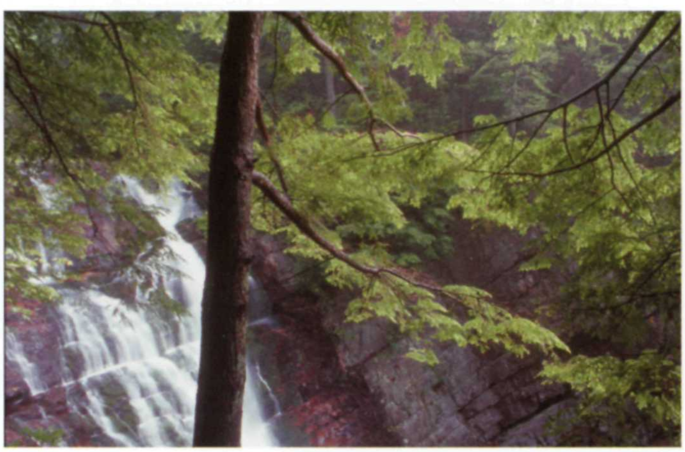
National Park Service
U.S. Department of the Interior

Northeast Region
Boston, Massachusetts

Appalachian Trail Vital Signs

Technical Report NPS/NER/NRTR--2005/026



ON THE COVER
Androscoggin River, ME
Blood Mountain Sunset, GA
Laurel Falls, TN
Mt Katahdin, ME

Appalachian Trail Vital Signs

Technical Report NPS/NER/NRTR--2005/026

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November 2005

U.S. Department of the Interior
National Park Service
Northeast Region
Boston, Massachusetts

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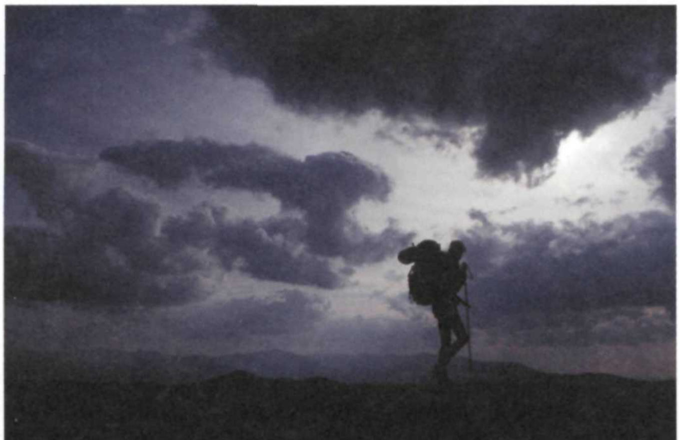



Appalachian Trail Vital Signs

"The Appalachian Trail is not merely a footpath through the wilderness, but a footpath of the wilderness."

--Benton MacKaye

Background:

The Appalachian Trail began as a vision of forester Benton MacKaye and was developed by volunteers and opened as a continuous trail in 1937. It was designated as the first National Scenic Trail by the National Trails System Act of 1968.

Appalachian National Scenic Trail (AT):

The Appalachian National Scenic Trail is administered primarily as a footpath by the National Park Service in cooperation with the United States Department of Agriculture Forest Service, the Appalachian Trail Conservancy and the 14 States encompassing the Trail, providing for maximum outdoor recreation potential as an extended trail and for the conservation and enjoyment of the nationally significant scenic, historic, natural, and cultural resources of the areas through which the Trail passes. It is the mission of the Appalachian National Scenic Trail to foster the Cooperative Management System of the Appalachian National Scenic Trail in order to preserve and provide for the enjoyment of the varied scenic, historic, natural and cultural qualities of the areas between the states of Maine and Georgia through which the Trail passes.

The Appalachian Trail is a way, continuous from Maine to Georgia, for travel on foot through the wild, scenic, wooded, pastoral, and culturally significant lands of the Appalachian Mountains. It is a means of sojourning among these lands, such that visitors may experience them by their own unaided efforts. The body of the Trail is provided by the lands it traverses, and its soul is in the living stewardship of the volunteers and partners of the Appalachian Trail Cooperative Management System.

Appalachian Trail Conservancy (ATC):

The Appalachian Trail Conservancy is a volunteer-based, private non-profit organization dedicated to the conservation of the 2,175-mile Appalachian National Scenic Trail, a 280,000-acre greenway extending from Maine to Georgia. The mission of the ATC is to ensure that future generations will enjoy the clean air and water, scenic vistas, wildlife and opportunities for simple recreation and renewal along the entire Trail corridor.

Formerly known as the Appalachian Trail Conference, the ATC is an 80-year-old organization whose roots are traced to the vision of Benton MacKaye, who convened and organized the first Appalachian Trail "conference" – a gathering of hikers, foresters and public officials – in Washington, D.C., in 1925. Today, the ATC works with 30 maintaining clubs and multiple partners to engage the public in conserving this essential American resource.

ATC coordinates the Appalachian Trail's management and protection in conjunction with a wide range of partners, including the Appalachian National Scenic Trail (NPS), USDA Forest Service, 14 states, and 30 Trail-maintaining clubs.

United States Department of the Interior

NATIONAL PARK SERVICE
Appalachian National Scenic Trail
Harpers Ferry Center
Harpers Ferry, West Virginia 25425

IN REPLY REFER TO:

November 3, 2005

Dear Friends of the Appalachian Trail:

This *Appalachian Trail Vital Signs Report* is the result of a collaborative effort by the Appalachian National Scenic Trail office of the National Park Service, the Appalachian Trail Conservancy, and the National Park Service's Inventory and Monitoring Program and Air Resources Division. It represents the first step in a series of milestones we plan to reach as we move forward into a new era of Appalachian Trail protection and management. Permit me the opportunity to explain.

We have seen several major developments in the Appalachian Trail management community over the past few years, including the near completion of the federal land protection program, the restructuring of the Appalachian Trail Conservancy (ATC), and the initiation of new conservation programs that complement ATC's traditional emphasis on maintaining the Appalachian Trail and supporting its volunteer stewardship. While the volunteer stewardship tradition of maintaining the A.T. remains firmly in place, these new directions highlight a major shift in our focus from protecting the Trail to conserving and managing the many significant natural and cultural resources that make the Trail such an exceptional resource.

There is an important rationale behind this sea change in our approach to managing the Trail. The Trail's icon status and strategic location along the rooftop of the eastern seaboard provide us, as managers of the Trail, with an unprecedented opportunity to develop a coordinated environmental monitoring program covering 14 states, six national parks, eight national forests, and a suite of more than 70 state and local jurisdictions. Developing such a program is no small challenge. It will require a lot of work to plan and implement, and will involve engaging new stakeholders. We are convinced, however, that this effort will be well worth it. Monitoring the environmental health of the Appalachian Trail can serve to engage and educate the general public, as well as national legislators and policy-makers, about important trends and changes in our natural environment.

This report establishes a common starting point for us as we begin development of an integrated, trail-wide, environmental monitoring program that will provide information to trail managers regarding the condition of specific natural resources. Please take the time to read it, and please provide us with your thoughts, comments, and suggestions.

Sincerely,

Pamela Underhill
Park Manager
Appalachian National Scenic Trail

Table of Contents

Introduction

The Appalachian National Scenic Trail (AT) extends along almost the entire Appalachian Mountain range in the eastern United States. The trail corridor averages 1,000 feet wide, spans fully 2,175 miles from Maine to Georgia and repeatedly traverses the major elevational, latitudinal, ecological and cultural gradients that characterize the eastern United States. Appalachian Trail lands include approximately 280,000 acres, making it one of the largest parks in the east.

Rhododendron: Round Bald, TN © Joe Cook

Knowing the condition of natural resources within national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations." The purpose of this document is to present the list of Appalachian Trail Vital Signs and determine what existing information from ongoing monitoring programs could be used and interpreted for the Appalachian Trail. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas in order to assess the efficacy of management practices and restoration efforts, and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with many threats, such as air and water pollution and invasive species, originating outside of park boundaries. Moreover, an ecosystem approach is needed because no single spatial or temporal scale is appropriate for all system components and processes. The appropriate scale for understanding and effectively managing a resource might range spatially from site-specific to regional, and might vary temporally from sub-annual to decadal or more. In some cases a regional, national or international effort may be required to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Middle Carter Mountain, New Hampshire
© Vermont Institute of Natural Science

The National Park Service initiated a new "Vital Signs" monitoring program in 1998 to develop long-term monitoring of natural resources within 270 units of the national park system. These 270 units were organized into 32 Networks to share staff and design and implement long-term ecological monitoring. The AT is identified as a natural resource park and included in the NPS Inventory and Monitoring program (I&M). The Appalachian Trail crosses 14 states, six NPS units, eight National Forests, 67 state owned units, 30 Appalachian Trail Conservancy (ATC) affiliated Trail Clubs, and five I&M networks (Figure 1). The geographic extent, number of partner agencies, and unique management structure of the AT requires an extensive amount of coordination to plan and design a program to monitor ecological changes along the AT. The results from such a large-scale, standardized monitoring effort would provide the much needed information to better manage the AT's natural resources as well as to better understand and track the condition of ecological systems along the eastern United States.

Vital signs are defined as a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Vital signs are defined as a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. This report documents the progress of the five Appalachian Trail Networks in selecting Vital Signs for the AT.

Planning for monitoring is one of the most important components in designing a successful, sustainable program. Oakley et al. (2003) liken the design of a monitoring program to getting a tattoo; "...you want to get it right the first time because making major changes later can be messy and painful." To avoid painful changes to programs in the future, the I&M Vital Signs Program has developed a three-phase planning approach that each Network must complete prior to implementing any new monitoring programs. Briefly, the process is as follows;

Phase 1 - define monitoring goals and objectives; begin the process of identifying, evaluating and synthesizing existing data; develop draft conceptual models; and complete other background work;
Phase 2 - prioritize and select vital signs and develop specific monitoring objectives for each park and the network; and,
Phase 3 - develop detailed plans to implement monitoring, including the development of sampling protocols, a statistical sampling design, a plan for data management and analysis, and expectations for reports and other presentation of results.

Natural resource monitoring provides site-specific information needed to identify and understand changes in complex, variable, and imperfectly understood natural systems and to provide insight into whether observed changes are within natural levels of variability or indicate undesirable human influence. Thus, monitoring provides a basis for identifying and understanding meaningful change in natural systems characterized by complexity, variability, and non-linear responses. Monitoring results can be used to identify threatened or impaired resources and initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making designed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems.

The intent of the NPS vital signs monitoring program is to track a subset of park resources and processes, representing significant indicators of ecological condition. Vital Signs must be a useful subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on these resources. By choosing a meaningful subset of ecological resources, NPS recognizes that tracking everything is neither possible nor desirable. In situations where natural

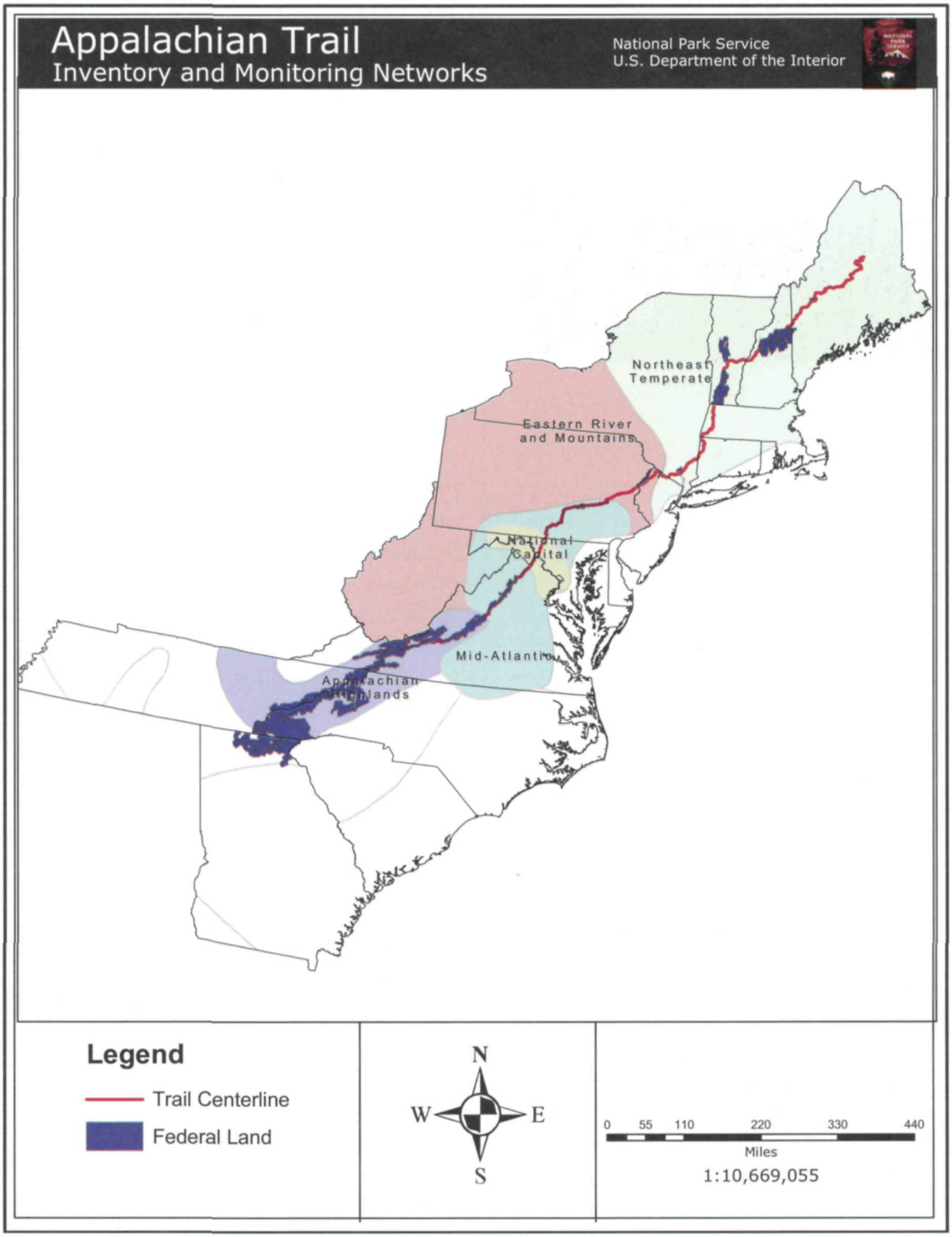


Figure 1. Appalachian Trail showing I&M Networks and federal lands.

View from the AT in Shenandoah NP
©Eva Moore

areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires or floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

Planning for ecological monitoring on the AT is the most important step in laying a strong foundation for an AT ecological monitoring program. Presently, many initiatives related in some way to monitoring are ongoing. AT staff have initiated the process of developing a resource management plan, and the ATC recently started an Appalachian Trail Environmental Monitoring Initiative. The USDA Forest Service and NPS prototype parks that encompass parts of the AT are also involved in long-term ecological monitoring and many other groups are conducting biological inventories and monitoring programs along or adjacent to the AT. Coordinating these efforts and developing a framework that defines the roles of the many AT constituencies in ecological monitoring is a vital, early step in the planning process.

The AT Networks convened a meeting, 13-14 October 2004, where all five I&M Networks, AT staff, ATC staff, the regional air quality specialist, and the director of the I&M program met to discuss the coordination and direction of the AT Vital Signs program. Prior to the meeting, the Northeast Temperate, National Capital Region, and the Appalachian Highlands networks completed Phase II of the Inventory and Monitoring process and had therefore selected vital signs for monitoring. The vital signs from these three networks were compiled and summarized to provide a starting point for selecting AT Vital Signs (Table 1). Because of the substantial overlap among the three networks that had already prioritized vital signs, the group thought that this list was comprehensive and appropriate for the AT. It was decided that the group would rank the comprehensive list of vital signs to select the highest priority vital signs for the AT (Table 2). The prioritized list would then provide the foundation to focus the summary of existing information related to each selected vital sign. This document presents a summary of the existing information from ongoing monitoring programs that cover most of the selected Appalachian Trail Vital Signs. Water quality is an important AT vital sign and summarizing existing water quality information is a necessary step in designing a monitoring program but beyond the scope of this document.

A coordinated, unified, AT environmental monitoring program provides an unprecedented opportunity to track the condition of priority natural resources along over 2,100 miles of green space from Frasier Fir forests in the south to Balsam Fir forests in the north. A well designed and executed AT monitoring program can provide a unifying principle and a means of linking and strengthen existing programs though the interpretation of existing data in relation to the AT. This report is a step in this process where specific monitoring vital signs are identified and available information is summarized, providing a starting point to focus the development of the AT Vital Signs Program.

Table 1. Summary of high priority vital signs identified by three I&M Networks bisected by the Appalachian Trail. Green boxes indicate the network selected this as a vital sign. Eighty percent of the vital signs were selected independently by at least 2 networks.
NETN = Northeast Temperate Network,
NCRN = National Capital Region Network,
APHN = Appalachian Highlands Network.

Level 1	Level 2	Vital Sign	NETN	NCRN	APHN
Air and Climate	Air Quality	Ozone	■	■	■
		Wet and Dry Deposition	■	■	■
		Contaminants	■	■	■
		Visibility and particulate matter		■	■
	Weather and Climate	Climate	■	■	■
		Phenology	■		
Geology and Soils	Soil Quality	Soil Erosion and deposition			■
Water	Hydrology	Water quantity	■	■	
	Water Quality	Water chemistry	■	■	■
		Nutrient enrichment	■	■	■
		Streams - macroinvertebrates	■	■	■
		Contamination	■		■
Biological Integrity	Invasive Species	Exotic species - early detection	■	■	■
	Focal Species or Communities	Wetland - vegetation	■		■
		Forest - vegetation	■	■	■
		High elevation - vegetation	■		■
		Breeding birds	■	■	■
		Reptiles and amphibians	■	■	
		White-tailed deer herbivory	■	■	■
		Insects	■		
		Forest Insect Pests		■	
	At-risk Biota	Priority RTE Species		■	■
Human use	Visitor and Recreation Use	Visitor usage	■		
Landscapes	Landscape Dynamics	Land cover / Ecosystem cover	■	■	■
		Land use	■		■
	Extreme Disturbance Events	Extreme disturbance events	■		■

Table 2. Selected vital signs for the Appalachian Trail based on the prioritization process of three networks and the AT Vital Signs meeting held 13-14 October 2004.

Level 1	*Level 2*	*Level 3*	*Vital Sign*	*Category*
Air and Climate	Air Quality	Ozone	Ozone	●
		Wet and dry deposition	Acid Deposition	●
		Visibility and particulate matter	Visibility and Particulate Matter	●
Water	Water Quality	Water chemistry	Water Chemistry	◆
Biological Integrity	Invasive Species	Invasive/Exotic plants	Early Detection	✚
	Focal Species or Communities	Forest vegetation	Forest - vegetation	✚
		Birds	Breeding Birds	✚
		Terrestrial communities	High Elevation - vegetation	✚
	At-risk Biota	T&E species and communities	Priority RTE Species	●
Human use	Visitor and Recreation Use	Visitor usage	Visitor Usage and Impact	●
Landscapes	Landscape Dynamics	Landscape dynamics	Landscape Dynamics	◆

✚ = Category 1 Vital Signs where Natural Resource Challenge funds are being used to develop and/or implement monitoring.

● = Category 2 Vital Signs where other funding is used and the monitoring contributes to an overall assessment of park natural resource condition.

◆ = Category 3 Vital Signs that need to be monitored in the future but due to funding limitations protocol devel opment is being deferred.

Chapter One
Ozone

According to its enabling legislation, the purpose of the Appalachian National Scenic Trail (AT) is to "provide for maximum outdoor recreation potential and for conservation and enjoyment of the nationally significant scenic, historic, natural, or cultural qualities of the areas through which such trails may pass" (Section 3(a), National Trails System Act, as amended, 82 Stat. 919 *et seq.*). Inherent in this purpose are (1) clean air, so that visitors can enjoy a healthy outdoor recreation experience, (2) scenic vistas unimpaired by poor visibility, and (3) natural and cultural resources unaffected by air pollution. In fact, the 1981 *Comprehensive Plan for the Appalachian Trail* recognized air quality as a Trailway value, and expressed concerns about potential future air quality degradation. Unfortunately, those concerns were well founded, because many parts of the Trail corridor today have high concentrations of a number of air pollutants.

One of those pollutants is ozone. High ozone concentrations cause respiratory problems in humans, and are a particular threat to people who are engaging in strenuous aerobic activity, such as hiking. High ozone levels can be dangerous for people with respiratory problems like asthma, and can even temporarily reduce lung function in healthy individuals. In 1997, the U.S. Environmental Protection Agency (EPA) established a new, more-stringent National Ambient Air Quality Standard (NAAQS) for ozone that is designed to better protect public health and welfare. The new NAAQS is based on a 3-year average of the annual 4th highest daily maximum 8-hour ozone concentration. This value cannot exceed 85 parts per billion (ppb), or the area will be designated *nonattainment*.

There are a number of ozone monitoring stations proximate to the AT. While the monitors are not necessarily representative of conditions on the AT because of differences in elevation and meteorology, the sites provide a general indication of regional ozone concentrations. Data collected at nearby monitors suggest that on many sections of the Appalachian Trail, summertime ozone concentrations reach levels that are harmful to humans. In April 2004, EPA published a list of counties that are not attaining the 8-hour ozone NAAQS. With the exception of New Hampshire, Vermont, and Maine, the Appalachian Trail passes through ozone nonattainment counties in all states. Recently, the NPS interpolated average 1994-1998 and 1999-2003 ozone data to derive pollutant concentration isopleth maps for the U.S. (Figure 1.1), with estimated values for specific NPS units. For the most part, there was no change in 8-hour ozone concentrations between the two averaging periods along the AT; however, conditions worsened in North Carolina and Vermont (Figure 1.2). The ozone nonattainment areas indicated by the 1999-2003 isopleth map are consistent with the areas along the Appalachian Trail designated nonattainment by EPA in 2004.

Statistically significant increases in 8-hour ozone concentrations occurred at two of the sites, Great Smoky Mountains National Park in Tennessee and Mount Washington in New Hampshire.

In addition to harming human health, ozone damages sensitive plant species by causing a visible spotting or "stipple" on the upper surface of plant leaves (Figures 1.3 and 1.4). Ozone can cause reduced photosynthesis, reduced growth, premature aging, and leaf loss with or without the occurrence of foliar injury. A list of ozone-sensitive species has been developed for the Appalachian Trail (Table 1.1). While the NAAQS is intended to protect both human health and vegetation, other ozone measurements are more indicative of

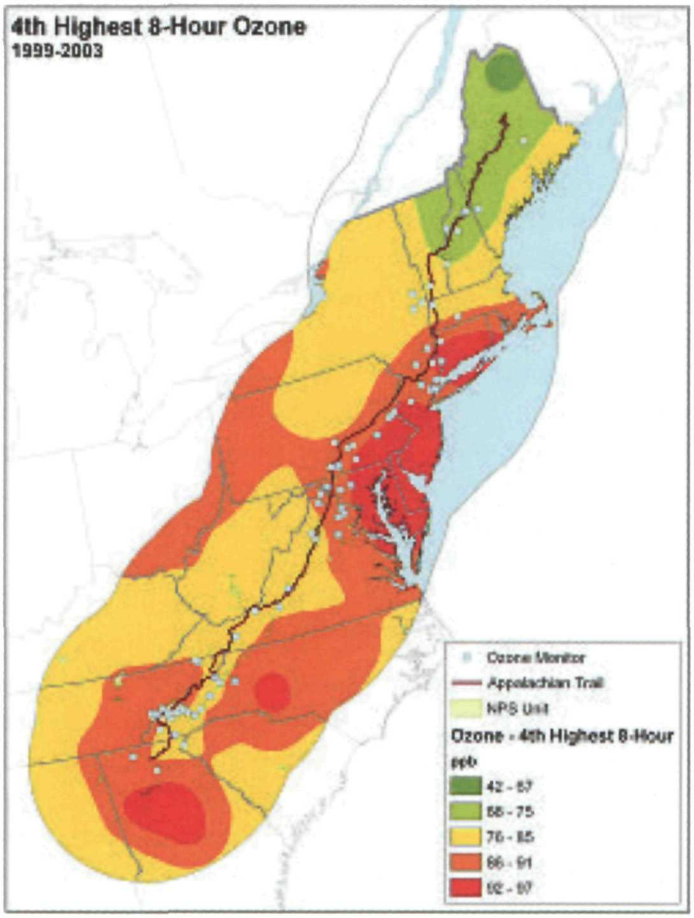


Figure 1.1. Average 8-hour ozone concentrations (courtesy NPS Air Resources Division)

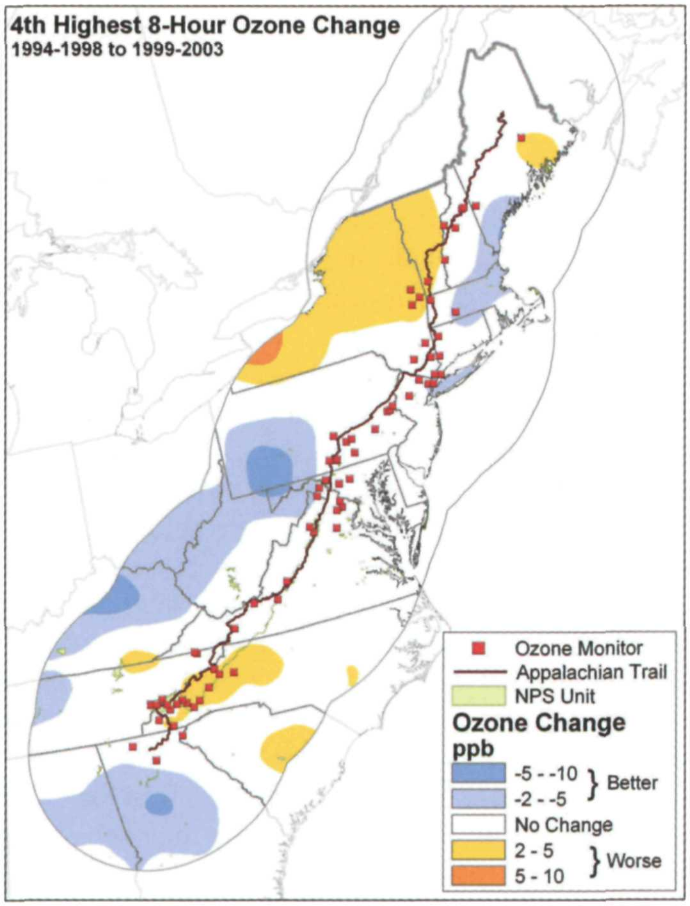


Figure 1.2. Difference in average 8-hour ozone concentrations (courtesy NPS Air Resources Division)

Figure 1.3. Yellow poplar with ozone injury (courtesy of NPS)

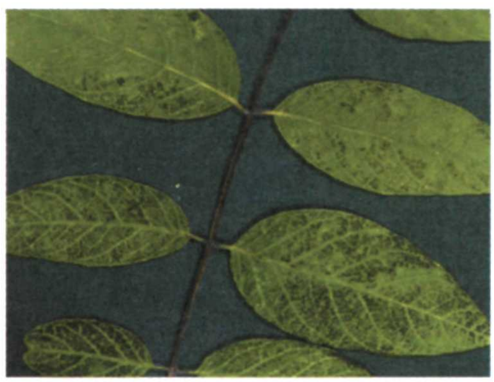


Figure 1.4. Spreading dogbane with ozone injury (courtesy of NPS)

Table 1.1. Ozone-sensitive species on or near the Appalachian National Scenic Trail.

Latin Name	Common Name
Aesculus octandra	Yellow buckeye
Ailanthus altissima	Tree-of-heaven
Apocynum androsaemifolium	Spreading dogbane
*Asclepias species**	Milkweed
*Aster species**	Aster
Cercis canadensis	Redbud
*Fraxinus species**	Ash
Krigia montana	Mountain dandelion
Liquidambar styraciflua	Sweetgum
Liriodendron tulipifera	Yellow-poplar
Parthenocissus quinquefolia	Virginia creeper
Philadelphus coronarius	Sweet mock-orange
*Pinus species**	Pine
Platanus occidentalis	American sycamore
Populus tremuloides	Quaking aspen
Prunus serotina	Black cherry
Rhus copallina	Flameleaf sumac
Robinia pseudoacacia	Black locust
Rubus allegheniensis	Allegheny blackberry
Rudbeckia laciniata	Cut-leaf coneflower
Sambucus canadensis	American elder
Sassafras albidum	Sassafras
Spartina alterniflora	Smooth cordgrass
Symphoricarpos albus	Common snowberry
Verbesina occidentalis	Crownbeard
Vitis labrusca	Northern fox grape

*some genera known to be sensitive
(from Kohut, R.J. 2004. Assessing the Risk of Foliar Injury to Vegetation from Ozone in the National Park Service Vital Signs Networks. National Park Service Report NPS D566. Denver, Colorado)

vegetation response. One such measure is the SUM06. SUM06 is the sum of all hourly average ozone concentrations greater than or equal to 60 ppb. In 1997, a group of ozone effects experts recommended SUM06 thresholds for natural vegetation. The experts recommended concentrations no greater than 8 to 12 parts per million-hours (ppm-hrs) to protect against foliar injury and 10 to 15 ppm-hrs to protect against growth effects on tree seedlings. A recently completed ozone injury risk assessment indicates a moderate to high likelihood of ozone injury of vegetation along significant portions of the AT. Injury is a particular concern for high-elevation, ridge-top plant communities, where elevated ozone concentrations are frequently more prevalent. Interpolated SUM06 ozone values exceeded vegetation injury thresholds along the majority of the AT for the 1999-2003 averaging period (Figure 1.5). Comparison of 1994-1998 and 1999-2003 averaging periods shows worsening ozone conditions in North Carolina and Tennessee, and either improving conditions or no change for the rest of the AT (Figure 1.6).

The NPS performed trend analyses for data collected from 1994 to 2003 at six ozone monitoring sites within about 1 mile of the Appalachian Trail. Statistically significant increases in 8-hour ozone concentrations occurred at two of the sites, Great Smoky Mountains National Park in Tennessee and Mount Washington in New Hampshire (Table 1.2). Continued monitoring will allow the NPS to evaluate whether future pollution control measures required in ozone nonattainment areas result in reduced ozone concentrations near the AT.

There are relatively few nearby ozone monitors located at the same elevation as the Appalachian Trail. Monitors at lower elevations may underestimate ozone concentrations on the AT. Operating portable or passive ozone monitors along the Appalachian Trail for 3 to 5 years, while not adequate for regulatory purposes, would allow the NPS to evaluate the adequacy of existing monitoring.

Ozone injury of vegetation has been documented in Great Smoky Mountains and Shenandoah National Parks, as well as on National Forest lands in the Southeast U.S. It would be useful to conduct systematic ozone injury surveys at a number of locations along the Appalachian Trail to determine the occurrence and severity of ozone injury. Surveys should focus on species with well-documented symptoms, use accepted protocols, and concentrate on areas with a high likelihood of injury, e.g., high SUM06 values and high soil moisture.

Table 1.2. Trends in 8-hour ozone concentrations at monitoring sites within about 1 mile of the Appalachian Trail (1994 to 2003).

Location	Concentration (% change per year)
Great Smoky Mountains NP, Tennessee	2.6
Shenandoah NP, Virginia	0.5
Franklin County, Pennsylvania	-0.5
Putnam County, New York	0.4
Mount Greylock, Massachusetts	0.5
Mount Washington, New Hampshire	0.5

Green = Statistically significant trend (courtesy NPS Air Resources Division)

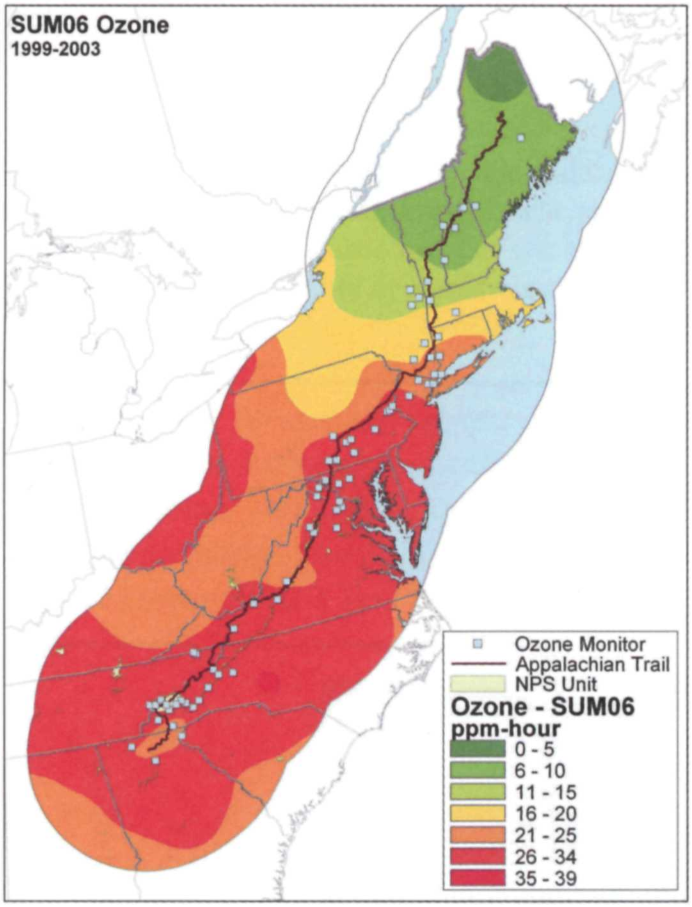


Figure 1.5. Average SUM06 ozone concentrations (courtesy NPS Air Resources Division)

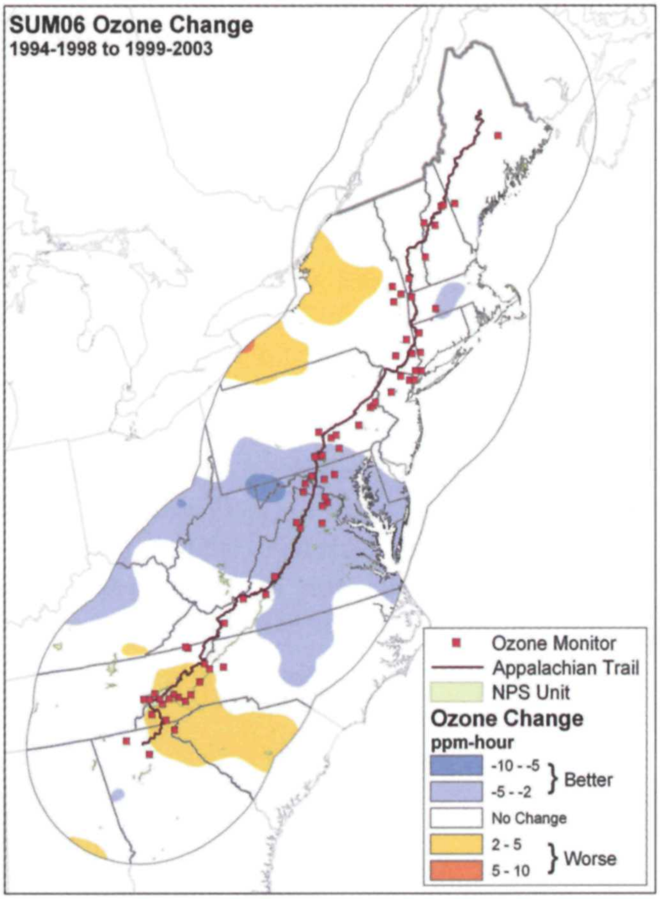


Figure 1.6. Difference in average SUM06 ozone concentrations (courtesy NPS Air Resources Division)

Chapter Two
Visibility

Small or "fine" particles in the air are the main source of human-caused visibility impairment. The particles not only decrease the distance one can see; they also reduce the colors and clarity of scenic vistas (Figures 2.1 and 2.2). The Interagency Monitoring of Protected Visual Environments (IMPROVE) program monitors visibility, primarily in areas designated Class I under the Clean Air Act. Class I areas receive the highest degree of protection, with only a small amount of additional air pollution allowed. The Appalachian Trail passes through six Class I areas: Great Smoky Mountains National Park (NP) in Tennessee and North Carolina, Shenandoah NP and the James River Face Wilderness Area (WA) in Virginia, the Lye Brook WA in Vermont, and the Presidential Range-Dry River WA and Great Gulf WA in New Hampshire. IMPROVE monitoring is conducted at a number of locations near

Class I areas receive the highest degree of protection, with only a small amount of additional air pollution allowed. The Appalachian National Scenic Trail passes through six Class I areas...

Figure 2.1. Example of day with good visibility at Great Smoky Mountains NP (courtesy NPS).

Figure 2.2. Example of day with bad visibility at Great Smoky Mountains NP (courtesy NPS).

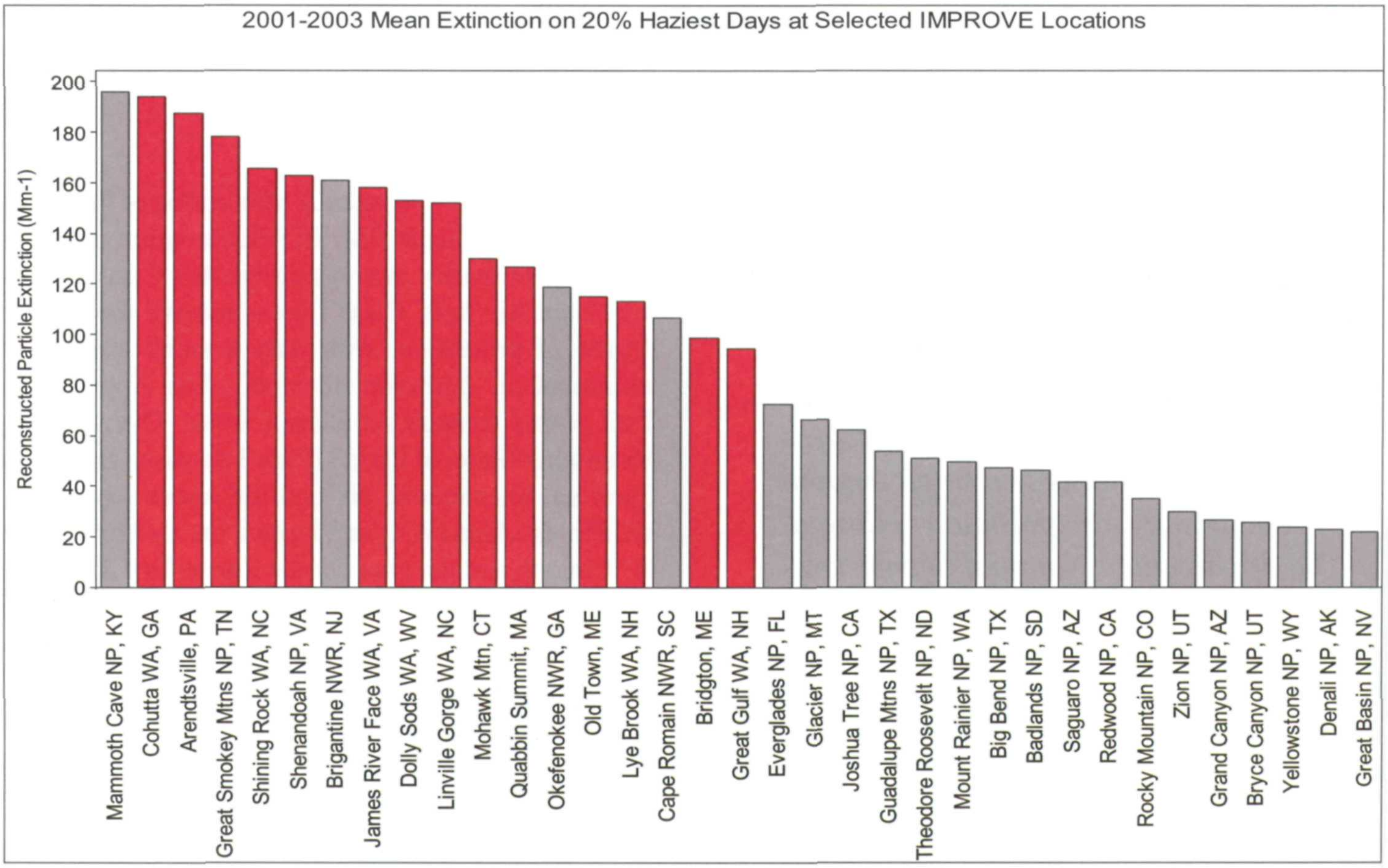


Figure 2.3. 2001-2003 average light extinction on days with worst visibility at selected IMPROVE sites (in Mm^{-1}). Red bars indicate sites that are near the Appalachian Trail (courtesy NPS Air Resources Division).

the AT, and visibility impairment has been documented at all locations. One measure of the effect particle concentrations in the air have on visibility is light extinction, which is reported in inverse megameters (Mm^{-1}). Light extinction is correlated with visual degradation, so the greater the light extinction, the worse the visibility. Typically, IMPROVE sites in the eastern United States report worse visibility than sites in the West (Figure 2.3).

In 1999, Congress passed the Regional Haze Rule, which requires states to develop and implement plans to reduce pollutants that contribute to visibility impairment in Class I areas. Improvements are supposed to occur on the days with worst visibility as well as on the days with best visibility. The NPS performed visibility trend analyses for four IMPROVE sites near the Appalachian Trail. Statistically significant improvements in visibility occurred between 1994 and 2003 at Lye Brook WA on the days with best visibility, and at Dolly Sods WA in West Virginia and Great Smoky Mountains NP on the days with worst visibility (Table 2.1).

Recently, the NPS interpolated 1994-1998 and 1999-2003 data to derive average best and worst visibility isopleth maps for the U.S. (Figures 2.4 and 2.6), with estimated values for specific NPS units. The analysis indicated visibility was worst along the southern portion of the AT and improved as one moved north. Visibility at all sites near the AT either improved or showed no change on the best days (Figure 2.5). A comparison of the two time periods for the days with worst visibility showed improving conditions on the southern part of the AT and worsening conditions along the section of the AT passing through Connecticut, Massachusetts, Vermont and New Hampshire (Figure 2.7). Only with long term monitoring will we be able to judge the success of the Regional Haze Rule in improving visibility along the Appalachian Trail.

Based on the location of existing IMPROVE monitors, Appalachian Trail managers have identified a number of sections where visibility monitoring is needed to better characterize visibility conditions for the AT. These sections include southern Virginia; Maryland; central and northern Pennsylvania, New Jersey and New York (2 to 3 new sites would be ideal); the Vermont/New Hampshire border; and Maine (1 to 3 sites). Ideally, IMPROVE particle data would be combined with real-time photographic data from existing (and potentially new) Webcam sites along the AT. A series of monitors at key locations along the AT would allow Appalachian Trail managers to document the range of visibility conditions, determine trends in visibility degradation, compare and contrast visibility parameters at different points on the Appalachian Trail, and portray this information to the public.

Table 2.1. Trends in visibility at four IMPROVE sites near the Appalachian Trail (in Mm^{-1}).

	Great Smoky Mountains NP Tennessee		Shenandoah NP Virginia		Dolly Sods Wilderness Area West Virginia[1]		Lye Brook Wilderness Area Vermont	
	Best Days	Worst Days	Best Days	Worst Days	Best Days	Worst Days	Best Days	Worst Days
1994	31	214	24	213	23	230	-	-
1995	29	189	28	186	29	200	11	109
1996	38	203	32	164	34	154	12	82
1997	35	193	27	156	32	167	12	105
1998	32	216	-	-	24	180	10	107
1999	35	190	21	138	31	155	11	103
2000	35	175	23	144	30	149	9	91
2001	29	186	30	160	31	150	9	121
2002	33	172	24	174	26	150	9	119
2003	26	173	19	153	25	159	8	101
Slope	-0.49	-3.91	-0.49	-4.25	-0.46	-5.89	-0.51	1.67

Green = Statistically significant trend (courtesy NPS Air Resources Division)

[1] Of the four IMPROVE sites, Dolly Sods WA is the furthest from the AT (approximately 70 miles).

Next page: all maps courtesy NPS Air Resources Division

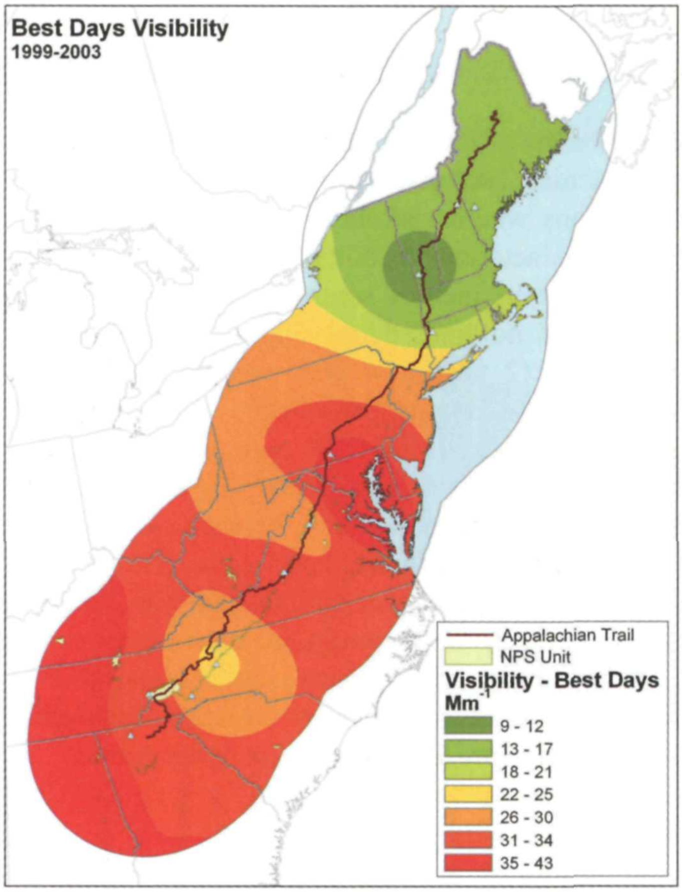


Figure 2.4. Average visibility on best days

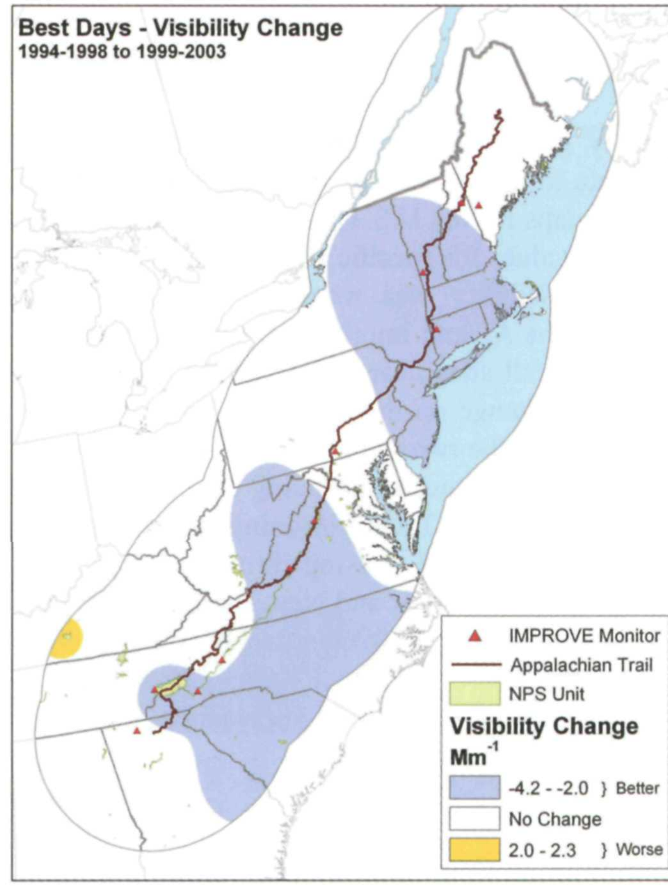


Figure 2.5. Difference in average visibility on best days

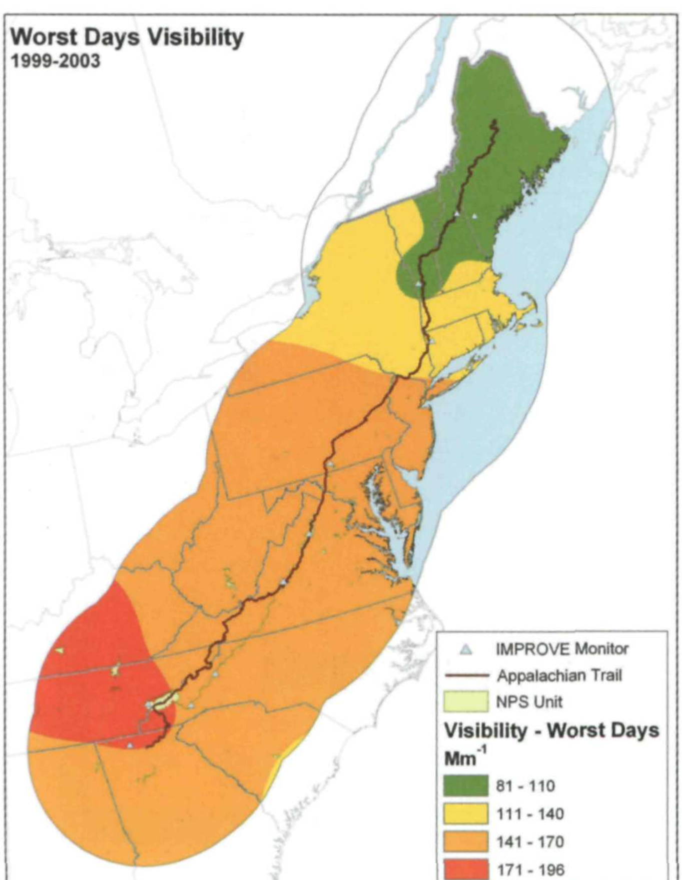


Figure 2.6. Average visibility on worst days

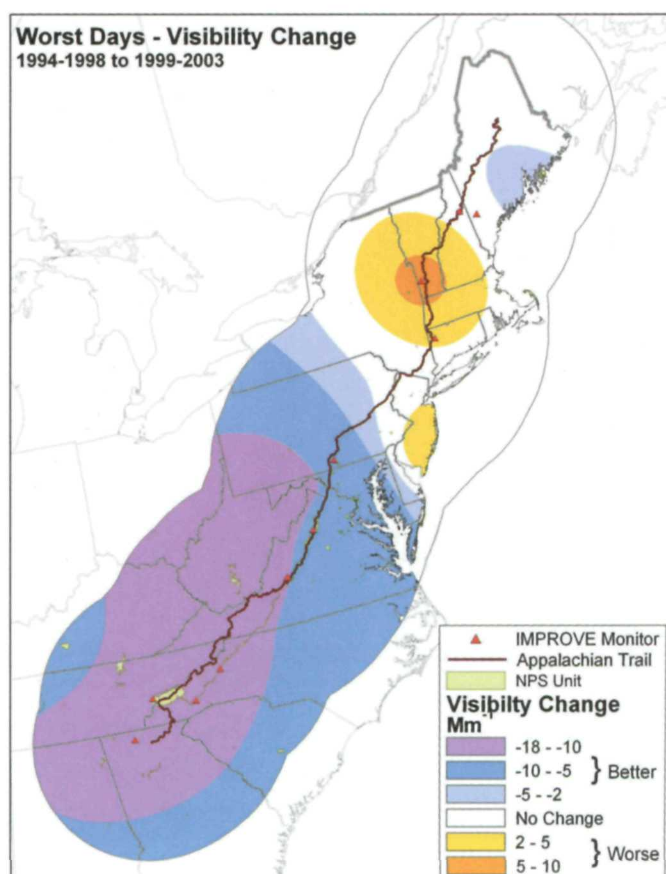


Figure 2.7. Difference in average visibility on worst days

Chapter Three
Atmospheric Deposition

Deposition of sulfur and nitrogen in rain and snow can acidify soils and surface waters, negatively affecting fish, plants, and other biota. Small ponds and streams at high elevations (Figure 3.1) are particularly susceptible because the soils in those watersheds often have limited ability to buffer acid deposition. The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of over 200 sites that monitor precipitation chemistry (Figure 3.2). A number of NADP/NTN sites are located near the Appalachian National Scenic Trail (AT). While all nearby monitoring sites are not necessarily representative of conditions on the AT because of differences in elevation and meteorology, the sites provide a general indication of regional deposition chemistry conditions and trends.

An analysis of 1985-2002 data collected at 15 NADP/NTN sites near the AT showed a significant decrease in sulfur concentration in precipitation at all sites while only three sites had a significant decrease in nitrogen concentration (Table 3.1). The data reflect documented decreases in emissions of sulfur dioxide in the eastern U.S. but little change in emissions of nitrogen oxides. Recently, the NPS interpolated average 1994-1998 and 1999-2003 precipitation chemistry data to derive nitrogen and sulfur concentration isopleth maps for the U.S., with estimated values for specific NPS units. Average 1999-2003 nitrogen concentrations in precipitation were elevated along the AT from Virginia through New York (Figure 3.3) while sulfur concentrations were elevated in all states except Maine (Figure 3.5). For the majority of the Appalachian Trail, there was either no change or an improvement in both nitrogen and sulfur concentration between the two averaging periods (Figures 3.4 and 3.6).

Figure 3.1. Horns Pond at Bigelow Preserve, Maine. (courtesy NETN)

Figure 3.2. NADP/NTN monitoring equipment at Hubbard Brook, New Hampshire. (courtesy NADP/NTN)

Table 3.1. Trends in nitrogen (N) and sulfur (S) concentrations in precipitation at NADP/NTN sites within about 60 miles of the Appalachian Trail, 1985-2002.

Location	N Concentration (% change per year)	S Concentration (% change per year)
Otto, North Carolina	-0.2	-2.8
Great Smoky Mountains NP, Tennessee	-0.8	-2.7
Mt. Mitchell, North Carolina	0.8	-2.0
Eggleston, Virginia	-0.4	-2.3
Charlottesville, Virginia	-0.6	-2.2
Shenandoah NP, Virginia	0.6	-1.8
Finksburg, Maryland	-1.4	-2.6
Milford, Pennsylvania	-0.7	-2.7
West Point, New York	-1.6	-3.2
Claryville, New York	-0.7	-2.9
Quabbin Reservoir, Massachusetts	-1.0	-3.6
Bennington, Vermont	-0.9	-3.4
Hubbard Brook, New Hampshire	-0.2	-2.7
Bridgton, Maine	0.5	-2.7
Greenville, Maine	1.0	-2.6

Green = Statistically significant trend

(From Lehmann, C.M.B., V.C. Bowersox and S.M. Larson. 2005. Spatial and temporal trends of precipitation chemistry in the United States, 1985-2002. Environmental Pollution 135:347-361)

For the majority of the Appalachian Trail, there was either no change or an improvement in both nitrogen and sulfur concentration between the two averaging periods.

Although limited sampling has taken place at several locations along the AT, a comprehensive, coordinated survey has not been conducted to determine the extent of acid-sensitive soils and surface waters on the Appalachian Trail. Acid sensitivity has been documented in other locations in the Southern Appalachian, Adirondack, and White Mountains, so it is likely that sections of the AT that traverse these mountain ranges would have sensitive soils and surface waters, as well.

While existing NADP monitors are adequate for evaluating regional wet deposition and trends, it would be necessary to install additional monitors on the Appalachian Trail to clarify on-site deposition. However, in order to ascertain the need for expanded deposition monitoring, it is advisable to first conduct synoptic surveys of Trail soils and surface waters to determine their sensitivity to deposition.

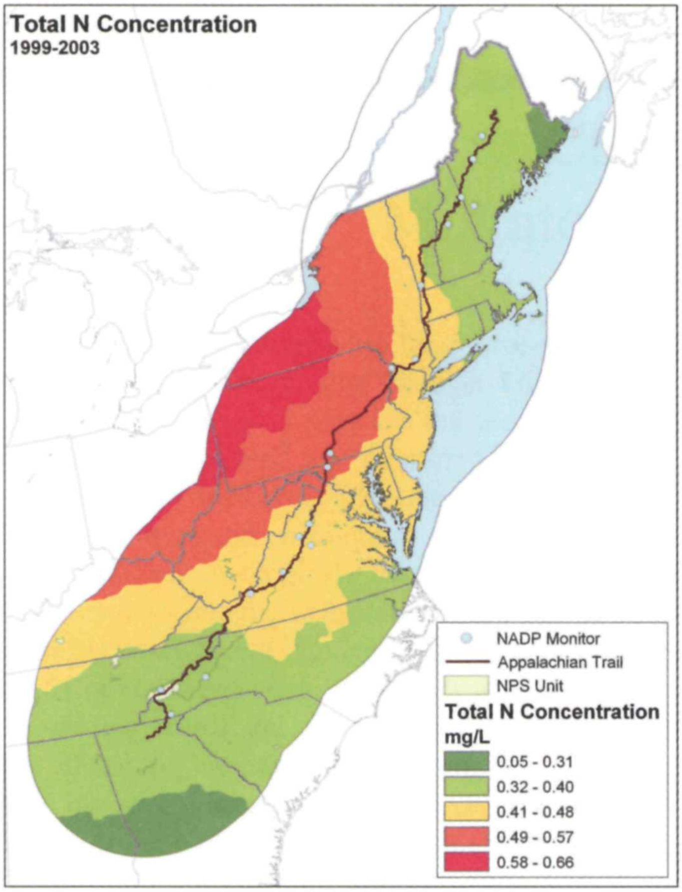


Figure 3.3. N Concentration in precipitation

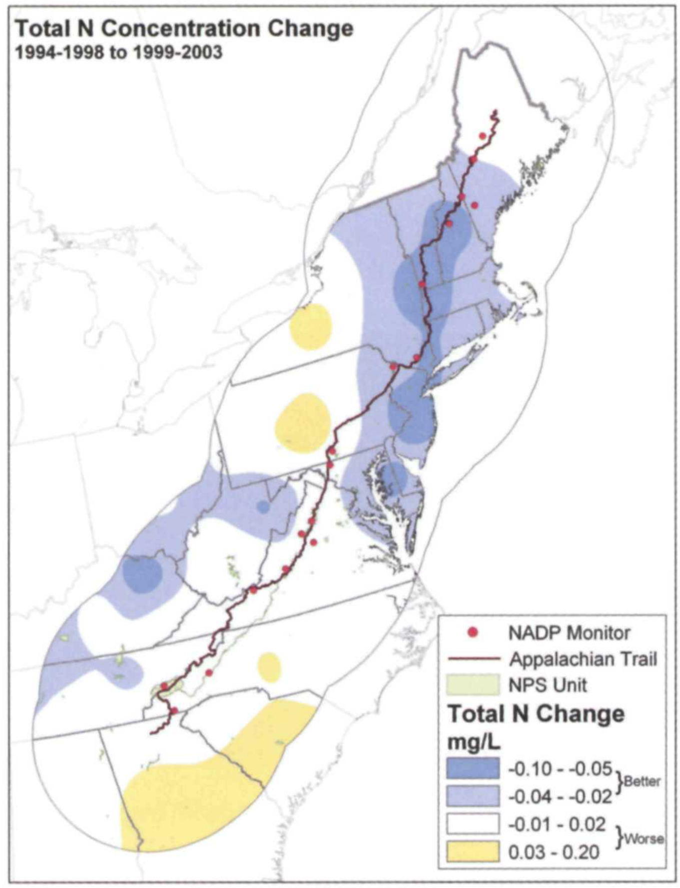


Figure 3.4. Difference in N Concentration in precipitation

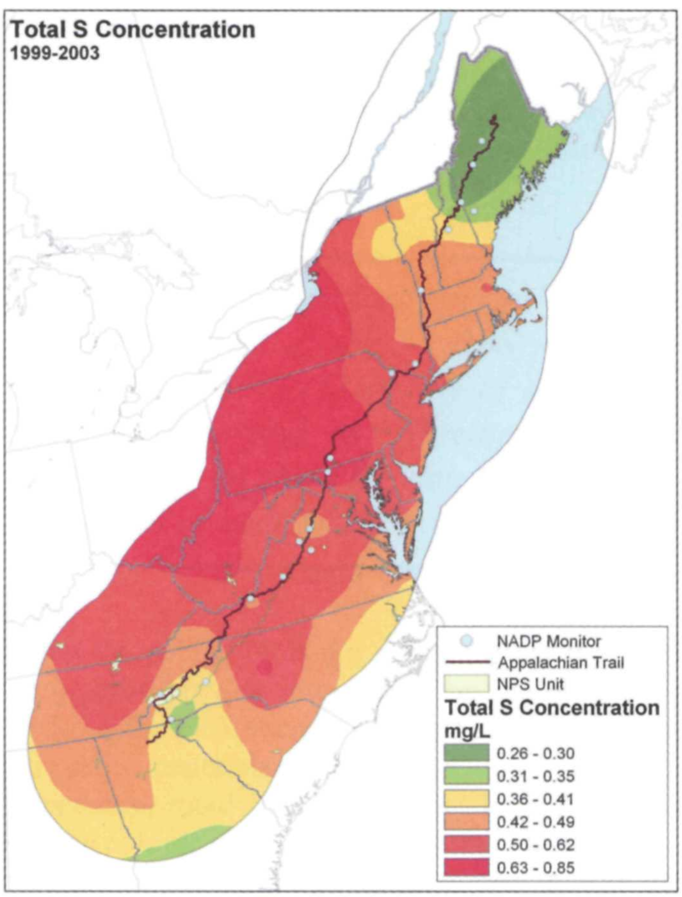


Figure 3.5. S Concentration in precipitation

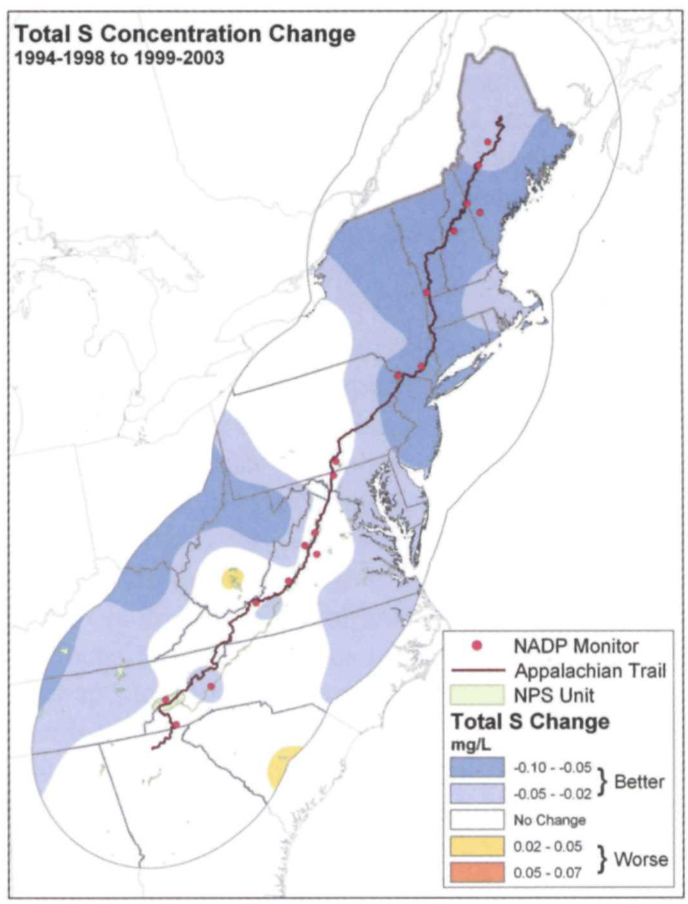


Figure 3.6. Difference in S Concentration in precipitation

All maps courtesy NPS Air Resources Division

Chapter Four
Migratory Breeding Birds

In developing comprehensive long-term monitoring plans, landbirds are among the best faunal groups to monitor because: 1) they are the most easily and inexpensively detected and identified vertebrates, 2) a single survey method is effective for many species, 3) accounting and managing for many species with different ecological requirements promotes conservation strategies at the landscape scale, 4) many reference datasets and standard methods are available, and 5) the response variability is fairly well understood. In addition, birds are a useful biotic indicator of the effects of habitat fragmentation, an ecological issue especially important for the Appalachian Trail. Although the National Park Service (NPS) has some management control over fragmentation within the parks, habitat fragmentation outside park boundaries is widespread within much of the eastern region. Management activities aimed at preserving habitat for bird populations, such as for neotropical migrants, can have the added benefit of preserving entire ecosystems and their attendant ecosystem services. Moreover, among the public, birds are a high profile taxa, and many parks provide information on the status and trends of the park's avian community through their interpretive materials and programs. The high body temperature, rapid metabolism, and high ecological position of birds in most food webs make them a good indicator of local and regional ecosystem change and therefore an important component of any long-term monitoring program.

Fifteen PIF Watch List species were detected on 32 of the 38 BBS routes (84%) and 33% (13 of 39) of all the species identified as "threatened or declining" on the PIF Watch List are found on or near the AT corridor.

Blue-winged Warbler ©Charley Eiseman

During the last two decades of the 20th century, a surge of interest in conserving birds and their habitats spurred the development of several unprecedented, partnership-based bird conservation initiatives. Each of these initiatives has produced landscape-oriented conservation plans for birds that lay out population goals and habitat objectives.

Partners In Flight (http://www.partnersinflight.org/) was launched in 1990 in response to growing concerns about declines in the populations of many land bird species, and in order to emphasize the conservation of birds not covered by existing conservation initiatives. The initial focus was on neotropical migrants, species that breed in the Nearctic (North America) and winter in the Neotropics (Central and South America), but the focus has spread to include most landbirds and other species requiring terrestrial habitats. The central premise of Partners In Flight (PIF) has been that the resources of public and private organizations in North and South America must be combined, coordinated, and increased in order to achieve success in conserving bird populations in this hemisphere. Partners In Flight is a cooperative effort involving partnerships among federal, state and local government agencies, philanthropic foundations, professional organizations, conservation groups, industry, the academic community, and private individuals.

Started in 1999, the North American Bird Conservation Initiative (NABCI, http://www.nabci-us.org/) is a coalition of government agencies, private organizations, academic institutions, and private industry leaders in Canada, the United States, and Mexico working to achieve integrated bird conservation that will benefit all birds in all habitats. NABCI participants aim to ensure the long-term health of North America's native bird populations by increasing the effectiveness of their bird conservation initiatives and programs, enhancing coordination among their initiatives and programs, and fostering greater cooperation among the continent's three national governments and their people.

Gaining insights into the long-term trends and shifts in certain avian species ranges will provide one measure for assessing the ecological integrity of AT ecosystems. The first step in the process of developing a Breeding Bird Vital Sign was to summarize existing data relevant to the avi-fauna of the Appalachian Trail. For this analysis, we used the Breeding Bird Survey (BBS) data obtained from routes intersecting, or in close proximity to, the AT corridor to provide a comprehensive bird species inventory and focused trend analysis on high priority species. Initiated in 1966, the North American Breeding Bird Survey is coordinated by the U.S. Geological Survey, Patuxent Wildlife Research Center. The BBS is conducted every June at over 3,500 routes across North America. Routes are 24.5 mile roadside counts with observers stopping every 0.5 miles to record all birds seen or heard during a 3-minute count. Analysis of the data results in continent-scale abundance maps, and trend information on individual species and groups such as neotropical migrants.

We used the Partners in Flight avian species prioritization list to select species for this analysis based on the PIF conservation score. Partners in Flight provides an objective process for ranking species conservation needs within physiographic regions to better focus and coordinate management efforts. We then summarized the BBS data within the Bird Conservation Regions developed by NABCI (Figure 4.1). The Appalachian Trail bi-sects two bird conservation regions where 38 BBS routes intersecting or within one mile of the Appalachian Trail are located (Figure 4.1). Thirteen BBS routes are located within the Northern Forest Bird Conservation Area and 25 routes are located in the Appalachian Mountains Bird Conservation Area providing a baseline for determining the status of priority species associated with the AT.

Golden-winged Warbler ©Charley Eiseman

The PIF Watch list divides each species into 3 general categories of concern; 1) species with multiple causes for concern across their entire range "Highest Priority", 2) species that are moderately abundant with declines or high threats "Threatened or Declining", and 3) species with restricted distribution of small populations "Range Restricted". Fifteen PIF Watch List species were detected on 32 of the 38 BBS routes (84%) and 33% (13 of 39) of all the species identified as "threatened or declining" on the PIF Watch List are found on or near the AT corridor. Given that many of the PIF Watch List species do not occur in forested landscapes or within the eastern U.S., 1/3 of the species is substantial and indicates that the Appalachian Trail plays a role in the conservation of migratory bird species.

The distribution of the 15 Watch List species along the AT differed with changes in latitude. Four species (Willow Flycatcher, Wood Thrush, Prairie Warbler,

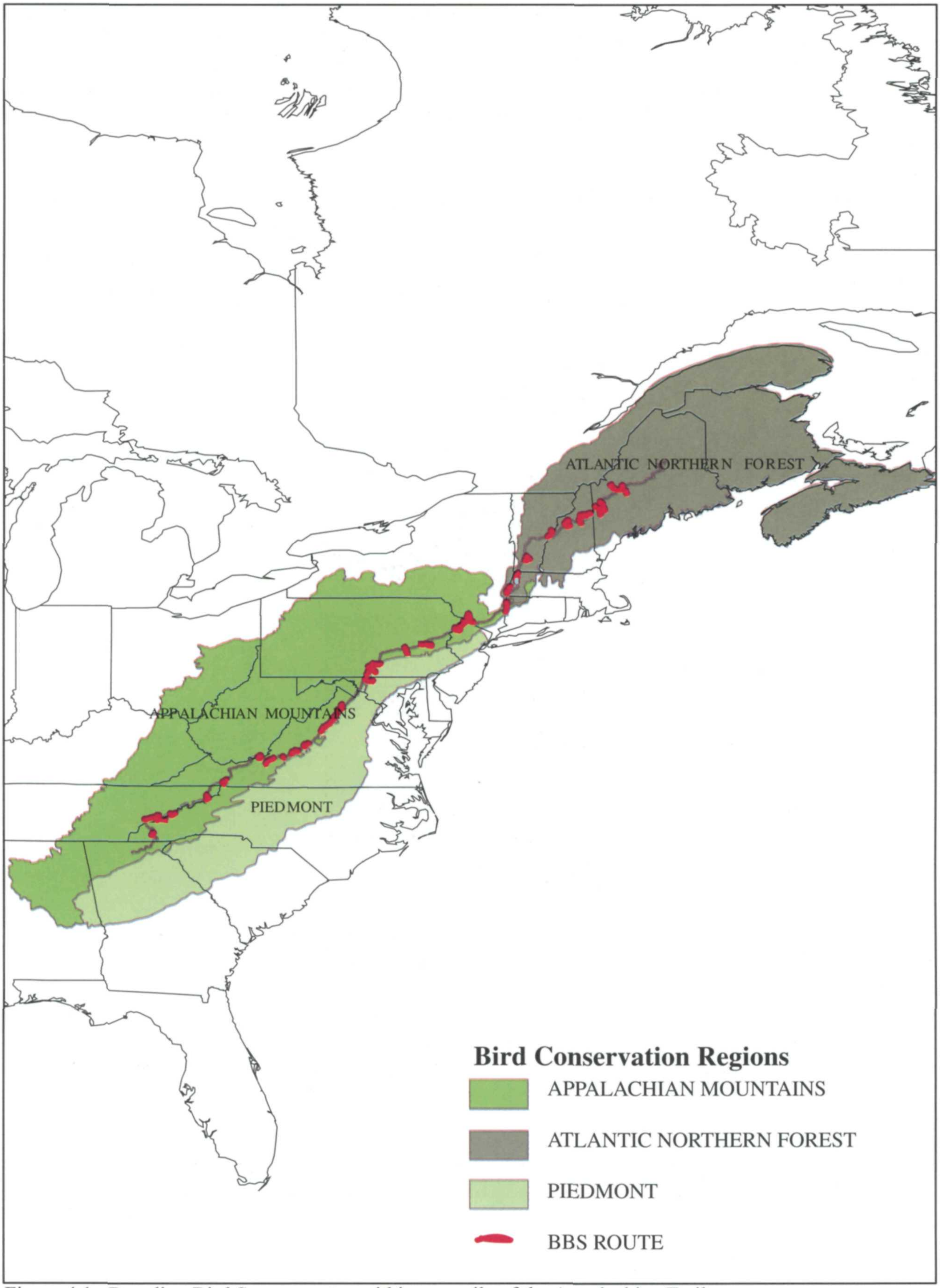


Figure 4.1. Breeding Bird Survey routes within one mile of the Appalachian Trail

Table 4.1. Trend summary of Partners in Flight Watch List species that occur on 32 Breeding Bird Survey (BBS) routes on or near the Appalachian Trail. For each physiographic region, a green box indicates the species was detected within that bird conservation region, the direction of the arrow indicates population trend within that region, a **?** indicates that trend detection is uncertain, and "no data" indicates that not enough data are available to estimate trend. The percent of AT BBS routes (38 total) where a species was detected, the percent AT routes with declining trends, and the BBS survey-wide trend are shown.

Partners in Flight Category[1]	Species	Atlantic Northern Forest	Appalachian Mountains	AT Routes with Species Present (# routes)	AT Routes with Declining Trend	BBS-wide Trend (1966-2003)
Highest Concern	Bicknell's Thrush	?		3% (1)	100%	-
Threatened or Declining	Red-headed Woodpecker			3% (1)	0%	-2.63%
	Olive-sided Flycatcher	↓		13% (5)	100%	-3.54%
	Willow Flycatcher	no data	no data	34% (13)	46%	-0.87%
	Wood Thrush	↓	←→	84% (32)	67%	-1.78%
	Blue-winged Warbler	?		18% (7)	86%	-0.63%
	Golden-winged Warbler		↓	16% (6)	100%	-2.39%
	Cerulean Warbler		?	24% (9)	25%	-4.21%
	Prairie Warbler	?	↑	24% (9)	67%	-2.60%
	Bay-breasted Warbler	?		8% (3)	50%	-2.37%
	Worm-eating Warbler		?	45% (17)	60%	0.45%
	Kentucky Warbler		?	32% (12)	75%	-1.01%
	Canada Warbler	←→	?	53% (20)	69%	-2.02%
	Rusty Blackbird	no data		3% (1)	100%	-9.93%
Range Restricted	Swainson's Warbler			5% (2)	-	9.92%

[1] The "Highest Concern" set of species all show a combination of small population size, restricted range, and population decline. The birds in the "Threatened and Declining" category have all declined seriously in recent decades, and are perceived to be still threatened, but have reasonably large ranges and population sizes. The "Range Restricted" category are species with small ranges and/or population sizes, but which have not been undergoing notable declines and do not face imminent threats.

and Canada Warbler) were detected on BBS routes in both bird conservation regions (Table 4.1). The Wood Thrush was the most widely distributed species and occurred on 84% of all AT BBS routes. The population trend for this forest breeding neotropical migrant differed among regions with declining populations in the Atlantic Northern Forest and stable populations in the Appalachian Mountains (Table 4.1). Five species (Bicknell's Thrush, Olive-sided Flycatcher, Blue-winged Warbler, Bay-breasted Warbler, and Rusty Blackbird) were detected only in the Atlantic Northern Forest region and 2 species (Red-headed Woodpecker and Swainson's Warbler) were detected only in the Appalachian Mountains region (Table 4.1). This targeted summary of BBS data provides a means by which to focus the Breeding Birds Vital Sign on species within specific regions given existing conservation prioritization. It also shows the level of uncertainty associated with estimating the population status of many breeding birds given the existing information. Population trends for 11 of the 15 AT watch list species were not available due to the lack of data or the uncertainty associated with the trend estimates.

More detailed analyses of changes in bird species abundance on AT BBS routes were conducted to determine the regional specificity and variability in population trend and how the AT BBS route trends compare with the survey-wide trend. Results are summarized as graphs for each species that show the percentage change per year for each route where the species was observed (Figure 4.2). The routes are presented in north to south order to give an indication of the latitudinal variation in species trends along the Appalachian Trail. Only those routes were a species was detected are shown on each graph to indicate the distribution of each species on AT BBS routes (Figure 4. 2).

Ten of the thirteen species (77%) with trend data available show declining trends on >50% AT BBS routes, similar to survey-wide patterns (Table 4.1). The Cerulean Warbler, however, appears to be doing better along the AT than in the region as a whole (Table 4.1 and Figure 4.2). This wetland forest breeder was detected on 9 BBS routes associated with the AT and all but one had stable or positive population trends (Figure 4.2). Wood Thrush shows a latitudinal pattern in population trend with northern BBS routes showing population declines and southern BBS routes showing population increases (Figure 4.2). Blue-winged and Golden-winged warblers, both early successional breeders, show population declines at national, regional, and AT BBS route levels.

The BBS was designed to provide a continent-wide perspective of population change for breeding bird species in the U.S. and Canada. Routes are randomly located in order to sample habitats that are representative of the entire region. A large sample size, (number of routes), is needed to average local variations and reduce the effects of sampling error, (variation in counts attributable to both sampling technique and real variation in trends). The survey produces an index of relative abundance rather than a complete count of breeding bird populations. The data analyses assume that fluctuations in these indices of abundance are representative of the population as a whole. Despite its complicated analyses, the BBS has proven to be a very valuable source of information on bird population trends and can provide meaningful information when interpreting the status of the avian community associated with the AT.

Analyzing population change on survey routes is probably the most effective use of BBS data, but these data do not provide an explanation for the causes of population trends. To evaluate population changes

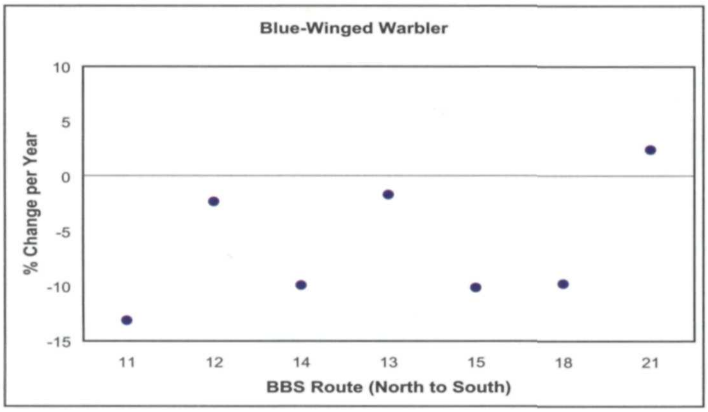
Canada Warbler ©Charley Eiseman

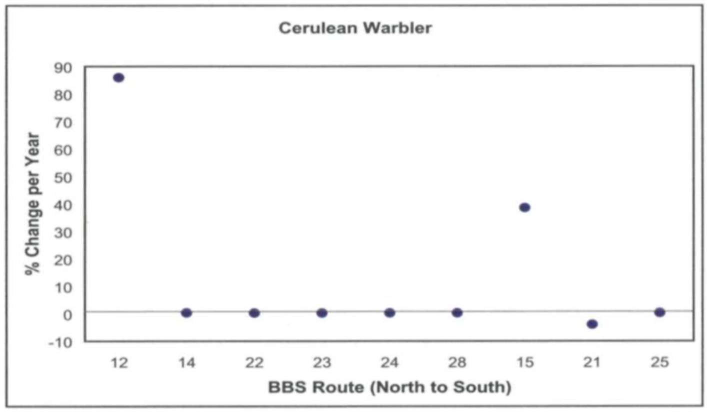
over time, BBS indices from individual routes are combined to obtain regional and continental estimates of trends. Although some species have consistent trends throughout the history of the BBS, most do not. Few species have consistent trends across their entire ranges, so geographic patterns in trends are of considerable interest to anyone concerned with the status of the continent's birds.

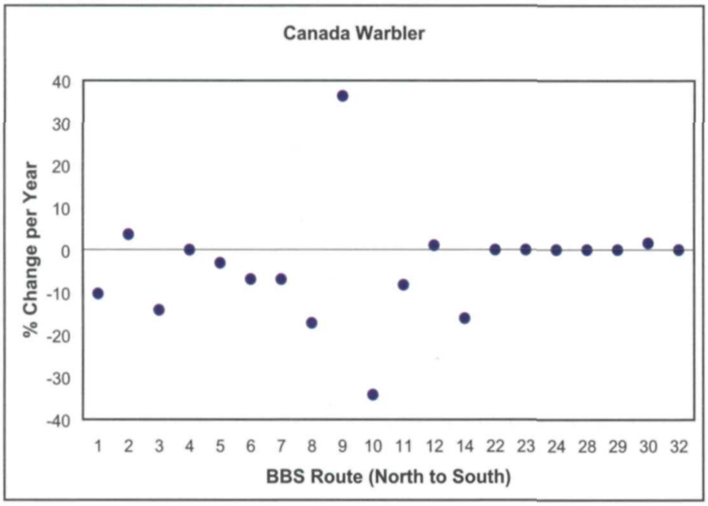
A volunteer-based breeding bird monitoring program for the AT would be an appropriate program to address the Breeding Bird Vital Sign, would engage a large interested public, and would be manageable with a moderate level of coordination. Well developed avian monitoring protocols exist and are being implemented in the Atlantic Northern Forest Bird Conservation Area that could be expanded AT corridor wide. The Vermont Institute of Natural Science (VINS) launched Mountain Birdwatch in the spring of 2000 in order to establish a long-term monitoring program for Bicknell's Thrush (see Chapter 5) and other montane forest birds. From the Catskills in New York to Mount Katahdin, Maine, trained volunteers conduct dawn surveys along foot trails that pass through some of the region's most awe-inspiring forests, including sections of the AT. By selecting a sub-set of breeding bird species (5 total) that occur in montane forests, these protocols are especially suited as a volunteer-based program. A volunteer-based breeding bird monitoring program with the goal of detecting changes in abundance for the Partners in Flight Watch List species in each Bird Conservation Area (Table 4.1) would provide valuable information about the status of these species not only along the AT but within the region.

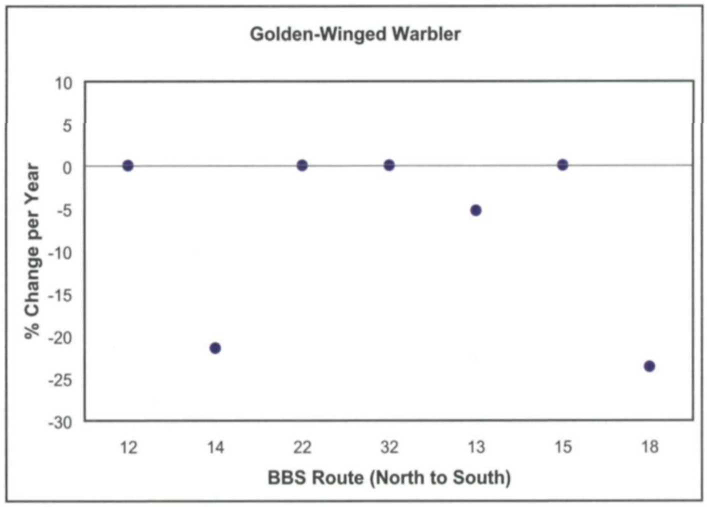
Willow Flycatcher ©Charley Eiseman

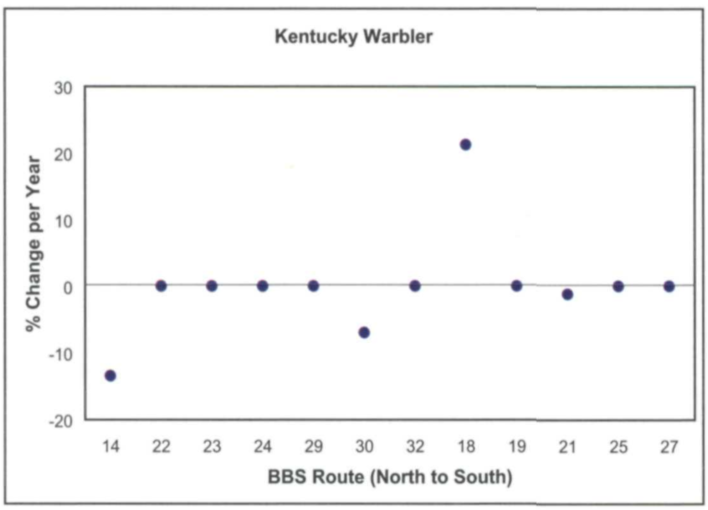
Opposite Page:
Figure 4.2. Population trend along Appalachian Trail Breeding Bird Survey routes.

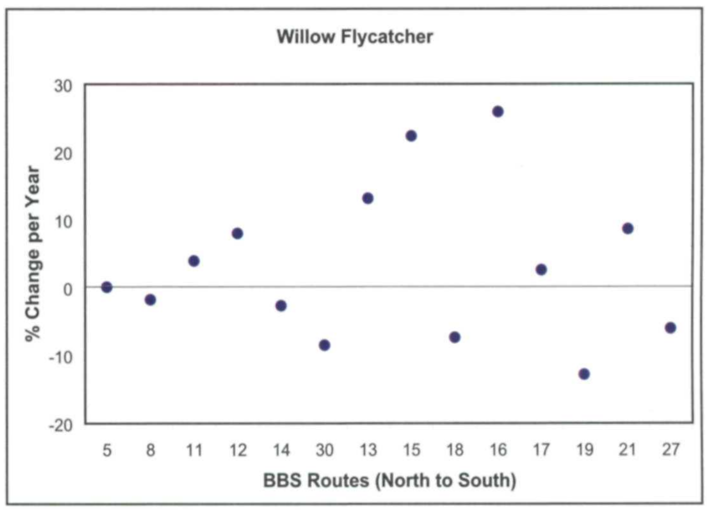

Blue-Winged Warbler
% Change per Year
10
5
0
-5
-10
-15
11 12 14 13 15 18 21
BBS Route (North to South)

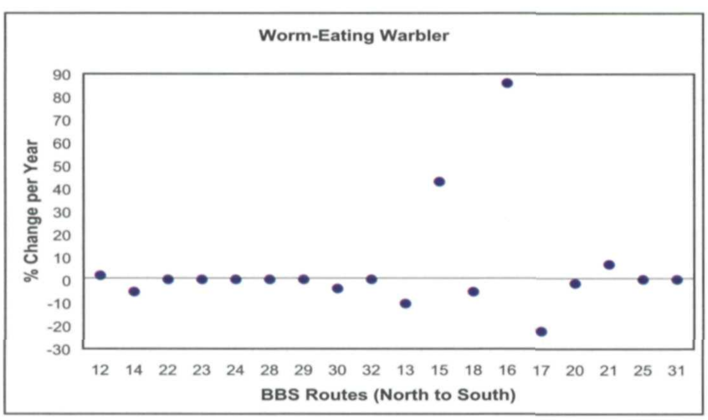

Cerulean Warbler
% Change per Year
90
80
70
60
50
40
30
20
10
0
-10
12 14 22 23 24 28 15 21 25
BBS Route (North to South)

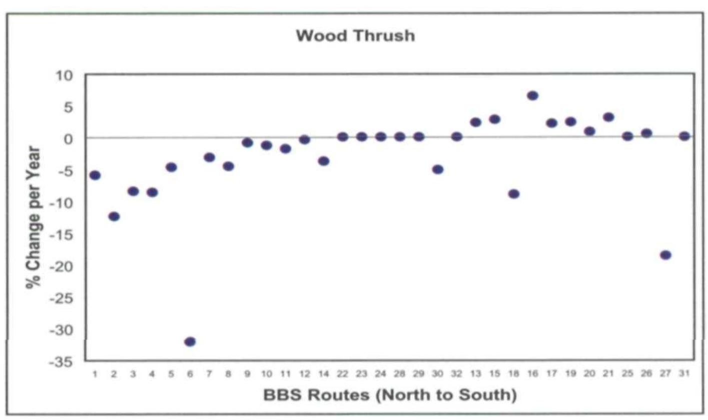

Canada Warbler
% Change per Year
40
30
20
10
0
-10
-20
-30
-40
1 2 3 4 5 6 7 8 9 10 11 12 14 22 23 24 28 29 30 32
BBS Route (North to South)


Golden-Winged Warbler
% Change per Year
10
5
0
-5
-10
-15
-20
-25
-30
12 14 22 32 13 15 18
BBS Route (North to South)


Kentucky Warbler
% Change per Year
30
20
10
0
-10
-20
14 22 23 24 29 30 32 18 19 21 25 27
BBS Route (North to South)


Willow Flycatcher
% Change per Year
30
20
10
0
-10
-20
5 8 11 12 14 30 13 15 18 16 17 19 21 27
BBS Routes (North to South)


Worm-Eating Warbler
% Change per Year
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
12 14 22 23 24 28 29 30 32 13 15 18 16 17 20 21 25 31
BBS Routes (North to South)


Wood Thrush
% Change per Year
10
5
0
-5
-10
-15
-20
-25
-30
-35
1 2 3 4 5 6 7 8 9 10 11 12 14 22 23 24 28 29 30 32 13 15 18 16 17 19 20 21 25 26 27 31
BBS Routes (North to South)

Chapter Five
Mountain Birds

Montane spruce-fir forest is an uncommon habitat type in northern New England, comprising less than 1% of the area's total land cover. Though rare in the region, it is the dominant forest type along approximately 140 miles of the Appalachian Trail in Vermont, New Hampshire, and Maine. A summer hike through the Northeast's high-elevation softwoods provides an opportunity to view a unique community of breeding landbirds that warrants special attention. This group includes several species of high conservation concern, most notably Bicknell's Thrush (*Catharus bicknelli*).

Bicknell's Thrush is a rare songbird that breeds in montane spruce-fir forests... and the extent of current and potential U.S. habitat is estimated at 136,250 ha, of which 24.3% occurs within one mile of the Appalachian Trail.

Bicknell's Thrush is a rare habitat specialist that nests in montane spruce-fir forests of the northeastern United States (Atwood et al. 1996) and adjacent portions of Canada (Ouellet 1993).

Montane spruce-fir habitat occurs primarily above 3,200 ft. in southern Vermont and as low as 2,300 ft. in northern Maine (Lambert et al. 2005). Red spruce (*Picea rubra*) dominates the lower reaches of this forest zone, where it mixes with heart-leaved paper birch (*Betula papyrifera* var. *cordifolia*) and mountain ash (*Sorbus americana* and *S. decora*). As elevation increases, red spruce gives way to balsam fir (*Abies balsamea*) and hardwoods become scarce. On high mountains, black spruce (*Picea mariana*) can be locally abundant where the forest grades into subalpine krummholz. Krummholz marks the upper boundary of the montane spruce-fir forest. The lower

Bicknell's Thrush © Steven D. Faccio

boundary is typically formed by a mix of yellow birch (*Betula alleghaniensis*) and red spruce (Thompson and Sorenson 2000). Montane spruce-fir forests are dynamic environments in which steep slopes and shallow soils expose many stands to the damaging effects of wind, ice, and erosion. The variety of age classes that results from natural disturbance provides diverse habitat structure for breeding birds.

Surveys by the Green Mountain National Forest (1991-2000), the Vermont Institute of Natural Science (1991-2004), and the White Mountain National Forest (1993-2003) detected 84 bird species on 119 routes located in montane spruce-fir forests in New York, Vermont, New Hampshire, and Maine. The four most abundant species accounted for 51% of all observations. These were Blackpoll Warbler (*Dendroica striata*), White-throated Sparrow (*Zonotrichia albicollis*), Yellow-rumped Warbler (*Dendroica coronata*), and Winter Wren (*Troglodytes troglodytes*). The 17 most common birds (Table 5.1) made up 93% of the records. A mix of migration strategies and nesting guilds are represented in this group. Insects are the most important food source for the montane forest bird community, however, several species also consume seeds and berries.

Table 5.1. Life history characteristics of most common species in northeastern montane spruce-fir forest (based on Ehrlich et al. 1988).

Species	Migration status[1]	Nest type and location	Diet
Yellow-bellied Flycatcher	LDM	open cup low or on ground (0-1 m)	insects
Boreal Chickadee	RES	cavity low or mid-story (1-3 m)	insects, seeds
Red-breasted Nuthatch	SDM-RES	cavity in mid-story or canopy (2-12 m)	insects, seeds
Winter Wren	SDM	roofed cup in roots, stump or cavity (0-2 m)	insects
Golden-crowned Kinglet	SDM-RES	pendant in mid-story or canopy (2-15 m)	insects
Ruby-crowned Kinglet	SDM	pendant in mid-story or canopy (4-10 m)	insects
Bicknell's Thrush	LDM	open cup in shrubs or mid-story (1-5 m)	insects, berries
Swainson's Thrush	LDM	open cup low, mid-story or canopy (1-6 m)	insects, berries
Nashville Warbler	LDM	open cup on ground	insects
Magnolia Warbler	LDM	open cup in shrubs or mid-story (1-3 m)	insects
Yellow-rumped Warbler	SDM	open cup low, mid-story or canopy (1-15 m)	insects
Black-throated Green Warbler	LDM	open cup in canopy (6-10 m)	insects
Blackpoll Warbler	LDM	open cup in mid-story (1-2 m)	insects
White-throated Sparrow	SDM	open cup low or on ground (0-1 m)	seeds, insects
Dark-eyed Junco	SDM-RES	sheltered cup on ground or low (0-1 m)	seeds, insects
Purple Finch	SDM-RES	open cup in mid-story or canopy (2-12 m)	seeds, berries
Pine Siskin	SDM-RES	open cup in mid-story or canopy (2-15 m)	seeds, insects

[1] LDM = long-distance migrant, SDM = short-distance migrant, RES = resident

Seven PIF-ranked species have been detected in low numbers on high-elevation bird surveys in the Northeast. Blackburnian Warbler (*Dendroica fusca*) and Northern Parula (*Parula americana*) are common in low- to mid-elevation softwoods and have been detected at the lower margins of montane spruce-fir. Black-backed Woodpecker (*Picoides arcticus*), Cape May Warbler (*Dendroica tigrina*), and Spruce Grouse (*Falcipennis canadensis*) are boreal species that nest on some of the more prominent mountains in New Hampshire and Maine. Canada Warbler (*Wilsonia canadensis*) and Bay-breasted Warbler (*Dendroica castanea*) are on the PIF Continental Watch List due to widespread decline and multiple causes for concern (Rich et al. 2004).

Bicknell's Thrush is a rare songbird that breeds in montane spruce-fir forests of New York, Vermont, New Hampshire, and Maine (Atwood et al. 1996). Small numbers also nest in coastal and highland

Table 5.2. Status and population trends of common birds of northeastern montane spruce-fir. Bold typeface indicates statistically significant trend (P < 0.05).

Species	Relative abundance[1]	PIF priority status	VT, NY, and ME mountains[2]	Northern New England[3]	Eastern Spruce-Hardwoods[3]
Yellow-bellied Flycatcher	common		5.7	NA	0.6
Boreal Chickadee	rare	high	NA	NA	-2.5
Red-breasted Nuthatch	rare		**-27.1**	2.4	**2.5**
Winter Wren	abundant		4.4	-0.1	**3.5**
Golden-crowned Kinglet	rare		7.4	0.2	3.0
Ruby-crowned Kinglet	rare		0.5	2.8	**-1.2**
Bicknell's Thrush	uncommon	high	2.0	NA	NA
Swainson's Thrush	common		-11.5	3.2	**-1.6**
Nashville Warbler	rare	high	-9.6	**-3.1**	0.5
Magnolia Warbler	uncommon		**20.8**	-1.5	**1.8**
Yellow-rumped Warbler	abundant		**12.5**	1.3	**1.8**
Black-throated Green Warbler	rare	high	NA	2.7	0.6
Blackpoll Warbler	abundant	high	-0.1	NA	**-5.7**
White-throated Sparrow	abundant		8.0	**-4.2**	**-1.0**
Dark-eyed Junco	common		-6.7	-1.6	**-2.2**
Purple Finch	rare	high	-4.1	**-2.8**	**-2.0**
Pine Siskin	rare		NA	15.6	-2.2

[1] rare = 1-2% of University of Vermont, Vermont Institute of Natural Science, and White Mountain National Forest point count records; uncommon = 2-5%; common = 5-10%; abundant = 10-15%

[2] Vermont Forest Bird Monitoring Program 1991-2000; n = 6-18 routes.

[3] North American Breeding Bird Survey 1966-2003; n = 10-298 routes.

spruce-fir forests of southeastern Canada (Ouellet 1993, Nixon 1999). It is the only breeding bird species endemic to this region. The extent of current and potential U.S. habitat is estimated at 136,250 ha (Lambert et al. 2005), of which 24.3% occurs within one mile of the Appalachian Trail. Since 1992, observers have reported Bicknell's Thrush on mountains within this trailside zone (Figure 5.1). Confirmed locations stretch from an unnamed peak south of Glastenbury Mountain in southern Vermont to Mount Katahdin in northern Maine. The winter range of Bicknell's Thrush is restricted to the Greater Antilles, with the majority of birds concentrated in the Dominican Republic (Rimmer et al. 2001a).

Extirpations of Bicknell's Thrush from several locations in the U.S. (Lambert et al. 2001) and Canada (Tufts 1986, Christie 1993, Nixon 1999) have elevated concern for this species. Unfortunately, recent trend analyses have been limited in scope, using a small number of routes and/or years (Deming et al. 2001, Faccio 2001, Rimmer et al. 2001b). Although some tests have suggested stable or changing numbers, none has produced a statistically significant result. The Vermont Institute of Natural Science and the USDA Forest Service are currently collaborating on a comprehensive trend analysis that will incorporate 14 years of Bicknell's Thrush point count data from 45 routes located in Vermont and New Hampshire.

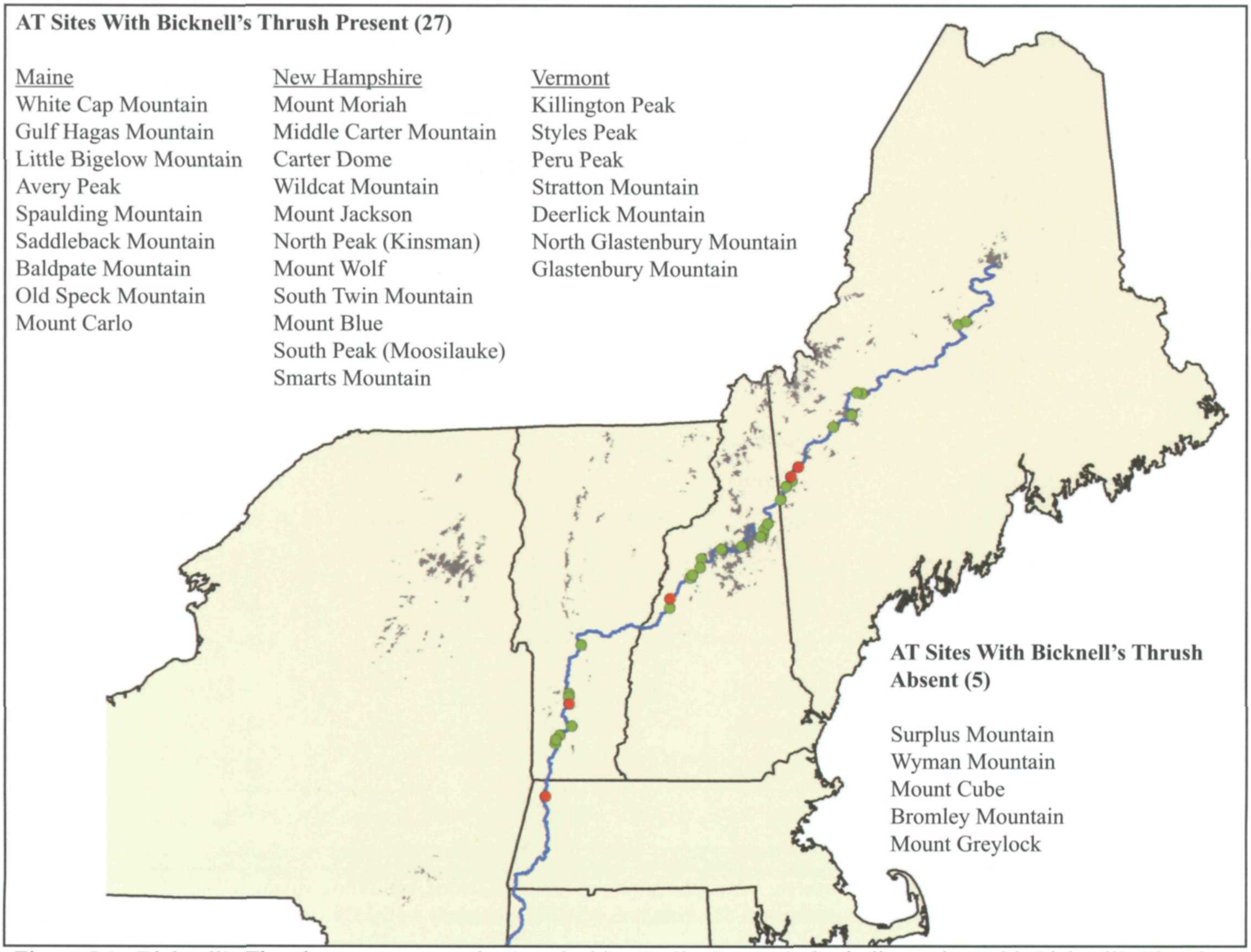


Figure 5.1. Bicknell's Thrush occurrence on the Appalachian Trail. Green circles indicate sites with Bicknell's Thrush present, red circles indicate surveyed sites where Bicknell's Thrush were not detected. Grey shading shows the potential habitat distribution for Bicknell's Thrush. Twenty-four percent of the total US habitat for Bicknell's Thrush occurs within one mile of the AT.

Preliminary results from the White Mountain National Forest indicate a 6.4% annual decline in Bicknell's Thrush abundance (P=0.053)

Within montane spruce-fir habitat, Bicknell's Thrush is most frequently found in patches of regenerating, mid-successional, or chronically disturbed forest (Rimmer et al. 2001a). Typical habitat characteristics include a dense softwood understory (Sabo 1980, Hale 2001, Pierce-Berrin 2001), a low canopy (Sabo 1980, Noon 1981, Hale 2001), and a high number of snags (Connolly 2000). These features arise in fir waves, in gaps beneath a broken canopy, and on exposed slopes and ridges. Bicknell's Thrushes also utilize forest edges adjacent to ski trails and other clearings. Most nests are built in balsam fir trees between 0.5 and 10 m off the ground, with an average nest height of 2 m (Rimmer et al. 2001a). Although use of mixed forests is rare in the U.S., surveys in Québec (Y. Aubry pers. comm.), New Brunswick (Nixon et al. 2001) and Nova Scotia (D. Busby pers. comm.) have detected Bicknell's Thrush in regenerating timberlands with a prominent hardwood component. Nesting in this habitat type has not yet been confirmed. Wintering birds primarily inhabit montane broadleaf forests, with lower numbers in mixed broadleaf-pine forests (Rimmer et al. 2001a).

Species with limited distributions, specialized habitat requirements, and low numbers are at increased risk of extinction. Bicknell's Thrush is no exception. Several government and non-government agencies recognize its vulnerability. Partners in Flight includes Bicknell's Thrush on its North American Watch List for Landbirds, calling for immediate action to maintain or increase its numbers in the Northern Forest Biome (Rich et al. 2004). The North American Bird Conservation Initiative lists Bicknell's Thrush among the Highest Priority landbirds for Bird Conservation Region 14, the Atlantic Northern Forest (Dettmers 2003). The World Conservation Union classifies Bicknell's Thrush as Vulnerable on its worldwide list of threatened birds (Stattersfield and Capper 2000). Bicknell's Thrush is a Species of Special Concern in Vermont and Maine and is on a watch list for special concern species in New Hampshire.

Bicknell's Thrush feeding © Steven D. Faccio

The destruction of wintering habitat is considered the greatest short-term threat to the species. More than 80% of the U.S. breeding grounds are conserved (Lambert 2003), although habitat alteration and removal is permitted on some management units. Nearly all of the Vermont and New Hampshire habitat along the Appalachian Trail occurs on National Park Service or National Forest property, where habitat alteration is prohibited or subject to environmental review. In western Maine, extensive areas of trailside habitat occur on unconserved land, especially above 2,700 feet between Old Blue Mountain and Stoney Brook Mountain.

The development of wind farms, telecommunication towers, and ski areas may reduce and further fragment high-elevation habitat, with unknown consequences for bird populations. Proposed projects near the AT include a ski area expansion on Mount Snow (VT) and a wind farm in the Redington-Crocker Range (ME). A study of two ski areas in Vermont found no differences in nesting success between ski areas and adjacent natural areas forty years after trail construction (Rimmer et al. 2004). Short-term impacts of ski trail development have not been examined. Effects of wind farm development on Bicknell's Thrush are the subject of ongoing study in northeastern Vermont.

Timber management at upper elevations in Maine may also affect habitat suitability for Bicknell's Thrush. Pre-commercial thinning in Canadian spruce-fir highlands has been found to reduce the species' numbers in the short term, with a rebound possible within four to eight years (Campbell et al. 2005). Clearcutting could also degrade Bicknell's habitat, however dense regeneration following harvest has the potential to create new habitat patches (Nixon et al. 2001). Further study is needed to assess the influence of timber management on Bicknell's Thrush in Maine highlands.

The greatest challenges facing Bicknell's Thrush on the breeding grounds may not be visible or possible to address through local management. Acid deposition, mercury contamination, and climate change could have profound effects on mountain ecosystems, which are especially vulnerable to these stressors. Mountaintop deposition of sulfur and nitrogen oxides occurs through precipitation and condensation of cloud water. Chronic exposure to these acidic compounds results in calcium depletion from thin and poorly buffered soils and from cell membranes in red spruce needles. Loss of foliar calcium can lead to winter freezing injury and may underlie forty years of red spruce decline throughout the East (DeHayes et al. 1999). Documented effects of acidification on birds include reduction of calcium-rich invertebrate prey, egg-laying irregularities (Graveland et al. 1994), and reduced reproductive success (Graveland and van der Wal 1996). Recent research in eastern North America revealed a negative effect of acid rain on the predicted probability of Wood Thrush breeding, with strongest effects observed in highland areas (Hames et al. 2002).

Birds in acidified, mountain ecosystems of the Northeast are at elevated risk for mercury contamination because conversion of mercury (Hg) to its toxic form, methylmercury (MeHg), is pronounced in acidic environments (Miskimmin et al. 1992) and because regional deposition of mercury is greatest at high elevations (Lawson 1999, Miller et al. 2005). Blood collected from Bicknell's Thrushes between 2000 and 2004 contained elevated levels of MeHg, especially in samples from older males (Rimmer et al. 2005). Although toxicity thresholds are unknown in insectivorous landbirds, the accumulation of MeHg with age could ultimately reduce longevity or impair reproduction.

Persistence of the Northeast's unique high-elevation bird community may require growing season temperatures to remain at or near their current levels. A warming climate threatens to significantly reduce montane spruce-fir habitat by allowing upslope encroachment of temperature-limited hardwoods such as American beech and yellow birch (Lambert and McFarland 2004). An increase of 3°C, which is within 100-year regional projections for average annual temperature (Hurtt and Hale 2001), could limit balsam fir to extreme northern latitudes (Iverson and Prasad 2002) or to small patches atop the Appalachian Trail's highest northern mountains (Lambert and McFarland 2004). An increase of 5°C could effectively eliminate this critical bird habitat from the Northeast (Lambert and McFarland 2004).

Mountain Birdwatch, coordinated by the Vermont Institute of Natural Science, aims to track changes in the distribution and abundance of Bicknell's Thrush and other mountain-dwelling landbirds of the Northeast. Volunteer observers monitor approximately 120 survey routes each year, including up to 32 routes on the Appalachian Trail. Mountain Birdwatch results are periodically pooled with data collected by the USDA Forest Service on the White Mountain National Forest and by Bird Studies Canada in New Brunswick and Nova Scotia. To date, Mountain Birdwatch records have been used to identify conservation opportunities, evaluate options for land management, and model Bicknell's Thrush habitat in New York, Vermont, New Hampshire, and Maine.

Mountain Birdwatch provides a strong framework for future monitoring of the AT's high-elevation landbirds. However, to achieve balanced geographic coverage in the Northeast, more sites should be established in Maine. In addition, a greater commitment of staff time to AT routes will be necessary to ensure that surveys are completed every year. Once strengthened in the Northeast, the network of survey routes could be expanded to include mountain sites along the southern section of the Appalachian Trail.

Chapter Six
Forest Vegetation

Many people equate eastern North America with a megalopolis--Boston, New York City, Washington DC, Atlanta, and the other sprawling urban areas that have left little room for natural diversity. The Appalachian Mountain forests, however, provide an extensive set of parks and protected areas, extending from Georgia to Maine, that are connected by the green corridor of the Appalachian National Scenic Trail. The eastern forests along the Appalachian Mountains are ancient and among the most diverse in temperate areas with over 6,000 plants, hundreds of birds, and more than 50 species each of mammals, reptiles, and amphibians. The AT bisects this diverse area creating a mostly forested corridor linking the Appalachian Mountains from north to south.

In the north, the Appalachian Trail is within the Northern Forest which covers more than 26 million acres in Maine, New Hampshire, Vermont, and New York and represents the largest contiguous blocks of forest land remaining in the eastern United States.

Forest condition was identified as a high priority vital sign for the Appalachian Trail because of the dominance of these ecological communities associated with the Appalachian Trail.

The Northern Forest is one of the United States' greatest remaining forests, the majority of which is undeveloped. More than 80% is privately owned, mostly by large timber corporations; less than 20% is within the bounds of public parks and forests; only 3% of the total is owned by the federal government.

Forests along the northern sections of the Appalachian Trail are dominated by spruce-fir and northern hardwoods from Maine through the higher elevations

Kinsman Mountain, New Hampshire
© Vermont Institute of Natural Science

of New Hampshire and Vermont. As the trail passes through Massachusetts and Connecticut, Northern Hardwood forest types begin to transition into Central Hardwood forests where species like Hickory and Oak begin to replace Maple and Birch. Moving south through the Hudson Valley, the AT is primarily located on ridgelines where Oak-Hickory forests are dominant.

In the southern Appalachians, spruce-fir forests are a unique ecosystem type that consist of a forest dominated by populations of red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*). These forests of the Southern Appalachians are similar to the boreal forests found in Maine and eastern Canada and are located at higher mountain elevations (> 4,000 feet). Southern spruce-fir forests occur in a series of island-like stands on mountains in North Carolina, Tennessee, and Virginia and are isolated from similar northern communities because the Central Appalachians are characterized by lower-elevation peaks. The northern spruce-fir communities differ in species composition from the southern communities being dominated by balsam fir (*Abies balsamea*) rather than the Fraser fir.

Surplus Mountain, Maine

The Appalachian Mountain forests face a number of threats including air pollution, human encroachment, invasive species, and global climate change to name a few. Over the past two decades, Appalachian ecosystems have exhibited indicators of stress and many forest species may be undergoing decline. Recent studies of high-elevation spruce-fir forests have shown high levels of tree mortality, decreases in crown condition, and declining growth rates for both the spruce and fir populations. A large portion of the decline of the Fraser fir is related to infestation by an introduced pest species, the balsam woolly adelgid (*Adelges piceae*). It appears likely that regional air pollution is detrimentally affecting the spruce populations and may be an additional stressor contributing to the decline of the fir populations.

Forest condition was identified as a high priority vital sign for the Appalachian Trail because of the dominance of these ecological communities associated with the AT. To determine the potential for assessing the condition of the forests along the AT using existing data, we acquired and summarized the U.S. Department of Agriculture (USDA) Forest Service, Forest Inventory Analysis (FIA) data for plots associated with the AT. As the Nation's continuous forest census, the FIA program provides information to assess America's forests and reports on status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership.

Data were requested from the FIA program to first determine the number of FIA plots located within 500' of either side of the AT (Figure 6.1). Eighty-four FIA plots are located within 500' of either side of the AT footpath using the FIA publicly accessible data where exact plot locations are not provided (Figure 6.1). Because of the extreme latitudinal range of the AT, little understanding of forest types would be gained by summarizing existing data for the entire length of the AT, which would be necessary given the low number of FIA plots directly located within the AT corridor. Therefore, we divided the AT into the ecoregion sections it crosses from the White Mountains in Maine to the Blue Ridge Mountains in Georgia (Figure 6.1). FIA data within each ecoregion were acquired and the percent of each forest type was summarized by ecoregion section to provide an initial assessment of the forest types along the AT (Figure 6.2).

Forest types were similar in the White Mountains, New England Piedmont, and Green–Taconic–Berkshire Mountains sections (Figure 6.2). These three sections were all dominated by the Maple/Beech/Birch forest type and all had Spruce/Fir forests present (Figure 6.2). Four-hundred-twenty-six miles of the AT are located within the White Mountains Section (Table 6.1). Based on FIA data from 1,529 plots, the forest lands in the White Mountains Section are dominated by Maple/Beech/Birch and Spruce/Fir with 85% of the forested acres in these two forest types (Figure 6.2). This ecoregion section is the only section bisected by the Appalachian Trail that has greater than 20% Spruce/Fir forest cover (Figure 6.2).

Sixty-nine miles of the Appalachian Trail cross the New England Piedmont Section where 342 FIA plots are located (Table 6.1). Forests within this section are also dominated by Maple/Beech/Birch (50% of total forest land) but include forest types not present in the more northern White Mountains Section. Many of the hardwood dominated forest types, such as Elm/Ash/Cottonwood and Oak/Hickory are at the northern extent of their ranges within the New England Piedmont Section. The Green-Taconic-Berkshire Mountains Section contains 219 miles of the AT from the Green Mountains in Vermont to the far southwestern corner of Massachusetts (Table 6.1). Maple/Birch/Beech forests dominate this ecological section with 77% of forest acres measured on 512 FIA plots within this forest type. The Lower New England Section contains 1,210 FIA plots and is dominated by Oak/Hickory and Maple/Beech/Birch forest (Figure 6.2). The AT crosses this ecoregion section for 111 miles from the far southwestern corner of Massachusetts to the northwestern corner of New Jersey. Sixteen tree species and nine forest types were present in the Hudson Valley Section based on 219 FIA plots (Table 6.1, Figure 6.2). Similar to the Lower New England Section, the Hudson Valley was dominated by both Maple/Beech/Birch and Oak/Hickory forests (Figure 6.2). Northern Ridge and Valley and Blue Ridge Mountain Sections include 1,292 miles of the AT, nearly 60% of the total length. These two ecoregions are dominated by Oak/Hickory forests with over 70% forest acreage in this forest type (Figure 6.2).

Information from existing FIA plots can provide information about regional trends in forest acreage and other variables, and may provide information on forest condition related to the AT. More complete analyses of existing FIA data need to be conducted to better determine the utility of this existing data source for interpretation to the forests of the AT. The USDA Forest Service Forest Health Monitoring (FHM) data is also useful for indicating regional trends in forest health that may affect the trail, but there are fewer of these plots associated with the AT. While FIA or FHM data for all ecoregions along the trail has not yet been comprehensively analyzed, smaller regional and/or state analyses of FHM data show some trends in forest health relevant to the Appalachian Trail.

For example, FHM data indicates that ozone injury affected southern AT ecoregions more than northern AT ecoregions in the late 1990's, and many sections of the AT somewhat less than surrounding lowlands (http://www.fhm.fs.fed.us/posters/posters05/ozone_injury.pdf). Efforts to analyze, map and predict forest dieback across the eastern US using FHM data in conjunction with climate and stressor data are ongoing, and will likewise yield information indicative of trends in forest health relevant to AT ecoregions (http://www.fhm.fs.fed.us/posters/posters03/dieback.pdf). Forest condition is an important vital sign for the AT, however substantial planning is necessary to design an AT specific forest monitoring program that clearly defines the program objectives and integrates the summary of existing information wherever appropriate.

Table 6.1. Forest Inventory Analysis (FIA) plots and miles of the Appalachian Trail in each ecoregion section.

	Ecoregion Section						
	White Mountains	**New England Piedmont**	**Green, Taconic, Berkshire Mtns.**	**Lower New England**	**Hudson Valley**	**Northern Ridge and Valley**	**Blue Ridge Mtns**
FIA Plots	1,520	342	512	1,210	219	1,769	1,704
AT miles	426	69	219	111	111	672	620

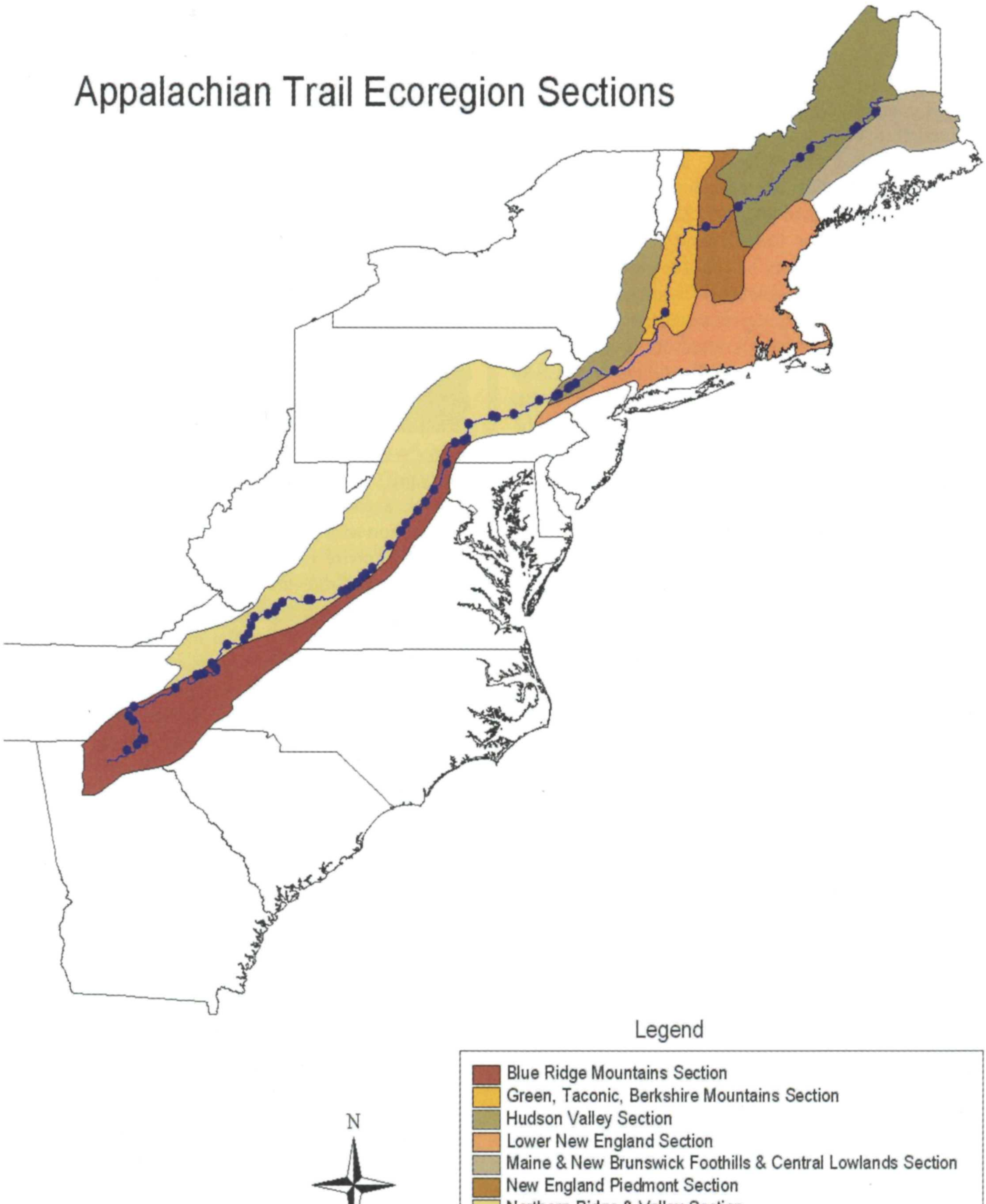
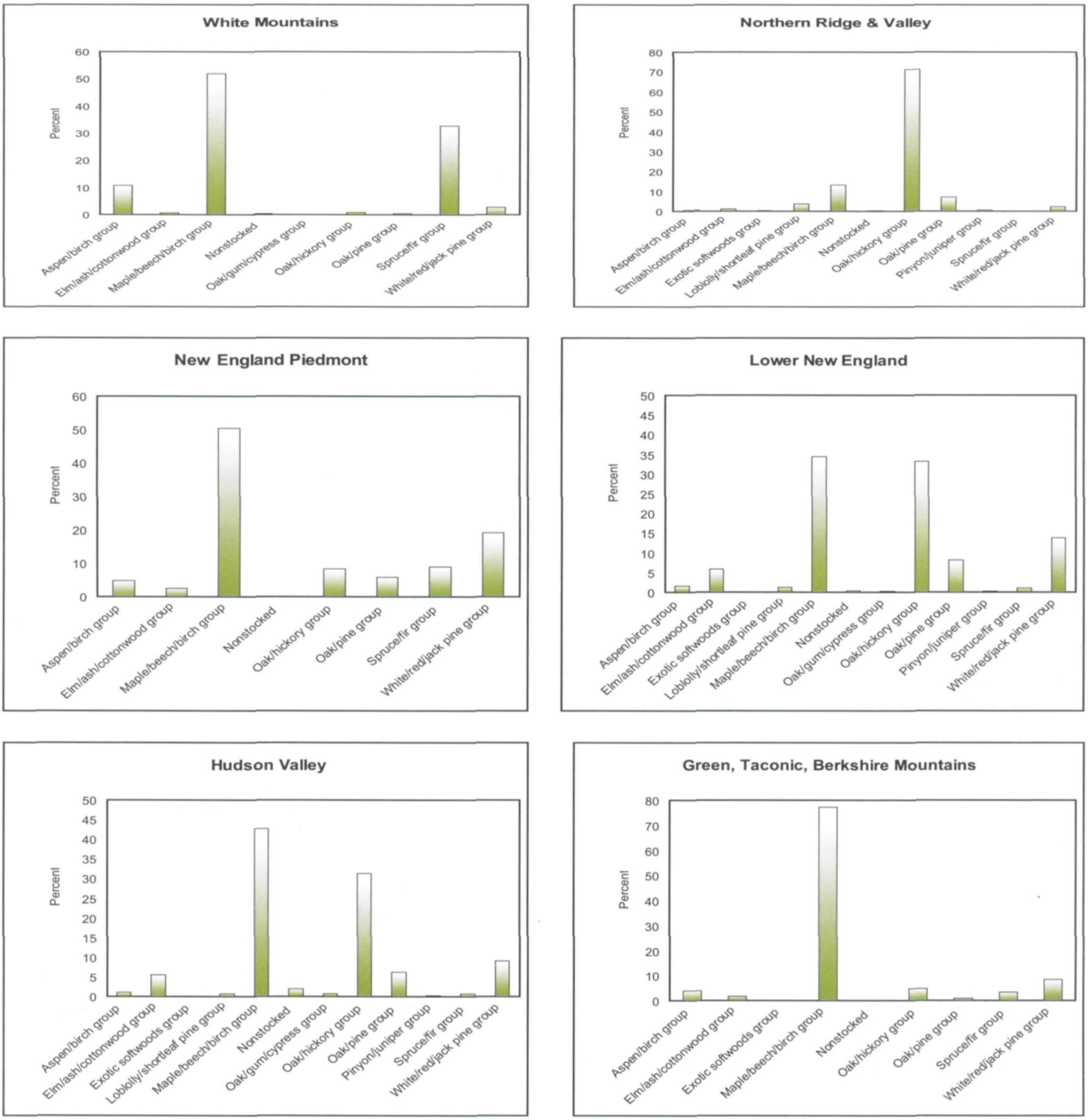


Figure 6.1. FIA plots located within 500' of either side of the Appalachian Trail.



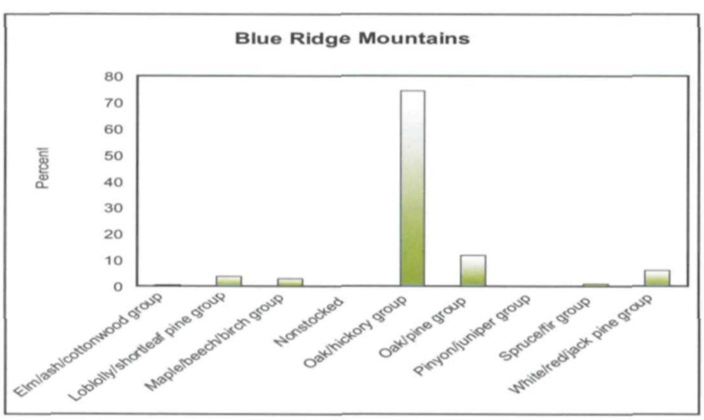


Figure 6.2. A summary of forest types within each ecoregion along the Appalachian Trail.

Chapter Seven
Rare, Threatened, and Endangered Species

Natural heritage inventories have been conducted on Appalachian Trail lands within all 14 states crossed by the Appalachian Trail. These inventories, conducted from 1989 to 2001, documented rare, threatened, and endangered species and rare or exemplary natural communities within the AT corridor. Vascular plants were documented in all 14 Natural Heritage inventories, in addition to rare or exemplary natural communities. However, documentation of rare, threatened, or endangered vertebrates within the AT corridor has varied from state-to-state. Furthermore, only a few states inventoried non-vascular plants and some invertebrates. The natural heritage inventories included descriptions and maps of each species, as well as threats and management recommendations to protect them.

The number of RTE occurrences within the AT corridor is believed to be the greatest of any NPS unit. Plants make up 88% of the RTE species occurrences identified in the inventories and 12% are animals.

The 14 AT natural heritage inventories documented approximately 2,050 occurrences of rare, threatened, or endangered (RTE) species and rare or exemplary natural communities of 515 natural heritage sites within the AT corridor (Table 7.1). The number of RTE occurrences within the AT corridor is believed to be the greatest of any NPS unit. Plants make up 88% of the RTE species occurrences identified in the inventories and 12% are animals. Approximately 330 of the occurrences are of globally rare species identified as G1, G2, or G3 by The Nature Conservancy (Table 7.2). The greatest number of globally rare species are found along the AT from Virginia southward. The largest concentrations of RTE species occurrences are located in the Presidential Range of New Hampshire (215 RTE species occurrences), the Mt. Rogers-Whitetop area of southwest Virginia (79 RTE species occurrences), and the Roan Mountain area along the North Carolina-Tennessee border (67 RTE species occurrences). Approximately 360 of the 2,100 occurrences are on Appalachian National Scenic Trail land. Only 15 occurrences of RTE species documented in the AT corridor are federally listed, and all of these are on other federal and state agency lands. All RTE species occurrences along the AT have been prioritized based on their global and state rank and their federal and state status.

One of the rarest plants along the Appalachian Trail

Table 7.1. The number of occurrences of rare, threatened, or endangered species and rare or exemplary natural communities within the Appalachian Trail corridor.

State	Acreage	Miles	Number of Occurrences
PA	30,000	229.8	44
NH	23,000	157.7	401
VT	22,500	145.5	60
CT	6,000	46.7	40
NC	27,500	234.0	284
VA	60,000	543.2	321
TN	10,800	73.2	167
WV	2,100	29.4	31
ME	40,300	274.6	157
MA	12,500	89.0	173
GA	7,166	75.6+8	214
NY	12,292	90.9	56
NJ	9,380	73.6	74
MD	5,372	37.0	32
Total	268,910	2,108	2054

Table 7.2. Federally threatened and endangered species along the Appalachian Trail. All species are found on USDA Forest Service land with the exception of the Shenandoah salamander, found on NPS land, and the small whorled pogonia, found on Connecticut state land.

Scientific Name	Common Name	Federal Status	Global Ranking	State
Geum radiatum	spreading avens	E	G1	NC/TN
Gymnoderma lineare	rock gnome lichen	E	G2	NC/TN
Glaucomys sabrinus coloratus	Carolina northern flying squirrel	E	G5T1	NC/TN
Glaucomys sabrinus fuscus	Virginia northern flying squirrel	E	G5T2	VA
Plethodon shenandoah	Shenandoah salamander	E	G1	VA
Isotria medeoloides	small whorled pogonia	E	G2	CT
Hedyotis purpurea var. montana	Roan Mtn. bluet	E	G1	NC/TN
Solidago spithamaea	Blue Ridge goldenrod	T	G1	NC/TN
Microhexura montivaga	spruce-fir moss spider	E	G1	NC/TN

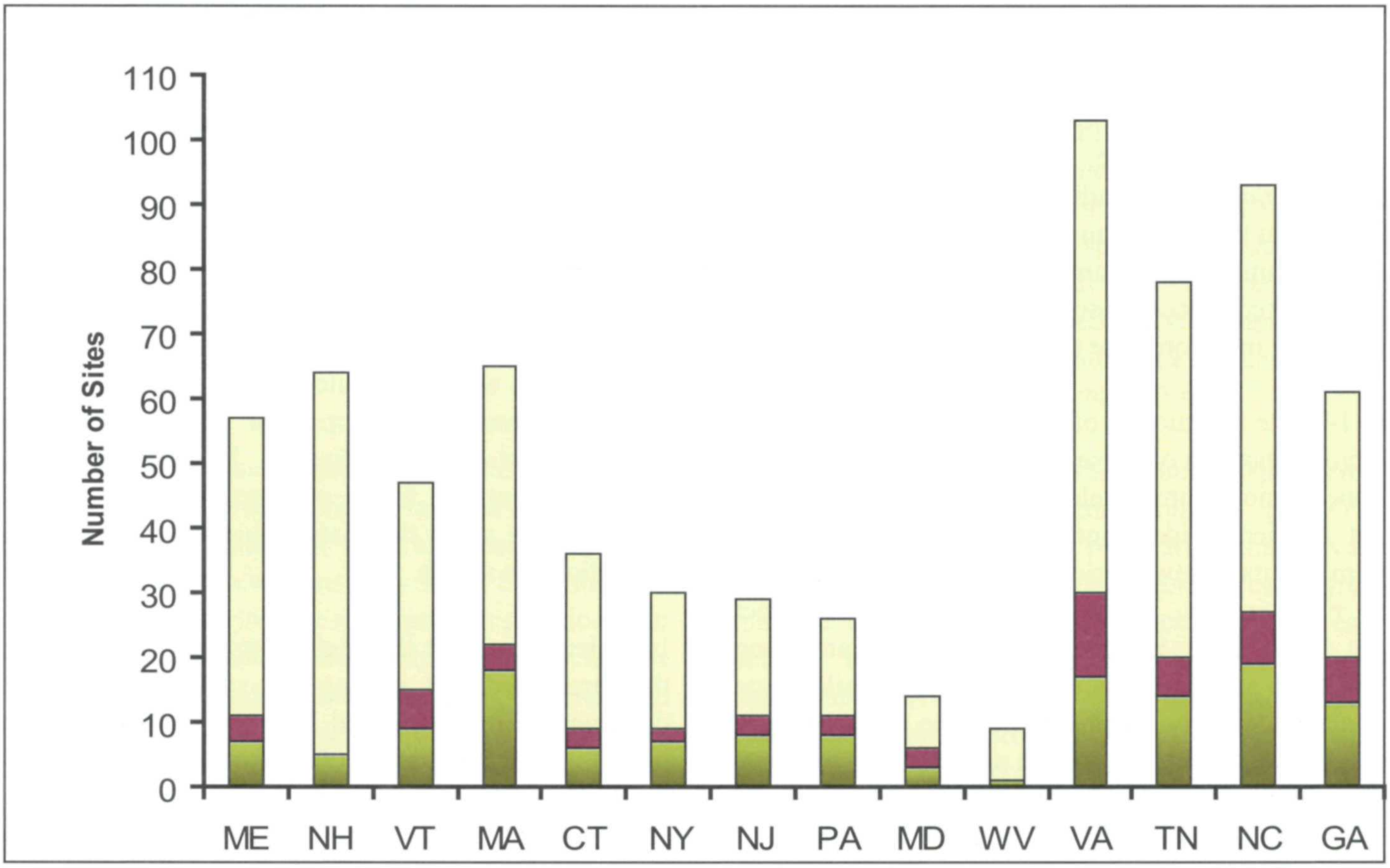
in New England is Robbins cinquefoil (*Potentilla robbinsiana*). Its global distribution is limited to two populations in New Hampshire's White Mountains: one in an alpine area in the Presidential Range and the other in the alpine area of Franconia Ridge. This species was formerly a federally endangered species, but as a result of the increasing size of these populations it was delisted in 2002. Another former federally listed species, the peregrine falcon (*Falco peregrinus*), has several known occurrences within the Appalachian Trail corridor.

Robbins cinquefoil (courtesy Appalachian NST)

In the southern Appalachians, Gray's lily (*Lilium grayi*) is a globally rare species that is among the showiest plant species to be found along the AT. It is found within the Appalachian Trail corridor on the grassy balds of the Roan Mountain Massif, where it has been subject to plant collection and recreational impacts in this high use area. Another Roan Mountain plant found along the AT is Blue Ridge goldenrod

Gray's Lily (courtesy Appalachian NST)

Figure 7.1. A total of 515 natural heritage sites were identified along the Appalachian Trail during the natural heritage inventories (tan section of each bar). Of these sites, 135 (26%) are included in the Natural Heritage Site Monitoring Program (green section of each bar) and 62 sites (12% of the total sites and 46% of the sites included the monitoring program, purple section of each bar) were monitored in 2004.



(*Solidago spithamaea*), which is known from only three locations in the world.

The purpose of the AT natural heritage monitoring program is to track the status of the rarest or most threatened plants, animals, and natural communities located along the AT, regardless of who the landowner is. Each of the natural heritage inventories for the 14 Appalachian Trail states recommended that many of the RTE species and sites identified within the AT corridor be monitored on a regular basis. Monitoring workshops have been held in all 14 of the AT states to train volunteers, a majority of which are from Appalachian Trail clubs. Since 1990, approximately 150 volunteer natural heritage monitors have been trained to monitor rare, threatened, and endangered plants, animals, and communities within the AT corridor. In recent years volunteers have been sought from outside AT clubs. The success rate of the volunteer monitoring program is high after a workshop, but declines over time.

Of the 515 natural heritage sites, 135 sites are currently in the natural heritage monitoring program (Figure 7.1). More than 95% of the occurrences placed in the monitoring program are of rare plants, with only a few rare animal species or plant communities placed into the program. In 2004, 46% (62 of 135) of the natural heritage monitoring sites were monitored, approximately the same percent as in 2003.

On the natural heritage monitoring forms, the volunteer monitors record the number of plants and areal extent of each RTE species occurrence, the vigor of the occurrence, the vigor change of the occurrence, any observed threats to the occurrence, and any actions that the monitor believes are necessary to protect the sensitive species. Of the 103 RTE species occurrences that were monitored in 2004, 35 of the occurrences were rated in excellent condition, 42 in good condition, 13 in fair condition, and 13 in struggling condition. Volunteer monitors indicated that 51 out of 83 RTE species occurrences monitored were in stable condition, 12 in improved condition, and 20 in declining condition, as compared to their condition in the preceeding year. (The reason for the reduced number of occurrences where vigor change was measured is because some RTE species ocurrences were being monitored for the first time.)

The 14 state inventories of the AT have indicated that a large proportion of these rare species are threatened by one or more human-related or natural threats. The most frequently identified threats found within the natural heritage inventories of the AT are trampling, trail maintenance, exotic plants, and exotic insect pests. Other threats include erosion, ATV's, competing vegetation, and plant succession. Even while some inventories were being prepared, some threats to rare species were addressed through management projects. As an example, in Massachusetts, trail-related impacts were having an effect on the state endangered agrimony (*Agrimonia parviflora)*. To protect the agrimony, a short relocation of the Appalachian Trail was constructed to bypass the population of these plants.

The natural heritage inventories offer hundreds of individual recommended actions to protect threatened and endangered species, such as controlling exotic species, vegetative manipulation to remove competing species, relocating the trail, controlling erosion, and use of signage to educate users. In 2002 the Appalachian Trail Conservancy and Dickenson University joined efforts to fence off several populations of the globally rare glade spurge (*Euphorbia purpurea)* in Pennsylvania from deer browsing and other animals.

In addition to monitoring recommendations, the natural heritage inventories also emphasized the importance of informing trail maintenance groups of the presence and location of threatened and endangered species. This communication would prevent the inadvertent harm of the species during trail maintenance activities. In 2001 approximately 200 rare plant identification sheets were prepared for threatened or endangered plants that had been documented immediately beside the tread of the AT. Each rare plant identification sheet included an illustration and color photo of the plant, along with a non-technical description of the plant, the best time to identify the species, and a topographic map showing the location of the plant along the AT. The rare plant identification sheets and instruction sheets explaining the trail maintenance project and details on how to avoid harming rare plant species were distributed through AT club leaders to trail maintenance groups that would be working where the plants were found. Preliminary results show substantially fewer occurrences of damage to RTE species since the distribution of the rare plant identification sheets.

In order to protect the highest priority species first, the threatened and endangered species occurrences documented in the natural heritage inventories were prioritized in 2002 and 2003. Recently, the top 100 highest priority threatened and endangered species on Appalachian National Scenic Trail land were evaluated for their threat level and specific threats. This will allow the most threatened species to receive prioritization of direct management actions. Implementation of some recommended management actions occurs each year, with a goal of increasing the number of actions implemented in future years.

The Appalachian Trail natural heritage monitoring program currently provides useful information regarding the status, vigor, and vigor change of some of the highest priority RTE species along the AT. With less than half of the sites in the volunteer monitoring program actually being monitored, professional staff or contractors are needed to fill in the gaps and follow up on those occurrences that are struggling or declining. As inventories of RTE vertebrates are completed the I&M program could work with the AT monitoring program to develop protocols for monitoring of these species.

Chapter Eight
Invasive Species

The Appalachian National Scenic Trail and the National Park Service are entrusted to protect, among other things, for present and future generations the native plant and animal communities that contribute to the unique nature of the Trail; yet, these "core mission" resources are being threatened and replaced by non-native and invasive aquatic and terrestrial plants and animals. In some cases, the biological richness and integrity of these Natural Resources may be forever changed.

Non-native and invasive species have been introduced to areas along the Appalachian Trail and other natural areas by humans, animals, wind and water. In some cases, human introductions may have been through hiking related activities or management practices. In large part, the spread of these problematic species has gone unchecked and is likely resulting in dramatic changes to natural systems, and could potentially displace many native plants and animals. Among the more significant of these resources are rare, threatened, and endangered species. Not-coincidentally, Trail resource managers believe that invasive plants may be the biggest threat to these rare species occurrences. . More than 70 of the approximately 500 rare, threatened, and endangered species sites in the A.T. corridor have a documented presence of exotic or introduced species (K. Schwarzkpf, personal communication). Clearly, the key to addressing this issue requires an understanding of the species involved; knowledge of the habitats most at risk; documenting the scope of the problem; initiating efforts to prevent and detect new invasions and control those that are underway; and, educating the public about the issue.

The National Park Service has a great interest in non-native and invasive species management, and has established Exotic Plant Management Teams (EPMT) as part of the Natural Resource Challenge to help manage problematic plants in selected regions and parks across the nation. While the focus of the EPMT program is to develop listings of invasive species and on implementing management programs, there remains a continuing need to identify and track invasions, monitor treatment effectiveness and to develop "early detection" methodologies as a preventive strategy. Early detection of invasive species is frequently cited as the best way to deal with non-native and invasive species, and has been selected as a vital sign by each of the five Inventory and Monitoring Program Networks that encompass the Appalachian Trail.

With respect to management and control of problematic species, NPS Management Policies (1988) do not differentiate between non-native and invasive species, even though invasive species present greater management challenges due to their more aggressive nature. While groups of invasive species other than plants (insects, for example) exist in the region and have caused well known problems, this Chapter is focused on non-native and invasive plants. Accordingly, this Chapter summarizes existing information on non-native and invasive plants for the Appalachian Trail, and offers recommendations for ways to proactively address this growing problem.

One of the most common threats to rare, threatened and endangered species is the presence of invasive exotic plants.

The Appalachian Trail passes through fourteen states, generally following the ridgelines of the Appalachian Mountain Range. These fourteen states include portions of 37 ecoregions, with 8 ecoregions directly intersecting or adjoining the AT. Data obtained from the USDA Plants database (2005), a national database that combines information from a number of sources, including states, Federal agencies, non-profit organizations, and universities indicates that this fourteen state region supports more than 10,800 species of vascular plants, with individual state lists ranging from 3590 to 5871 species. Approximately 2200 species in this region were introduced to North America, with individual state listings of non-native species ranging from 611 to 1315 species, (12% to 23% of individual statewide lists, Table 8.1). When the data for the 14-state region are linked to other databases and data sources that focus on a species 'invasiveness', including Invasives.org, the Invasive Plant Atlas of New England (IPANE; Mehrhoff et. al., 2003), and the Invasive Plants of the Eastern United States: Identification and Control (Bargeron et. al, 2003), we find that approximately 2% to 3% of species found on individual statewide lists are identified as noxious or invasive within the eastern US by at least one state, the Federal government, or the National Park Service.

Based on recorded observations in the National Park Service NPSpecies database, existing trail-focused inventories have documented 1,033 vascular plant species through nearly 5,300 observations. NPSpecies data originates from a variety of sources, including the Natural Diversity (NatDiv) database developed and maintained by the Appalachian National Scenic Trail, state Natural Heritage Programs, and a series of Appalachian National Scenic Trail sponsored projects by Elliman (2004), and Lesh (2002). Data from ongoing work by Elliman (2005) and Canter (2005) were not available in time for this review. Of the 5300 observations and 1033 vascular plant species contained in NPSpecies, 117 non-native plant species (about 11% of total plant species) are documented by more than 400 observations somewhere along the AT.

Table 8.2 summarizes existing data (total number of vascular plant species and exotic species) in the NPSpecies database for each state and compares it to the percentage of the total and exotic species known to occur in each state, respectively, and underscores a need for additional floristic inventory work and documentation of invasive plant populations along

Table 8.1. Number of Plant Species by States traversed by the Appalachian Trail.

State Name	Total Species	Rank	Introduced Species	Rank	% Introduced	Rank	Noxious Species	Rank	% Noxious	Rank
Connecticut	4465	10	918	5	20.56%	4	126	8	2.82%	4
Georgia	5718	3	670	11	11.72%	14	121	9	2.12%	14
Maine	3946	12	749	9	18.98%	6	100	12	2.53%	11
Maryland	4983	7	922	4	18.50%	7	153	2	3.07%	1
Massachusetts	5016	6	1160	3	23.13%	1	137	6	2.73%	7
New Hampshire	3590	14	611	14	17.02%	9	99	13	2.76%	6
New Jersey	4746	9	917	6	19.32%	5	134	7	2.82%	3
New York	5871	1	1315	1	22.40%	2	151	3	2.57%	10
North Carolina	5809	2	878	8	15.11%	12	150	5	2.58%	9
Pennsylvania	5389	5	1204	2	22.34%	3	156	1	2.89%	2
Tennessee	4824	8	660	12	13.68%	13	119	10	2.47%	13
Vermont	3667	13	674	10	18.38%	8	92	14	2.51%	12
Virginia	5506	4	880	7	15.98%	10	150	4	2.72%	8
West Virginia	4024	11	623	13	15.48%	11	112	11	2.78%	5

Total Species and Introduced Species numbers from USDA Plants database , Noxious Species numbers were compiled from various sources, including USDA (2005), Bargeron et. al. (2003), Mehrhoff, et. al. (2003), and Douce, et. al. (2005)).

Table 8.2. Species, by state, documented in NPSpecies for the Appalachian Trail

State	Total Species		Exotic	
	Trail	% of Statewide List	Trail	% of Statewide List
CT	659	14.8	83	9.0
GA	49	0.9	0	0
MA	59	1.2	0	0
ME	23	0.6	0	0
MD	16	0.3	0	0
NC	77	1.3	8	0.9
NH	77	2.1	0	0
NJ	51	1.0	11	1.2
NY	33	0.6	15	1.1
PA	10	0.2	0	0
TN	42	0.9	0	0
VA	68	1.2	0	0
VT	21	0.6	0	0
WV	14	0.3	0	0

Statewide List from USDA Plants database

the Appalachian Trail. Connecticut, where the Appalachian National Scenic Trail sponsored a comprehensive inventory project in 2003 (Elliman, 2004), is the only state where the data may approximate the total number of species that may exist within that state's trail segment (an inventory similar to the 2003 Connecticut inventory is currently underway in Massachusetts). During that inventory, of the 659 species that were identified, 83 are non-native, 33 are considered invasive in the eastern United States (Invasives.org, 2005), and 18 are on a priority listing of invasive species found in the eastern US (Bergeron, 2003).

The Appalachian National Scenic Trail recognizes the need for information on exotic and invasive plants, describing them in the recent draft Resource Management Plan (2005) as "*. . . One of the most common threats to rare, threatened and endangered species is the presence of invasive exotic plants. . .*" The Resource Management Plan goes on to state that "*. . . most sections of the corridor have not been surveyed.*" In 2002, the "AT Policy on Exotic Species" set a foundation for a program with education, monitoring and control components and goals that directed priority for action to locations where exotic species threaten endangered species occurrences and to controls that would have the highest likelihood for success. The program also proposed a number of studies to assess the exotic species problem. Prior to 2002, the primary source of knowledge of the presence and impact of exotic plant species within the trail corridor came from the 14 state natural heritage inventories completed between 1989 and 2001 that were focused on documenting rare species and communities along the Appalachian Trail and threats to those species and communities. Recognizing that exotic species identified in these reports were typically limited to locations of rare species occurrences, trail staff included the following statements about the state of knowledge regarding exotic species in a 2002 project justification:

"*The Appalachian National Scenic Trail currently has a limited knowledge of the presence of exotic plants and insect pests within the AT corridor. . .*", and that.

". . . exotic species are one of the major threats to RTE species and other biological resources within the Trail corridor . . . in NJ, NY, and MA, an *estimated 1500 acres of exotic plants are found . . . More than 55 different exotic plants have been documented within the AT corridor; however, most sections of the corridor have not been surveyed, and no area has been mapped for exotic plants, except in NC and TN. . . ."*

Since 2002, progress has been made, and the number of exotic species documented within the A.T. corridor has more than doubled. However, without consistent and dedicated funding, the progress has been made on an opportunistic basis.

- In 2002, Appalachian State University and Southern Appalachian Man and the Biosphere (SAMAB) jointly administered a project for a student (Lesh, 2002) to identify and map invasive species within the Trail corridor in NC and TN. This study documented 13 species at 63 locations along a 400 mile segment of the Trail. Although the data are incomplete, the report concluded that 95% of the invasive plant populations were within about 100 feet of road crossings, power lines or some other anthropogenic disturbance.
- For the past three years the Appalachian Trail has funded SAMAB to documents and detect new invasions of exotic species at road crossings and other locations along the Trail in NC, TN, and southern VA.
- Strategies and scopes of work for plant inventories along the AT now call for documentation of complete species lists, vegetation types, and community descriptions including locations of invasive species impacting significant areas. This kind of work has been done in CT and MA (Elliman, 2004 and in progress 2005).
- AT staff have engaged three EPMT's within three National Park Service regions (Northeast, National Capital and Southeast), with the National Capital EPMT mapping and undertaking control efforts in VA and PA to treat 8-species on approximately 5.9 acres of land at 4-locations over 5 days. Additional internal documents from 2002 indicate that 21-species on approximately 832 acres were targeted for treatment.
- During 2005 a thru-hiker affiliated with Virginia Tech began to document the presence and location of key invasive species along the Trail from Virginia to Maine (Canter, ongoing). A preliminary report to ATPO resource management staff suggests that the presence of exotic species along the AT is greatest between northern Virginia through New York and that some long segments of the AT have a continuous presence of invasive species. Among the most problematic and widespread are garlic mustard, multiflora rose, Japanese honeysuckle, autumn olive, Japanese barberry, Japanese stilt grass, *Phragmities* and purple loosestrife.

While these projects contribute to understanding the number and distribution of invasive species along the trail, there remains a need to consolidate data from disparate resources and ongoing work into a single location in order to better assess and track the extent and impact of the invasive species problem along the Appalachian Trail. Although the National Park Service *NPSpecies database* contains a substantial amount of data, it is not currently a comprehensive source for native or invasive species. While all data from NatDiv, Lesh (2002), Elliman (2004) as well as several other sources are present in NPSpecies, additional sources are believed to exist. The presence of additional data can be inferred by comparing NPSpecies accounts with existing reports and documents. Examples of sources that differ in content from what NPSpecies currently contains include the Virginia Natural Heritage Report (1994) which documented 13 exotic plants in 8 rare, threatened, and endangered species locations, while NPSpecies lists 0 exotic species for the Virginia portion of the Trail. Similarly, the West Virginia Natural Heritage Inventory (1996), reported that 33 exotic species were present, while NPSpecies documents 0 exotic species for the West Virginia portion of the Trail.

Increased understanding of the problem may come from estimating the total species and potential invasive species within the trail corridor based on existing state and county level data. Such an estimate is possible if we assume:

- That plant species associate more strongly with ecoregions than with states, and that the species to ecoregion association is exclusive; and,
- That the ratio of the number of species in an ecoregion section to the total species in the 14-state region is proportional to the ratio of total acreage in the ecoregion section to the acreage in the 14-state region.

Using these assumptions, if portions of the eight ecoregions directly associated with the Appalachian Trail comprise approximately 22% of the 14-state area within 37 ecoregions; then, the total number of species of vascular plants, introduced plants, and invasive/noxious plants may also be reduced to approximately 22% of the region-wide totals to estimate the number of vascular plant species present along the Appalachian Trail. Scaling the totals by 22% yields an estimate of 2,375 vascular plant species potentially present somewhere along the AT, and 485 introduced plant species (i.e., not native to North America). An estimate of invasive or noxious species is also possible. Using a regionally focused list (species considered invasive or noxious by the Federal Government, at least one state, and/or the National Park Service anywhere in the eastern United States) adjusted using the above scaling factor, the estimate of invasive or noxious species is approximately 86 species. Using the focused estimate in combination with existing Appalachian Trail data, approximately 63% (54 out of 86) of plant species considered invasive in the eastern United States and potentially along the AT have been identified. The remaining 37% are either not present, have yet to be identified, or they are present and have been identified but have not been documented in one of the databases used by trail resource management staff or in NPSpecies.

The assumptions and associated estimates are based on data with a number of known limitations. For example, species that occur within the region are based on statewide inventories that may not be complete. Further, the assumption that the exclusive association of a plant species to an ecoregion is not reasonable -- the reality is that many species associate with multiple ecoregions and the number of species present in Trail portions of ecoregions is probably not equal. Despite these, and other limitations, the estimates generated by this exercise are still useful for the purpose of understanding the potential magnitude of the invasive vascular plant species problem.

The above estimates might be improved by using county-level vascular plant inventory data from locales closer to the Trail; however, only 22 of the 91 counties near the Trail have completed species lists. Of the states north of VA, where the bulk of Appalachian Trail fee ownership lands occur, only MA and VT counties have data available. As additional counties compile species lists, a more accurate picture of invasive species that may occur along the trail will be possible. These lists may also contribute to early detection of potential new invaders that are documented in the county but have not yet reached the Trail environs.

A key part of dealing with invasive species entails the development of a comprehensive invasive species priority list. The Invasive Plants of the Eastern United States: Identification and Control (Bargeron, 2003) is an example of such a list. While other lists exist, this list can be used as a starting point from which AT managers can work to tailor a trail specific invasive species 'hit list.' When comparing the species on the Invasive Plants of the Eastern United States list to the list of 10,800 species found in the 14-state region, 73 of 97 species on the hit list are found in the 14-state region (Table 8.3), and 23 species (plus 2 genera) of the 73 have already been identified along the AT (Table 8.4). More specifically, of the 113 species reported in CT by Elliman (2004), 18 are on this prioritized list (Table 8.5).

Another important part of dealing with invasive species is to understand the true magnitude of the issue via a systematic inventory and documentation of invasive species along the AT. This effort, while

Table 8.3. Invasive Species found in the 14-state Appalachian Trail Region (from Invasive Plants of the Eastern United States: Identification and Control, 2003).

Species	Common	Number Of States	CT	GA	MA	MD	ME	NC	NH	NJ	NY	PA	TN	VA	VT	WV
Alliaria petiolata	garlic mustard	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Berberis thunbergii.	Japanese barberry	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coronilla varia.	purple crownvetch	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Elaeagnus umbellata.	autumn olive	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Euphorbia cyparissias.	cypress spurge	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hemerocallis fulva	orange daylily	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Morus alba	white mulberry	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Polygonum cuspidatum	Japanese knotweed	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rosa multiflora	multiflora rose	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vinca minor	common periwinkle	14	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Acer platanoides	Norway maple	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Centaurea biebersteinii	spotted knapweed	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Centaurea stoebe micranthos	spotted knapweed	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Cirsium arvense	Canada thistle	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Lespedeza bicolor	shrubby lespedeza	13	X	X	X	X		X	X	X	X	X	X	X	X	X
Lonicera japonica	Japanese honeysuckle	13	X	X	X	X	X	X	X	X	X	X	X	X		X
Lonicera morrowii	Morrow's honeysuckle	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Lythrum salicaria	purple loosestrife	13	X		X	X	X	X	X	X	X	X	X	X	X	X
Sorghum halepense	Johnsongrass	13	X	X	X	X		X	X	X	X	X	X	X	X	X
Ailanthus altissima	tree of heaven	12	X	X	X	X	X	X		X	X	X	X	X		X
Lolium arundinaceum	tall fescue	12	X	X	X	X	X	X			X	X	X	X	X	X
Myriophyllum spicatum	eurasian watermilfoil	12	X	X	X	X		X	X	X	X	X	X	X	X	
Rubus phoenicolasius	wine raspberry	12	X	X	X	X		X		X	X	X	X	X	X	X
Broussonetia papyrifera.	paper mulberry	11	X	X	X	X		X		X	X	X	X	X		X
Dioscorea oppositifolia	Chinese yam	11	X	X		X		X		X	X	X	X	X	X	X
Euonymus alata	winged burning bush	11	X		X	X		X	X	X	X	X		X	X	X
Lespedeza cuneata	Chinese lespedeza	11	X	X	X	X		X		X	X	X	X	X		X
Lonicera tatarica	Tatarian honeysuckle	11	X		X	X	X		X	X	X	X		X	X	X
Miscanthus sinensis	Chinese silvergrass	11	X	X	X	X		X		X	X	X	X	X		X
Paulownia tomentosa	princesstree	11	X	X	X	X		X		X	X	X	X	X		X
Pueraria montana	kudzu	11	X	X	X	X		X		X	X	X	X	X		X
Ulmus pumila.	Siberian elm	11	X	X	X	X			X		X	X	X	X	X	X
Wisteria sinensis	Chinese wisteria	11	X	X	X	X		X			X	X	X	X	X	X
Akebia quinata	chocolate vine	10	X	X	X	X		X		X	X	X		X		X
Ampelopsis brevipedunculata	Amur peppervine	10	X	X	X	X		X	X	X	X	X		X		
Hedera helix	English ivy	10		X	X	X		X		X	X	X	X	X		X
Lonicera maackii	Amur honeysuckle	10		X	X	X		X		X	X	X	X	X		X
Microstegium vimineum	Nepalese browntop	10	X	X		X		X		X	X	X	X	X		X
Wisteria floribunda	Japanese wisteria	10		X	X	X	X	X	X	X		X	X	X		
Elaeagnus angustifolia	Russian olive	9	X		X	X	X			X	X	X	X	X		
Rhodotypos scandens	jetbead	9	X		X				X	X	X	X		X	X	X
Ligustrum sinense	Chinese privet	8	X	X	X	X		X		X			X	X		

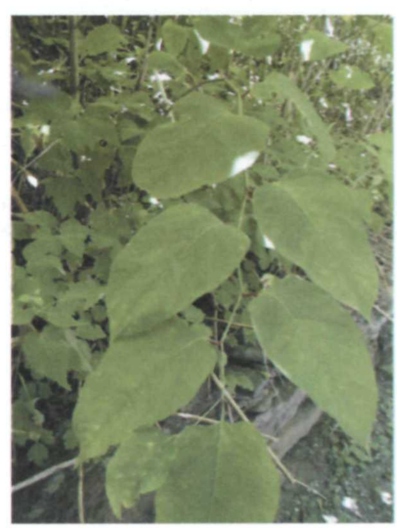
Table 8.3. Invasive Species found in the 14-state Appalachian Trail Region (from Invasive Plants of the Eastern United States: Identification and Control, 2003) (continued).

Species	Common	Number Of States	CT	GA	MA	MD	ME	NC	NH	NJ	NY	PA	TN	VA	VT	WV
Myriophyllum aquaticum	parrot feather watermilfoil	8	X	X				X		X	X	X	X	X		
Orobanche minor	small broomrape	8		X		X		X		X	X	X		X		X
Vinca major	bigleaf periwinkle	8		X	X	X		X			X	X	X	X		
Euonymus fortunei	winter creeper	7	X		X					X	X	X	X	X		
Lonicera fragrantissima	sweet breath of spring	7		X		X		X			X	X	X	X		
Galega officinalis	goat's rue	6	X		X	X	X				X	X				
Polygonum perfoliatum	mile-a-minute weed	6				X				X	X	X		X		X
Trapa natans	water chestnut	6			X	X					X	X		X	X	
Eichhornia crassipes	common water hyacinth	5		X				X			X		X	X		
Elaeagnus pungens	thorny olive	5		X	X			X					X	X		
Ligustrum japonicum	Japanese privet	5		X		X		X					X	X		
Melia azedarach	Chinaberrytree	5		X				X			X		X	X		
Murdannia keisak	Marsh dewflower	5		X		X		X					X	X		
Phyllostachys aurea	golden bamboo	5		X		X		X					X	X		
Pistia stratiotes	water lettuce	5		X		X		X		X	X					
Alternanthera philoxeroides	alligatorweed	4		X				X					X	X		
Rosa bracteata	Macartney rose	4		X				X					X	X		
Solanum viarum	tropical soda apple	4		X				X				X	X			
Heracleum mantegazzianum	giant hogweed	3					X				X	X				
Ligustrum lucidum	glossy privet	3		X		X		X								
Nandina domestica	sacred bamboo	3		X				X						X		
Pyrus calleryana	Bradford pear	3				X		X						X		
Carduus tenuiflorus	winged plumeless thistle	2								X		X				
Lygodium japonicum	Japanese climbing fern	2		X				X								
Triadica sebifera	tallow tree	2		X				X								
Commelina benghalensis	Tropical spiderwort	1		X												
Cyperus entrerianus	deeprooted sedge	1		X												
Quercus acutissima	sawtooth oak	1										X				
Solanum torvum	turkey berry	1				X										
Striga asiatica	Asiatic witchweed	1						X								
Striga spp.	witchweed	1						X								

Table 8.4. Invasive Plants (23 species plus 2 genera) of the Appalachian Trail (as documented by Elliman (2004), Lesh (2002), and/or Schwarzkopf) that are listed on Invasive Plants of the Eastern United States: Identification and Control (undated).

Species	Common
Acer platanoides L.	Norway maple
Ailanthus altissima (P. Mill.) Swingle	tree of heaven
Albizia julibrissin Durazz.	mimosa
Alliaria petiolata (Bieb.) Cavara & Grande	garlic mustard
Berberis thunbergii DC.	Japanese barberry
Carduus nutans L.	musk thistle
Centaurea biebersteinii DC	spotted knapweed
Cirsium arvense (L.) Scop.	Canada thistle
Cirsium vulgare (Savi) Ten.	bull thistle
Coronilla varia L.	purple crownvetch
Cynanchum spp. L.	swallow-worts
Euonymus alata (Thunb.) Sieb.	winged burning bush
Euphorbia cyparissias L.	cypress spurge
Lespedeza cuneata (Dum.-Cours.) G. Don	Chinese lespedeza
Ligustrum vulgare L.	European privet
Lonicera japonica Thunb.	Japanese honeysuckle
Lonicera morrowii Gray	Morrow's honeysuckle
Lythrum salicaria L.	purple loosestrife
Microstegium vimineum (Trin.) A. Camus	Nepalese browntop
Morus alba L.	white mulberry
Phragmites australis (Cav.) Trin. ex Steud.	common reed
Polygonum cuspidatum Sieb. & Zucc.	Japanese knotweed
Ranunculus ficaria L.	lesser Celandine
Rosa multiflora Thunb. ex Murr.	multiflora rose
Vinca minor L.	common periwinkle

Purple Loosestrife; *Lythrum salicaria* (courtesy NETN)



Knotweed; *Polygonum japonica* (courtesy NETN)

Table 8.5. Invasive Plants (18 species) on the Connecticut portion of the Appalachian Trail (as documented by Elliman (2004) and included in Invasive Plants of the Eastern United States: Identification and Control (undated).

Species	Common
Acer platanoides L.	Norway maple
Ailanthus altissima (P. Mill.) Swingle	tree of heaven
Alliaria petiolata (Bieb.) Cavara & Grande	garlic mustard
Berberis thunbergii DC.	Japanese barberry
Centaurea biebersteinii DC	spotted knapweed
Cirsium arvense (L.) Scop.	Canada thistle
Cirsium vulgare (Savi) Ten.	bull thistle
Cynanchum spp. L.	swallow-worts
Euonymus alata (Thunb.) Sieb.	winged burning bush
Euphorbia cyparissias L.	cypress spurge
Ligustrum vulgare L.	European privet
Lonicera morrowii Gray	Morrow's honeysuckle
Lythrum salicaria L.	purple loosestrife
Microstegium vimineum (Trin.) A. Camus	Nepalese browntop
Phragmites australis (Cav.) Trin. ex Steud.	common reed
Ranunculus ficaria L.	lesser Celandine
Rosa multiflora Thunb. ex Murr.	multiflora rose
Vinca minor L.	common periwinkle

large, would provide trail resource managers with a complete understanding of the current status of the problem, would provide objective information upon which management strategies could be based, and would help resource managers identify potential threats to rare, threatened, and endangered species before serious management issues materialize. Though comprehensive, this approach would be expensive, time consuming and not particularly efficient given limited funding.

A more cost effective approach may be to target investigations using existing information. For example, based on the Lesh (2002) inventory of invasive species in NC and TN we may be able to assume that 95% of exotic species are typically found near anthropogenic disturbances, and that most of the exotic species will be within 100 feet of the disturbance. Using this as a guide, search areas would be limited to known road crossings, power-lines, parking lots, erosion prone areas, and other known disturbances, and invasive species detection efforts could be focused within a specified distance of those known locations. Existing GIS datasets for many of these items already exist and could be used to prioritize search areas. Additional areas would be investigated as new disturbances are located along the trail. Invasive species management, like the work performed in Pennsylvania and Virginia by the National Capital Region Exotic Plant Management Team in 2004, as well as early detection efforts would certainly benefit from a focused detection strategy.

To be fully successful, the invasive species program must be integrated at all levels (Trail, Network, AT Conservancy, other cooperators, etc) and should address the key elements of the National Invasive Species Management Plan: Prevention; Early Detection and Rapid Response; Control; Education; and, Research and Restoration. Appalachian Trail staff and partners should be equipped to: identify and locate invasive species; assess the local need for cooperative action with adjacent land managers and trail clubs; identify state of the art integrated pest management actions; recommend control mechanisms; and, be able to maintain and monitor treated areas. Implicit in these requirements is the need to integrate the institutional knowledge possessed by resource managers into a comprehensive data management system.

The most important role of the Inventory and Monitoring Program and the Northeast Temperate Network in invasive species management will be to work with AT resource managers to develop, organize and make available native, exotic and invasive species data, and assist with analysis, synthesis, modeling and reporting. Further, Network programs may provide assistance with sampling design, design of protocols, early detection and distribution monitoring, and data management. Vital signs monitoring will be an integral, but limited component of the adaptive management cycle for invasive species on the Appalachian Trail, with responsibility for management actions directed at setting priorities and maintaining, preserving and/or restoring specific resources falling to the Trail staff and partners. With this partitioning of roles and responsibilities in mind, a program to address invasive plants should: 1) develop and refine management goals for selected invasive plants (identify desired future conditions for forests, rare species communities, set goals for invasive species management); 2) compare current conditions to desired conditions (develop a list of invasive species and document status); 3) develop and implement management strategies to achieve desired conditions (control, education, management); 4) monitor trends in condition of resources and evaluate effectiveness of management actions; and, 5) adapt management to achieve desired conditions.

The Appalachian Trail has a great interest in developing a fully functional invasive species management program. The following recommendations are offered as a way to achieve a better understanding of the exotic species problem. The following key elements should be considered during development of the Appalachian Trail invasive species program (in recommended order):

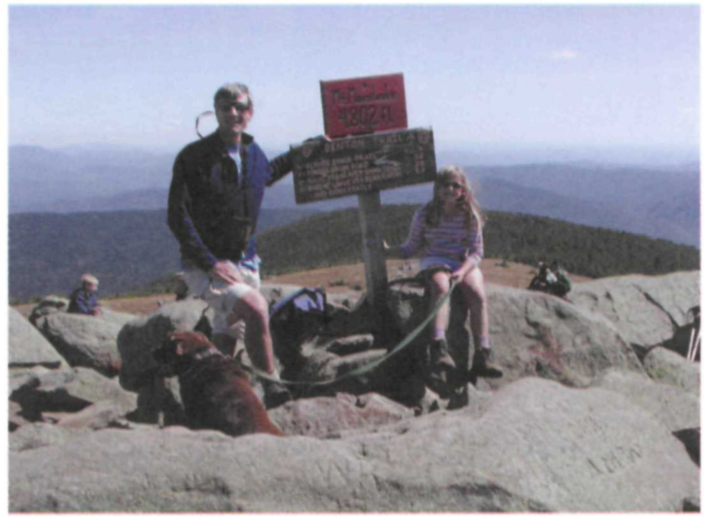
1. Work closely with regional EPMT coordinators to create a list of invasive species that threaten Trail resources;
2. Build an understanding of each species on the list;
3. Develop a new database structure to store all existing trail related species data (i.e., not just exotic species data), newly acquired field data, and to link with NatureServe and individual state Natural Heritage programs;
4. Integrate data from existing trail focused studies (i.e., species lists, geospatial data, RTE occurrences, disturbance areas, etc.) into the new database to improve the knowledge of species occurrences;
5. Integrate data and information from additional sources including state and county level data, non-profit organizations and special interest groups (for example, Invasive Plant Atlas of New England);
6. Develop GIS maps of habitats of high resource value;
7. Utilize existing GIS datasets depicting existing disturbances (roads, power lines, etc) to develop predictive GIS maps showing high probability areas to target for inventory early detection;
8. Initiate efforts to prevent and detect new invasions;
9. Develop desired future conditions -- do this before control to evaluate progress toward performance goals;
10. Use exotic species prioritization tools (i.e., Alien Plant Ranking System, or Invasive Species Assessment System) to target potential management actions;
11. Initiate efforts to control invasions that are underway;
12. Establish rigorous, but realistic standards for tracking treatment areas (effectiveness monitoring);
13. Educate the public about the significance of this issue.

Chapter Nine
Visitor Usage

Although the Appalachian Trail still provides visitors with the illusion that they are in a remote area, more often than not they have lots of company. Several million people set foot on the Appalachian Trail each year– most for just a few miles, but some who hike for weeks or months, and hundreds or thousands of miles at a time. The impacts associated with this level of visitor use are a significant challenge for managers. Not only are there direct impacts to soils, vegetation, water, and wildlife: there are impacts to other visitors as well.

Most of these impacts are concentrated into a relatively small area consisting of the AT footpath itself, which is 2,175 miles long and averages about 24 inches in width, 160 miles of side trails of the same average width, 324 shelter or designated overnight use sites with an average size of one-half acre, and more than 4,000 dispersed campsites and scenic overlooks.

Visitor use impacts associated with the Appalachian Trail include use of the footpath itself, overnight use areas (both designated and bootleg), and human waste management.



Mt. Moosilauke, New Hampshire
© Steven D. Faccio

The environmental impacts associated with this level of visitor use are, to a certain extent, unavoidable. The challenge for managers is to avoid those impacts that are non-essential (such as campers felling trees or collecting live wood for firewood) and minimize those impacts that are unavoidable (such as trampling and soil compaction along the AT footpath).

The footpath itself is the primary recreational feature of this unusual park unit. Averaging twenty-four inches in width, it sustains most of the impact of AT visitors. Managers strive to create and maintain a footpath that provides visitors with a challenging experience while balancing the need to ensure reasonably safe conditions for visitors and minimize impacts to physical resources. Many sections of the Appalachian Trail are exceptionally uneven and primitive, with rocks, roots, and other obstacles creating frequent grade variations or obstacles. Some sections of the AT also traverse through highly developed settings, and may include boardwalks, handrails, and a uniform, firm, and stable surface. However, although significant variation occurs throughout the length of the Appalachian Trail, most of the AT is designed with an open and obvious tread, native surfacing, bridges, rock steps, and other structures as necessary for resource protection, and directional and interpretive signs.

AT managers need accurate data on trail conditions to monitor trends and direct trail maintenance efforts. Several types of field-based trail condition assessments exist that can be used to identify problems (Marion & Leung 2001). A model developed by U.S. Geologic Survey Recreation Ecologist Jeff Marion uses the following inventory indicators to assess impacts associated with trail footpath use (Leung & Marion

1999):

- Soil erosion: (low: 1 – 2 ft.; moderate: 2.1 – 3 ft.; severe: 3 ft or greater)
- Multiple tread (more than one definable tread)
- Excessive root exposure
- Excessive width (3 – 6 ft., greater than 6 ft.)
- Wet or muddy soils (more than half the tread width)
- Standing water on treadway

Marion's study of trail conditions along the Appalachian Trail in Great Smoky Mountains National Park established baseline conditions. Trail conditions were poor in areas with ridgetop alignments where flat terrain prevented proper water drainage or where steep slopes contributed to excessive erosion. The methodology used in this study (problem assessment monitoring) was subsequently integrated with a point sampling approach for assessing trail conditions in Shenandoah National Park, including conditions on several sections of the Appalachian Trail. These studies provided a set of procedures that could be applied to monitor trail conditions along the entire length of the Appalachian Trail.

In addition to these quantifiable impacts, there are also impacts that are difficult to determine direct causal relationships for or quantify. "Unsurfaced trail treads are susceptible to a variety of trail impacts. Common impacts include vegetation loss and compositional changes, soil compaction, erosion, and muddiness, exposure of plant roots, trail-widening, and the proliferation of visitor-created side trails. Trails, and the presence of visitors, also impact wildlife, fragment wildlife habitat, and cause avoidance behavior in some animals and attraction behavior in others to obtain human food" (Marion & Leung, 2001).

The National Park Service's Facility Management Software System (FMSS) also provides a database tool that is used to record the condition of the trail and identify trail maintenance needs. As of July 2005, 20% of the AT footpath has been assessed, using a random sampling methodology. The extrapolated results indicate that 43% of the trail footpath is in good condition; 32% is in fair condition, and 26% is in poor condition. No parts of the trail inventoried to date were listed as being in serious condition (Table 9.1).

Appalachian Trail managers employ a variety of strategies to minimize the impacts of visitor use. Appropriate trail design, construction and maintenance are perhaps the most effective tools available to AT managers. By avoiding steep grades, poor soils, and sensitive resource areas, AT managers can substantially

Table 9.1. Quantifiable direct impacts associated with visitor use on the Appalachian Trail.

Area	Description	Square Feet	Acres
Appalachian Trail	2,175 miles with a 24-inch wide tread	22,968,000	527.2
Side Trails	159.84 miles with a 24-inch wide tread	1,689,600	38.8
Shelter sites	280 with 44 overnight-use areas: average overnight use area of 0.5 acres	7,056,720	162.0
Bootleg sites	4,000: average overnight use area of 268 square feet per campsite	1,072,000	24.6
Total		**32,733,520**	**751.5**

limit visitor impacts (Birchard and Proudman, 2000). Other strategies include "hardening" of the existing trail footpath and structural features, limiting use in certain areas, and deployment of "ridgerunners" and "caretakers" to monitor use and encourage visitors to practice "Leave No Trace" principles to minimize their impacts on AT resources.

Leave No Trace

"Leave No Trace" is a national program that promotes and inspires responsible outdoor recreation and stewardship of America's public lands. The Leave No Trace outdoor ethic is made up of seven basic principles:

- plan ahead and prepare
- travel and camp on durable surfaces
- dispose of waste properly
- leave what you find
- minimize campfire impacts
- respect wildlife
- be considerate of other visitors

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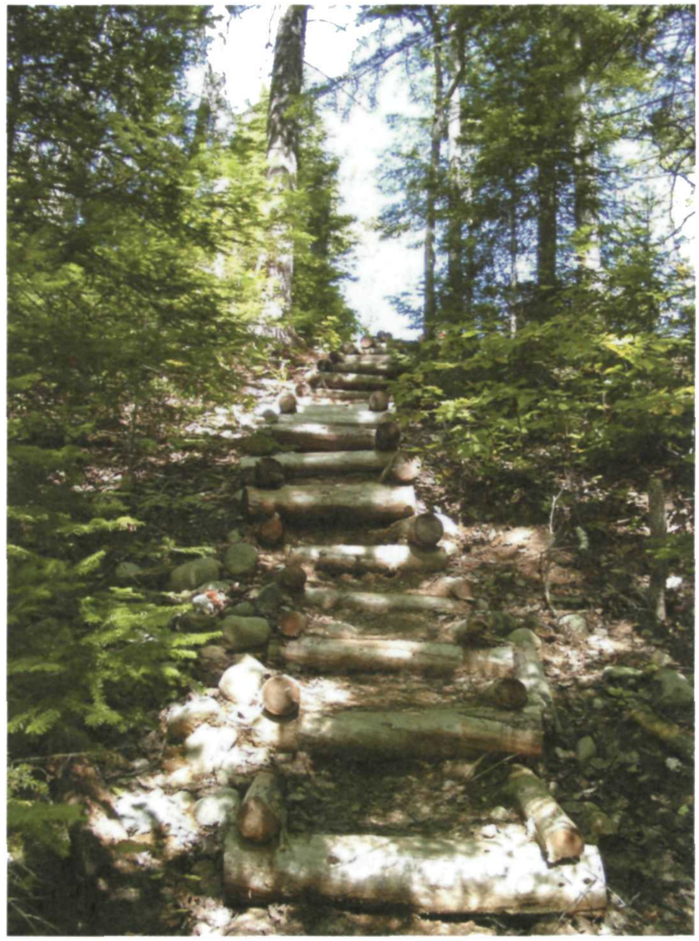
Appalachian Trail managers also can employ regulatory or policy guidelines to concentrate use in areas that can withstand heavy use, disperse visitors in areas that can withstand limited levels of use, and restrict or prohibit visitors from entering areas where visitor impacts are unacceptable. Research on trampling impacts has shown that the majority of resource impacts associated with trail use occur with initial or low levels of use. Furthermore, substantial increases in visitation on moderate-use trails and campsites generally yield relatively small additional amounts of impact. The implications of these findings for managers are, in a nutshell: impacts can be minimized most effectively by focusing visitor use on a limited number of trails



AT in Bigelow Preserve Maine (courtesy NETN)

that have been designed and maintained to sustain high levels of use. Dispersing use or limiting use to control impacts is generally ineffective, except at very low levels of use (Leung & Marion 2000).

Overnight shelters are another fundamental component and long-established tradition of the Appalachian Trail (*Appalachian Trail Comprehensive Plan*, 1981). Since 1925, the Appalachian Trail Conservancy's policy has been to support the construction, use, and maintenance of "a connected series of primitive lean-tos and camps" along the AT. In general, these shelters are spaced a day's hike apart for an average hiker (roughly ten miles apart). According to the Appalachian Trail Conservancy, design and construction of these facilities should reflect an awareness of, and harmony with, the Appalachian Trail's primitive qualities (*Appalachian Trail Conference Local Management Planning Guide*, 1997). Overnight use also occurs at designated and informal campsites.

Procedures for monitoring conditions at shelters and campsites along the Appalachian Trail have been refined in recent years. Williams and Marion (1995) developed and applied an initial monitoring protocol to seven huts and 125 campsites along the Appalachian Trail as part of a larger study at Shenandoah National Park. This process included an assessment of campsite size, area of vegetation loss, area of exposed soil, tree damage, root exposure, and number of campfire sites. Another study by Marion and Leung (1997) applied monitoring procedures to shelters and campsites at Great Smoky Mountains National Park. A further study applied similar procedures to shelters and campsites along the AT in central and northern North Carolina (Konopka, 2001, 2003).

In 1999, 2000, and 2001, Marion, the Appalachian Trail Conservancy, and local Trail Club and agency partner managers conducted a study of 17 overnight use sites that were known to receive heavy overnight visitation resulting in significant resource or social impacts (Marion 2003). In that study, researchers analyzed and documented conditions at these 11 shelters and 6 camping areas, and then proposed and implemented management recommendations at several locations intended to reduce visitor impacts to soils, vegetation, and other resources. Further monitoring is needed to confirm the effectiveness of these measures, but initial observations indicate that the measures have significantly reduced visitor impacts at these sites.

Bootleg campsite along the Appalachian Trail
©Jeffery L. Marion

However, visitor impacts at designated overnight use areas may be a comparatively small part of the problem. According to the Appalachian Trail Conservancy, most overnight visitors stayed in huts and shelters three decades ago. A recent survey of AT visitors found that 56% of the overnight visitors stayed in huts and shelters; but 12% camped near shelters, 23% stayed at designated campsites or tent sites, and 9% camped elsewhere along the AT (Manning et al, 2000).

The 9% of visitors who camped at "bootleg" sites along the Appalachian Trail have the potential to cause the most significant damage to AT resource values. Most shelter sites along the AT have been in existence for decades. Research by Marion and others indicates that impacts to vegetation and soils associated with use of these established sites are probably well established, and that further incremental impacts are relatively small. Further, impacts associated with construction of any new shelter or overnight use sites are analyzed in environmental analyses prior to construction and mitigating measures are incorporated into the project design to ensure that no significant resources are affected.

By contrast, unregulated sites are usually created by visitors in new areas without advance knowledge of potential adverse impacts, and are often created near areas that have vulnerable natural resources, such as streams, lakes, springs, and rock outcrops. Even infrequent use of these "bootleg" campsites can quickly damage soils and vegetation, as well as any rare plant or animal species that may be present. In 1999, the Appalachian Mountain Club, the Appalachian Trail Conservancy, and the White Mountain National Forest collaborated on a study titled "An Inventory of Bootleg Campsites on the Appalachian Trail in the White Mountain National Forest" (Kahdahl 1999, unpublished). The study documented conditions at 402 unauthorized bootleg sites that were identified along a 131.7-mile section of the Appalachian Trail between Grafton Notch, Maine, and Glencliff, New Hampshire. Most of the sites were relatively small, but 17 sites were greater than 1,000 square feet. The total area of disturbance was 107,887 square feet, or an average of 268 square feet per site. In general, the most severe impacts were associated with sites located near water sources or at high elevations, where fragile soils and vegetation were affected.

Human waste management has been another perennial challenge for Appalachian Trail managers. In some instances, poor sanitation management has led to direct and indirect contamination of water sources. Increased attention to this issue by AT managers during the last decade has resulted in substantial improvements.

Sanitation options range from user-made cat-holes to standard pit privies to composting privies. Currently, there are 265 constructed privies along the AT: 31 hot composting privies (bin-style), 39 cool composting privies (above-ground mouldering style), 186 pit privies, and 9 vault toilets that require pumping. In 2004, Appalachian Trail managers initiated an evaluation of sanitation facilities as part of the trail-wide condition assessment. Of the 96 sanitation facilities that have been assessed to date, eight have been deemed to be in need of relocation or repair. However, these studies have focused primarily on structural needs, not on the potential effects of pathogen migration on water quality and other resource values.

Several AT managers have stated that a baseline study of sanitation facilities and their potential effects may be the most important need in terms of assessing current visitor use (Sommerville, Proudman, personal communication 2005). The best currently available information is contained in the *Backcountry Sanitation Manual* (Appalachian Trail Conference and Green Mountain Club 2002), which provides guidance on the design and location of backcountry sanitation systems and includes personal observations on the effectiveness of sanitation systems at several high-use sites along the Appalachian Trail.

In summary, no studies of visitor impacts on natural or cultural resources have ever been conducted on a trail-wide scale. The Appalachian Trail Conservancy is currently assessing the condition of the trail footpath,

Composting Toilet along the Appalachian Trail
©Jeffery L. Marion

shelters, campsites, and sanitation facilities through the application of the National Park Service's FMSS process. Once completed, this data should provide a baseline for measuring visitor impacts on those facilities as part of documenting over-all maintenance needs. Further research will be needed to quantify impacts to water, air, soils, and wildlife.

In the interim, inferences can be made from several studies that have measured visitor impacts along certain sections of the Appalachian Trail, such as the sections of the AT that pass through Great Smoky Mountains National Park in North Carolina and Tennessee and the White Mountains in New Hampshire. Soil erosion, campsite proliferation, and adverse effects of poor sanitation appear to be the most significant challenges facing AT managers.

Because of its geographic expanse, generally wet and cold environment, relative ease of access and high use levels, the Appalachian Trail provides an ideal laboratory for experimental design of trails, overnight use areas, and backcountry sanitation facilities. Strong anecdotal references indicate that trail hardening, Leave No Trace training, and ridgerunner and caretaker programs have had positive effects in reducing the impacts of visitors on Appalachian Trail resource values. Other programs directed at reducing

View from Bigelow Preserve Maine
(courtesy NETN)

visitor impacts, particularly programs focused on improving sanitation and reducing adverse impacts to water quality, could have similar positive benefits.

Chapter Ten
Alpine and High ElevationVegetation

The highest elevation plant communities of the Appalachian Trail, in both New England and the southern Appalachians, are among the rarest and most significant plant communities in the eastern United States. Alpine plant communities are sometimes referred to as "islands," which are surrounded by forests of conifers and deciduous trees. In Maine and New Hampshire, alpine vegetation may be found atop some of the highest summits over which the AT passes. In the southern Appalachians no alpine areas exist, and the high summits over which the AT travels are often topped by red spruce-Fraser fir forest, grassy balds, or heath balds, all of which are unique vegetation types to this region of the country.

In the Northeast, the alpine plant community, consisting of alpine vegetation above the treeline, is found on only of a few of the highest peaks in Maine, New Hampshire, Vermont, and New York. In Maine, alpine plant communities are an S2 plant community, and in New Hampshire, they are an S1 plant community. A significant portion of the limited alpine acreage in the Northeast lies within the Appalachian Trail corridor. The alpine areas of the AT corridor in New Hampshire and Maine represent the only alpine area that is within a National Park Service unit in the eastern United States.

The alpine floristic community that is found on some of the highest summits over which the AT passes is considered to be unique in the eastern United States.

This alpine plant community is composed primarily of low-growing shrubs, cushion plants, and graminoids. Dominant alpine species include alpine willow (*Salix uva-ursi*), Lappland rhododendron (*Rhododendron lapponicum*), alpine bearberry (*Arctostaphylos alpina*), bog bilberry (*Vaccinium uliginosum*), dwarf bilberry (*Vaccinium caespitosum*), black crowberry (*Empetrum nigrum*), diapensia (*Diapensia lapponica*), mountain sandwort (*Minuartia groenlandica*), alpine holy grass (*Hierochloe alpine*), Bigelow sedge (*Carex bigelowii*), and deer-hair sedge (*Scirpus cespitosus*). More than 60 species of plants here are considered to be true arctic-alpine species. While many of the plants in the alpine zone are state threatened or endangered, only nine of them are globally rare species, such as Robbins cinquefoil (*Potentilla robbinsiana*), Boott's rattlesnakeroot (*Prenanthes bootii*), and mountain avens (*Geum peckii*). Most of the alpine species are more widespread in arctic regions of the globe.

Alpine Vegetation on Saddleback Mountain, Maine
©ATC File Photo

Only eight mountains in Maine extend into the alpine zone, and five of these are located along the Appalachian Trail corridor (Figure 10.1). Along the AT, alpine ridge plant communities occur at Mt. Katahdin, Bigelow Mountain, Saddleback Mountain and The Horn, Baldpate Mountain, and Goose Eye Mountain. Treeline along the Appalachian Trail in Maine generally occurs above 3,500 feet, though the elevation varies somewhat, depending on climate,

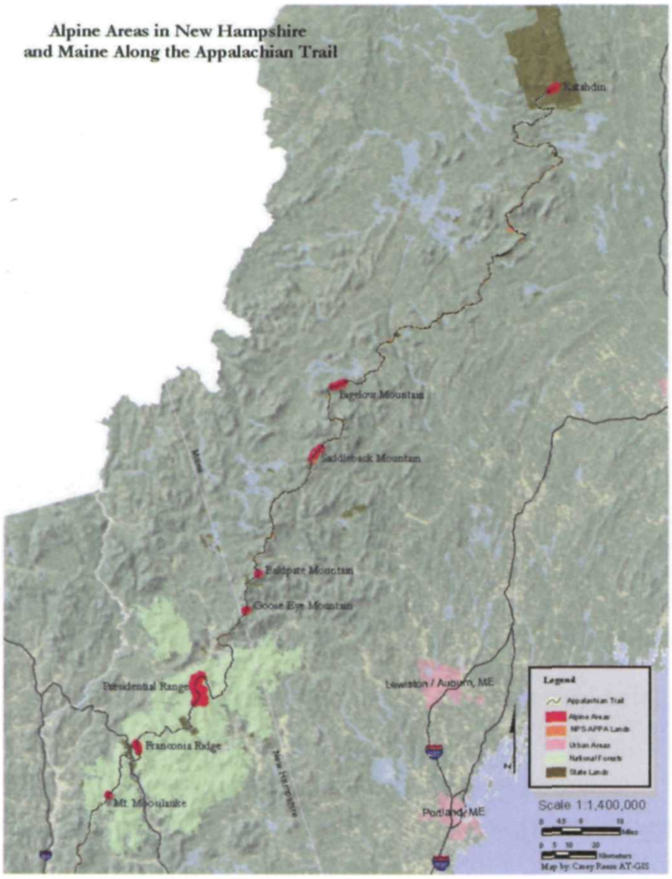


Figure 10.1. Alpine areas in New Hampshire and Maine along the Appalachian Trail.

slope, and other factors. On Saddleback Mountain and Whitecap Mountain, krummholz plant communities may be found in the ecotone between alpine areas and spruce-fir forest. Trees in the krummholz communities are typically less than five feet tall. Alpine tarn plant communities along the AT in Maine are found at Bigelow/The Horns and Mahoosuc Arm/Speck Pond. Speck Pond, located at an elevation of about 3,400 feet, is the highest tarn in Maine.

Of the approximately 1,700 acres of the AT corridor in Maine above 3,500 feet, approximately 650 acres are found in alpine plant communities. Of the five Maine alpine ridge plant communities noted above, only Saddleback Mountain, including the Horn, is in NPS ownership. On Saddleback and The Horn, 29 alpine plant species occur in the 132 acres of the alpine vegetation zone. Two small alpine bogs also occur on Saddleback Mountain. Because of its large size, limited anthropogenic impacts, and state rare species, the alpine ridge community on Saddleback and The Horn is considered to be an outstanding example of its type in Maine.

The four other alpine ridge plant communities within Maine's Appalachian Trail corridor are on state land. Mt. Katahdin is the northern terminus of the AT and the highest peak in Maine at 5,267 feet. Mt. Katahdin and Baxter State Park support the greatest diversity of alpine plant species in Maine, numbering about 50 species. The AT passes through approximately 236 acres of alpine area on Mt. Katahdin. The alpine area on Bigelow Mountain, which includes 24 alpine plants, is limited to about 135 acres and the AT footpath passes through the center of this area. In the Mahoosuc Range, an alpine plant community may be found on Goose Eye Mountain and other peaks. On Goose Eye Mountain, approximately 68 acres of alpine area are immediately adjacent to the AT footpath. On Mt. Carlo, also in the Mahoosuc Range, one source (Uncut Timber Stands and Unique Alpine Areas on State Lands, 1986) indicates that there are approximately 25 acres of alpine vegetation on the summit of Mt. Carlo; however, the Natural Heritage Inventory of the Appalachian Trail Corridor in Maine (1997) does not indicate the presence of an alpine plant community on this mountain. Approximately 74 acres of the 168-acre alpine area on Baldpate Mountain are traversed by the Appalachian Trail.

In New Hampshire's White Mountains, the alpine plant community of the Presidential Range is the largest and most diverse of the alpine areas in the Northeastern United States (Figure 10.1). Local conditions of wind, exposure, aspect, moisture, and depth of snow cover contribute to microhabitats that support different assemblages of plants. On average, alpine ridge communities in the Presidential Range are found above 4,700 feet. The Appalachian Trail passes through 12.7 miles of continuous alpine vegetation from Mt. Madison to Mt. Pierce (Mt. Clinton) in the Presidential Range. Approximately 1,080 acres of alpine area lie within the AT corridor along this segment of the Trail, almost all of it within White Mountain National Forest. Along the middle portion of this segment, the AT crosses Mt. Washington, the highest peak in the Northeast at 6,288 feet. Southwest of the continuous alpine area in the Presidential Range lie one or two acre alpine plant communities on the summits of Mt. Jackson (4,052 feet) and Mt. Webster (3,910 feet). Krummholz of balsam fir and black spruce is often found between 4,000 and 4,700 foot elevations. In the Presidential Range, there are at least 63 species of plants that are considered truly arctic-alpine. Dominant alpine species are similar to those previously noted for the alpine areas in Maine.

The next largest alpine area along the Appalachian Trail in New Hampshire is on Franconia Ridge, which extends more than two miles from Little Haystack Mountain to Mt. Lafayette (Figure 10.1). Approximately 188 acres of alpine vegetation are found along this portion of the AT. Several smaller alpine areas are also found within the Appalachian Trail corridor of New Hampshire. Just east of Franconia Ridge, a small one acre rocky alpine summit is present on Mt. Garfield at an elevation just below 4,500 feet. Farther east, South Twin Mountain has an approximately one-half acre of alpine vegetation on its 4,900 foot summit. Nearby Mt. Guyot, at 4,560 feet, has several acres of an alpine plant community on its rounded summit.

Mt. Moosilauke is the most southwestern peak of the White Mountains to have an alpine plant community, in addition to being the southernmost peak along the Appalachian Trail corridor to have an alpine plant community (Figure 10.1). Approximately one-half mile of the Appalachian Trail passes through the alpine plant community, consisting of 25 acres, on Mt. Moosilauke at an elevation of 4,600-4,800 feet.

Spruce/Fir Forest along a mountain top. ©Evans, Chris. The University of Georgia. www.forestryimages.org

The most obvious and immediate threats to alpine areas in New England are generally considered to be trampling and other recreation impacts. Large scale anthropogenic threats such as acid precipitation and climate change are big question marks with regard to the mechanisms and magnitudes of their potential impacts on the alpine plant communities. Climate change could potentially reduce the number of mountains having alpine vegetation at their summits.

To mitigate the threats of trampling, Appalachian Trail clubs have invested in trail definition projects, such as scree walls, that are designed to keep hikers on a discrete treadway, thus preserving the vegetation on either side. AT clubs and agencies have also invested heavily in education programs designed to alert visitors to the fragility and sensitivity of the alpine environment. Franconia Ridge, Mt. Moosilauke and Mt. Katahdin have ridgerunners and summit stewards that interact with the public and encourage hikers to stay on the trail and avoid trampling the alpine vegetation. Also, most alpine peaks have signs at treeline indicating that the hiker is about to enter a fragile area.

The combination of the treadway definition and education has led to a general improvement in the condition of alpine vegetation near the Appalachian Trail in some areas. Long term monitoring on Franconia Ridge has shown that over the last two decades the trampled area has decreased, and now it is quite common to see alpine species growing right next to the scree walls that define the treadway. Some areas on Mt. Katahdin and some of the lesser peaks in Maine could benefit from additional treadway improvements. More sophisticated monitoring with either permanent plots or a "photo points" monitoring system is needed in other locations to assess the long-term trends in these sensitive alpine areas.

Three of the rarest and most significant plant communities in the eastern United States (the red spruce-Fraser fir forest, grassy balds, and heath balds) occur in the southern Appalachians of North Carolina, Tennessee, and Virginia. These high elevation plant communities are unique to the southeastern United States.

The montane spruce-fir forest is the highest and rarest of the forest cover types in the southern Appalachians, covering about 65,750 acres, or 0.2%, of the Southern Appalachian Assessment area (the mountainous area from northern Virginia to northeast Alabama). Like the alpine areas of New England, the spruce-fir forest can be considered "islands" of conifers above the surrounding deciduous forest vegetation. Southern Appalachian red spruce-Fraser fir forest may be found in the Great Smoky Mountains (NC/TN), Balsam Mountains (NC), Black Mountains (NC), Roan Mountain (NC/TN), Grandfather Mountain (NC), and Mt. Rogers/Whitetop (VA) (Figure 10.2).

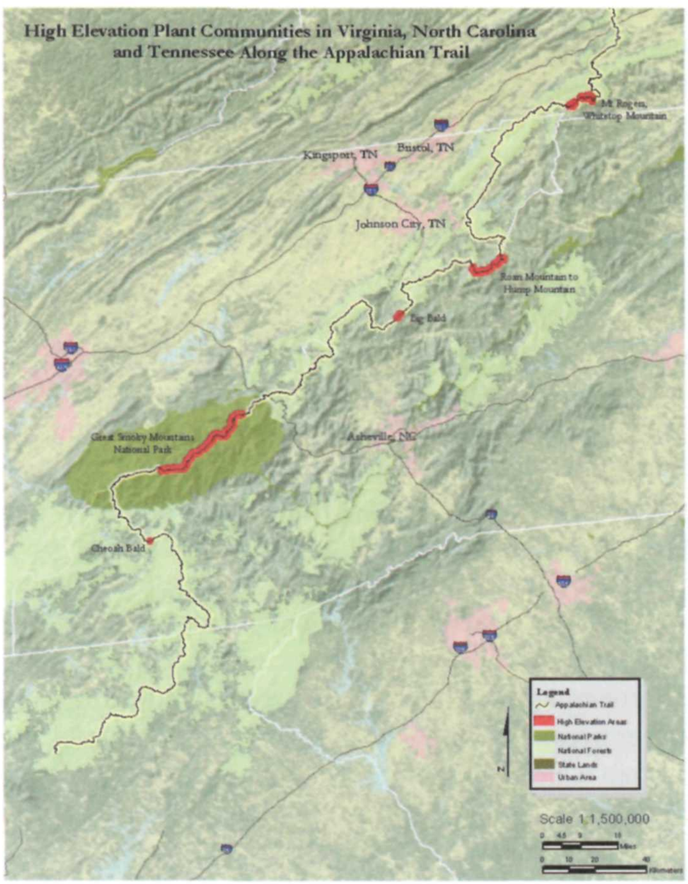


Figure 10.2. High elevation plant communities in Virginia, North Carolina, and Tennessee along the Appalachian Trail.

This forest is dominated by red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*). The red spruce is the same species found in greater abundance in northern New England and southeast Canada. The Fraser fir, however, is a globally rare southern Appalachian endemic species limited to the summits of a few of the highest peaks in the southern Appalachians. Red spruce occurs in southern Appalachians as low as 4,500 feet in mixtures with northern hardwoods. Red spruce often dominates forest stands in the 5,000 to 5,500 foot elevation range. Fraser fir begins to appear around 5,500 feet in mixture with red spruce, and above 6,000 feet may form pure stands. Deciduous tree species such as yellow birch (*Betula lutea*), mountain ash (*Sorbus americana*) and mountain maple (*Acer spicatum*) are occasional components of the spruce-fir forest. Shrubs include Catawba rhododendron (*Rhododendron catawbiense*), mountain cranberry (*Vaccinium erythrocarpum*), smooth blackberry (*Rubus canadensis*), and hobblebush (*Viburnum alnifolium*). The herbaceous layer frequently includes wood sorrell (*Oxalis montana*), mountain woodfern (*Dryopteris campyloptera*), sharp-leaved aster (*Aster acuminatus*), blue-bead lily (*Clintonia borealis*), and mountain goldenrod (*Solidago glomerata*).

The southern Appalachian spruce-fir forest has been severely threatened by multiple factors. High-elevation spruce-forest communities have been reduced to current levels by the past century of logging, exotic insect infestations, and possibly other factors not yet fully understood. In the past several decades, Fraser firs have suffered extensive mortality due to infestations of balsam woolly adelgid (*Adelges piceae*) during the last 30 years. Decreases in crown vigor and annual growth are also apparent in red spruce. Current threats to the spruce-fir forest of the southern Appalachians include exotic species infestations, air pollution, and degrading of habitat by opening forest canopies, raising soil temperatures, and decreasing soil moisture. Acid deposition components of sulfate, nitrate, and hydrogen ions at high elevations greatly exceed those at lower elevations. Field studies have shown that red spruce in the southern Appalachians is experiencing calcium and zinc deficiencies. Research has also demonstrated that the high elevation forests appear to be nitrogen saturated.

By far the largest concentration of spruce-fir forest in the southern Appalachians is found in Great Smoky Mountains National Park along the North Carolina-Tennessee border (Figure 10.2). Approximately 48,720 acres of spruce-fir forest is found in the Great Smokies, which represents 74% of the total southern Appalachian spruce-fir forest. Twenty-eight miles of the Appalachian Trail from Double Springs Gap (or Jenkins Knob) to Old Black passes through a largely continuous stand of spruce-fir forest. The highest peak along the entire Appalachian Trail, Clingman's Dome (6,643 feet), is located within this section of spruce-fir forest. Smaller areas of spruce-fir forest in the Smokies are located on Inadu Knob and Camel Hump, and scattered spruce and fir may be found to the west of Jenkins Knob. Based on an elevational analysis, approximately 4,160 acres of spruce-fir forest lie within 500 feet of the Appalachian Trail corridor in the Great Smoky Mountains.

Approximately 135 AT miles northeast of the Great Smoky Mountains, another area of spruce-fir forest occurs along portions of the Roan Mountain Massif, which encompasses a series of high elevation peaks and gaps along the North Carolina-Tennessee border (Figure 10.2). Approximately 1,100 acres of the Appalachian Trail corridor rises above 5,000 feet along a 14-mile stretch of trail between Hughes Gap and Doll Flats. Less than one-half of the Appalachian Trail over the Roan Mountain Massif passes through spruce-fir forest, with much of the remainder passing across grassy bald and heath bald plant communities. One sizeable stretch of the AT that passes through spruce-fir forest is between Carvers Gap and Coltons Cliff. Much of Roan Mountain lies within Cherokee and Pisgah National Forests, with additional land under the management of the Southern Appalachian Highlands Conservancy.

In general, the Roan Mountain Massif is regarded as one of the richest repositories of temperate zone diversity in the eastern United States. Within a 4,600-acre area, Roan Mountain encompasses many rare plant communities, including red spruce-Fraser fir forest, grassy balds, heath balds, and high elevation seeps. Roan Mountain provides habitat for four federally listed plants, three federally listed animals, and over 80 southern Appalachian endemic or regionally rare species. Within the 1,100-acre Appalachian Trail corridor are found twelve globally rare plants, including Gray's lily (*Lilium grayi),* Blue Ridge goldenrod (*Solidago spithamea),* spreading avens (*Geum radiatum*), and Roan rattlesnake root (*Prenanthes roanensis*), and four globally rare animals, Carolina northern flying squirrel (*Glaucomys sabrinus coloratus),* ground beetle (*Trechus roanicus),* Fraser fir geometrid (*Semiothisa fraserata*), and Spruce-fir moss spider (*Microhexura montivaga*).

Not far north of the Tennessee-Virginia border, a third island of red spruce-Fraser fir forest is located in the vicinity of Mt. Rogers and Whitetop Mountain within Mt. Rogers National Recreation Area, managed by the USDA Forest Service (Figure 10.2). The summit of Mt. Rogers, the highest mountain in Virginia at 5,729 feet, is covered in spruce-fir forest. The occurrence of Fraser fir here is the most northern occurrence of its range. On Whitetop Mountain, red spruce may be found in nearly pure stands or scattered with northern hardwood species. Approximately 750 acres of the Appalachian Trail corridor rises above 5,000 feet in elevation through the Mt. Rogers-Whitetop area, with the area of the corridor passing through spruce fir forest being somewhat less than this.

Grassy balds are another globally rare plant

A grassy bald on Big Bald, NC/TN
(courtesy Appalachian NST)

community that can be found on high elevation southern Appalachian peaks. These balds commonly occur on south or southwest-facing ridgetops, domes, and gentle slopes at elevations above 5,000 feet.

High winds, frequent fog, and high precipitation characterize the climate, which is similar to that of adjacent spruce-fir forest areas. Soils may be moist and deep, or they may be shallow and rocky where they grade into rock outcrops. Grassy balds are dominated by grasses, sedges, and herbaceous species and they sometimes include patches of shrubs and small trees. Sedges tend to dominate on moist soils, and mountain oat grass tends to dominate on drier soils. Grassy balds are frequently surrounded by other high-elevation plant community types, including heath balds, montane spruce-fir, and northern hardwoods. The presence of some grassy balds is believed to have been influenced by grazing activities and fires.

Grassy balds are smaller in extent than the spruce-fir forest, but more widely distributed along the higher elevations of the AT corridor in North Carolina and Tennessee. South of Great Smoky Mountains National Park, the AT passes over Wayah Bald, Wine Springs Bald, Siler Bald, Rocky Bald, and Cheoah Bald. These balds are believed to have originated by human disturbance, and except for Cheoah Bald, they are now covered in high elevation deciduous forests and shrubs. In Great Smoky Mountains National Park, the AT passes over both Silers Bald and Spence Bald, which are both considered grassy balds. Northeast of the Great Smoky Mountains, the AT passes over Big Bald, which is a 220-acre natural bald. Five globally rare species have been documented from Big Bald.

The largest area of grassy balds, approximately 2,500 acres, along the Appalachian Trail can be found along the Roan Mountain Massif. To the east of Carvers Gap, Round Bald, Jane Bald, Grassy Ridge Bald, and Hump Mountain. Several federally endangered and globally rare species, such as spreading avens (*Geum radiatum*) and Roan Mountain bluet (*Houstonia montana*) are found here. Other globally rare species found on the grassy balds of Roan Mountain include wretched sedge (*Carex misera*), Roan rattlesnakeroot, bent avens (*Geum geniculatum*), and Gray's lily.

The only grassy bald documented in VA is found along the AT on the southern and western slopes of Whitetop Mountain. This grassy bald covers about 125 acres at elevations between 4,800 and 5,500 feet. The bald is dominated by grasses, sedges, and herbaceous vegetation, but it also includes scattered individuals and small stands of shrubs and wind-stunted trees. This bald supports large populations of the globally rare Blue Ridge St. John's wort (*Hypericum mitchellianum*) and Roan rattlesnake root.

Among the greatest threats to grassy bald communities and their associated species are encroachment of woody vegetation, heavy recreational use, and rare plant collection. Air pollution may also be playing a part in the decline of the grassy balds.

Heath balds are another plant community that is characteristic of some of the higher elevation peaks along the AT corridor in NC, TN, GA, and VA. Heath balds are dominated by ericaceous shrubs, including many species of rhododendrons and blueberries (*Vaccinium sp.*), as well as mountain laurel (*Kalmia latifolia*) and other species. Heath balds are commonly found on steep, exposed slopes and ridges, and occasionally on rock outcrops. They are not exclusively a high elevation vegetation type, since they range in elevation from 2,000 feet to 6,500 feet. The soils are generally shallow, acidic, nutrient-poor, and organic. Shrub cover is usually dense, as is the case at Rocky Top, Thunderbird, and Charlies Bunyon along the AT in the Great Smokies. However, the shrub cover can be open and garden like, as is the case at the natural Catawba rhododendron gardens of Roan Mountain. Herbaceous cover is generally sparse due to the dense cover of shrubs or the presence of exposed rock; however, there is sometimes a fairly dense herbaceous strata. Any trees that are present are scattered and stunted.

Long term monitoring of the size and health of grassy balds and heath balds in the southern Appalachians could occur, in cooperation with the USDA Forest Service and Great Smoky Mountains NP.

Chapter Eleven
Landscape Dynamics

One of the most profound effects of humans on the landscape is alteration of habitats critical to plants and animals. As people construct roads and build houses, they convert once-continuous habitats into areas of non-habitat and fragment large areas of habitat into patches that are too small to support native species. In the Northeast, most ecosystems have experienced loss and fragmentation of habitat, and these changes are a principal threat to native biodiversity. National parks are limited in size and many species require critical seasonal habitat that exists or genetic interchange that occurs outside park boundaries. Changes in land use near a park can influence actions to manage invasive species or maintain water quality. Therefore, park managers need information about changes to the landscape both inside and outside parks to effectively conserve a park's native flora and fauna.

Many networks in the I&M Program have identified landscape dynamics as a high-priority vital sign because change adjacent to parks can alter water quality and flow regimes, increase invasive plant and animal introductions, reduce contiguous forest, and influence ambient sounds and clear night skies, among other impacts. For example, feral cats, which prey on native birds, amphibians, and small mammals, are now common in many northeastern parks. To address such issues, the network initiated a project in 2003 using remote sensing data to determine the present land cover and estimate land-cover changes since the early 1970's.

Remote sensing is well documented as an effective tool for mapping and characterizing cultural and natural resources (e.g., Holz 1985; Lo 1986; Jensen 1996; Campbell 1997). The multispectral capabilities of remote sensing allow observation and measurement of biophysical characteristics, and the multitemporal and multisensor capabilities allow tracking of changes in these characteristics over time. These capabilities also make remote sensing very useful for evaluating results of different land-management techniques (Quattrochi & Pelletier 1991).

The first step in developing a land-cover change monitoring program is to characterize the existing landscape within and around each park and, if possible, determine how the extent of ecosystems has changed over time. Many types of remote sensing data could be used to determine changes in land cover and provide a consistent, repeatable sampling methodology to monitor change. Project investigators selected the Landsat series of satellite data because it provides a 30-year history from the early 1970s with nearly continuous coverage to the present time. Eight park units and 10 Appalachian National Scenic Trail segments are included in the project, effectively creating a retrospective assessment of land-cover change at 18 sites in the Northeast (Figure 11.1).

In the Northeast, most ecosystems have experienced loss and fragmentation of habitat, and these changes are a principal threat to native biodiversity.

Landsat multispectral imagery data acquired by Multispectral Scanner (MSS) sensor in the 1970's, Thematic Mapper (TM) sensor in the 1980's, and Enhanced Thematic Mapper Plus (ETM+) sensor in the 2000's were used to produce the land cover maps for the selected National Parks and AT segments. Landsat imagery data were distributed in scenes and each scene covers about 185x185 square kilometer areas. The time of image acquisitions for the 15 scenes that were used for the AT sites are listed in Table 11.1. All images were geometrically rectified and georeferenced to the universal transverse mercator

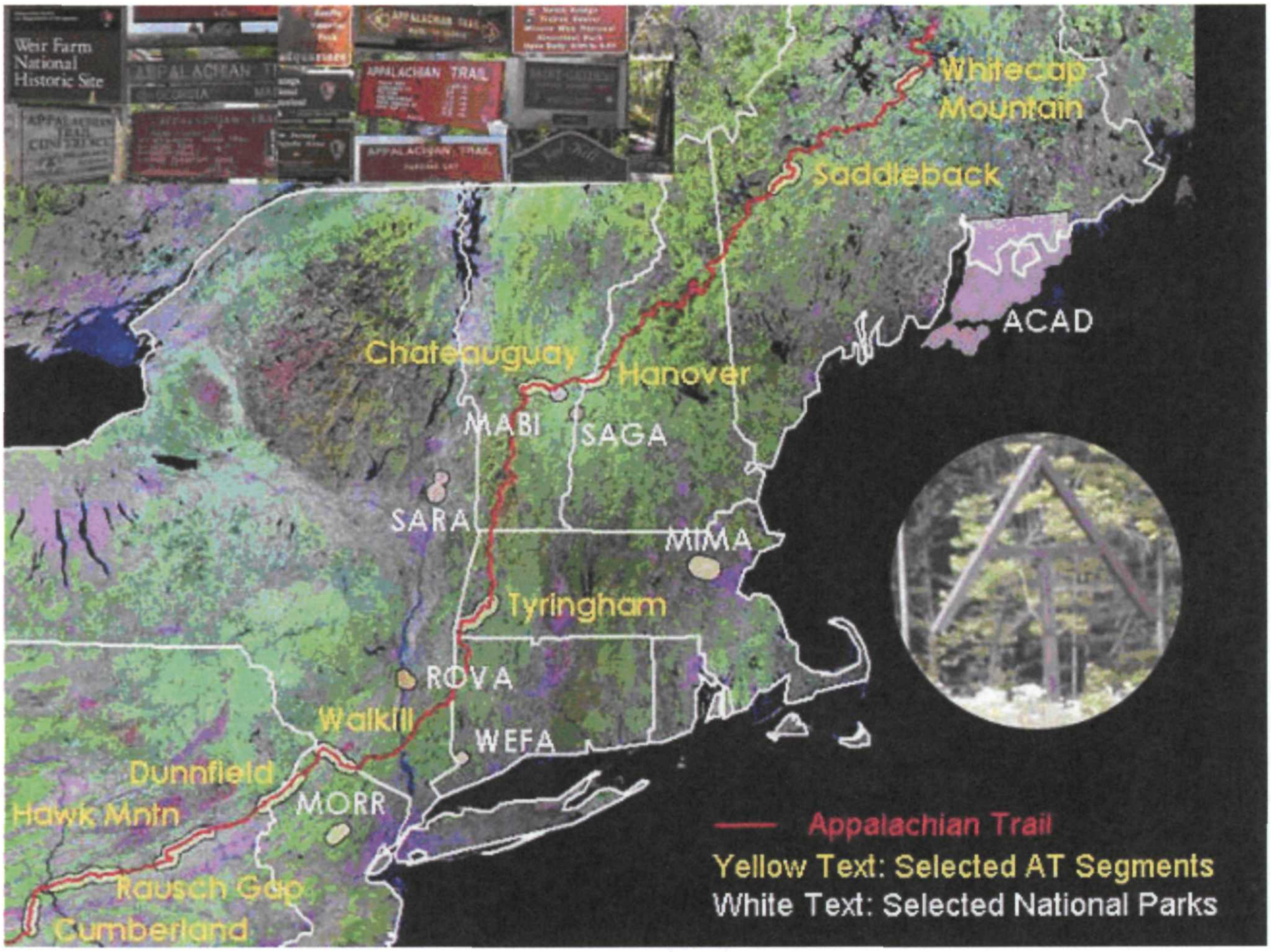


Figure 11.1. The selected National Parks and Appalachian Trail segments for the NETN land-cover and land-use change detection project.

(UTM) map coordinates.

The land-cover change assessment at each site includes within-park changes and changes within a 3-mile (5-km) buffer around each park. Analysis within these buffer zones provides information for resource managers to quantify land-cover changes adjacent to the parks over the past 30 years and can help in setting priorities for monitoring and restoration. Knowing that old field habitat in the landscape around the park has been converted to residential development increases the importance of these habitats in the park and gives park managers the information they need to make management decisions.

In August 2003 and June 2004, the University of Rhode Island (URI) research team undertaking the project visited each of the 18 study sites to meet with NPS and Appalachian Trail Conservancy (ATC) natural resource managers and volunteers. During these meetings the team reviewed the satellite images and learned about the unique characteristics of each study site. In partnership with these NPS and ATC representatives, the URI team created a so-called virtual field reference database (VFRDB) that contains more than 2,800 geo-referenced digital photographs. These photographs, with precise geographic location and general compass direction observed at the time of field reconnaissance, permit cross-checking the land-cover data with the Landsat scenes and offer a reference that could be used for the long-term monitoring of land-cover change around the parks. A final step in

Table 11.1. Landsat scenes that cover the selected 10 AT segments and times of image acquisitions.

Site Name	ETM+	TM	MSS
Whitecap Mountain, ME	7/24/2002	6/21/1987	8/11/1976
Saddleback Mountain, ME	7/31/2002	9/13/1986	9/20/1972
Hanover, NH	9/08/2002	9/28/1989	9/26/1978
Chateauguay-No-Town, VT	9/08/2002	9/28/1989	9/26/1978
Tyringham Valley, MA	9/08/2002	9/28/1989	7/24/1973
Walkill Valley, NJ	8/14/2002	6/12/1988	8/02/1975
Delaware Water Gap, NJ	8/14/2002	6/12/1988	8/02/1975
Hawk Mountain, PA	9/06/2002	9/10/1989	10/06/1973
Rausch Gap, PA	9/06/2002	9/10/1989	10/06/1973
Cumberland Valley, PA	9/06/2002	9/10/1989	10/06/1973

this project will provide a "gap analysis," which will assess the extent of land-cover types on conservation lands (lands that cannot be developed) around each park and trail segment. The analysis will determine whether, for example, any ecosystems are missing or rare, and thus how well these areas adjacent to parks protect priority ecological systems. Information from this project will therefore be applicable to a wide audience, including park personnel, ATC volunteers, other networks, and local land planners.

The land cover classification scheme includes 15 categories (Table 11.2) adapted from the USGS land use and land cover classification system (Anderson et al., 1976). Supervised classification was employed to obtain the land cover data for each of the time periods. Based on the image classifications initial change analysis results were obtained.

The ten Appalachian Trail segments, totaling about 225 miles (362 kilometers) from Maine to Pennsylvania, were selected based on observed changes and on the potential for future change as perceived by managers. The descriptions of the sites from north to south are as follows.

Table 11.2. Classification scheme for the land cover mapping and change analysis.

Code	Class Name	Description
11	Urban	Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).
12	Urban Grass	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.
21	Herbaceous Vegetation	Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.
31	Grass/Open land	Areas of natural vegetation predominantly grasses, grasslike plants (modified from Rangeland).
32	Shrubland	Areas of natural vegetation predominantly shrubs on rocky mountains (modified from Rangeland).
41	Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
42	Coniferous Forest	Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
51	Water	All areas of open water.
61	Wetlands	Areas where the soil or substrate is periodically saturated with or covered with water.
71	Barren Land	Areas characterized by gravel, sand, or other earthen material, with little or no "green" vegetation present.
72	Bare Rockface	Areas characterized by bare rock on mountains, with little green vegetation present.

Whitecap Mountain, Maine: This segment is about 13 miles (21 kilometers) located between Gulf Hagas Mountain (western terminus) to Little Boardman Mountain (eastern terminus). This remote alpine summit is in a region where significant land conservation is likely to occur adjacent to the Appalachian Trail corridor. Views are expansive and vegetation is krumholz with some alpine species. Whitecap is in the midst of land that has been historically logged, but conservation interest in the area is high. This interest may lead to land-use changes (cessation of logging adjacent to the corridor) in the near future. There is also a summit station that contains solar panels and antennae for radio repeaters. The presence of these facilities may make Whitecap more appropriate for a study area that required installing equipment in a remote setting such as an air quality monitoring station (Table 11.3).

Table 11.3. Change analysis adjacent to Whitecap Mountain, Maine

AT Whitecap (5km Buffer)	**1976** (acres)	**1987** (acres)	**2002** (acres)
Deciduous Forest	22,456	23,611	20,979
Coniferous Forest	19,996	11,326	8,487
Mixed Forest	11,916	14,348	18,782
Water	1,737	1,796	1,974
Wetland	964	1,075	786
Barren Land	4,388	8,582	6,340
Regrowth Forest	-	577	3,940

Saddleback Mountain Maine: This segment is about 4 miles (7 kilometers) located between the western shore of Eddy Pond (western terminus) to the bottom of the valley between the peaks of The Horn and Saddleback Junior. This area is known for it arctic-alpine vegetation community on the smooth bedrock dome of the peak. Ranked as one of the most important places on the Appalachian Trail for species rarity, Saddleback is also the subject of considerable interest from the AT community due to the proximity of a ski area. The potential for future ski area expansion at Saddleback points to the desirability of additional information about vegetation, watercourses and other resources. Alternately, should the ski area cease to operate, there is interest in a conservation project to further protect important habitats and to provide further buffers between the AT and development. There are also ATV issues and camping issues at Eddy Pond at the foot of the mountain where additional resource information could inform appropriate recreation management for the site (Table 11.4).

Table 11.4. Change analysis adjacent to Saddleback Mountain, Maine

AT Saddleback (5km Buffer)	**1976** (acres)	**1987** (acres)	**2002** (acres)
Urban	83	504	1,429
Urban Grass	-	250	393
Deciduous Forest	24,638	34,810	25,742
Coniferous Forest	32,648	20,664	25,269
Mixed Forest	23,680	23,731	22,399
Water	164	171	141
Barren Land	6,385	5,545	7,142
Regrowth Forest	-	1,449	4,316

Hanover, New Hampshire (White Mountain National Forest): This segment is about 13 miles (21 kilometers) that includes the entire extent of the Appalachian Trail within the Town of Hanover, New Hampshire. The town of Hanover has about 13 miles of the Trail within its borders. The effects of development on the AT are unclear at this point. As farms get turned into housing lots or fields revert to woods, wildlife will likely be affected, as will vistas for hikers. The Town of Hanover has already highlighted the value of the AT corridor in their open space plan and made the conservation of additional adjoining parcels the town's highest priority (Table 11.5).

Table 11.5. Change analysis adjacent to Hanover, New Hampshire (White Mountain National Forest).

AT Hanover (5km Buffer)	1978 (acres)	1989 (acres)	2002 (acres)
Urban	1,049	1,448	2,492
Urban Grass	305	570	1,324
Deciduous Forest	23,583	27,525	22,776
Coniferous Forest	8,838	11,361	14,437
Mixed Forest	18,257	10,324	9,817
Water	1,435	1,821	1,660
Wetland	1,140	3,001	2,685
Herbaceous Vegetation	5,745	5,703	4,316
Barren Land	2,136	563	2,796

Chateauguay – No-Town Area (Vermont Fish and Wildlife and Green Mtn. Nat. Forest): This section of the Appalachian Trail, about 21 miles (33 kilometers) located in the towns of Barnard, Bridgewater, Killington and Stockbridge, VT, is in the midst of a large undeveloped area between two popular resort communities (Killington and Woodstock). The AT is quite primitive and isolated despite its proximity to areas where second home development is rampant and the historical farming and timber economy is starting to change in favor of development. There is great community interest in preserving the Chateauguay-No-Town area in its current undeveloped state. The four towns that are included in the area have developed a working group that includes the regional planning commission, local land trusts and the ATC. The purpose of the working group is to seek additional land protection for the area on a willing seller basis. Additional information about wildlife habitat, important watercourses, or the presence of rare species would aid conservation efforts. Also, if the area does experience development as a result of the proximity to growing population centers some monitoring data would be helpful for understanding the effects of the change in land use (Table 11.6).

Table 11.6. Change analysis adjacent to Chateauguay No-Town area (Vermont Fish and Wildlife and Green Mountain National Forest).

AT Chateauguay (5km Buffer)	1978 (acres)	1989 (acres)	2002 (acres)
Urban	442	691	1,300
Urban Grass	198	613	321
Deciduous Forest	43,334	53,221	53,541
Coniferous Forest	10,953	7,152	7,159
Mixed Forest	16,767	8,490	7,651
Water	183	683	301
Wetland	748	2,895	1,468
Herbaceous Vegetation	4,352	5,276	5,412
Barren Land	2,827	511	1,933

Tyringham Valley and Sheffield, Massachusetts: The section of Appalachian Trail, about 30 miles (48 kilometers), through Tyringham, is host to several Natural Heritage sites as well as some rare aquatic animal species in Hop Brook. Largely and historically agricultural, the NPS corridor through the floodplain of Hop Brook also includes several special use permits. The trail also enjoys the benefit of many open areas and agricultural fields in Sheffield. Market pressures on agriculture and pressure from development are considered substantial in both of these areas (Table 11.7).

Table 11.7. Change analysis adjacent to Tyringham Valley and Sheffield, Massachusetts.

AT Tyringham (5km Buffer)	1973 (acres)	1989 (acres)	2002 (acres)
Urban	1,505	1,775	2,803
Urban Grass	-	1,108	1,690
Deciduous Forest	48,228	52,883	58,305
Coniferous Forest	12,777	8,657	8,843
Mixed Forest	18,271	15,397	10,512
Water	2,040	2,131	3,389
Wetland	3,732	3,828	4,684
Herbaceous Vegetation	18,188	13,217	10,516
Barren Land	-	4,960	2,940

Walkill Valley (NPS AT, NJ DEP and Walkill National Wildlife Refuge): Much of the Walkill Valley has been protected by the public land acquisition efforts of the NPS and USFWS and the State of New Jersey. The Refuge is currently acquiring lands to protect wetland and grassland bird habitat along the Walkill River, including the remnants of what previously was a large sod farm, commonly referred to as "the black dirt area". The AT currently crosses the Walkill River on a county road bridge, but discussions are underway to construct a pedestrian only bridge across the 120-foot river span in the next five to ten years. Numerous wetland, song and raptor bird species are present, as well as a variety of reptiles and amphibians. This segment is about 24 miles (38 kilometers) located between High Point and Waywayanda Mountain in Sussex County, New Jersey (Table 11.8).

Table 11.8. Change analysis adjacent to Walkill Valley (NPS AT, NJ DEP and Walkill National Wildlife Refuge.

AT Walkill (5km Buffer)	1975 (acres)	1988 (acres)	2002 (acres)
Urban	1,396	5,031	7,202
Urban Grass	798	2,213	283
Deciduous Forest	46,455	44,510	45,526
Coniferous Forest	2,995	2,721	3,961
Mixed Forest	7,891	5,822	4,651
Water	1,459	2,309	2,012
Wetland	2,282	3,251	1,311
Herbaceous Vegetation	24,056	21,010	20,817
Open Grassland	-	191	1,274

Dunnfield Creek – Sunfish Pond NPS – Delaware Water Gap National Recreation Area and NPS AT, NJ DEP (Worthington State Forest): The segment is about 29 miles (46 kilometers). Dunnfield Creek is located on the New Jersey side of the Delaware Water Gap. This is an extremely popular destination, between the Poconos and Manhattan. Historically, the steep banks of Dunnfield Creek have been protected by the presence of large Hemlock trees that now are severely infested by the hemlock woolly adelgid. Although biological controls, ladybird beetles (*pseudoscymnus tsugae*), were released to mitigate the damage caused by the adelgid, the effectiveness of the beetles appears to be marginal. This area offers an opportunity to observe the devastating affect of the adelgid, measure soil loss, and assess the affects on the clear and cold creek, with the loss of the dense hemlock canopy in the ravine (Table 11.9).

Table 11.9. Change analysis adjacent to Dunnfield Creek-Sunfish Pond NPS-Delaware Water Gap National Recreation Area and NPS AT, NJ DEP (Worthington State Forest).

AT Dunnfield (5km Buffer)	**1975** (acres)	**1988** (acres)	**2002** (acres)
Urban	2,741	4,274	5,309
Urban Grass	1,693	422	1,194
Deciduous Forest	60,608	53,226	66,285
Coniferous Forest	5,595	4,933	2,844
Mixed Forest	18,624	21,772	15,135
Water	3,803	3,894	4,114
Wetland	2,692	3,769	2,248
Herbaceous Vegetation	14,900	17,067	10,803
Barren Land	-	839	1,938
Bare Rockface	-	123	464

Hawk Mountain Sanctuary: The Kittatiny Ridge runs some 200 miles from New Jersey almost to the Maryland state line. It is a globally significant migration flyway for thousands of raptors and millions of songbirds and is the focus of attention of the Kittatiny Coalition, a consortium of interested environmental and conservation public agencies and private organizations. The ridge offers recreational opportunities, scenic landscapes, serves as a critical wildlife habitat link in the Appalachian forest, and provides the headwaters for many of the important public water systems and fish habitat. This segment is about 40 miles (64 kilometers) located between Schuylkill River in Port Clinton (western terminus) and the Lehigh River near Palmerton (eastern terminus), Pennsylvania (Table 11.10).

Table 11.10. Change analysis adjacent to Hawk Mountain Sanctuary.

AT Hawk Mountain (5km Buffer)	**1973** (acres)	**1989** (acres)	**2002** (acres)
Urban	2,739	6,248	6,385
Deciduous Forest	93,831	74,868	73,843
Coniferous Forest	3,452	4,253	4,749
Mixed Forest	3,752	1,969	2,273
Water	633	1,271	829
Herbaceous Vegetation	27,949	43,297	43,975
Barren Land	5,482	4,598	4,825
Bare Rockface	-	878	492

Rausch Gap/ St. Anthony's Wilderness, Pennsylvania: This area is the largest undeveloped, roadless section of the Appalachian Trail in the mid-Atlantic region. Although not federally designated wilderness, it is a significant block of unbroken public land in central Pennsylvania with a rich history. There are faint remnants of the long gone village of Yellow Springs including building foundations, mine infrastructure, and a handful of headstones in a deserted family cemetery. There are several rare plant communities identified in the AT Natural Heritage Site Inventory for Pennsylvania and the only mammal specie (Allegheny wood rat) identified. There is an old rail bed that traverses the center of this area, which the Pennsylvania Game Commission maintains for administrative access into their lands. Clarks Creek and Stony Creek, both popular trout streams are located here. The segment is about 35 miles (57 kilometers) that starts outside Pennsylvania state game land #211, directly north of the game land's western most point (western terminus) to the eastern boundary of Pennsylvania state game land 80 (eastern terminus) (Table 11.11).

Table 11.11. Change analysis adjacent to Rausch Gap/St. Anthony's wilderness, Pennsylvania.

AT Rausch Gap (5km Buffer)	**1973** (acres)	**1989** (acres)	**2002** (acres)
Urban	1,223	2,420	3,605
Deciduous Forest	102,736	101,894	99,464
Coniferous Forest	6,408	2,140	1,865
Mixed Forest	3,946	1,277	2,118
Water	979	1,129	507
Herbaceous Vegetation	23,517	29,596	30,938

Cumberland Valley: The Cumberland Valley is a rapidly developing residential and commercial area, due in part, to major transportation corridors that traverse the area. These include Interstate 81, the Pennsylvania Turnpike, and US Route 11. The center of the valley is home to numerous trucking terminals served by the major east/west and north/south routes. Land use planning is a significant concern to AT managers, as the trail corridor across the valley rarely exceeds 1000 feet. Historically the valley has been a major agricultural center with deep limestone soils. Beyond the loss of farmland and changes in land use, a major concern associated with rampant development across the valley is the proliferation of invasive species including mile-a-minute weed, Japanese barberry, ailanthus, and others. This segment is about 17 miles (27 kilometers) located between the northern border of Cumberland County to Center Point Knob (southern terminus) (Table 11.12).

Table 11.12. Change analysis adjacent to Cumberland Valley.

AT Cumberland (5km Buffer)	**1973** (acres)	**1989** (acres)	**2002** (acres)
Urban	1,974	4,942	6,141
Urban Grass	-	-	761
Deciduous Forest	27,927	25,166	26,499
Coniferous Forest	1,381	965	1,267
Mixed Forest	2,647	1,839	1,575
Water	356	495	764
Herbaceous Vegetation	38,877	39,540	35,929

The change analysis results reveal how the landscapes adjacent to these AT segments have been changed between the early 1970's to the beginning of the 2000's. The Whitecap Mountain segment, for example, experienced dramatic changes of deforestation and regrowth of the forests (Figure 11.2). For the Hanover segment, urban development has been the major impact in the past 30 years (Figure 11.3). Our change detection data indicate that the urban areas within the 5 km buffer of the AT segments increased from 1,448 acres in 1989 to 2,492 acres in 2002. The land cover types of urban grass increased from 570 acres to 1,324 acres during the same time period. For the Tyringham segment a natural disaster, such as a tornado touchdown in the 1990's, in the area left the sign of forest damage. Both human induced land cover change and the impact from natural force altered the landscape. The Landsat images recorded and illustrated the landscape change. The GPS field photos identified the specific locations on the Landsat images for the damaged site (Figure 11.4). The Landsat remote sensing data augmented by the most recent Space Shuttle Topography Mission (SRTM) data can create 3-D views for the segments along the Appalachian Trail, which is helpful in management and monitoring activities (Figure 11.5).

By the time of this writing the URI team is still working on the project towards finalizing the change analysis. The results listed in the following discussions are not final yet and will be updated in the project report.

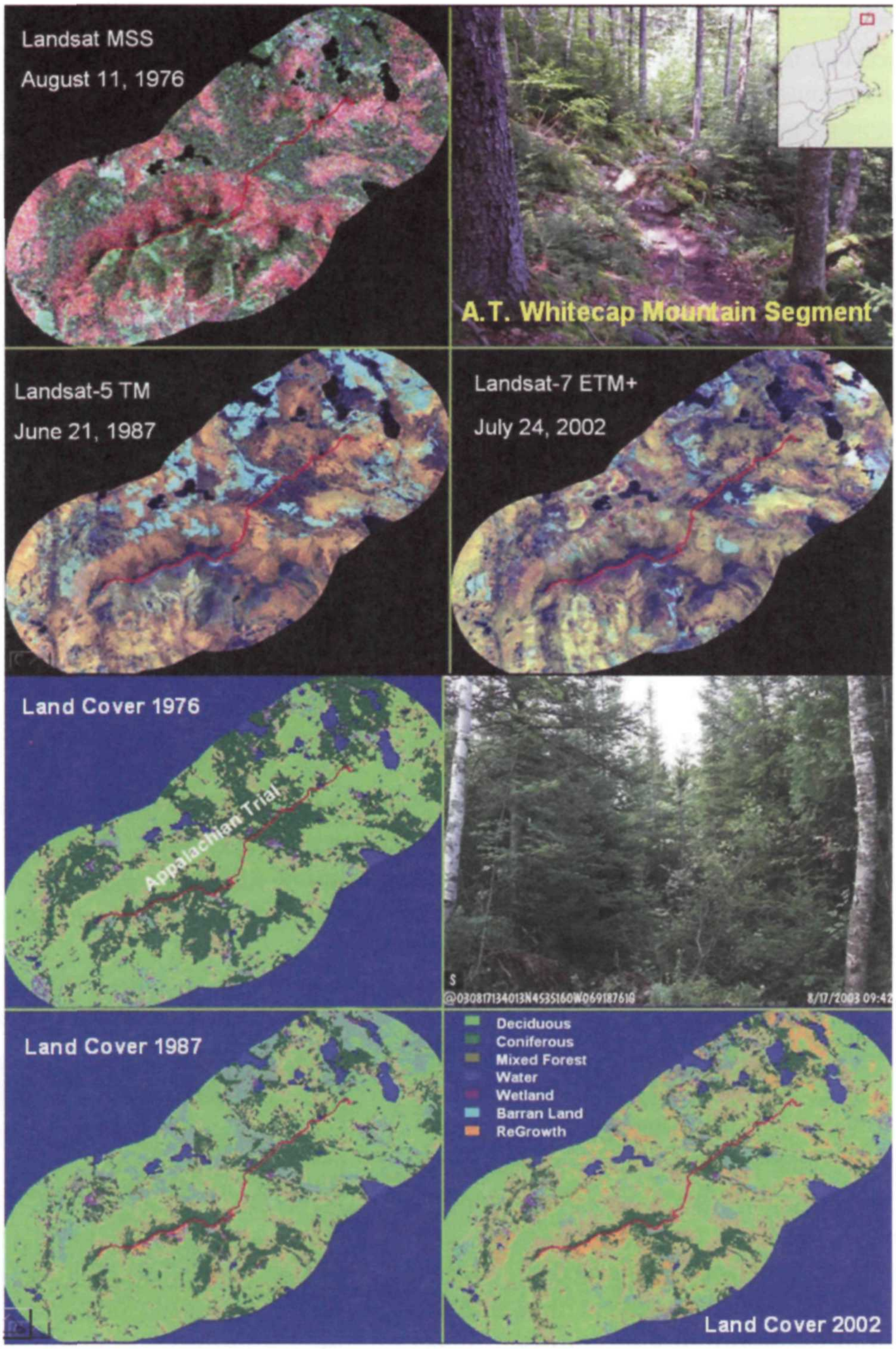


Figure 11.2. Examples of Landsat images and the classification result of land-cover maps for the Whitecap Mountain segment between 1976 and 2002. (Photos by Y.Q. Wang)

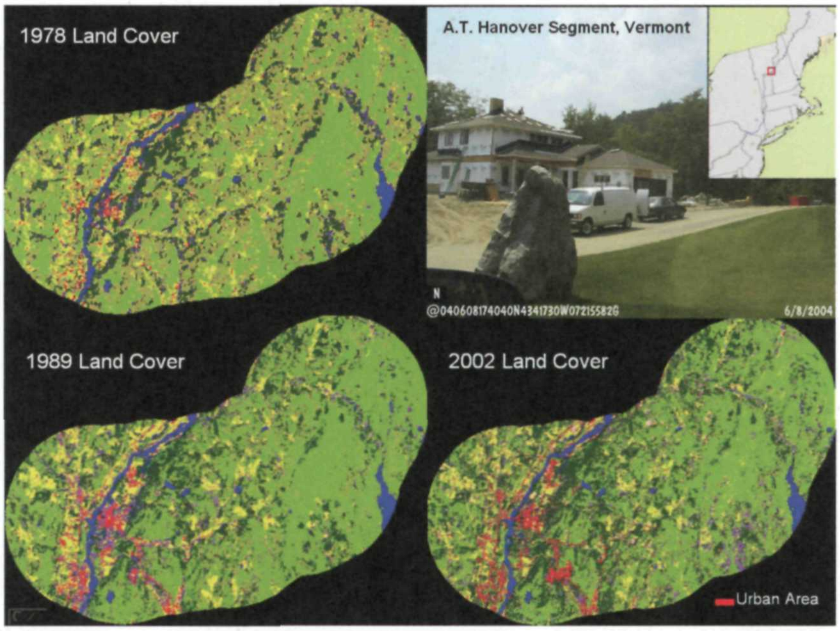


Figure 11.3. Land-cover change around the Hanover valley segment. The red color in the land-cover maps represent urban development areas. (Photo by Y.Q. Wang)

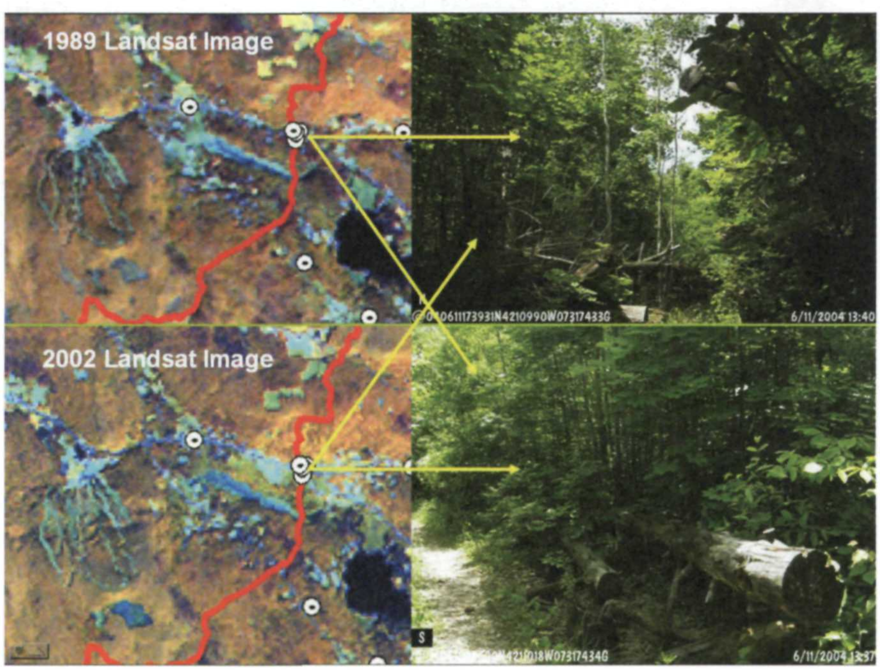


Figure 11.4. The coniferous forest coverage (dark red on Landsat images) within the Tyringham Valley Appalachian Trail segment was replaced as open fields by human development. Landsat images recorded the change of the landscape. The location of the damaged forest site by a tornado touchdown was identifiable through GPS photos as well as on the Landsat images. (Photos by Y.Q. Wang)

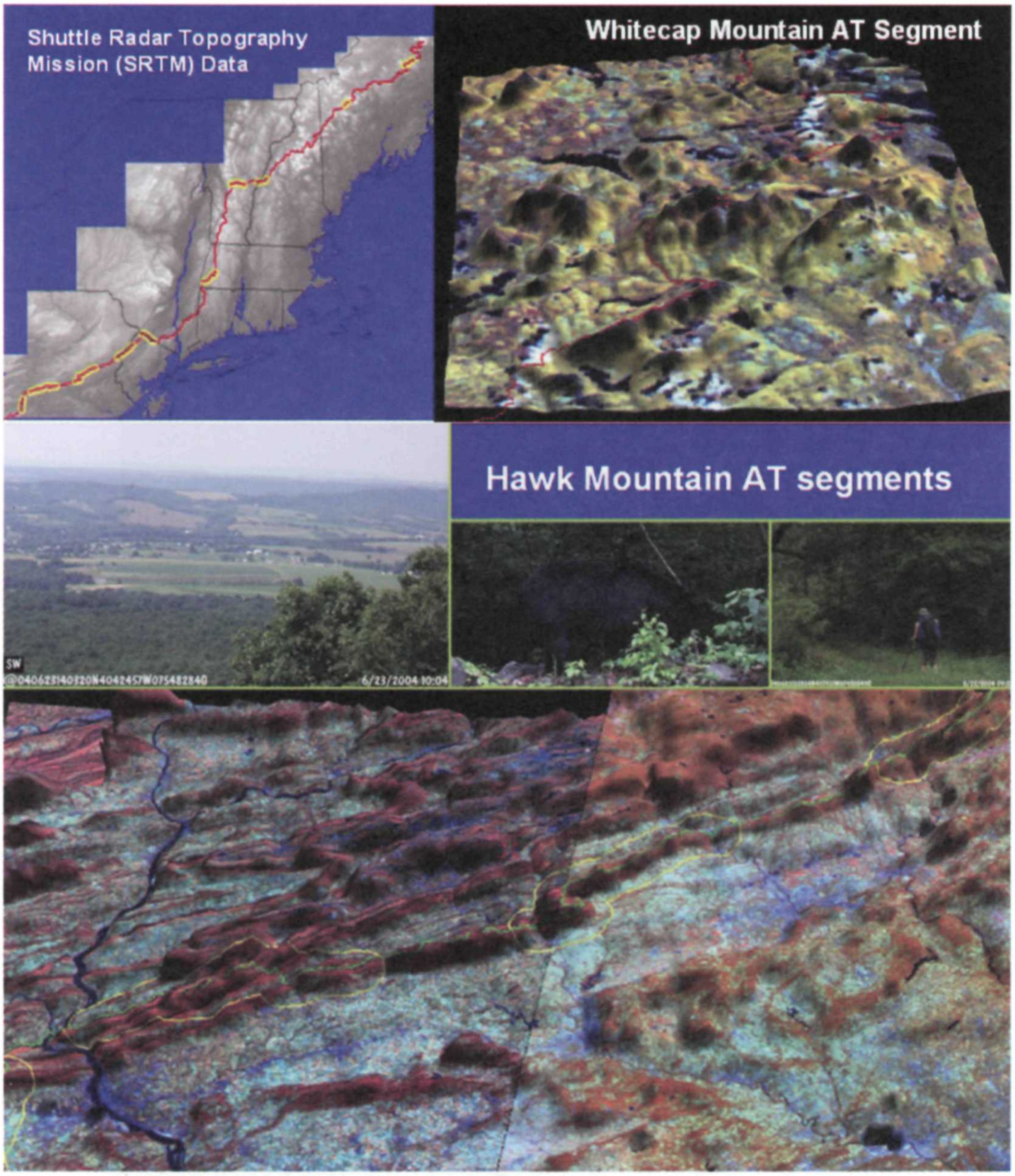


Figure 11.5. The 3-D views of the Whitecap Mountain and Hawk Mountain segments by Landsat image on top of the SRTM topographic data. (Photos by Y.Q. Wang)

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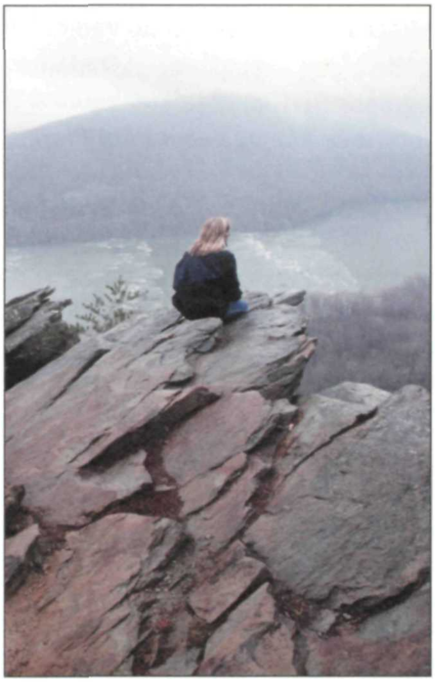

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