeast and Mid-Atlantic; second, that species take advantage of microclimates and microhabitats available in complex landscapes, and finally, that species can move to adjust to climatic changes if these landscapes are permeable[12] and connected (Anderson et al. 2012; Anderson et al. 2013). Anderson and others hypothesized that sites with a large variety of landforms and long elevation gradients will retain more species even as the climate changes by offering ample microclimates and thus more options for rearrangement. They then mapped key geophysical settings and land use patterns to identify the most resilient places in the landscape—the places most likely to be natural strongholds for species and nature into the future.

The Western Maine Mountains region is expected to be an important natural stronghold for biodiversity because of its elevation range and varied landforms (e.g., cool ravines, warm southern slopes, cold streams, wind-swept summits) as well as its high landscape connectivity. The region is considered very permeable—its relatively unfragmented landscapes allow the continuous flow of natural processes, including not only the dispersal and recruitment of plants and animals, but the rearrangement of existing communities. (Anderson et al. 2012). These characteristics should help buffer climate change effects and allow for directional range shifts, north-south and east-west migrations, and upslope dispersal (Anderson et al. 2012; Anderson et al. 2015).

Mountain tops may be particularly important to the region's biodiversity, at least in the short term. Research suggests that, although the areal extent of high elevation habitat is expected to decline as temperatures rise (Whitman et al. 2013a; Beckage et al. 2008), subalpine and alpine community composition may be relatively stable because their distribution is thought to be more closely tied to icing and the low cloud ceiling typical of higher elevations rather than temperature (Spear 1989; Kimball et al. 2014; Randin et al. 2008). Mid and high

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12 Landscape permeability indicates the number of barriers and degree of fragmentation within a landscape. A permeable landscape allows for range shifts and reorganization of communities.

elevation micorefugia[13] are likely to be critical for the survival of many species in the future, especially alpine flora and fauna and species that thrive where snowfall is high, such as lynx, marten, snowshoe hair and moose (Carroll 2005).

The Western Maine Mountains play an important role in regulating local, regional, and global climate.

A walk through the woods on a mid-summer day gives a sense of how forests at our latitude influence local and regional climate. Forests are likely to be much cooler and more humid than more open habitat types. This is in part because precipitation often exceeds evapotranspiration rates in forests. In addition, tree canopies are rougher than cleared or developed land, which decreases wind speed and water loss from evaporation. As a result, temperate forests are typically sources of surface water (Sun and Liu 2013). For example, it is estimated that over 60% of our water supply comes from forest lands in the United States (Brown et al. 2008). Forest soils are regarded as 'sponges' because their deep extensive root systems and layer of leaf litter on the forest floor soak up water. For this reason, soil erosion is rare in forests—they provide the best water quality among all land uses. Forests also affect microclimate by altering solar radiation and how rain and snow fall through large forest canopies (Lee 1981) and by keeping streams cool in summer.

The Western Maine Mountains region also plays a role in moderating climate at the global level. The mountain snowpack that accumulates in winter helps regulate the earth's climate by reflecting solar radiation that would otherwise be absorbed by a darker surface and reradiated as heat into the atmosphere. This phenomenon is known as the albedo effect. More importantly, because trees are tall and long-lived, they sequester a great deal of carbon. In most forests, 95% of the biomass is in woody tissue—boles, limbs and roots (Hunter 1990; Packham and Harding 1982). Soils also sequester carbon and, because decomposition is slow in the cool damp forests of northern and western Maine, these areas serve as a carbon sink. It is estimated that the world's forests store 45% of terrestrial carbon and that they have the potential to absorb almost half of global annual carbon dioxide emissions (Pan et al. 2011). In addition, research suggests that older forests sequester more carbon than younger ones (Kauppi et al. 2015; Stevenson et al. 2014; Birdsey 1992), making the older forests that exist at high elevations, in the Baxter area and in other ecological focus areas of the Western Maine Mountain region that much more important. A shift to sustainable forest management for long-lived wood products that can be used in place of energy intensive construction materials such as cement and steel has great potential to further reduce fossil fuel emissions (Oliver et al. 2014).

Conclusions

The Western Maine Mountains region is a spectacular and rugged landscape defined by forest, rock, snow, clouds, and distance. From its windswept summits to the deep clear lakes and wet meadows of its valleys, it is a region of exceptional diversity and beauty. Study after study highlights the region's significance—with

Study after study highlights the region's significance—with its globally significant alpine and montane forest ecosystems embedded within the largest area of contiguous forest in the eastern United States; as part of the largest remaining block of unfragmented forest in the Atlantic Flyway; as the last stronghold for brook trout in the United States; as the link between marten and lynx populations in the United States and Canada. The combination of boreal and temperate species, steep elevation gradients, and continuous forest make it a resilient landscape in a changing climate—one that is expected to retain the rich diversity and coherency of its natural communities farther into the future than the surrounding lowlands, and one that will provide both refuge and an essential ecological linkage for species such as woodland songbirds, brook trout, moose, marten and lynx that are likely to shift their ranges north and east in response to a warming climate.

13 Microrefugia are defined as areas with locally favorable environmental conditions in which small populations can survive outside their main distribution area (Rull 2009).

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Apart from its many ecological values, the Western Maine Mountains region serves as a source of inspiration and spiritual renewal. It is impossible not to be impressed by the countless mountain streams singing over stone, mica sparkling in granite, the densely woven forests of dwarf balsam, the scree-covered ridges, the alpenglow of dusk and the 'fox fire' of northern lights in winter. Thousands are drawn to the region's heights, which are linked by the wildest one hundred miles of the 2,190 mile long Appalachian Trail. And thousands more are drawn to its forests, streams and lakes—to walk, watch, fish, hunt or simply escape the buzz of civilization.

In his book, *The Forest Unseen*, David Haskell describes the value of a small patch of old forest in the southern Appalachians, which applies equally well to the Western Maine Mountains. It is "a *relatively unfragmented, uninvaded forest where the old ecological rulebook has yet to be entirely torn up and blown away. These ants, these flowers, these trees contain the genetic history and diversity from which the future will be written. The more wind-tattered pages we can hold on to, the more materials evolution's scribe will have to draw upon as it reworks the saga.*" The Western Maine Mountains region is one of the most intact forested landscapes in North America, one that retains nearly all of the plants and animals that were here before us. It serves as a reservoir, a refuge, and a resilient critical linkage. We are fortunate to be starting with pages that have yet to become "wind-tattered". By working to ensure that the mountains and forests of the region remain diverse, resilient and connected to forested landscapes to the north, south, east and west, we have an unparalleled opportunity to influence how the future will be written.

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The Environmental Consequences of FOREST FRAGMENTATION in the Western Maine Mountains

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Occasional Paper #2

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The Environmental Consequences of Forest Fragmentation in the Western Maine Mountains

ABSTRACT

The extraordinary ecological values of the Western Maine Mountains region are under threat from a process called "habitat fragmentation." Habitat fragmentation occurs when habitats are broken apart into smaller and more isolated fragments by permanent roads, utility corridors, buildings, clearings or changes in habitat conditions that create discontinuities in the landscape. Research in Maine, the Northeast and around the world demonstrates unequivocally that fragmentation—whether permanent or temporary—degrades native terrestrial and aquatic ecosystems and reduces biodiversity and regional connectivity over time and in a number of ways. Negative effects include:

- increased mortality and habitat loss from construction of roads and other fragmenting features
- increased mortality and other direct impacts associated with infrastructure after construction
- changes in species composition and reduced habitat quality from edge effects
- changes in species composition and behavior as habitat patch size declines
- changes in hydrology and reduced aquatic connectivity
- introduction and spread of exotic species
- changes in the chemical environment
- pressures on species resulting from increased fishing, hunting, and foraging access
- loss of scenic qualities and remote recreation opportunities

Fragmentation has already significantly degraded ecosystems in much of the eastern United States and in temperate forests throughout the world. By contrast, in large part because historical forest management maintained vast connected forest blocks in the region, the Western Maine Mountains' biodiversity, resilience and connectivity are unparalleled in the eastern United States. The region is a haven for populations of many of Maine's iconic species, including moose, lynx, marten, brook trout, and rare forest birds, and provides an essential corridor for species to move to other northeastern states, the North Woods and Canada in a time of climate change. To maintain the region's unique values, it is essential to avoid introduction of new fragmenting features, especially those that would permanently intrude into intact blocks of forest habitat, such as new utility corridors and new high volume roads. It is also critically important to find ways to support landowners who seek to maintain large intact forest blocks and to support them in managing forests for connectivity and structural complexity. If proactive steps are taken now, there is a tremendous opportunity to avoid habitat fragmentation and maintain the region's many ecological values—values that have defined Maine for generations and are of critical importance in North America.

INTRODUCTION

The Western Maine Mountains lie at the heart of the most intact and least fragmented landscape remaining in the eastern United States. This vast region lies near the northern terminus of the Appalachian Mountain range in the United States and includes some of its highest peaks. It extends from the Katahdin region 160 miles southwest to Boundary Bald Mountain and the Mahoosucs Range on Maine's western border, encompassing an area of more than five million acres. It is a region of extraordinary ecological importance, both because it is the key ecological linkage between the forests of the northern Appalachians and those to the north, south and west, and because of the biodiversity it harbors.[1]

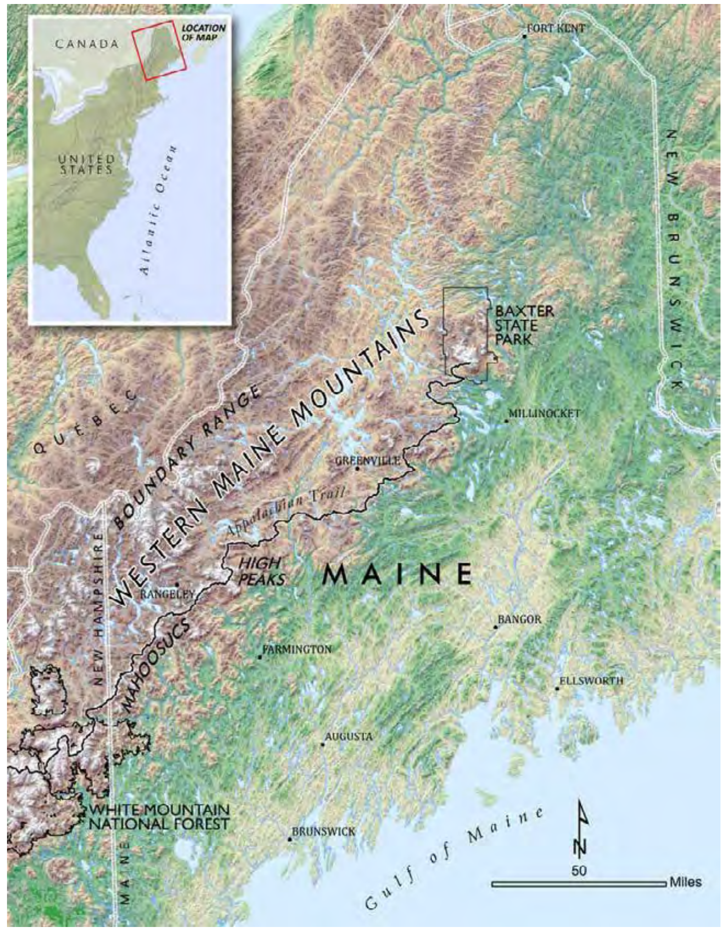


Figure 1. The Western Maine Mountains region.

The southern edge of the Western Maine Mountains region marks the divide between the most resilient[2] and connected landscapes of the Northern Appalachian-Acadian Forest Ecoregion[3] and more fragmented and less resilient landscapes to the south and west. This paper summarizes the potential deleterious impacts of forest fragmentation on the flora, fauna and ecosystems of the region. Fragmentation is generally defined as the breaking apart of a continuous landscape into smaller and more isolated fragments (Forman 1995). In the Western Maine Mountains, fragmentation occurs when permanent features such as roads, utility corridors, buildings or clearings create breaks in the forested landscape (Charry 1996). Recent work by Di Marco et al. (2018) shows that there is a direct correlation between the risk of species extinction and human footprint. Impacts such as direct habitat loss, habitat degradation through increased isolation of plant and animal populations, greater exposure to edge effects, and invasion by disturbance-adapted species are cumulative, leading to degraded ecosystems over time and, eventually, loss of regional connectivity and biodiversity (Watson et al. 2018; Lindenmayer and Fischer 2006; Haddad et al. 2015). This is the situation in much of the eastern United States and in temperate forests throughout the world.

1 For a detailed description of the ecological values of the Western Maine Mountains, see McMahon (2016).

2 Resiliency refers to the ability of a region to maintain species diversity and ecological function as the climate changes.

3 Ecoregions are large units of land with similar environmental conditions–especially landforms, geology and soils, which share a distinct assemblage of natural communities and species. The Northern Appalachian-Acadian Forest Ecoregion includes the mountainous regions and boreal hills and lowlands in northern New England and Maritime Canada. The ecoregion includes the Adirondack Mountains, Tug Hill, the northern Green Mountains, the White Mountains, the Aroostook Hills, New Brunswick Hills, the Fundy coastal section, the Gaspé peninsula and all of New Brunswick, Nova Scotia and Prince Edward Island (Anderson 2006).

In the classic definition of fragmentation, habitat patches are surrounded by a "matrix"[4] of lands dominated by human activities, such as farmland or urban centers (Hunter and Gibbs 2007). By contrast, the Western Maine Mountains region is a forested landscape, largely unfragmented by major roads and other permanent features. This matrix of managed forestland provides valuable habitat for most of Maine's forest species and generally serves to connect patches of mature or undisturbed habitat. However, changes in the forest landscape from harvesting can also have fragmenting effects, especially for species that require mature forest or forest interior habitat. The degree of impact depends on factors such as the species in question, harvest intensity, and the size of harvest blocks. Although these impacts are generally temporary, they are of concern—particularly in combination with impacts of permanent fragmentation—and are in need of further study.

This paper begins with an overview of the ecological significance and condition of the Western Maine Mountains' landscape and a brief review of how the region has changed over time due to forest fragmentation associated with land use change and forest management. This is followed by a summary of the potential impacts of current and future fragmentation on the region's biodiversity, resilience in the face of climate change, and ability to serve as the critical link between the forests of the northern Appalachians and those to the north, south and west. To paraphrase Aldo Leopold (1966), the region needs to be viewed as an integrated whole rather than a collection of conservation lands and private commercial land holdings. Private and public landowners, through their land use decisions and management, will play a key role in maintaining the region's ecological values into the future.

Habitat fragmentation and why it matters

Hunter and Gibbs (2007) wrote that a modern traveler looking down from a plane generally does not see vast expanses of unbroken landscape but instead will likely see a landscape like a patchwork quilt—a mosaic of different land uses. Hunter and Gibbs define "habitat fragmentation" as the gradual breaking apart of a natural landscape into smaller habitat blocks. They wrote that fragmentation typically begins when people build roads into a natural landscape and then "perforate" the landscape further with associated development. This typically leads to additional roads, energy infrastructure and land conversion and, over time, results in "patches" of natural habitat that are smaller and farther apart (Fig. 2). Larger habitat patches in a landscape mosaic are better able to support stable populations of more species than small ones. Hunter and Gibbs attribute this to three things: First, larger patches have a greater variety of environments—different elevations, soils, geology, streams and wetlands, which in turn support a greater variety of species. Second, larger patches will support more species that require larger home ranges. Finally, animals and plants from other patches can more easily migrate in to replenish struggling or declining species if similar habitat patches are close by and if the areas in between (matrix habitat) are connected and allow for movement. Fragmenting landscapes into smaller habitat patches over time is a leading cause of degradation of ecosystems and loss of biodiversity.

[4] Matrix forest can be defined as the largest background patch in a landscape and is characterized by extensive cover, high connectivity, and/or exerts a dominant role on ecological processes (Forman 1995). In the Western Maine Mountains, most of the region is considered matrix forest.

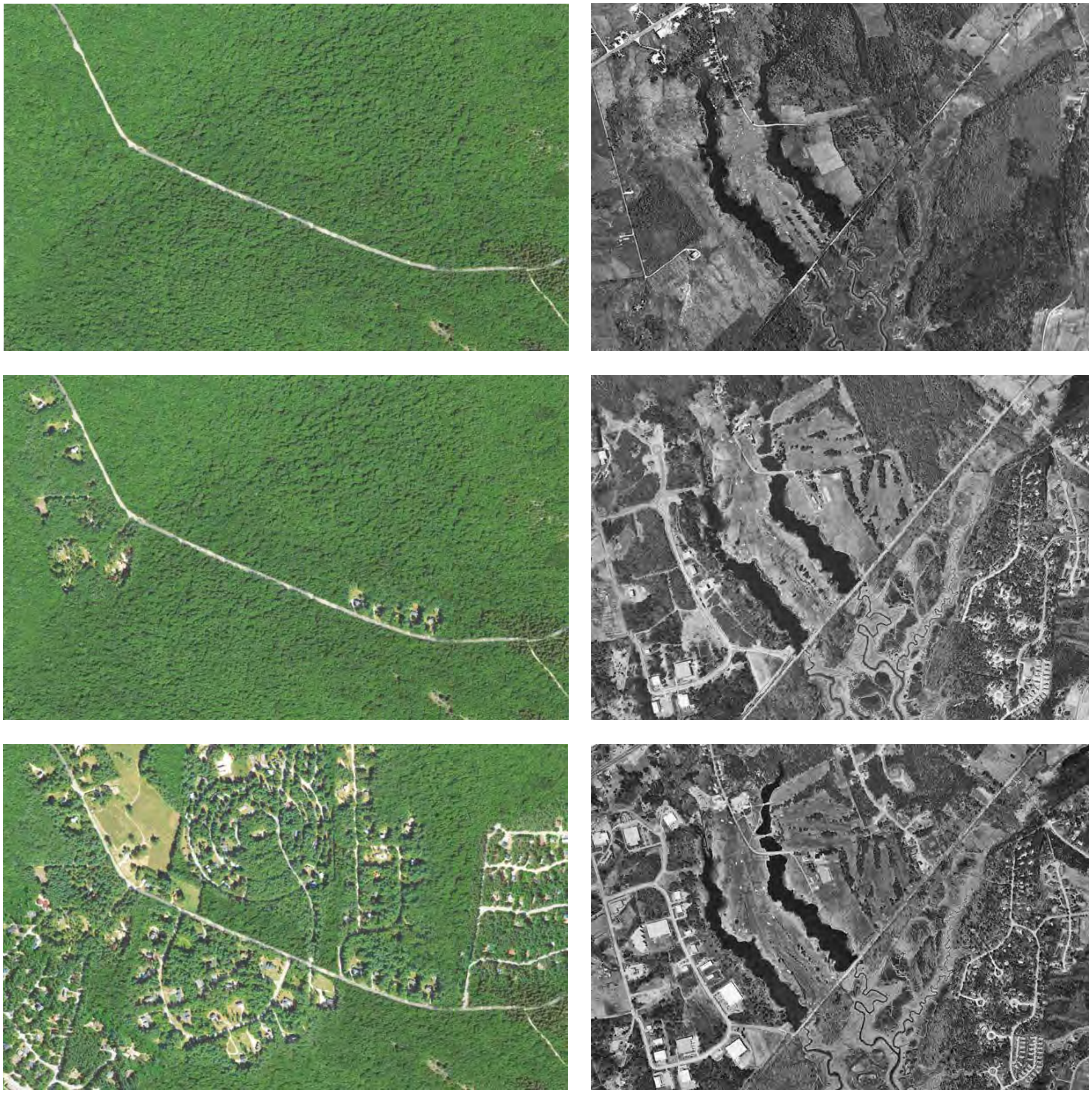
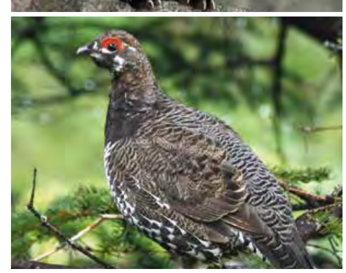


Figure 2. The left column shows a hypothetical progression from: (1) initial fragmentation by a new road or other linear feature, (2) a landscape fragmented by the road and associated development "perforating" the landscape and (3) a landscape with additional sprawling fragmenting features, resulting in progressive fragmentation of the landscape into smaller natural areas. The right column shows an actual example of change between 1956 to 1995 from a partially fragmented landscape to a highly fragmented landscape in a southern Maine community. Photo-illustrations in left column by Waterview Consulting. Photos in right column courtesy of the Greater Portland Council of Governments.

Figure 3. (following page) The Western Maine Mountains provide critically important core habitat for species that are iconic to Maine and a host of rare animals and plants. Photos are of moose, black bear, Canada lynx, river otter, American marten, spruce grouse, and brook trout. Photo credits, see inside front cover.

THE REGION TODAY



A diverse, resilient and connected landscape[5]

From the standpoint of biodiversity, the Western Maine Mountains region is exceptional. It includes all of Maine's high peaks and a rich diversity of ecosystems, from alpine tundra and boreal forests to ribbed fens and floodplain hardwood forests. It is home to more than 139 rare plants and animals, including 21 globally rare species and many others that are found only in the northern Appalachians. It includes more than half of the United States' largest globally important bird area,[6] which provides crucial nesting habitat for 34 northern woodland songbird species and critical habitat for high-elevation and coniferous-forest specialist birds such as Bicknell's thrush—a state endangered species—bay-breasted warbler and black-backed woodpecker. Maine is the last stronghold for wild brook trout in the eastern United States, supporting 97% of its intact lake and pond wild trout populations. Seventy-three percent of these wild brook trout lakes are in the Western Maine Mountains (Whitman et al. 2013; DeGraaf 2014). The region provides core habitat for umbrella species[7] such as American marten and Canada lynx–habitat that supports more than 85% of all of Maine's terrestrial vertebrate wildlife species, including iconic species of the north, such as the common loon, black bear, bobcat and moose (Hepinstall and Harrison in prep.; DeGraaf and Yamasaki 2001).

In addition to its remarkable biodiversity, the region is exceptional because it remains a largely unfragmented, lightly settled and connected landscape. It lies at the heart of the Northern Appalachian-Acadian Forest Ecoregion, which is the largest and most continuous area of temperate forest in North America, and perhaps the world (Haselton et al. 2014; Riitters et al. 2000). This high degree of connectivity, combined with large elevation gradients and a diversity of physical landscapes, makes the Western Maine Mountains a highly resilient landscape in the face of climate change and a critical ecological link between undeveloped lands to the north, south, east and west. Resilient sites are those that are projected to continue to support biological diversity, productivity and ecological function even as they change in response to climate change. In The Nature Conservancy's Conservation Gateway climate resilience map of the eastern United States, the Western Maine Mountains stand out in terms of biodiversity, climate flow[8] and

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5 This summary of the region's ecological significance is adapted from McMahon (2016).

6 The National Audubon Society gave this global designation to the region because of its high bird richness and abundance as well as the extent and intactness of its forests, which lie within the Eastern Atlantic Flyway—the major migratory route for hundreds of neotropical bird species.

7 Hunter and Gibbs (2007) define umbrella species as those with large home ranges and broad habitat requirements. Protecting habitat for their populations protects habitat for many other species across a broad set of ecosystems.

8 Climate flow is defined by The Nature Conservancy as the movement of species populations over time in response to the climate. Intact forested areas typically allow high levels of plant and animal movement.

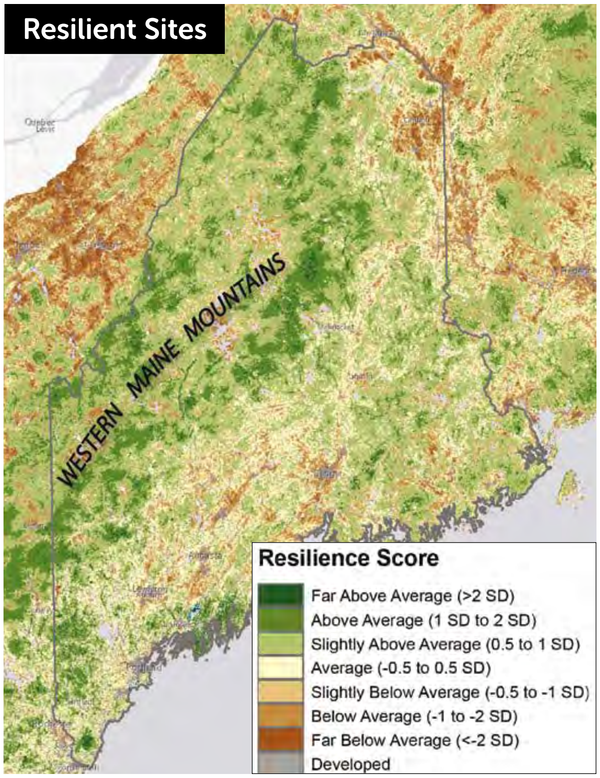

Figure 4. This map shows that the Western Maine Mountains provide sites of above and far-above-average resiliency throughout the region. Resilient sites are expected to buffer their resident species from climate change and continue to support biodiversity, productivity, and ecosystem function even as they change in response to climate change. Analysis and graphic courtesy of The Nature Conservancy, Maine.

Sources and Sinks

Hunter and Gibbs (2007) define "sources" as subpopulations that produce a substantial number of emigrants that disperse to other patches and "sinks" as subpopulations that cannot maintain themselves without a net immigration of individuals from other subpopulations. The Western Maine Mountains region harbors significant source populations of many species and already serves as a north-south and east-west link between peripheral sink populations in New Hampshire and Vermont and source populations in northeastern Maine and the Gaspé (Carroll 2007).

climate-resilient sites.[9] Eighty percent of the region is of above-average resilience, based on geophysical setting and local connectedness (Fig. 4).[10] This compares to 60% for the state as a whole and an average of 39% in southern Maine. A review of The Nature Conservancy's Conservation Gateway maps for the rest of New England and the eastern United States indicates that resiliency is even lower outside of Maine, making the Western Maine Mountains one of the most resilient and connected landscapes east of the Mississippi. In addition, it is the critical link between the other highly resilient areas in the Northern Appalachian-Acadian Forest Ecoregion—the Adirondacks, the St. John and Allagash valleys and the Gaspé.

Climate-resilient sites are more likely to sustain native plants, animals and natural processes into the future. The region is expected to retain more species as the climate changes than other parts of the state because its varied topography offers ample microclimates and thus more options for rearrangement (Anderson et al. 2012; Anderson et al. 2013). Northern Maine already has the highest species richness of mammalian carnivores in the eastern United States,[11] and the Western Maine Mountains support the largest moose, lynx, and marten populations in the lower 48 states. Furthermore, the region is a stronghold for brook trout, land-locked salmon, spruce grouse and a host of other species. In addition to providing a refuge for northern and coldwater species, the region serves as a source of individuals that can recolonize new habitats as they become avail-

9 Resilient sites buffer their resident species from the direct effects of climate change by providing temperature and moisture options in the form of connected microclimates that can differ by as much as 10–15°C. Sites with high microclimate diversity allow plants and animals to persist locally even as the regional climate appears unsuitable, thus slowing down the rate of change.

10 Geophysical setting is a landscape classification that considers topography, elevation range, wetland density and soil variety. Local connectedness is the absence of barriers or fragmenting roads, dams, development, etc. that prevent plant and animal populations from taking advantage of local microclimates.

11 The region supports breeding populations of 7 species of mustelids (fisher, marten, mink, ermine, long-tailed weasel, river otter, striped skunk), 3 species of canids (grey fox, red fox, coyote), and 2 cats (bobcat, lynx).

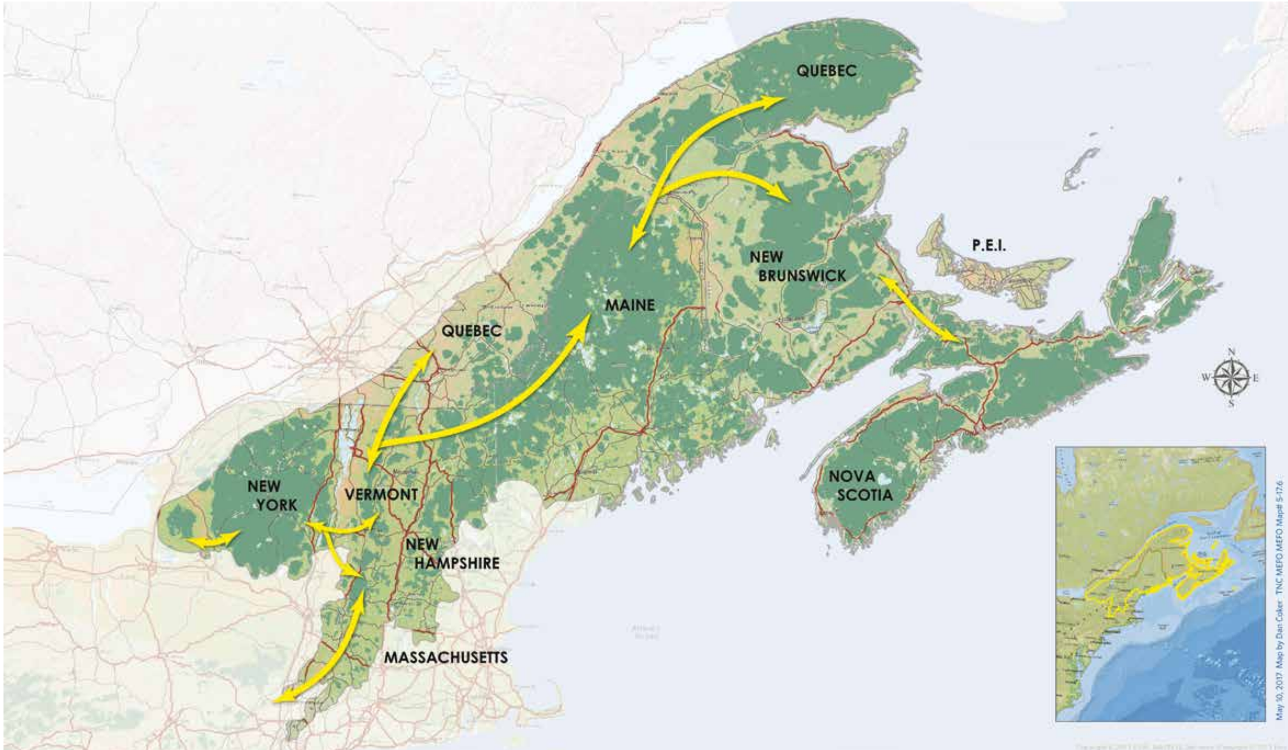

Figure 5. Northern Appalachian Region Forest Cover and Critical Linkages.
Map courtesy of The Nature Conservancy, Maine.

able. For example, the region links moose populations at the southern edge of their range in New Hampshire and Vermont that are increasingly impacted by climate change and parasitic infections by ticks with larger, healthier populations in northern Maine and Quebec.

At a continental scale, northern Maine will become an increasingly important dispersal corridor as species move north into Canada (Trombulak and Baldwin 2010) (Fig. 5). Species survival may depend not only on the presence of refugia but also on how quickly the climate changes. Loarie and others (2009) modeled projected rates of temperature change in different ecosystems under different emissions scenarios during the 21st century. They found that the rate of change is expected to be lowest in mountainous biomes and temperate coniferous forests, suggesting that the landscapes of the Western Maine Mountains are more likely to effectively shelter many species into the next century than areas with low relief (Loarie et al. 2009; Loarie et al. 2008; Thuiller et al. 2005). Whitman et al. (2013) emphasize the importance of conserving cool refuges such as cold stream networks, mountains, and closed canopy forests to help species survive and transition as Maine's climate changes.

A forested landscape

The Western Maine Mountains region is ~97% forested (excluding water), which is about 8% higher than the average forest cover in Maine, the most forested state in the nation (Fig. 6, following page, for a regional comparison) (New England Forestry Foundation, NEFF, in press).[12] The North Woods of Maine, of which the

[12] Percentages of land in conservation ownership and forest management for the Western Maine Mountains are derived from other studies that focused on slightly different geographic boundaries. Schlawin and Cutko percentages were calculated for the Central-Western-White Mountains section of the USFS Bailey Ecoregion map of Maine (Bailey 1995). The 2018 NEFF analysis is of an area they refer to as the Mountains of the Dawn region.

region is a part, is the only place in the eastern United States where such a large area of contiguous land has remained continuously forested since European settlement. This is due to a variety of factors, including limited suitability for agriculture, soils that are productive for tree growth, remoteness from more heavily settled areas, and the timber and nontimber values of its vast forest—most of which has been in private and corporate ownership and actively managed for forest products for more than two centuries.

State/Region	% Forestland		% Change from 2007–2017	Approximate Change in Acres
	2007	2017		
Western Maine Mountains	**96.8%**	**96.5%**	**–0.3%**	**–12,000**
Maine	89.8%	89.2%	–0.6%[13]	–116,000
Connecticut	55.3%	58.4%	3.1%	95,000
Massachusetts	61.2%	60.6%	–0.5%	–26,000
New Hampshire	83.8%	82.8%	–1.0%	–57,000
Rhode Island	54.0%	54.4%	0.4%	3,000
Vermont	77.3%	76.0%	–1.3%	–80,000
New England (incl. ME)	80.3%	79.8%	–0.5%	–184,000
New England (excl. ME)	71.1%	70.8%	–0.3%	–67,000

Figure 6. Forested Area as a Percent of Total Area (excluding water) in the New England states. Percent change is change in percent of forestland from 2007–2017.[14] Adapted from NEFF (in press).

Managed forestland in the Western Maine Mountains is composed primarily of naturally regenerated forests. According to most recent FIA data,[15] only 2% is planted, and most of this is with native species (Ten Broek and Giffen 2018). Under natural conditions, forest types generally occur in predictable patterns associated with climatic gradients and soil conditions determined by glacial deposition (NEFF in press; Legaard et al. 2015). Northern hardwood species predominate across lower hilltops and mid-slopes, with higher site quality. Spruce-fir species predominate on ridge tops, high elevation slopes and poorly drained lowlands. Mixed wood stands commonly occur along ecotones or as a result of successional dynamics following disturbance.

13 Considering just land area, Maine is 89% forested (FIA 2017 data).

14 Data are from the Forest Inventory and Analysis (FIA) Program of the U.S. Department of Agriculture (USDA) Forest Service. Percentages are for forestland, as a percentage of sampled land area, as opposed to total area, which would include area in water. Percent change is measured from the first complete inventory cycle (generally 2002/3 to 2007) to the latest complete inventory cycle (2017 estimates) (NEFF, in press).

15 The FIA Program of the USDA Forest Service annually surveys the country's forests to determine trends in forest area and location; tree species composition, size and health; total tree growth, mortality and removals by harvest; wood production and utilization rates by various products; and forest land ownership. The inventory has recently expanded to collect data on soils, understory vegetation (including invasives), tree crown conditions, coarse woody debris and lichen community composition on a subsample of plots.

Shade-intolerant hardwood species commonly follow intense disturbance. Periodic defoliation by spruce budworm is the most prominent large-scale natural disturbance. Small scale disturbances that result in small canopy gaps such as windthrow and senescence are also common (Legaard et al. 2015; Lorimer and White 2003; Seymour et al. 2002). Managed carefully, in time, these naturally regenerating forests should allow natural structural and successional processes to take place and provide habitat for a full suite of native wildlife species (NEFF in press).

A brief summary of current land use

Virtually all of the forestland in the Western Maine Mountains not specifically set aside for reserves or other conservation purposes is commercially managed for a variety of forest products. About 88% of these managed lands are privately held (NEFF in press). Since the 1990s, the North Maine Woods, including the Western Maine Mountains region, has undergone a dramatic transition in ownership. Large swaths of the region have passed from industrial landowners—who had long-term management goals because their timberland supplied their own mills—to timber investment management organizations, real estate investment trusts and other financial investors, whose investment strategies usually involve holding land for a much shorter period (Irland 2005; Lilieholm et al. 2010; Trombulak and Baldwin 2010). Between 1994 and 2005, forest products industry ownership of forestland declined from 59% to 16%, and the percentage held by investors such as publicly traded real estate investment trusts rose from 3% to 40% (Barton et al. 2012). Today, the majority of the Western Maine Mountains is owned by investors.[16] Some landowners, such as Weyerhaeuser (formerly Plum Creek), have secured rezoning of forestland to allow for resorts and residential subdivisions in remote, lightly settled landscapes (Lilieholm et al. 2010; Hagan et al. 2005). In addition to a shift in ownership, the number of landowners has increased and size of land holdings has decreased significantly in the past two decades (Hagan et al. 2005). For example, the 2.3 million-acre Great Northern Paper ownership of 1989 had been transferred to at least 15 different landowners as of 2005. The impacts of the increased parcelization and turnover of landholdings on biodiversity and connectivity are unclear, but likely to be negative.

Legally conserved lands[17] make up about 29% of the region's area. Forest management is allowed on 20 of this 29%. The remaining 9% is forever-wild or in reserves. Most conserved land that allows timber harvesting is privately held and under conservation easement. It is worth noting that most of Maine's forever-wild acreage is in the Western Maine Mountains, primarily in Baxter State Park, the White Mountain National Forest, The Nature Conservancy's Debsconeag Lakes Wilderness Area, Bureau of Parks and Land's Nahmakanta Ecological Reserve, Mahoosuc Unit and Bigelow Reserve, and additional lands within the 100-Mile Wilderness and the National Park Service's Appalachian Trail Corridor (Schlawin and Cutko 2014). Most of these reserves are centered around mountainous areas. They constitute some of the largest roadless areas in the state and New England (Publicover and Poppenwimer 2002) and contribute to the exceptional resilience of the region.

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[16] As of 2017, predominant landowners in the Western Maine Mountains included Weyerhaeuser, Wagner Forest Management, MacDonald Investment, BBC Land LLC, Katahdin Timberlands and E.J. Carrier (James W. Sewall Company 2017 map of Forest Land Owners of the State of Maine).

[17] Conservation lands include those where forest management can take place (Type 1) and those where extractive uses are not allowed (Type 2). The latter are sometimes termed "forever wild" or "reserve" lands. These lands include places such as Acadia National Park, the National Park Service's Appalachian Trail, federal Wilderness Areas in the White Mountain National Forest and Moosehorn Wildlife Refuge, State Ecological Reserves, many land trust ownerships and much of Baxter State Park (Schlawin and Cutko 2014).

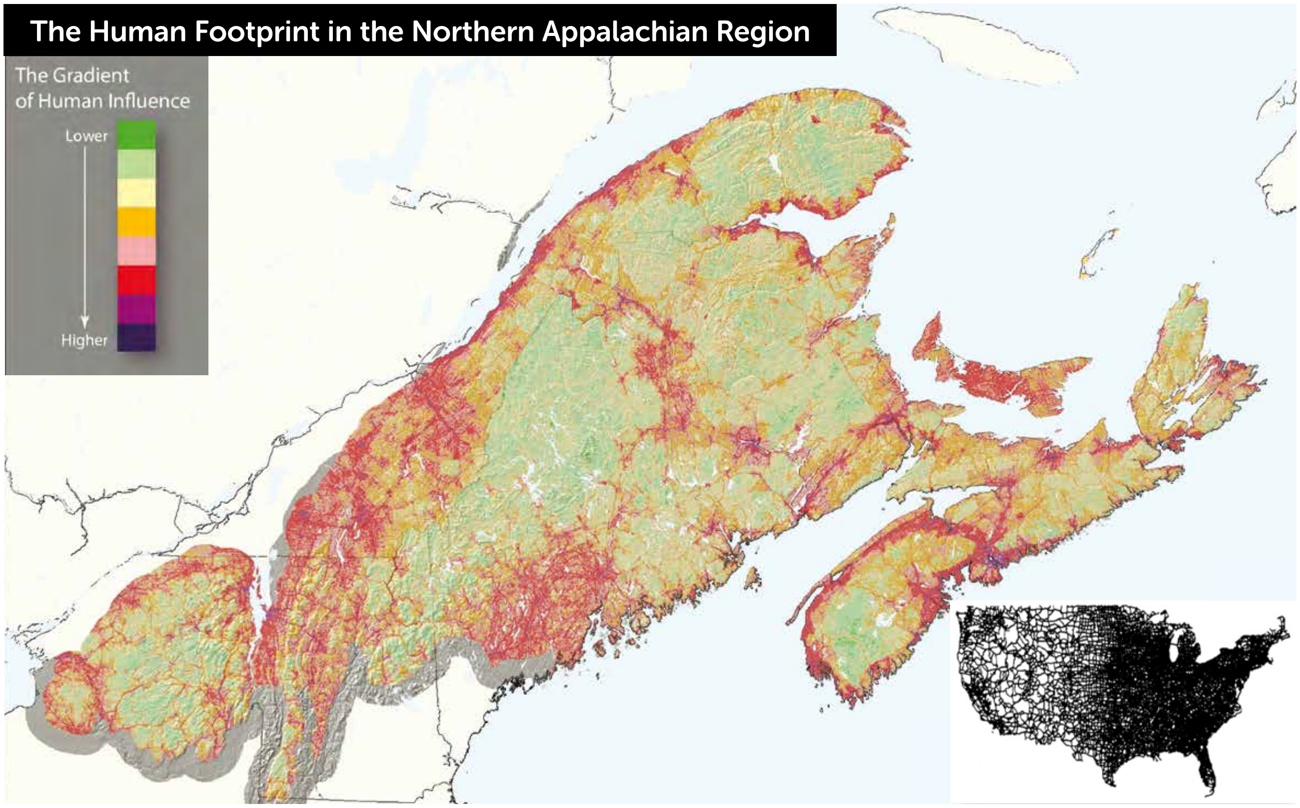

Figure 7. The Human Footprint map of the ecoregion and the map of the U.S. highway system (inset), viewed together, show that the Western Maine Mountains and Maine's North Woods are much less fragmented than any other area in the eastern half of the country. Human Footprint data from Two Countries One Forest, map courtesy of The Nature Conservancy, Maine.

Currently, the Western Maine Mountains region has a far lower density of major permanent roads than more developed areas of Maine, and New England as a whole.[18] The Land Use Planning Commission (2010) estimate of public road density in the unorganized towns was 0.1 miles per square mile compared to an average of 1 to 3 miles per square mile in the organized towns. In settled portions of the northern Appalachians, public road building remains an ongoing process. Baldwin and others (2007) found that approximately 1,200 miles of roads were built in settled landscapes in Maine between 1986–2003, impacting more than 92,000 acres of adjacent habitats. Furthermore, they estimated that regular, public roads in the Northern Appalachian-Acadian Forest Ecoregion as a whole—especially those that provide access to subdivisions, would double by 2013 (Baldwin et al. 2007). The majority (93.5%) of these new roads perform local functions and are short (<1,000 feet in length) residential roads typical of sprawl. Increased permanent road and energy infrastructure development within and along the boundaries of the Western Maine Mountains has the potential to impact tens of thousands of acres through direct habitat loss and edge effects, which will have a significant impact on regional connectivity.

Prior to the 1970s, there were few logging roads in the region. Those that existed were largely primitive and narrow and used for supplying remote logging and sporting camps. This changed when the river drives

[18] Good data on private roads in the unorganized towns are lacking. 2010 estimates from the Land Use Planning Commission indicate that there are on the order of 1,500 miles of public roads and over 20,000 miles of private roads in the unorganized towns.

ended and salvage operations during the spruce budworm outbreak of the 1970s and 1980s began. In 1997, the Maine Department of Conservation estimated that there were ~20,000 miles of private roads on the approximately 10 million acres of unincorporated land in Maine, with an anticipated 500 miles of new road being added each year (Publicover and Poppenwimer 2002; Maine Department of Conservation 1997). If this trend is accurate, based on a simple proportion and not accounting for roads that are reclaimed or abandoned, there would be between 10,000 and 15,000 miles of private logging roads within the five million-acre Western Maine Mountains region today. Aside from major haul roads, most logging roads in the region are low-volume, unimproved, single-lane, dirt or gravel roads without significant, cleared verges. Compared to public roads, these roads receive episodic use from forestry machinery and relatively light use by the public for fishing, hunting and other recreation where these activities are permitted (Alec Giffen, personal communication). Major haul roads such as the Golden Road, Telos Road, and Ragmuff Road receive more use and have a larger footprint and hence a greater fragmenting effect.

The Western Maine Mountains region, along with the Adirondacks, contains the most extensive roadless areas in Maine and the eastern United States (The Nature Conservancy Conservation Gateway). Publicover and Poppenwimer (2002) conducted a detailed inventory of "roadless areas" in the Northeast, which they defined as areas greater than 5,000 acres with no public roads, discernable active private logging roads or areas that have been heavily harvested in the past two to three decades. They estimated that, in 1996–1997, 43 roadless areas in the Western Maine Mountains fit this definition, encompassing about 870,000 acres, 15% of the region. The largest areas were Baxter State Park, the Debsconeag Lakes area and White Mountains National Forest. An additional 55 areas (mostly smaller tracts on private land) were scattered throughout other parts of the state to the north and east. By 2000, the number of roadless areas in the Western Maine Mountains had shrunk to 40 areas encompassing about 720,000 acres (Publicover and Poppenwimer 2006). Currently, the region is estimated to contain 46 such areas encompassing about 603,000 acres,[19] and most areas outside of the Western Maine Mountains have been eliminated due to road building and harvesting over the past two decades (Publicover and Poppenwimer, unpublished data).

Today, although there is an extensive system of logging roads in place, approximately 48% of the region's forest is more than one kilometer (3,300 feet) from the edge of a permanent public or major logging road,[20] which is beyond the distance where the most degrading road "edge" effects occur[21] (Laurance et al. 2002; Laurance et al. 2017).[22] This compares to only 5% of forestland beyond this threshold in southern Maine and a global average of 30% (Haddad et al. 2015) (Fig. 8a and 8b, following pages).

Rural development in the Western Maine Mountains is limited, occurring primarily along the region's southern and eastern edges, on some lake shores, and along permanently paved roads. This development consists primarily of single-family camps and homes, sporting camps, small subdivisions and small businesses, such

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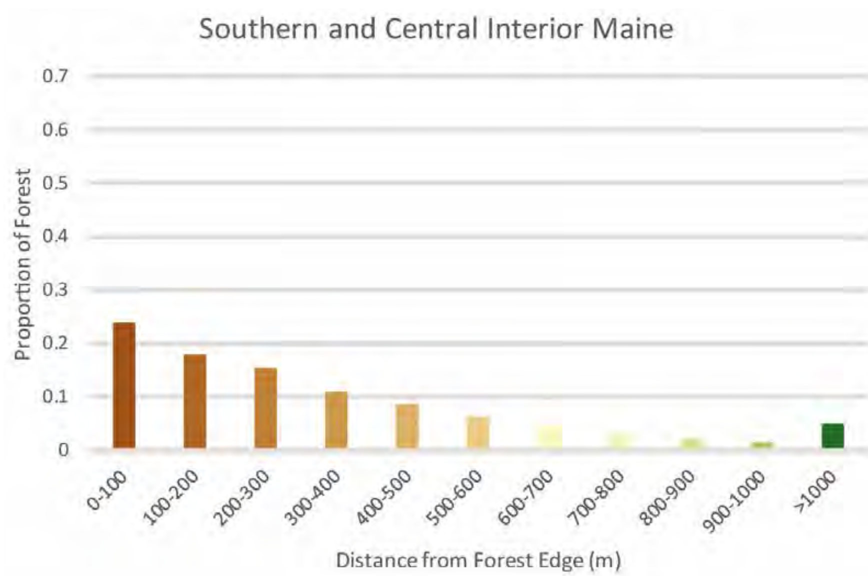
19 In a classic example of fragmentation, the increase in the number of roadless areas is due to several formerly large contiguous areas being separated into multiple much smaller areas.

20 The E911 roads dataset used here is the most comprehensive statewide dataset for permanent roads. It includes all public and major private roads in organized towns and should be a reasonable indicator of major/permanent roads in the North Maine Woods (Daniel Coker, senior spatial scientist, The Nature Conservancy, personal communication). It was not possible to determine which smaller roads were included or excluded.

21 See page 17 for a fuller discussion of edge effects.

22 The area included in the Western Maine Mountains region for purposes of this analysis include nearly all of the Central-Western–White Mountains biophysical section and approximately one third of the St. John Upland biophysical section, as defined in Bailey (1995).

as general stores. The only major highways in the region are Route 201, Route 6/15 and Route 16/27. There are no major transmission lines crossing the undeveloped portions of the Western Maine Mountains north of Indian Pond. Six wind farms have been constructed in the southwestern portion of the region (U.S. Energy Information Administration 2017).[23] Between 2007 and 2017, approximately 116,000 acres (0.6%) of Maine's forest were converted to nonforest land uses. The Western Maine Mountains lost an estimated 12,000 acres during this period (NEFF in press).



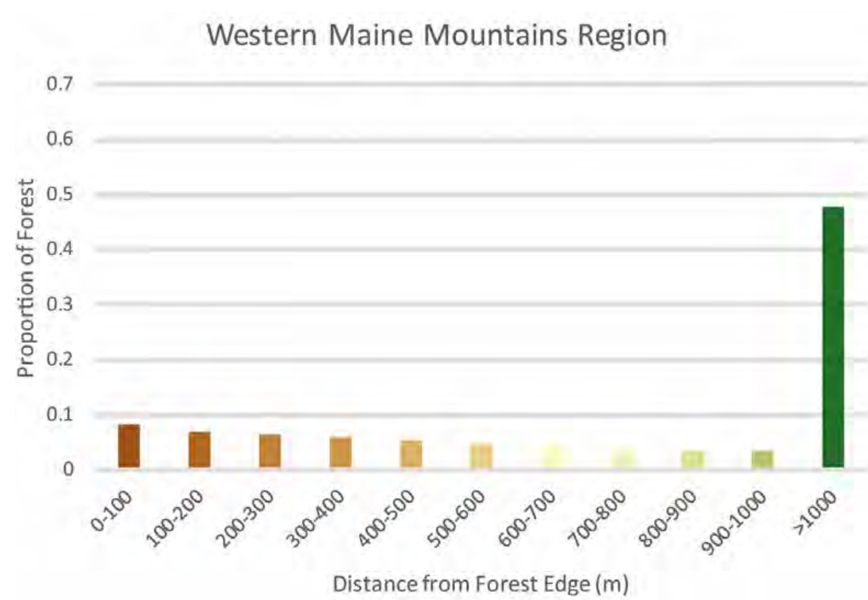


Figure 8a. Comparative percentage of distance to edge in southern and central interior Maine and in the Western Maine Mountains region based on data reflected in Figure 8b, following page. Analysis courtesy of The Nature Conservancy, Maine.

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23 As of 2017, wind farms in the region include Kibby and Chain of Ponds, Bingham Wind, Record Hill, Saddleback Ridge, Spruce Mountain Wind and Canton Mountain (U.S. Energy Information Administration 2017).

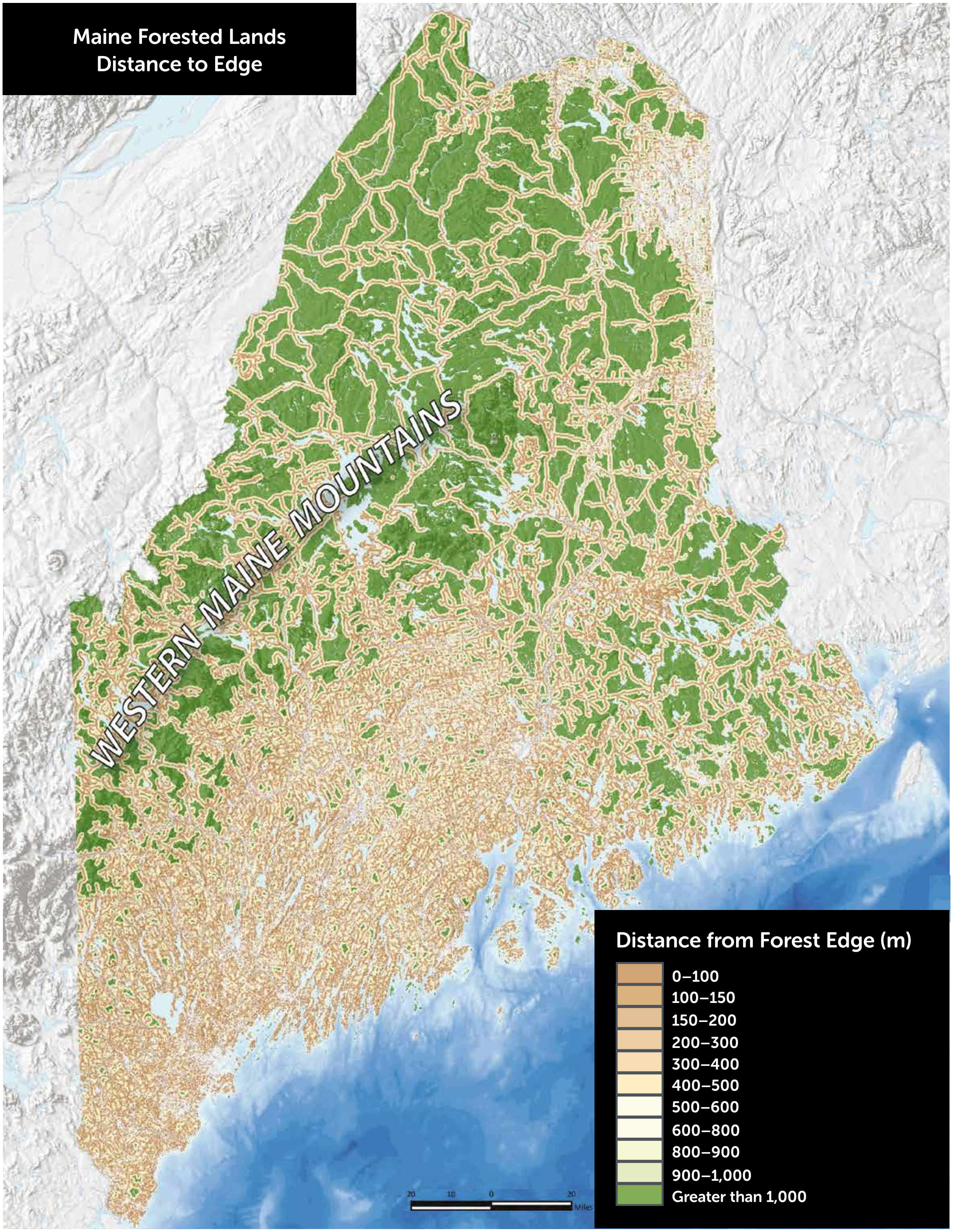

Figure 8b. Habitat blocks (green) and major roads are shown. Forest distance from an edge varies dramatically from northern Maine to southern Maine. Analysis and graphic courtesy of The Nature Conservancy, Maine.

A SUMMARY OF FOREST FRAGMENTATION IMPACTS

Forest fragmentation defined

Forest fragmentation is often defined as the breaking apart of forested landscapes into smaller and more isolated pieces. Implicit in this definition are changes in habitat patch size and distance between patches, as well as changes in the condition of the surrounding forest. These changes typically occur simultaneously and continuously, resulting in a large cumulative impact over time. However, it is a much more complicated process than this. In the Western Maine Mountains, fragmentation is largely caused by permanent features such as public roads, subdivisions and energy infrastructure. These features not only reduce the total amount of forest in a landscape, but they alter the environment in adjacent habitat because of edge effects. Fragmenting a forest landscape significantly increases the amount of forest edge next to a road, clearing or other fragmenting feature, which, in turn, greatly increases the total amount of land impacted. In addition, connectivity is impacted by the quality of habitat that remains in the surrounding forest. The extent that this forestland retains habitat value and is "permeable" to the movement of plants and animals depends on how it is managed and the species in question.

Forest fragmentation has the potential to compromise the Western Maine Mountains' biodiversity and connectivity and to drive ecological processes beyond the range of natural variability (Rowland et al. 2005). Different species are affected by fragmentation in different ways, depending on biological attributes such as habitat specialization, niche specialization, home range size, dispersal ability, mobility and a host of other factors (Lindenmayer and Fischer 2006). Some effects are immediate and local in extent while others occur at a landscape scale and are cumulative, playing out over decades or more. Other effects may be temporary, such as clearings created by timber harvests, or relatively minor, such as impacts associated with narrow, lightly used woods roads.

Research in Maine, the Northeast, and around the world demonstrates unequivocally that forest fragmentation—whether permanent or temporary—reduces native biodiversity and regional connectivity over time. A review of the literature indicates that fragmentation negatively affects terrestrial and aquatic ecosystems in a number of ways. The most severe effects, which are caused by roads, energy infrastructure, subdivisions and other permanent forms of fragmentation include:

- increased mortality and habitat loss from construction of roads and other fragmenting features
- increased mortality and other direct impacts associated with infrastructure after construction
- changes in species composition and reduced habitat quality from edge effects
- changes in species composition and behavior as habitat patch size delines[24]
- changes in hydrology and reduced aquatic connectivity
- introduction and spread of exotic species
- changes in the chemical environment
- pressures on species resulting from increased fishing, hunting, and foraging access
- loss of scenic qualities and remote recreation opportunities

In addition, forest management can have transitory fragmenting effects, such as acting as a barrier for species that need large connected areas of mature forest to thrive. New research suggests that this may compromise the ability of managed forestland to function as habitat or an ecological linkage for some species (see for example, Simons-Legaard et al. 2013).

24 The terms "habitat patch," "patch," and "fragment" are used interchangeably in this paper.

Although each of these impacts are described separately on the following pages, they are interrelated and occur to varying degrees depending on the type of fragmenting feature, whether the feature results in permanent loss of habitat, the time elapsed since fragmentation began, and the habitat requirements of the species involved. It is essential to keep in mind that fragmentation is a continuous and cumulative process where the impacts of many smaller fragmenting features combine to create a large and often unpredictable regional impact, resulting in ongoing environmental degradation and species loss over time.

Mortality and habitat loss from construction of roads and other human infrastructure

Construction of roads, utility corridors and other human infrastructure kills any sessile or slow-moving animal and all vegetation in the path of the feature (Trombulak and Frissell 2000). Direct habitat loss from the footprint of these features can be significant. New projects have the potential to significantly increase the rate of fragmentation in the region. For example, the proposed New England Clean Energy Connect Project would destroy nearly 1,000 acres of wetland and forest habitat in the Western Maine Mountains, and edge effects from the permanently cleared utility corridor and access roads would increase the impacted area by an additional 13,000 acres, assuming a 1,000-foot edge effect on either side). In addition, during the 1–2 year construction period, an estimated 500 acres would be needed for roads and staging areas and additional wetlands would be filled. Other documented impacts of roads and utility corridor construction include elevated mortality of trees and other species in the adjacent forest, mortality of soil biota from physical changes in the soil under and adjacent to the roads, mortality of aquatic species from direct transfer of sediment into nearby streams and wetlands, and avoidance and other changes in behavior due to vehicle noise and light (Trombulak and Frissell 2000; Laurance et al. 2002; Laurance et al. 2017; Charry 2007).

Mortality and other impacts of infrastructure after construction is complete

Mortality of animals from road collisions is well documented (Van der Ree et al. 2015; Charry 2007; Trombulak and Frissell 2000). Roads and other linear infrastructure negatively impact wildlife through increased mortality, decreased habitat amount and quality, changing species movement patterns, and fragmentation of populations into smaller subpopulations, which are more vulnerable to local extinction. Roads are considered a driving factor in the decline of many species globally, from moose and grey wolves to insects and other invertebrates (Van der Ree et al. 2015; Benitez-Lopez et al. 2010; Andrews et al. 2008; Glista et al. 2007; Muñoz et al. 2015). They can also impede restoration efforts. For example, a 1989–1992 effort to reintroduce Canada lynx to New York state failed because the released lynx were largely transient and suffered high road mortality throughout the region (Daniel Harrison, professor of wildlife ecology, University of Maine, personal communication).

Figure 9. Canada lynx crossing road. Road collisions can be a major cause of lynx mortality. Photo by Jeremiah John McBride, CC BY-ND 2.0, https://www.flickr.com/photos/bullfrogphoto/3411471411.

In Maine and elsewhere, research indicates that amphibians and reptiles are particularly susceptible to roadkill because many species, such as wood frogs and spotted salamanders, migrate between wetlands where they breed and uplands where they live during the nonbreeding season. In addition, individuals are generally inconspicuous and sometimes slow-moving, and in the case of turtles, it takes a long time for individuals to become sexually mature—which increases the likelihood that animals will be killed by collision before they are able to reproduce, and young are vulnerable after hatching (Baldwin et al. 2007; Gibbs and Shriver 2002; Rosen and Lowe 1994; Fahrig et al. 1995). Road size, density and traffic volume and distance from wetlands, streams and pools affect the magnitude of these impacts. For example, dense networks of wide roads with high traffic volume can have significant impacts on breeding populations of turtles. Roads are the major cause of decline of spotted and Blandings turtles in southern Maine (Beaudry et al. 2008) and are contributing to the decline of wood turtles in the state, since these species move from streams to uplands to nest (Compton 1999). According to Gibbs (2002), "as little as 2–3% additive annual mortality is likely more than most turtle species can absorb and still maintain positive population growth rates."

Figure 10. Wood turtle crossing road. Declining turtle populations in many parts of Maine are attributed to road collisions. Photo by John Mays.

In addition to direct mortality, roads and utility corridors may serve as conduits for the movement of organisms across the landscape that are detrimental to native forest species—fostering the spread of alien plants and predators, or as a barrier or filter that prevents or impedes the movement of some sensitive species (Forman and Alexander 1998). For example, white-footed mice and some other rodent species are reluctant to cross roads (Merriam et al. 1989; Oxley et al. 1974). Others, such as black bears, have been documented to shift their home ranges away from areas with high road densities, and some predator and prey species may preferentially travel along road corridors, increasing the risk of collision and altering predator-prey interactions (Brody and Pelton 1989; Trombulak and Frissell 2000). Highly fragmented landscapes that result in unsuitable habitat around ponds at distances greater than 3,300 feet (1 kilometer) can preclude the recolonization of pools by amphibians and result in local extinctions of other wetland-dependent taxa, including small mammals, nonbreeding amphibians, and reptiles (Laan and Verboom 1990; Gibbs 1993). DeMaynadier and Hunter (2000) found that salamander populations avoid crossing wide (~40 feet) heavily used logging roads, while the impacts of narrow (<16 feet) woods roads were insignificant. Hung culverts and other drainage infrastructure associated with roads can also act as barriers, preventing upstream fish passage and access to breeding and feeding habitat for aquatic species. This is discussed further under aquatic connectivity.

As energy infrastructure expands in the Northeast and elsewhere, additional impacts are becoming apparent, such as avian and bat collisions with transmission lines and wind turbines; altered reproductive success and physiology of insects, mammals, birds, trout, and other species groups associated with electromagnetic radiation; loss of roosting sites; and altered movement patterns (Rytwinski and Fahrig 2015, Smallwood 2013; Jochimsen et al. 2004; Fensome and Matthews 2016; Van der Ree et al. 2015). In addition to direct collisions, there is growing evidence that electromagnetic radiation from transmission lines can have significant impacts on wildlife. For example, Fernie and Reynolds (2005) conclude that exposure of birds to electromagnetic radiation "altered the behavior, physiology, endocrine system, and the immune function of birds, which generally resulted in negative repercussions on their reproduction or development. Such effects were observed in multiple species, including passerines, birds of prey, and chickens in laboratory and field situations, and in North America and Europe." Long-term and before-and-after studies are needed on other species groups.

Changes in species composition and reduced habitat quality from edge effects

When a forest is fragmented by a road, clearing or other disturbance, there will be a zone of impact along the forest edge.[25] Edge habitat is typically windier, warmer, and drier than the forest interior (Hunter and Gibbs 2007). The extent of this "edge effect" is greater along high contrast edges—such as between a utility corridor and a forest, than along low contrast edges—such as between a regenerating clearcut and adjacent uncut forest. The relative amount of edge increases as patches become smaller and more complex in shape (Fig. 11a and Fig. 11b). The amount of edge is also greater for long narrow clearings, such as roads and utility corridors, than for more compact clearings of the same size, such as clearcuts.

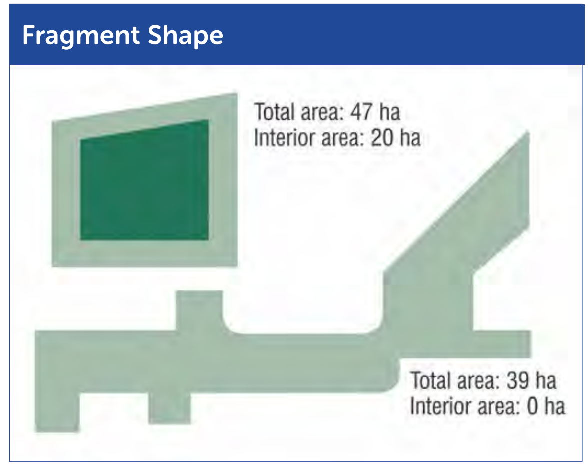

Figure 11a. Shape affects the percent of area affected by edge effects, as is shown by a comparison of the interior area available in two different shaped blocks of land. Adapted by Barbara Charry for Maine Audubon, from Verner et al. Wildlife 2000 1986, reprinted by permission of Wisconsin Press.

The habitat lost or altered by edge effects can be many times greater than the footprint of the fragmenting feature itself (Laurance et al. 2017; Harper et al. 2005; McGarigal et al. 2001; Tinker et al. 1997). The longest-running forest fragmentation study from the Amazon indicates that the impact zone of fragmenting features such as permanent roads can extend from 30 feet to more than 1,300 feet into adjacent forestland (Laurance et al. 2002; Laurance et al. 2017). Increased insolation, changes in air temperature and humidity, altered plant, animal and microbial species composition, species invasions, and a host of other edge effects were observed. South of the Western Maine Mountains, most forests are well within the range where human activities, altered microclimate, and nonforest species may influence and degrade forest ecosystems. Here, habitat fragmentation often leads to the establishment of early successional habitat along forest edges because plants adapted to interior mature forest conditions typically have low dispersal capacities compared to disturbance-adapted "weedy" plants (Harper et al. 2005). This favors generalist species at the expense of forest interior species. In the United States, there is a great body of research that documents the impacts of development and edge habitat on birds (see reviews by Forman and Alexander 1998, Lindenmayer and Fischer 2006, and Van der Ree et al. 2015). For exam-

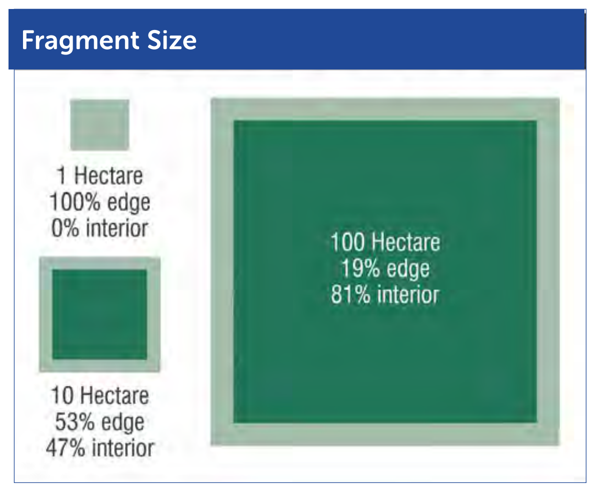

Figure 11b. Size affects the percent of interior area affected by edge effects, as shown in this comparison of the interior area of three different sized blocks. As fragment (block) size increases, the relative proportion of edge habitat decreases and interior habitat increases. Adapted by Barbara Charry for Maine Audubon, from Landscape and Urban Planning (36) Collinge, pg. 64, reprinted with permission from Elsevier Science.

25 The edge of a habitat patch can be broadly defined as a marginal zone where the microclimatic and other ecological conditions differ from the those in the patch's interior (Lindenmayer and Fischer 2006; Matlack 1993).

ple, the decline of many ground-nesting, forest-interior species in the Northeast, such as the ovenbird and wood thrush, have been attributed to increased predation pressure from raccoons, cats and other generalist species that thrive along forest edges (Ortega and Capen 1999; De Camargo et al. 2018). Increased nest predation and reduced reproductive success can extend more than 2,000 feet into the adjacent forest. Other forest species, such as interior-forest–feeding bats, are affected by changes in insect prey, roosting habitat and other habitat features in forest edges (Grindal and Brigham 1998). The relationship between edge effects and patch size is complicated. Rosenberg et al. (1999) found that tanager species respond differently in different parts of their range and that landscape features interact to create population sources and sinks. The more continuity of forest cover and presence of many forest age classes on the landscape may reduce some species' sensitivity to edge effects.

The following table (Fig. 12) provides a summary of penetration distances of different edge effects associated with permanent fragmenting features documented from a 22-year experiment on forest fragmentation in the Amazon (Laurance et al. 2002; Laurance et al. 2017). Although analogous studies have yet to been done in the Northeast, there is abundant evidence that many of these edge effects are contributing to species declines and extinctions in the region (see reviews by Pfiefer et al. 2017 and Harper et al. 2005). One type of edge effect—invasion by exotic species—is discussed in more detail on page 22.

Disturbances that penetrate > 100 m	Disturbances that penetrate 50–100 m	Disturbances that penetrate 20–50 m
Increased wind disturbance	Reduced soil moisture	Higher understory foliage density
Elevated tree mortality/damage	Lower canopy-foliage density	Increased seedling growth
Invasion of disturbance-adapted butterflies	Increased air temperature	Invasion of disturbance-adapted plants
Altered species composition of leaf-litter ants	Increased temperature and vapor pressure deficit	Lower leaf relative-water contents
Invasion of disturbance-adapted beetles	Reduced understory bird abundance	Lower soil moisture content
Altered species composition of leaf-litter invertebrates	Elevated litter fall	Higher vapor pressure deficit
Altered abundance and diversity of leaf-litter invertebrates	Increased photosynthetically active radiation in understory	Higher leaf conductance
Altered height of greatest foliage density	Lower relative humidity	Increased phosphorus content of falling leaves
Lower relative humidity	Increased number of treefall gaps	Reduced density of fungal fruiting bodies
Faster recruitment of disturbance-adapted trees		
Reduced canopy height		

Figure 12. Documented Edge Effects Associated with Permanent Fragmenting Features from the Biological Dynamics of Forest Fragments Project. (Adapted from Laurance et al. 2002; Laurance et al. 2017.)

Although the Western Maine Mountains region has an estimated 10,000 miles of logging roads, the edge effects along most of these are less than that of typical roads in developed parts of the state because of lower traffic volumes, narrower road widths, unpaved surfaces, limited verge clearing and because some roads are gated when not in use. Nevertheless, studies in other areas suggest the cumulative impact of logging road networks can be significant (McGarigal et al. 2001; Forman and Alexander 1998). While the pace of private road construction has likely slowed as landowners have their modern transportation network mostly built out and some older roads have been abandoned, others are being replaced with newer, better and likely larger surfaces. The only place where road density is decreasing is in designated reserves where public agencies and conservation organizations have worked to close roads. More information is needed to evaluate the overall impacts of the logging road system on forest fragmentation in the region.

Changes in species composition and behavior as habitat patch size declines

A habitat patch is a relatively homogeneous habitat area that differs from its surroundings. Hunter and Gibbs (2007) give three main reasons why large habitat patches have more species than small ones. First, a large patch will almost always have a greater variety of environments than a small fragment, and each will provide niches for different species. Second, a large patch is likely to have both common and uncommon species, but small fragments are likely to have only common species. For instance, species with larger home ranges, such as black bear or bobcat, are unlikely to survive in smaller fragments. Finally, small fragments will, on average, have smaller populations that are more susceptible to being extirpated than a large population.[26]

Habitat requirements are species-specific. In Maine, patch size appears to be particularly critical for species associated with mature forest conditions, larger patch sizes and forest interiors. Many Maine birds, such as red-shouldered hawk, black-throated blue warbler, Canada warbler, ovenbird and wood thrush, require hundreds of acres of continuous, relatively closed-canopy forest to reproduce successfully, as do mammals with large home ranges, such as moose, bobcat, black bear and American marten (Charry 1996; Askins 2002). For example, Chapin et al. (1998) found that resident American martens established home ranges in areas where median intact forest patch size ranged from 375 to 518 acres, for males and females respectively. These area-sensitive and habitat specialist species will start disappearing when the size of habitat blocks falls below a certain threshold (Askins 2002; Blake and Karr 1984; Whitcomb et al. 1981). Roads, clearings, residential development and other features can act as barriers, preventing animals from using habitat that is nearby for breeding or feeding. Populations can become subdivided, and eventually animal species are lost from an area as it gets too small to support an isolated population, or is too far from a source population for recolonization to occur (Lindenmayer and Fischer 2006; Charry 1996; Forman and Alexander 1998; Laurance et al. 2017; and others). Conversely, species sensitivity to fragmentation may be lower in regions with greater overall forest cover (Rosenberg et al. 1999).

Hanski (1998) hypothesizes that when the total amount of suitable habitat in the landscape falls below 20–30%, the viability of local populations is reduced. Other studies suggest that population declines accelerate when available habitat falls below even higher thresholds (Andrén 1994). For example, Homan et al. (2004) found that wood frogs were less likely to occupy breeding pools where the amount of suitable forest habitat

[26] In 1967, MacArthur and Wilson put forward the groundbreaking theory that island size and degree of isolation are highly correlated with biodiversity. Hunter and Gibbs observed that while island biogeography theory does not always directly apply to terrestrial landscapes, it provided insights fundamental to understanding the effects of reducing patch size and connectivity in terrestrial landscapes.

within approximately ~3,300 feet (1 kilometer) was less than 45% and spotted salamanders were less likely where forest habitat within ~1,150 feet of a pool was less than 40%.

Forest fragmentation also influences plant populations. In their *State of the Plants* report, the New England Wildflower Society (2015) documented a mean 67% loss of previously recorded range for 71 rare plant species. One of the main contributing factors was fragmentation of habitat across species' ranges, which isolated populations and reduced their ability to disperse.

Small size combined with increased isolation of habitat patches can also affect behavior, biology and interactions of species. Impacts include reduced breeding success, changes in predator-prey relationships, changes in ability to disperse and increased competition for resources (Lindenmayer and Fischer 2006). For example, before their demise as a result of chestnut blight, it was believed that stands of American chestnut needed to be above a certain size to produce enough seed to overcome pressure from seed predators (Rosenzweig 1995; Lindenmayer and Fischer 2006).

Changes in hydrology and reduced aquatic connectivity

Fragmentation of terrestrial habitats often leads to fragmentation of river and stream networks. The division and isolation of watersheds and stream networks by dams, roads and culverts is one of the primary threats to aquatic species in Maine and the United States (Martin and Apse 2011). Intact forested blocks are essential to protecting stream networks. Forested stream corridors intercept sunlight, moderating water temperature (Moore et al. 2005). Riparian trees also contribute the majority of coarse organic material, in the form of leaves and downed wood, and fallen leaves frequently form the base of the food webs of small streams (Vannote et al. 1980). Large woody material generated from large fallen trees adjacent to streams has a major influence on stream ecosystem structure and function (Dolloff and Warren 2003).

The impact of aquatic fragmentation on aquatic species generally involves loss of access to quality habitat for one or more life stages of a species. For example, dams and impassable culverts prevent brook trout populations from reaching upstream thermal refuges, which are critically important as the climate warms. In addition, roads can have significant effects on the physical environment. Roads can interrupt subsurface flows and patterns in aquatic systems when water flows are rerouted into road ditches and culverts (Lindenmayer and Fischer 2006; Forman and Alexander 1998). The impervious nature of roads increases runoff, erosion, sedimentation and water-level fluctuations, and can flood adjacent wetlands (Andrews et al. 2008; Al-Chokhachy et al. 2016). Temporary pools in ditches and ruts can be population sinks for amphibians that breed there instead of higher quality vernal pools (Andrews et al. 2008).

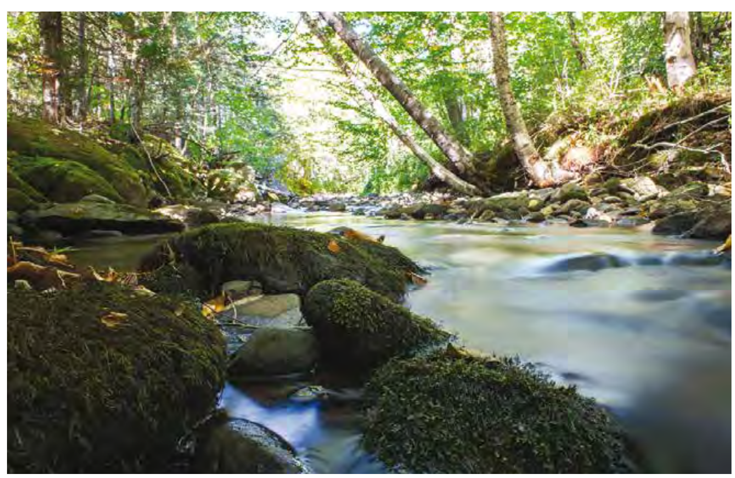

Figure 13. Cool mountain streams, like this one in the High Peaks region of the Western Maine Mountains, provide critical habitat for brook trout and other coldwater species. Photo by Charlie Reinertsen Photography.

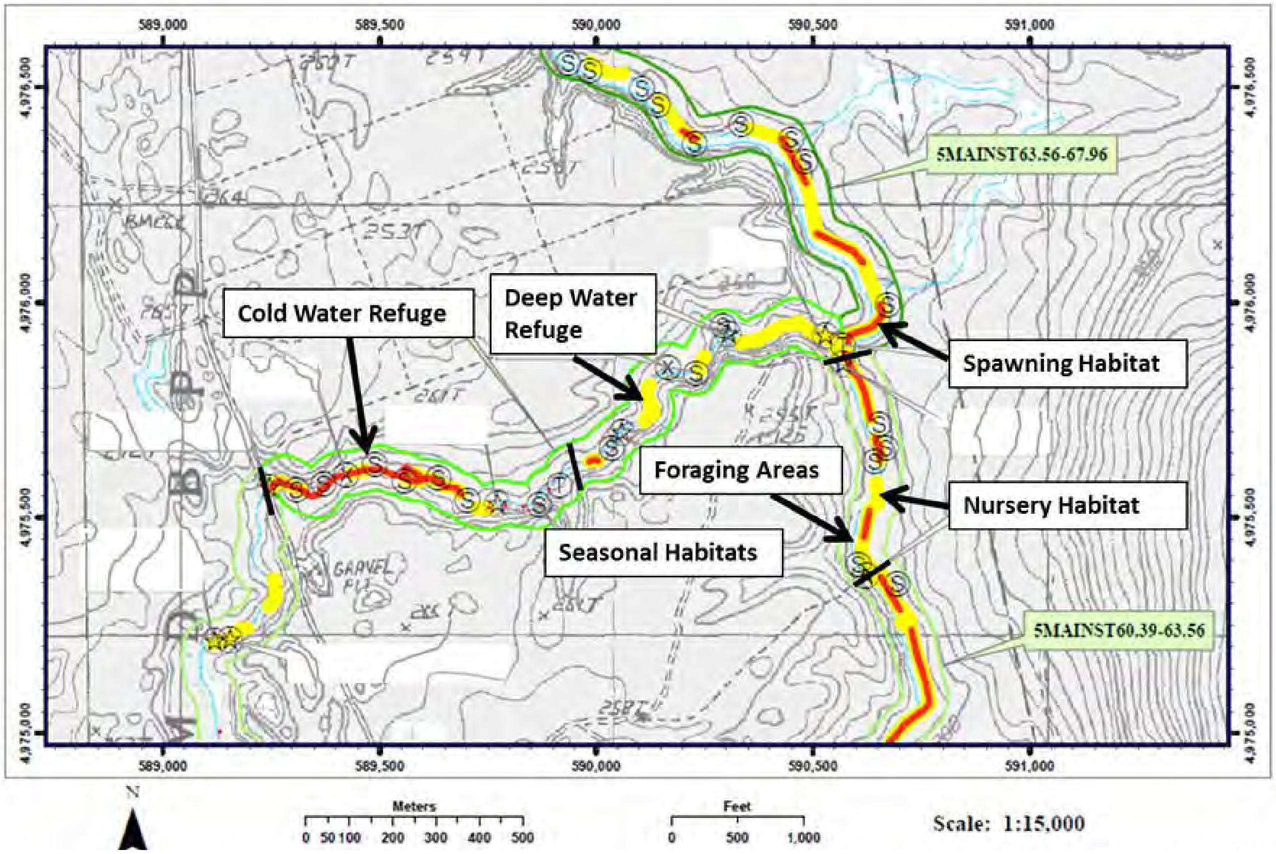

Figure 14. Fish need to move: brook trout use a variety of in-stream habitats to meet their daily and annual needs for feeding, resting and breeding. They often move up and down streams and into tributaries to find food and refuge. Graphic modified from the Maine Atlantic Salmon Atlas (2006) by Alex Abbot and the U.S. Fish and Wildlife Service's Gulf of Maine Coastal Program.

A bellwether species in the Western Maine Mountains is brook trout, which requires cool, clean, connected networks of streams and lakes (Fig. 14). A 2006 range-wide study of this species found that Maine is the only state in the eastern United States with extensive intact populations of wild, self-reproducing brook trout in lakes and ponds. Furthermore, Maine is the last true stronghold for stream-dwelling populations of wild brook trout, supporting more than twice the number of intact subwatersheds than the other sixteen states in their eastern range combined (Trout Unlimited 2006). Although wild brook trout waters are found elsewhere in northern Maine, they are most prevalent in the Western Maine Mountains (Trout Unlimited 2006; DeGraaf 2014). The high habitat integrity of the region is due to a combination of cool temperatures and an abundance of large, connected stream networks. The cooler region provides optimal conditions, with fewer competing, nonnative fish species than the southern or coastal parts of the state. Large patch size of intact brook trout habitat allows fish to migrate to cooler water when portions of their habitat grow too warm.

The Nature Conservancy's Conservation Gateway maps show a region with few dams and high stream connectivity. This is not the case for much of southern Maine, where many public- and private-road stream crossings in the region do not meet recommended standards.[27] Maintaining aquatic connectivity is critical to

[27] These include: (1) spanning the entire width of the natural stream; (2) setting the elevation to match the natural stream; (3) matching the slope to the natural stream; and (4) ensuring that the stream bed is made up of natural materials (see Maine Department of Transportation and www.maineaudubon.org/projects/stream-smart).

maintaining brook trout populations in northern Maine (Trout Unlimited 2006; Fesenmyer et al. 2017; Coombs and Nislow 2014). Conserving habitat for this umbrella species, in turn, will ensure the survival of other plants and animals that require pristine aquatic habitats.

Introduction and spread of exotic species

Invasion by exotic plant species is a common and widespread impact of fragmentation that can result in displacement of native species. In general, non-native invasive plant species thrive in disturbed and early successional habitats. Invasive plants can become established in roadside ditches, along utility corridors, on soils disturbed by residential or commercial development and on soils disturbed by timber harvests that border developed areas. In addition, seeds can be introduced in road fill and through planting of exotic ornamental species. Common traits of invasives include rapid growth, light and drought tolerance, bird-disseminated seeds, and the ability to outcompete native plants (Webster et al. 2006).

Invasive non-native woody plant species have the potential to profoundly alter the structure and function of forest ecosystems. Invasive woody and herbaceous plants rapidly colonize forest edges and may penetrate more than 330 feet into the forest interior, altering or eliminating habitat for native plants (Charry 1996). Wetland and aquatic invasives pose a similar threat in wetland and aquatic ecosystems. Because many invasive plant species have the ability to form dense monocultures, they have a competitive advantage in forest understories, particularly in edge habitat. In addition, most species have relatively few—if any—natural predators in their introduced ranges (Webster et al. 2006; Woods 1993). Other impacts include changes in soil chemistry and biota—which may suppress native tree regeneration—and reduced or eliminated foods used by pollinators, fruit and seed eaters and herbivores (Silander and Klepeis 1999; Charry 1996; Webster et al. 2006; Burnham and Lee 2010; Ehrenfield et al. 2001; Heneghan et al. 2006; Hunter and Mattice 2002).

Large forest blocks appear to resist woody plant invasions better than land that has a history of agricultural or residential use (Mosher et al. 2009). The resistance of large intact forest blocks to invasion probably stems from two main factors: the deep shade created by mature trees and the buffering effect of large block size, which serves to isolate interior portions of the forest from invasive seeds. If present land use trends continue, increased fragmentation of forest parcels may allow edge-adapted invasive plants such as glossy buckthorn, oriental bittersweet, Japanese barberry, and bush honeysuckles to get a deeper foothold into forest blocks. Eventually, this could allow woody invaders to take advantage of disturbances such as logging within the major forest blocks of the region, displacing native species as a result (Mosher et al. 2009; Webster et al. 2006; Silveri et al. 2001).

Figure 15. Oriental bittersweet infestation in Cape Elizabeth, Maine. Photo from Maine Natural Areas Program, Maine.gov.

Many terrestrial invasive plant species and wetland invasives, such as purple loosestrife and phragmites, are already well established in southern Maine and have expanded to the edges of the Western Maine Mountains (*iMapInvasives Database*). These species thrive in utility corridors and roadside ditches (Fig. 16). With roughly one third of Maine's flora comprised of non-native plant species (and most of these already established in the southern part of the state), the cause-and-effect relationship between fragmentation and the establishment of non-native plant species poses a significant threat to native species and habitats in northern Maine (Mosher et al. 2009; Charry 1996).

Figure 16. Phragmites, an invasive exotic grass, established along a southern Maine highway. Photo by Janet McMahon.

Woody invasive plants are part of a much larger invasion of alien species of plants, insects, and disease that has the potential to fundamentally alter the composition and structure of eastern forests (Webster et al. 2006). Invasions by insects such as emerald ash borer, Asian longhorn beetle, and browntail moth are tied to both inadvertent transport by people and climate change. The relationship between the spread of these species and forest fragmentation is unclear, although new roads will increase the likelihood of transport by people and vehicles into the region.

There is currently a low incidence of terrestrial invasives in the Western Maine Mountains, although invasive plant species are established along the southern border of the region. No aquatic invasive plant species, invasive insect pests or invasive tree species, such as Norway maple and black locust, are currently documented in the Western Maine Mountains. Three invasive herbs have been confirmed in the interior of the Western Maine Mountains and sixteen invasive herbs and shrubs have been confirmed at the region's margin, primarily in developed areas[28] (*iMapInvasives Database*) (Fig. 17, following page). Fragmentation from major utility corridors, roads and new residential and commercial development has the potential to open the region to these and other invasives.

[28] MNAP lists 68 species of invasive plant species that are currently documented in Maine or are probable. I reviewed MNAP's *iMapInvasives Database* to determine presence/absence of all documented species in the region. The three species confirmed in the Western Maine Mountains' interior include reed canary grass, common reed and coltsfoot. Because field effort in the region is low compared to other parts of the state, invasive species occurrences may be under-reported. I have not surveyed the Western Maine Mountains systematically, however, my observations in areas visited suggest that most terrestrial invasive plant species are absent or rare, especially in the region's interior.

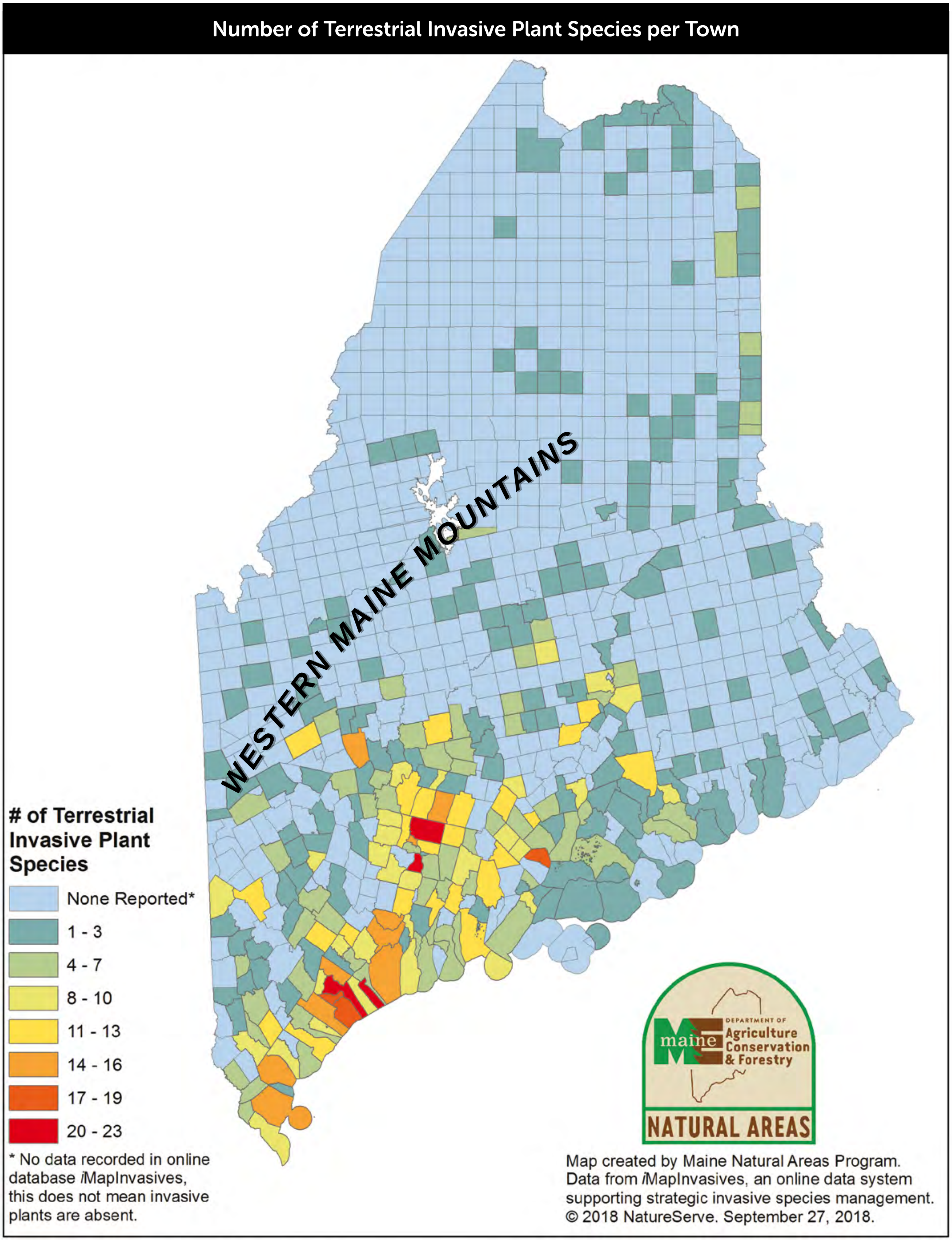

Figure 17. Documented terrestrial invasive plant species in Maine. The Western Maine Mountains are relatively free of terrestrial plant species. Fragmentation from major utility corridors, roads and new residential and commercial development has the potential to open the region to these invasives. Map courtesy of the Maine Natural Areas Program in the Maine Department of Agriculture, Conservation and Forestry.

Changes in the chemical environment

Use and maintenance of roads, utility corridors and windfarms contribute at least five different general classes of chemicals to the environment: heavy metals, salt, organic molecules, ozone and nutrients (Trombulak and Frissell 2000). These are mostly derived from fuel additives, deicing salts and herbicides. Contamination of soils, plants and animals can extend tens to hundreds of meters from a road or power line right of way depending on the contaminant, wind, and if the chemicals reach flowing water. Trombulak and Frissell summarize a number of impacts on plants and animals, such as the poisoning of habitats so they no longer have adequate carrying capacity, mortality or reduced health and growth from exposure, bioaccumulation of chemicals that makes species toxic to predators and increased concentrations of salts that can attract large mammals to roadsides, increasing vehicle collision risk. The high skin permeability of amphibians make them particularly susceptible to toxins from road salts and other chemicals (Andrews et al. 2008).

Pressures on species resulting from increased fishing, hunting and foraging access

Increased road density and access into remote areas can lead to increased hunting, trapping, fishing, poaching, disturbance to wildlife, trampling and other direct human impacts on biodiversity in forest and aquatic ecosystems (Laurance et al. 2002 and 2017; Haddad et al. 2015; Brocke et al. 1988). A study of the relationship between density of publicly accessible roads and moose populations in Nova Scotia found that natural populations declined when road density exceeded a threshold of 0.6 km/km^2 (~1.4 mi/mi^2). This was attributed to the fact that most moose hunting occurred along roads (Beazley et al. 2004). They concluded that road density may be among the key factors influencing habitat productivity, and thus critical habitat area and population viability, for moose in mainland Nova Scotia, as well as for other species sensitive to the effects of roads, such as Canada lynx, American marten and black bear.

The USDA Forest Service has found that illegal introduction and harvest of fish species are more likely to occur in areas with ready access (Gucinski et al. 2000). Increased road density and improved access into remote ponds have been linked to regional declines of lake trout and introduction of invasive fish species such as smallmouth bass in northern Ontario (Kaufman et al. 2009). In Maine, unauthorized introductions of invasive fish species, such as small and largemouth bass, are threatening native fish species populations—especially brook trout—and can ultimately impact entire aquatic systems. In the past, the majority of introductions occurred in populated portions of the state, but in the past decade, introductions are occurring at a higher rate in western and northern Maine where most of the state's wild brook trout populations are located. Improved road access and development are likely contributing factors (Merry Gallagher, research fisheries biologist, Maine Department of Inland Fisheries and Wildlfe, personal communication). Increased access is also likely to lead to overharvesting of species such as chaga, ginseng and ramps that are collected for food, medicine and other purposes.

Loss of scenic qualities and remote recreation opportunities

Maine has a long tradition of hunting, fishing, guiding and remote camping that is closely bound to the undeveloped and scenic character of its northern forests, lakes and mountains. These uses are a major and growing economic driver in northern Maine (David Publicover, senior staff scientist, Appalachian Mountain Club, personal communication). Degradation of the skyline caused by utility corridors, major road right of ways, sprawl from development, wind farms and associated light pollution are general aesthetic impacts of for-

Figure 18. Fishing at Lake Mooselookmeguntic. Photo by Sarah Haggerty.

est fragmentation. These affect remote recreation and other human values associated with large undeveloped areas. Most vistas from mountains and water bodies in the Western Maine Mountains provide long scenic and unbroken views. Roads are generally screened by the forest canopy, but wind towers and transmission lines with wide, cleared right of ways are conspicuous features on the landscape. Other than Routes 201, 16/27 and 6/15, there are currently no major highways or transmission corridors impacting the high scenic value of the region. The proposed New England Clean Energy Connect Project transmission corridor would be one of the largest fragmenting features in the Western Maine Mountains region, dividing it in two and crossing 53.5 miles of forest.

Potential fragmenting effects associated with forest management

Many species that need intact forest patches for their core habitat are also affected by the condition of the matrix forest surrounding these patches. It is well recognized that the condition of the matrix forest that surrounds intact mature habitat patches can affect regional biodiversity and landscape connectivity. In general, connectivity and biodiversity are reduced when the matrix forest becomes simplified in terms of species and structural diversity. Prevedello and Vieira (2010) found that a matrix that is more similar in structure to intact habitat patches will increase functional habitat and decrease isolation of patches. Timber harvesting can have a significant fragmenting effect, although the degree of impact depends on the extent, intensity and frequency of harvesting. As the extent and intensity of harvesting increases, the extent of interior forest habitat—especially large contiguous blocks—decreases. And while the impact of any individual harvest is temporary, cumulative harvesting patterns typically create a shifting mosaic of early successional stands, edge habitat and interior forest habitat across the landscape.[29]

Managed forest makes up about 90% of the Western Maine Mountains. While this forest remains largely unfragmented by permanent features such as public roads and residential development, it has been greatly

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[29] It is important to note that forest management and timber harvesting can be practiced in a manner that maintains or enhances wildlife habitat over time (DeGraaf et al. 2007).

modified by forest practices in the past half century. In the presettlement forest, where large-scale stand-replacing disturbances were rare events, the majority of the landscape would have been composed of older stands that were allowed to develop uninhibited into a late-successional condition (Lorimer 1977; NEFF in press). Today, although a full suite of native tree species remains, there has been a broad ecological shift away from late successional taxa, such as red spruce and hemlock, in favor of early- and mid-successional taxa, such as red maple and aspens (Thompson et al. 2013). In the past half century, large areas of spruce-fir forest have been converted to deciduous and mixed types due to regeneration of hardwoods after high-intensity spruce-fir harvests. In addition, the total amount of mature forest on the landscape has decreased along with the patch sizes in which these mature forests occur, and there is a correspondingly larger amount of edge between intact mature forest and harvested forest (NEFF in press; Legaard et al. 2015). Today only 1.4% of Western Maine Mountains forests are in a late-successional condition[30] and only 3% are classified as large saw timber[31] by the Maine Forest Service (NEFF in press). This compares to a presettlement forest where 59% or more of the forest was older than 150 years (Thompson et al. 2013; Lorimer and White 2003; Barton et al. 2012). An initial assessment of Ecological Reserve Monitoring data quantifies differences in forest structure between older stands in reserves and Maine's managed forests. Ecological reserves have greater average live-tree basal area, more large and very large trees, more standing dead trees, and more downed woody material (Kuehne et al. 2018). In short, the combination of spruce budworm era salvage cuts in the 1970s and 1980s and widespread partial harvesting[32] since the 1990s has created a modern forest that is younger, more homogeneous, and less coupled to local climatic controls (Thompson et al. 2013).[33]

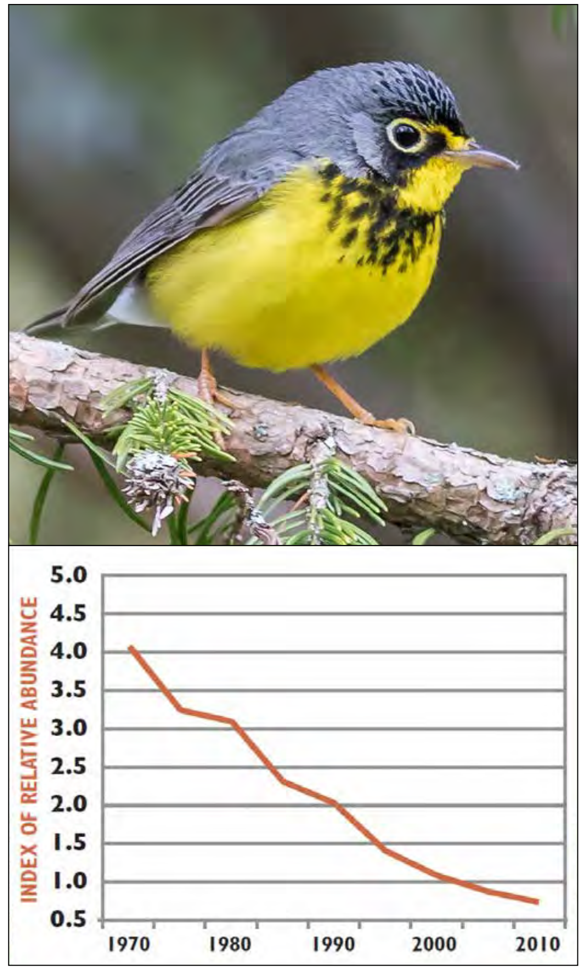

Figure 19. Species requiring mature coniferous or mixed forest habitat, such as the Canada warbler, are decreasing due in part to loss of summer breeding habitat. Graphic courtesy of Maine Audubon.

The result of these structural changes is a change in both plant and animal species composition at all forest stages (Legaard et al. 2015).[34] Species that require larger connected patches of older forest are particularly susceptible. For ex-

30 Late-successional stands are greater than 120 years old, have a multi-storied canopy, and have at least 15 trees per acre (either alive or standing dead) > 16″ DBH (diameter at breast height). Unmanaged late-successional stands tend to have cohorts of trees of different ages, large living and dead trees, large-diameter logs on the forest floor, vertical structural complexity and different-sized canopy gaps (Franklin et al. 2002).

31 Stands with > 100 ft^2 basal area in trees > 5.0″ DBH in which trees > 15″ comprise at least 50% of the basal area.

32 Partial harvests are areas that have been subject to a commercial partial harvest, including shelterwood and any other harvest method involving partial overstory removal (McGarigal et al. 2001; Legaard et al. 2015). The result is typically a dispersed low-density canopy.

33 See Legaard et al. (2015), Simons-Legaard et al. (2018) and NEFF (in press) for detailed analyses of current forest condition.

34 Legaard et al. (2015) used a time series of Landsat satellite imagery (1973–2010) to evaluate cumulative landscape changes in an area of western and northern Maine that included about half of the Western Maine Mountains.

ample, Payer and Harrison (2003) found that forests with large patches of large trees in a mature condition, either deciduous or coniferous, generally provide the structural stand attributes required by a wide variety of species such as American marten, northern flicker, wood thrush and northern long-eared myotis (a bat) (NEFF in press). Although not researched in Maine, a similar pattern is evident for forest birds in boreal habitats to the north. For example, Schmiegelow et al. (1997) found that, as the acreage of older forest declined, neotropical migrant bird species that require mature forest conditions declined in both connected and isolated fragments of such habitat, and resident species declined in isolated fragments.

Changes in forest structure also impact pool-breeding amphibians, which in the Northeast are sensitive to harvesting practices that reduce overstory canopy levels to less than 50%. Canopy closure, along with natural litter composition and coarse woody material within 100 to 400 feet of vernal pools, are important habitat elements required by salamanders and other amphibians (deMaynadier and Houlahan 2008; Popescu and Hunter 2011; Ross et al. 2000).

Changes in the composition and structure of the matrix forest as a result of harvesting, although temporary, can also impact generalist species such as white-tailed deer. Near the northern edge of their geographic range, where snow can restrict mobility and access to forage, white-tailed deer depend on mature conifer forests for wintering habitat. In a 1975–2007 time-series Landsat imagery analysis, Simons-Legaard et al. (2018) documented that fragmentation and reduction of mature conifer forest habitat significantly reduced the amount of deer wintering areas[35] in the Western Maine Mountains. The extent of currently zoned deer wintering habitat and habitat under cooperative agreement in the region is currently estimated to be only 34% of what is recommended (Nathan Bieber, personal communication). Simons-Legaard et al. conclude that continued forest-type conversion is expected to extend the effects of habitat fragmentation on northern deer populations and other species that require mature conifer forest into the future (Simons-Legaard et al. 2018).

Other than research on forest trees, there has been little research on the impacts of patch size and condition on vascular and nonvascular plants. Some lichen, liverwort and bryophyte species are dependent on the woody debris and dead and dying trees associated with older stages of spruce-fir forest development. These structural features can require several decades to recover, unless the woody material is intentionally left (Selva 1994; Gawler et al. 1996; Rowland et al. 2005). Small isolated populations can become too far apart to recolonize the areas in between and exchange genetic information.

We are just beginning to understand the scope of these changes in the forest matrix and their long-term effects on species dispersal, richness, abundance and persistence, community composition and ecosystem function. While connectivity within the matrix forest of the Western Maine Mountains is currently high, there is growing evidence that American marten, forest birds and other species that require larger patches of mature forest are declining in the region as the stepping stones of suitable habitat become fewer and farther between. This topic is in urgent need of study by the scientific community.

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[35] The Maine Department of Inland Fisheries and Wildlife defines deer wintering areas as forested areas used by deer when (a) snow gets to be more than 12 inches deep in the open and in hardwood stands, (b) the depth that deer sink into the snow exceeds 8 inches in the open and in hardwood stands, and (c) when mean daily temperature is below 32 degrees Fahrenheit. Ideal wintering areas (primary winter shelter) are dominated by mixed or monospecific stands of cedar, hemlock, spruce and fir, with a stand height of 35 feet.

LONG-TERM CONSEQUENCES OF FOREST FRAGMENTATION

Fragmentation is a continuous and cumulative process that leads to degraded habitats and loss of species over time. There is a growing body of research that suggests that the ecological dynamics in fragmented landscapes are a stark contrast to the dynamics in intact landscapes (Haddad et al. 2015). Although there are currently few long-term studies of the impacts of permanent forms of forest fragmentation on biodiversity and connectivity in the Northern Appalachian-Acadian Forest Ecoregion, research from elsewhere shows strong and consistent responses of organisms and ecosystem processes to fragmentation arising from decreased habitat patch size, decreased connectivity and the creation of habitat edges (Haddad et al. 2015; Lindenmayer and Fischer 2006). In general, the greater the difference between forested patches and their surrounding environment and the smaller and more isolated patches become, the greater the impact on biodiversity and ecosystem function. Haddad et al. (2015) identify three processes that drive long-term and progressive impacts of fragmentation: (1) temporal lags in extinction, (2) immigration lags and (3) ecosystem function debt.

Extinction debt

Temporal lags in extinction, or "extinction debt" is simply the delayed loss of species due to fragmentation. Hagan and Whitman (2004) suggest that we may be accruing "extinction debt" in Maine forests, describing the process as follows:

> Once old forest elements such as large trees or logs are lost from a stand (e.g., as a result of a clearcut, or even a selection cut), it can take centuries for the species [dependent on such features] to return to that location. A species first has to wait for these structural features to redevelop, and then the species has to find them. Scientists are beginning to understand that forest continuity is key to many forest species. [This temporal] continuity refers to the persistence of big trees and big logs in a forest stand over a very long period of time (centuries), even though the stand might be subjected to many different disturbances, such as fire, wind, disease, or even selection logging. Species that move or disperse slowly through the landscape, and prefer large old trees or logs, are the species most at risk to the loss of older forests.

In addition to the inability of organisms to disperse, extinction debt from fragmentation may be tied to genetic traits of populations, rarity, reproductive mode, life span and a host of other factors (Haddad et al. 2015). Extinction debt is often overlooked because many of the species lost tend to be small and uncharismatic, such as insects, fungi and mosses—and yet these species may be critical for ecosystem function. In the Western Maine Mountains, changing land use patterns from permanent and temporary forms of fragmentation have already caused changes in species composition and will likely cause changes in plant and animal abundance over time. Two of these changes include the increased proportion of early successional species and the large-scale reduction in the structural complexity of forest stands on which other forest organisms and ecological processes may depend (Rowland et al. 2005; Hagan and Whitman 2004). To fully understand the implications of extinction debt in the forests of the Western Maine Mountains, more long-term studies are needed.

Immigration lag

In general, smaller and isolated fragments are slower to accumulate species after disturbance than large or connected habitat blocks. In other words, because it takes longer for species to recolonize small patches, the successional transition from cleared land to mature forest conditions may take longer to occur (Haddad et al. 2015; Cook et al. 2005). This phenomenon is called "immigration lag" (Haddad et al. 2015). Most fragmentation studies have been done in agricultural or suburban landscapes, long after the onset of fragmentation. Research on industrial forest land suggests that the process of immigration lag is a complex one. For example, Hagan et al. (1996) found that densities of several forest-dwelling bird species can increase within a forest stand soon after the onset of fragmentation as a result of displaced individuals packing into remaining habitat. However, because forest songbirds are highly territorial during the breeding season they cannot simply shift elsewhere unless there is unoccupied habitat. Furthermore, it is widely thought that these species establish territories in the best habitat available. If displaced, they could be forced into poorer quality habitat resulting in reduced pairing success and productivity over time. This was the case for ovenbirds in the Hagan et al. (2015) study. Their models and data suggest that large tracts of forest are important because they are relatively free from the variety of plant and animal population dynamics that might take place near new edges, including the encroachment of individuals displaced by habitat loss. Immigration lag may also mask the risk of invasion by exotic species since there may be a long lag between introduction, colonization, and rapid range expansion of some invasive species (Webster et al. 2006).

Ecosystem function debt

Ecosystem functions, such as nutrient cycling and decomposition rates, can also be reduced or lost over time—a process called ecosystem function debt. Evidence suggests that during forest succession, this delayed loss of function is greater in smaller, more isolated fragments (Cook et al. 2005; Billings and Gaydess 2008). The mechanisms for this are complex. Functional debt can result when fragmentation causes food webs to be simplified as species are lost, or when altered forest succession patterns resulting from permanent fragmentation or forest practices that cause changes in tree density, light and moisture, which impair ecosystem function (Haddad et al. 2015).

While there is abundant evidence that the forests of the Western Maine Mountains continue to change as silvicultural practices interact with natural successional processes and a changing climate, Legaard et al. (2015) and Simons-Legaard et al. (2018) are the first two studies to document spatial changes in the forest over time in Maine. Their research suggests that the long-term processes described above are beginning to play out in the Western Maine Mountains. The American marten provides an example of how a species responds to long-term habitat changes associated with fragmentation. While the forests of the region currently support marten, recent research suggests that forest harvest practices on two-thirds of Maine's commercial forestland are creating habitat that no longer serves the needs of this umbrella species, and by implication the many other terrestrial forest vertebrate species that use similar habitat (Hepinstall and Harrison in prep.); Simons-Legaard et al. 2013; Fuller and Harrison 2005; Homyack et al. 2010; McMahon 2016).

A changing climate

If left unchecked, increased fragmentation from permanent and temporary features is expected to exacerbate the impacts of climate change on biodiversity and connectivity in the region. Whitman et al. (2013) summarize how Maine's biodiversity and ecosystems are likely to change in the coming decades.

> The region can anticipate shifting species distributions, with an increasing number of novel species moving in from the south and many species with northern distributions moving north. Changes in seasonal rainfall patterns may exacerbate late summer dryness and increase levels and frequency of drought stress for plant communities and aquatic systems. Increasing temperatures may allow wildlife parasites such as winter moose tick (*Dermacentor albipictus*) and forest pests such as hemlock woolly adelgid (*Adelges*

Figure 20. Northern Maine and the Western Maine Mountains are now a stronghold for moose in the eastern United States. Photo by Charlie Reinertsen Photography.

tsugae) to become more prevalent, stressing native wildlife populations and degrading their habitats. Because each species will respond individually to these threats, the composition of natural communities and wildlife habitats that we take for granted will change. While populations of some species and their habitats will increase, climate change could lead to extirpation of other species and significant changes to natural communities and wildlife habitats (Cahill et al. 2012).

Forest fragmentation increases the vulnerability of Maine's native flora and fauna to climate change (Fernandez et al. 2015; Rustad et al. 2012). For example, declines in the diversity of native flora in New England's mixed northern hardwood forests are attributed to a high degree of habitat specialization, a highly fragmented range, depauperate understories due to repeated clearing and barriers to dispersal (New England Wildflower Society 2015). Three of the top four stressors are caused or aggravated by forest fragmentation, including habitat conversion, invasives and succession. All of these stressors are expected to become more pronounced as the climate changes.

The resiliency of the Western Maine Mountains in the face of climate change is largely due to the extent and connectivity of the region's forests. These forests provide far greater benefits to climate stabilization than the alternative of land development (Fahey et al. 2010). Because heavily forested areas sequester more carbon than they emit and the wood they produce can be used to substitute for more energy- and emissions-intensive building materials, keeping forested lands intact will help mitigate climate change regionally. Conversely, developed lands are net sources of carbon dioxide to the atmosphere (Fahey et al. 2010).

Figure 21. Fall in the Western Maine Mountains. Photo by Charlie Reinertsen Photography.

CONCLUSIONS

The Western Maine Mountains region is an ecological treasure that faces unprecedented threats from forest fragmentation. New land uses and policies that fragment the region's forests—such as the proposed New England Clean Energy Connect transmission corridor, the Land Use Planning Commission's proposed changes to the adjacency rule, which would allow new commercial and residential development to stretch for miles along currently undeveloped public roads, and large scale developments, such as Weyerhaeuser's Moosehead Lake concept plan—have the potential to profoundly change the ecology of the region by bringing extensive new human infrastructure into remote areas and creating new nodes of development (Lilieholm et al. 2010). In addition, forest practices have created a younger more homogeneous forest, conditions that threaten species that require large patches of older forest, such as American marten and many songbirds. However, when the land remains forested, even if harvesting temporarily modifies forest composition and structure, the potential for connectivity is retained because forest patches can regrow and expand. By contrast, once a utility corridor, road or development is in place, it effectively forever disrupts the connectivity of the landscape.

Fragmentation increases the risk of species extinctions and exotic invasions and decreases the ability of species to respond to a warming climate. The capacity of the Western Maine Mountains to sustain biological diversity and ecosystem integrity into the future will hinge upon the total amount and quality of its forests, wetlands and streams and their degree of connectivity. Unless proactive steps are taken, these changes have the potential to forever alter and degrade one of the most intact forested landscapes in the eastern United States and compromise its ability to serve as a critical ecological link between forests of the Northeast and Canada.

To maintain the region's unique values, it is essential to avoid introduction of new fragmenting features, especially those that would permanently intrude into intact forest blocks, such as new utility corridors, new centers of development, and new high volume roads. It is also critically important to find ways to support landowners who seek to maintain large intact forest blocks and to find ways to support them in managing forests for greater spatial and temporal connectivity and structural complexity. Maintaining an unfragmented and intact forest is not only critical to the region's biodiversity and ecological health, but it is crucial to Maine's economy and a defining part of the Maine way of life.

The biodiversity, resilience and connectivity of the Western Maine Mountains are unparalleled in the eastern United States. The region offers one of the last opportunities for large landscape-scale conservation with protected areas connected through linkages and stepping stones embedded within an intact forest matrix (Keeley et al. 2018). As one of the few temperate forests in the world managed through natural regeneration, the Western Maine Mountains region continues to support a full complement of native forest wildlife and is the last regional stronghold for brook trout, moose, lynx, marten and a host of other species. It remains a highly connected forested landscape—one that is far less fragmented than increasingly developed lands to the south. The actions of landowners, conservation organizations, government officials and agencies, and local communities and citizens together will determine whether these species and the region's many unique values persist into the future.

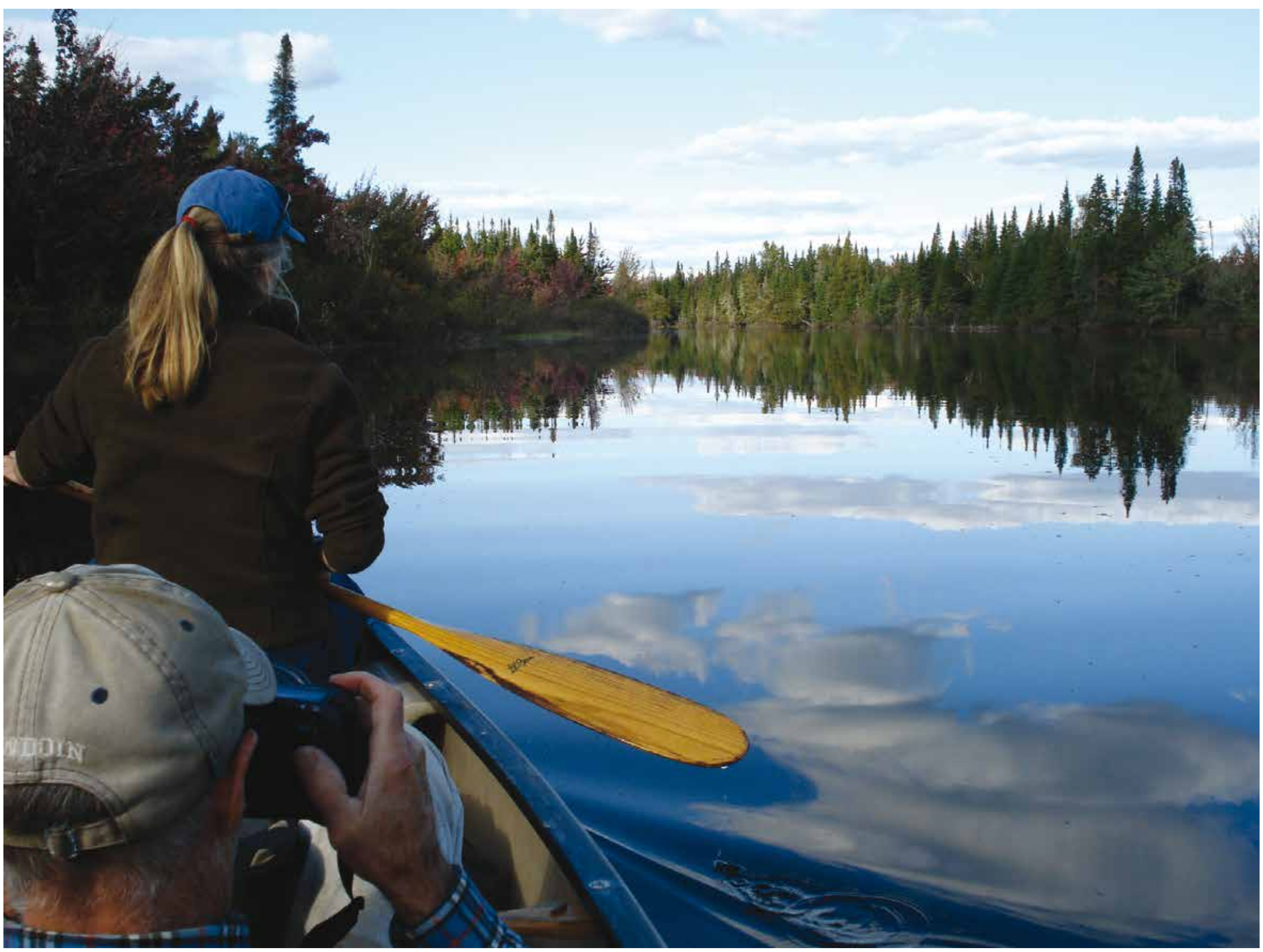

Figure 22. Canoeing on Flagstaff Lake. Photo by Sally Stockwell.

Figure 23. Unbroken view in the High Peaks region of the Western Maine Mountains.
Photo by Charlie Reinertsen Photography.

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State of Maine
Department of Environmental Protection
In the matter of

Central Maine Power Company
New England Clean Energy Connect

Pre Filed Testimony of Robert Haynes,

Coordinator Old Canada Road Scenic Byway

Group 1:

Old Canada Road
Friends of the Boundary Mountains
Wilderness Guides

Topic 1 : Scenic Character and Existing Uses

Personal Introduction

Project introduction (not part of verbal testimony)

OCR introduction

Scenic Character and Existing Use

I am Robert Haynes and am a self-employed consulting Forester in Skowhegan Maine. I graduated from the University of Maine with a B.S. in Forestry in 1977. I have enjoyed a position as Coordinator of the Old Canada Road National Scenic Byway for the past 18 years and, am also a project abutter. My testimony will focus on the Northern project area north of the Kennebec River.

Project Overview

New England Clean Energy Connect is a creative and demanding project that may deliver electricity to New England customers, partially fulfilling requirements of the 83D document drafted by the Massachusetts legislature. This document was crafted to initiate green replacement electricity for the local and regional plants that are to be, or have been decommissioned. Several new renewable sources were identified in the RFP, including solar, off shore wind, on shore wind, and water from Hydro Quebec generating facilities. While solar and wind could provide jobs to Massachusetts residents, power from Hydro Quebec is totally dependent on others to deliver the contracted supply. Others in this case, expanded to other states and two other countries for a commodity the commonwealth could produce locally for a reduced cost and greater security. Vermont remains ready to construct the system needed to move power from northern Quebec under Lake Champlain and under- ground to a point accessible to Massachusetts, now. The Vermont project provides 720 million dollars in community benefit funds, over 40 years or 18 million dollars per year. The NECEC project in Maine offered 22 million in benefit to a small geographic area, 550,000 dollars over 40-year period although it was a lump payment at the project onset. The commonwealth continues to prefer Maine for obvious reasons. Recently however CMP and Hydro Quebec upped the Maine benefit 258 million dollars, mostly from projects benefitting CMP such as items needing transmitted power like car charging stations, assistance with purchasing heat pumps, and low- income payment assistance. Also offered was creation of a new entity to own and manage the project aimed at isolating Maine ratepayers from any issues with NECEC. Presently, 2/26/19, the NECEC project has none of the necessary certificates or permits to begin the project. Their website notes that they expect to have them by the end of 2018, two months ago. The new money offered buys a serious amount of skid grease, which our Governor has been attracted to, creating a very difficult situation for our regulators. It does nothing to make the construction less obtrusive or objectionable to residents.

Points:

The apparent purpose of the project is to secure the market for the next 40 years with a power supply whose generation method is outdated, and illegal to build in Maine or Massachusetts.

If the project can stand alone on its own benefits, why would a responsible company (s) feel the need to send 258 million dollars to improve its chances of acceptance?

Certification

The Certificate of Convenience and Necessity that CMP is seeking from the Maine Public Utilities Commission means just that: Need and Convenience. This would work for a new line to new residences or business or an up- grade. The purpose of the certificate is to move power from the Canadian border to the southern Maine border to sell in the higher priced market. A lawyer for CMP cites that the Certificate of Convenience and Need drafted by the Maine legislature was meant to cover New England, not just Maine. The project was filed under the wrong title. This is a merchant line and needs to be examined under corresponding criteria. Language in the Massachusetts request emphasizes "clean" numerous times, as it is the goal to have the Commonwealth meet emission goals by a particular date. A conspicuous missing detail is "How Clean or renewable?". Existing contracts with local southern New England Distributors do not provide that detail. Project opponents have said power could come from any source Hydro Quebec chose at the time as long as the volume was as contracted. Does this mean cleaner than what was decommissioned? Clean as possible? As it stands now power from tar sands could be imported: as long as the price was beneficial. Positions exist on both sides of the clean issue and range from carbon to methane to ocean nutrients. No fact- based position is available. This is imperative. Why would the commonwealth want to invest a billion dollars in the delivery of power that was not the cleanest possible? And, pay 260 million dollars every year for the delivery. Hydro Quebec was selected because it may have the volume and opportunity to send hydro generated electricity to New England but there is no requirement that it must be 100% water generated. Maine receives benefit from the tax dollars the infrastructure creates, but any new construction could do that. In looking at the intervenors in the PUC, DEP and LUPC arenas, they all lack a vital member: an organization that supports the project on its own merits. All are there for spin off benefits that have no relation to the damage the project may do. In other words, no money is allocated to direct damage except for funds, required by law, for unavoidable wet land damage. No one except the applicant is expounding on the project benefit to Maine, except a recently formed and liberally financed (by Central Maine Power Company) non-profit, Western Mountains and Rivers Corporation. Other supporting intervenors are rightfully doing their job by encouraging new jobs for their members and taxes for their municipalities. Any town would jump at the opportunity to have a 1,000- acre construction project locate within their boundary, but it would involve much planning and community involvement. CMP avoided broad community involvement by forming the noted non- profit. Central Maine Power made a large gamble that Hydro Quebec was the answer to New England's energy situation, but advances in solar, off shore wind, battery storage and efficient gas turbines have made that bet obsolete. Ten years ago, success may have been within reach. For security, cleaner electricity and local jobs Massachusetts should step up and provide for local needs. It has the technology, talent and apparently the funding in place. Where is the "Spirit of America"?

Points: Why are we considering a project that has no merit to the State of Maine?

What sources of power are considered clean or clean enough for the Massachusetts market? Does this supply line accomplish the RFP request for "clean energy"?

Why the ethical disconnect? Buy something produced by a generator illegal to construct in Maine or Massachusetts?

Design

As designed the project is located on applicant land purchased (northern portion) for the specific powerline purpose, months before the project was awarded and surveyed years before purchase. The location serves two purposes, one of which is to connect to an existing power corridor south of the Kennebec River and two, is to follow potential sources of wind generation, should that option ever present itself. The corridor is 300 feet wide and 53 miles long, but due to the application, only 150 feet can be considered, at this time. As designed, the vegetation will be removed, excavation completed necessary to locate concrete footings of sufficient size to support the 100 foot- plus tower and the tons of cable necessary for transmission. Logistics of this are daunting particularly when weather fluctuates from -30 to 100 degrees Fahrenheit. Elevation creates its own challenges particularly as soil depth is inversely proportionate to elevation. Wet land soils or muck, seem to have no bottom making tower location challenging. Factors of weight, temperature, and wind are complicated.

When the land was purchased, there was no consideration for a vegetative buffer. When the abutting owner cuts timber up to the property line, as they have the right to do, the entire tower will be exposed from across the cut instead of only the top 50 feet. This expands the appearance of a power corridor 150 feet plus the cut width to the vantage point, which lengthwise would be about 10 miles of the Spencer Road. Undergrounding of lines this size and sensitivity is a common practice. This transmission line will hang in an area of tremendous wind (Coburn Mt.) and be maintained by a company with a less than stellar maintenance record. This is not the Central Maine Power Company that won the J.D Power Awards years ago. Undergrounding would increase reliability, not require herbicide, commercial timber could continue to be grown on the 150 foot wide (1,000 acre corridor) and wildlife would have un-interrupted travel. Furthermore, additional Maine contractors would be available to do much of the work. All of the above, herbicide, view, timber growth, wildlife and jobs, remain very serious concerns of residents along the Byway, and ignored by the applicant.

Point- Considering undergrounding satisfies most concerns of citizens, why wasn't it considered?

What is Old Canada Road National Scenic Byway?

Old Canada Road National Scenic Byway (OCR) was designated as one of 45 such roads of national significance in 2000 by the Federal Highway Administration. Since then additional roads have been added, bringing the total to 150 nationwide in 2019. Byways are selected on their high recreational, scenic, cultural, historical, and geographical qualities. The Byway is governed by a Board of Directors operating as a 501 c 3 corporation since 2001. In eight years, over a million dollars was secured by OCR through federal and other competitive grant sources benefiting our 78- mile road from Canada through Solon. Central Maine Power has been a very cooperative landowner participating most recently in a corridor lease for a 225,000 thousand -dollar trail project in the Forks and West Forks on the Kennebec and Dead Rivers. This provided exceptional views of both rivers and in most places is ADA compliant. Tourism is tremendously important in the Byway region. Maintaining the experience expected by our travelers is part of the Byway mission. Funding for the National Scenic Byway program ended in 2011 but last month, with help from outdoor partners it is well on the way to getting back to original levels starting with the overwhelmingly passed (404-19) House vote in support of HR831- Reviving America's Scenic Byways Act of 2019 that will reopen nominations for scenic byways. Language is in the Senate to reauthorize program funding of fifty million dollars, with some changes.

Maine as a term is a destination in itself. The Upper Kennebec Valley is a tremendously valued subset of that name. Coburn Mountain, Number Five Mountain, Moose River Bow Trip, Attean Pond, Spencer Lake all are frequent destinations for travelers and residents most extensively in summer, fall and winter. Visitors come to experience what they do not have at home, open space, extensive views and a sense of wilderness. A sense of wild may be more accurate as wilderness has gone. A harvested forest re-growing trees may be all that is necessary for a wonderful experience. In the book The Experience Economy published in 1999 by Pine and Moore, the authors elaborate on "experience tourism". Visitors are not traveling to Maine to pick up a balsam pillow and a light- house snapshot, but are coming for a memory they can talk about for years at family gatherings. An unbroken landscape is required for this experience. Maine is tremendously fortunate to have commercial landowners that allow public use of their property. Public use and commercial forestry have always co-existed in Maine. An above ground powerline is not compatible with positive visitor experiences or the vocations of those in the recreational outdoor industry. A physical bisector with markers over one hundred feet tall is an inconsistent use of the area and incompatible with traditional use. True change is coming and all need to be adaptable and responsible to decrease our climate impact. One could argue that Massachusetts, Maine and CMP are postponing that positive change by haggling over money. Vermont is ready to go and has the same environmental benefit. Hydro Quebec wins either way and Maine has an additional 1000 acres to sequester carbon, continued stellar view sheds and uninterrupted tourism economy.

Scenic Character and Existing Use

Points from pg.4

- The apparent purpose of the project is to secure the market for the next 40 years with a 1200MW power supply whose generation type is outdated.
- If the project can stand alone on its own benefits, why would a responsible company (s) feel the need to send 258 million dollars to improve its chances of acceptance?
- Why is a project being considered that has no merit to the State of Maine?
- Why weren't the advantages of placing the cable underground where appropriate, considered?
- There is no proof that the power is generated by water.
- Why is it acceptable to encourage environmental damage in another country while not allowing it in our own?

Scenery is not just a pretty view. It creates intrigue as to what may have happened within the view and always creates the question of what is beyond. The story is remembered as vividly as the view, perhaps more so. Scenic Character is another term alluding to massive views of a perhaps a daunting climb or intimidating running- river. Travelers and residents enjoy Maine, as much for what it has, and many times, more, for what it does not. A day without cell phone service can be quite a pleasant novelty. Scenery creates a destination and destinations require time that translates into income for recreational business and those offering meals and lodging. Power lines are not destinations- they are available at home. Injected here could be the dollar value of the lodging, meals, guide fees, supplies and other associated income to area business. As an indicator over 800 snowmobiles were in the Forks last weekend. The accepted income associated with that industry years ago was five hundred dollars per sled for individuals owning their own. Rentals increase that number dramatically as they run three hundred dollars per day. Sled enthusiasts do not just ride for the thrill but for the scenery as well. In winter, more line will be exposed, from the concrete up.

Unfortunately, for the applicant this Moose River Basin area has two very popular hikes that peer down on the transmission line. Visual impact assessment cannot compete with the fact that looking down from height of 3,700 and 3,100 feet to a corridor at 1,400 feet makes a 150- foot wide corridor very visible. Hunting and camping guides have used this area since there were hunters and campers. Aside from the wood products industry, tourism and recreation are the most important business in the area. Saddling it with the burden of a 100- foot tall powerline and associated permanent clear- cut corridor is unconscionable, when there is another option. Exhibit 1 shows the Moose River Basin area and its remarkable lack of development, which this corridor will bisect. While concentrating on the portion of corridor west of Rt. 201 and the Scenic Byway the poles will also be seen from, the pavement in the north bound direction at Johnson Mountain and in the south bound direction at Parlin Pond. Along the Spencer Road to the Number Five Mountain destination, the line will be visible as it runs parallel to the road in places and crosses as well.

Should this line be constructed as planned the items listed as Points above, will be included in conversations regarding the towers. Children will ask their parents why the big tower is there. Knowledgeable parents will answer in a variety of statements summarized in the above questions. The view of the tower ignites the question and there only takes one in view to begin the conversation. The answers as taken from above are not ones we want told.

There is a statement in which we could all take pride- something like.....

"See that long patch of cleared ground? Unbelievably, under there is a cable that moves, certified green, renewable power from Canada to southern New England lighting a million homes and helping our environment! " " Wow, who did that?" Well that would be Central Maine Power Company and the State of Maine!

This is the positive spin the project needs for exemplary success.
To achieve it only two things need to happen:

1-CMP and Hydro Quebec need to provide all **details regarding the source** of the transmitted power ensuring its' clean status.
2-Where ever possible the **line must be underground**.

Cost will be greater, but the cost of placing the line below grade was not the reason Northern Pass was rejected.

Conclusion

It is evident to OCR that CMP has not made sufficient effort to allow the construction project to blend into the existing natural environment or shown that the towers wouldn't negatively affect existing uses and scenic character.

Chapter 315 Section 10 Scenic resources.

10. **Scenic resources.** The following public natural resources and public lands are usually visited by the general public, in part with the purpose of enjoying their visual quality. **Under this rule, the Department considers a scenic resource as the typical point from which an activity in, on, over, or adjacent to a protected natural resource is viewed. This list of scenic resources includes, but is not limited to, locations of national, State, or local scenic significance. A scenic resource visited by large numbers who come from across the country or state is generally considered to have national or statewide significance. A scenic resource visited primarily by people of local origin is generally of local significance.** Unvisited places either have no designated significance or are "no trespass" places. Sources for information regarding specific scenic resources are found as part of the MDEP Visual Evaluation Field Survey Checklist (doc. #DEPLW0540) provided in the application.

A. National Natural Landmarks and other outstanding natural and cultural features (e.g., Orono Bog, Meddybemps Heath); **#5 Bog**

B. State or National Wildlife Refuges, Sanctuaries, or Preserves and State Game Refuges (e.g., Rachael Carson Salt Pond Preserve in Bristol, Petit Manan National Wildlife Refuge, the Wells National Estuarine Research Reserve);

C. A State or federally designated trail (e.g., the Appalachian Trail, East Coast Greenway); **Old Canada National Scenic Byway, ITS snowmobile trail**

D. A property on or eligible for inclusion in the National Register of Historic Places pursuant to the National Historic Preservation Act of 1966, as amended (e.g., the Rockland Breakwater Light, Fort Knox); **Prisoner of War Camp**

E. National or State Parks (e.g., Acadia National Park, Sebago Lakes State Park);

F. Public natural resources or public lands visited by the general public, in part for the use, observation, enjoyment and appreciation of natural or cultural visual qualities. (e.g., great ponds, the Atlantic Ocean). **Coburn Mountain Public Land, Moore Pond Public Land, #Five Mountain Trail (private land purchased for public benefit)**

Applicants for permits under the NRPA are required to demonstrate that a proposed activity meets the standards of the NRPA that have been established by the Legislature. Standard 1 in Section 480-D of the NRPA requires an applicant to **demonstrate that a proposed activity will not unreasonably interfere with existing scenic and aesthetic uses.**

CMP has not made efforts to assure the project will not interfere with scenic aesthetic uses.

8B. **Design.** When circumstances do not allow siting to avoid visual impacts on a **scenic resource, elements of particular concern should be designed in such a way that reduces or eliminates visual impacts to the area in which an activity is located, as viewed from a scenic resource. Applicants should consider a variety of design methods to mitigate potential impacts, including screening, buffers, earthen berms, camouflage, low profile, downsizing, non-standard materials, lighting, and other alternate technologies.**

OCR maintains that CMP did not make design allowances to mitigate any impacts to scenic character or existing use

OCR asserts that CMP has made no effort to minimize project effects within sight of OCR or any of the scenic land-marks along the Spencer Road and suggests that the Maine Department of Environmental Protection take appropriate action.

Sincerely for the Old Canada Road Board of Directors,

Robert Haynes

Robert Haynes, Coordinator

State of Maine

Somerset, ss. February 28, 2019

Personally, appeared before me the above named Robert Haynes and made oath as to the truth of foregoing pre-filed testimony.

Davida D. Barter

Davida D. Barter, Notary Public

My commission expires: 3/16/2020

DAVIDA D. BARTER
NOTARY PUBLIC - MAINE
MY COMMISSION EXPIRES 03/16/2020

1
2
3
4
A
B
C
D
E
MOOSE RIVER
DENNISTOWN PLT
Dennistown
FORSYTH TWP
Dyerville
Jackman
Jackman Mill
ATTEAN TWP
JACKMAN
HOLEB TWP
Holeb
MAINE PUBLIC RESERVED LAND
BRADSTREET TWP
T5 R7 BKP WKR
APPLETON TWP
UPPER ENCHANTED TWP
SKINNER TWP
HOBBSTOWN TWP
KING AND BARTLETT TWP
THORNDIKE TWP
LONG POND TWP
Long Pond
PARLIN POND TWP
Lake Parlin
JOHNSON MOUNTAIN TWP
CHASE STREAM TWP
Indian Pond
LOWER ENCHANTED TWP
West Forks
WEST FORKS PLT
MOXIE GORE
Lake Moxie
The Forks
Continue on Map 29
Continue on Map 30
Map 40
Contour interval 100 ft
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