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Warm Springs Mountain Cowpasture River

Conservation Area Plan

The Nature Conservancy in Virginia
Charlottesville, Virginia
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Preface

Conservation by Design states The Nature Conservancy's conservation goal is "the long term survival of all viable native species and community types." In order to accomplish conservation of all native biodiversity, the Conservancy has developed many tools for conservation planning at the ecoregional and site-based scale. Through the Central Appalachians ecoregional planning process, Warm Springs Mountain and many smaller sites along the Cowpasture River and within its watershed are identified as high priority areas. In March 2002, The Nature Conservancy bought over 7,000 acres of Warm Springs Mountain from Virginia Hotsprings, Inc., creating the largest nature preserve purchased and managed by the Conservancy in Virginia. Together, the mountain preserve, the pristine Cowpasture watershed and smaller sites of biodiversity significance comprise the Warm Springs Mountain/Cowpasture River conservation area.

To address conservation strategies for this landscape, The Nature Conservancy of Virginia invited the U.S. Forest Service and Division of Natural Heritage to participate in the development of a conservation area plan and partner in its implementation. The following individuals participated on the conservation area planning team:

- Phil Coulling, Ecologist, Virginia Department of Conservation and Recreation, Division of Natural Heritage
- Gwynn Crichton, Conservation Planner, The Nature Conservancy of Virginia
- Linda Crowe, Director of Protection, The Nature Conservancy of Virginia
- Steve Croy, Ecologist, George Washington and Jefferson National Forest
- Judy Dunscomb, Director of Conservation Science, The Nature Conservancy of Virginia
- Mike Leahy, Mountain Steward, Virginia Department of Conservation and Recreation, Division of Natural Heritage
- Sam Lindblom, Fire Training Coordinator, The Nature Conservancy
- Michael Lipford, State Director, The Nature Conservancy of Virginia
- Wil Orndorff, Karst Protection Specialist, Virginia Department of Conservation and Recreation, Division of Natural Heritage
- Pat Sheridan, Warm Springs District Ranger, George Washington and Jefferson National Forest

Other partners who contributed to the plan, particularly to the understanding of the species, communities and ecological systems in the conservation area, include:

- Paul Bugas, Fisheries Biologist, Virginia Department of Game and Inland Fisheries
- Andy Dolloff, Assistant Professor of Fisheries Science and Project Leader, U.S. Forest Service Southern Research Station Coldwater Fisheries Research Unit
- Gary Fleming, Ecologist, Virginia Department of Conservation and Recreation, Division of Natural Heritage

- Gary Kappasser, Hydrologist, George Washington and Jefferson National Forest
- Chris Ludwig, Chief Biologist/Coordinator, Virginia Department of Conservation and Recreation, Division of Natural Heritage
- Rick Reynolds, Non-game Biologist, Virginia Department of Game and Inland Fisheries
- Ryan Smith, Aquatic Ecologist, The Nature Conservancy's Freshwater Initiative
- Rick Webb, Professor, University of Virginia Department of Environmental Sciences
- Members of the Cowpasture River Preservation Association

The team used The Nature Conservancy's "5-S Framework" to develop the conservation area plan. A conservation area plan is defined as a blueprint for conservation action that defines a baseline from which to measure the success of actions over time. The 5-S's are defined below:

- **Systems**: the conservation targets occurring in an area, and the natural processes that maintain them, that will be the focus of conservation area planning.

- **Stresses**: the types of degradation and impairment afflicting the system(s) at a site.

- **Sources**: the agents generating the stresses.

- **Strategies**: the types of conservation activities deployed to abate sources of stress (threat abatement) and persistent stresses (restoration).

- **Success**: measures of biodiversity health and threat abatement at a site.

The planning team convened for three separate daylong meetings at TNC's state office in Charlottesville to address the 5-Ss over the course of 6 months. In addition, the conservation planner conducted research and held individual meetings with expert biologists and ecologists with knowledge of the Warm Springs/Cowpasture River conservation area in order to better inform the planning process. Supplemented by work of the conservation planner, the team selected conservation targets (systems), analyzed and ranked stresses and sources of stress for each target, and identified conservation strategies to abate threats. The resulting conservation plan will focus and direct The Nature Conservancy of Virginia's work at the Warm Springs Mountain/Cowpasture River conservation area for the next 5 to 10 years. The following report documents the results of the planning process.

Please direct questions, inquiries or comments to:

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Executive Summary

Background

The Warm Springs Mountain/Cowpasture River (WSM/CR) conservation area is found within Alleghany, Bath and Highland counties of western Virginia in the heart of the Ridge and Valley province of the Central Appalachians and the Upper James drainage basin. The area totals 359,500 acres (562 square miles) and includes the entirety of Warm Springs Mountain and the Cowpasture River watershed. The headwaters of the Cowpasture River begin just south of the West Virginia/Virginia border in Highland County, and moves southward where the mainstem eventually merges with the Jackson River outside of Clifton Forge in Alleghany County to form the James River. The WSM/CR conservation area is characterized by typical Ridge and Valley topography covered with extensive hardwood and mixed hardwood-pine forests, a rich karst landscape interspersed with cave openings, sinkholes and intermittent streams, and the sinuous, free flowing Cowpasture River that winds its way through a rural valley of pastureland and small farms. Currently, approximately 55% of the land within the WSM/CR boundary is in public ownership, primarily managed by the U.S. Forest Service (USFS) as part of the George Washington-Jefferson National Forest.

The contiguous forested mountains, the unaltered condition of the Cowpasture River, and the rarity and endemism of species found in local natural habitats such as shale barrens and caves make this area remarkable. Roughly 90% of the conservation area is forested. Warm Springs Mountain and ridges extending eastward to Highway 42 comprise a 77,000 acre unfragmented, largely roadless forest block. Through the Central Appalachians Ecoregional Plan it was determined to be one of 28 sites in the ecoregion identified to capture intact forest communities. The Cowpasture River is an outstanding example of a medium gradient, small Ridge and Valley river, considered by many experts to be the most pristine river in Virginia, as it is free-flowing with high water quality and healthy aquatic communities.

The Virginia Division of Natural Heritage tracks 53 extant species within the conservation area, 28 of which are considered globally rare, in addition to 22 natural community types. These species and communities include the rare roughhead shiner (*Nortropis semperasper*) which thrives in the Cowpasture River and is native only to the upper James, the rare small-footed myotis bat (*Myotis leibii*), the Appalachian grizzled skipper (*Pyrgus wyandot*), multiple populations of the variable sedge (*Carex polymorpha*) on Warm Springs Mountain, the shale barren rock-cress (*Arabis serotina*) and the Millboro leatherflower (*Clematis viticaulis*) which are endemic to shale barren communities, and at least two obligate cave invertebrates have been identified as endemic to single caves in the conservation area.

Conservation Targets

Eight focal conservation targets were selected to best capture the characteristic and unique biodiversity and ecological processes in the Warm Springs Mountain/Cowpasture River conservation area (Table i.). They include ecological systems, communities and species groups at multiple scales and across different levels of biological organization. The **Central Appalachians Mixed Hardwood Forest Matrix** target includes a gradient of widely distributed common forest types typical of the Ridge and Valley physiographic province. These forest types include large patches of oak-hickory on sideslopes, richer stands of sugar maple, basswood, ash and poplar in coves and slopes that have rich herbaceous understories, and eastern hemlock forests which occur in ravines, gorges, and along steep riparian zones. This variety of mixed hardwood forests occurs within sub-mesic to sub-xeric moisture regimes and grade into a drier or xeric forest target, **Pine-Oak-Heath Woodlands,** found on ridgetops and exposed sideslopes**.** These woodlands are fire dependent communities consisting of chestnut oak, pitch pine and various species of blueberry and mountain laurel. *Montane pine barrens* are globally rare variants of this community group, appearing as dwarfed shrublands, and only known in Virginia to occur on Warm Springs Mountain. **Alluvial Floodplain Forests and Grasslands** historically occurred throughout the valley bottoms in riparian corridors but have been largely converted to pasture and agriculture by both Native Americans and European settlers.

The conservation area harbors significant occurrences of obligate terrestrial cave invertebrates. While these **Cave Invertebrate Communities** are not exceptionally diverse, the species exhibit a high degree of endemism to individual caves or cave systems. In addition, several (up to seven) species of **Bats**, including the rare small-footed myotis and federally-listed Indiana bats, use caves for wintering habitat. These species also use a wide range of ridgetop, forest, and riparian areas for foraging and maternity colonies. The Cowpasture River, which is fed in part by springs issuing from vast cave systems, provides high quality habitats for an array of aquatic fauna. These fauna comprise an exemplary **Small Central Appalachian River Aquatic System**, including warm water fishes, mussels, crayfish, and aquatic insects. The aquatic fauna also exhibit significant endemism to the Upper James drainage, particularly the rare roughhead shiner. Wild brook trout populations occur throughout the cold water, high gradient tributaries of the watershed as well.

Smaller scale, more localized targets include **Shale Barrens, Outcrops and Acidic Woodlands** and **Montane Non-alluvial Wetlands**. This conservation area is considered the global epicenter of shale barrens, which are populated with several rare plant species that are endemic to these communities. Montane non-alluvial wetlands such as mountain ponds and acidic seepage swamps are specialized habitats for unique assemblages of plant species, also providing critical breeding habitat for odonates and amphibians.

Biodiversity Health

The overall biodiversity health score is ranked as "good" (Table ii), meaning the conservation targets collectively demonstrate ecological integrity or viability within their natural range of variation. This reflects the fact that the landscape *context* of the WSM/CP conservation area is rural with large contiguous forested habitat, a free flowing river system, and an undisturbed karst network. However, while the context may be optimal overall, the *condition* of the forest targets in particular is ailing, averaging a "fair" rank. Over the past century, there has been a steady decline in forest health and integrity due to invasive plant species, forest pests and pathogens, poor air quality, fire suppression, and a long history of intensive logging. Therefore, while the biodiversity health score of the conservation area is good, this may obscure the fact that the forest systems are unstable; however, we do not have enough information at this time to more adequately assess the loss of ecological integrity in these systems.

Threats to Conservation Targets

Overall, the threat rank for the Warm Springs Mountain/Cowpasture River conservation area is higher for the terrestrial targets than for the subterranean and aquatic targets (Table iii). The karst and aquatic targets are threatened to a much lesser extent than the forest targets due to a lack of large-scale agriculture, confined animal feeding operations, high-density residential development or alterations to the hydrologic regime such as dams or reservoirs. Overall, there are few local threats to the targets in this conservation area at this time. Rather, the most problematic threats to terrestrial targets are regional, the two most highly ranked being **invasive forest pests and pathogens** and **invasive, non-native plant species**. These vectors are fueled by historical disturbances of land such as logging and clearing and are driving the decline of forest health throughout the Appalachians. Pathogens include gypsy moth, the hemlock woolly adelgid, dogwood anthracnose and the chestnut blight. Some of the more notorious invasive exotic plant species such as garlic mustard (*Alliaria petiolata*), Japanese grass (*Microstegium vimineum*), and bittersweet (*Celastrus orbiculatus*) can be found aggressively invading forest edges and interiors. The infestation of most invasive pathogens and plants is not acute at this point with the exception of the hemlock woolly adelgid that is currently decimating the hemlocks. However, invasive species are predicted to quickly worsen over the next 10 years, as they are highly intractable and difficult to control once they have become established in an area.

Other "medium" ranked threats contributing to the degradation of forest structure and composition include excessive herbivory by deer, fire exclusion and logging. **Excessive deer browse** in the understories of forest targets adversely impacts the regeneration of oaks, hemlocks, shrubs and herbaceous species, denuding the forest floor in some locations. The **exclusion of fire** is considered detrimental to forest health as it has been shown to be a natural ecological process necessary for the germination of certain pine species and the propagation of oak seedlings. **Logging practices** such as large clearcuts or shelterwood cuts can be destructive to the ecological integrity of functioning forest ecosystems. Extensive logging occurs primarily on private lands and for wildlife management areas on public lands. **Acid deposition**, currently ranked as low, could potentially be the most harmful of any threat to the forests by rendering naturally acidic soils as sterile, precluding forest regeneration at higher elevations. Better data are needed to more fully characterize the severity of this threat.

Conservation Strategies

TNC-VA and its partners will implement several conservation strategies in the Warm Springs Mountain/Cowpasture River conservation area to abate the most severe threats to conservation targets and to improve their ecological integrity and health (Table iv). In order to develop strategies, threat abatement and restoration goals are articulated to focus the objectives and desired outcomes of the strategies. A summary of these goals and strategies that aim to fulfill them are as follows:

<u>Threat Abatement or Restoration Goal 1</u>. Prevent new introduced, non-native, invasive forest pests/pathogens and plant species from spreading into landscape.

> **Strategy 1.** Develop national and state policies that will determine ecologically sound detection and prevention measures to prohibit the introduction and slow the spread of new invasive species.

<u>Threat Abatement or Restoration Goal 2</u>. Control the most threatening established pests and pathogens (i.e. hemlock woolly adelgid, gypsy moth and dogwood anthracnose) in priority areas on Warm Springs Mountain Preserve.

> **Strategy 2.** Implement best available treatments to prevent and reduce impacts by problem pests or pathogens in high priority biologically significant areas through use of bio-controls, insecticide treatments or introductions of disease resistant cultivars. This must be done in a way that does not negatively impact rare species present in these forest targets.

<u>Threat Abatement or Restoration Goal 3</u>. Control most threatening invasive, exotic weeds on priority tracts in conservation area.

> **Strategy 3.1.** Implement direct control measures of targeted invasive species, particularly garlic mustard, on Warm Springs Mountain Preserve and publicly-owned priority conservation areas where feasible.
>
> **Strategy 3.2.** Utilize, improve and promote publicly funded cost share programs for weed control such Forest Land Enhancement Program (FLEP), Wildlife Habitat Incentive Program (WHIP) or Conservation Reserve Enhancement Program (CREP).

Threat Abatement or Restoration Goal 4. Reduce deer populations to biological carrying capacity of landscape.

Strategy 6. Work with the Department of Game and Inland Fisheries and USFS to amend the state and federal deer management plans to reduce deer populations by increasing the doe bag limit, restricting stag take, and extending the hunting season with additional doe hunting days.

Threat Abatement or Restoration Goal 5. Restore historic fire regime for Pine-Oak-Heath Woodlands on Warm Springs Mountain Preserve and USFS lands within forest block for several examples (5+) greater than 50 acres. Where possible, restore historic fire regime for the montane and acidic oak-hickory forest types found in the Central Appalachians Mixed Hardwood Forest Matrix.

Strategy 4. Promote and implement prescribed fire to restore and maintain Pine-Oak-Heath Woodlands on public lands and Warm Springs Mountain preserve and work with USFS to prioritize areas for prescribed burning and develop fire management plans, while advocating for increased allocations for the USFS fire management programs.

Threat Abatement or Restoration Goal 6. Protect all priority conservation areas within WSM/CR landscape.

Strategy 6.1. Protect viable occurrences of conservation targets through acquisition, conservation easement or special designations. This includes acquiring Warm Springs Mountain (accomplished in April of 2002), designating priority conservation areas as Research Natural Areas in the revision of the George Washington National Forest management plan, protecting caves that fall on USFS lands through the Federal Cave Resources Protection Act, and working with the Valley Conservation Council and the Virginia Outdoors Foundation to obtain donated and acquired easements.

Strategy 6.2: Implement compatible land use planning and zoning that will protect priority conservation areas from development or confined animal feeding operations through working with localities and recommending the protection of conservation targets in their county comprehensive plans.

Threat Abatement or Restoration Goal 7. Restore and maintain up to a 50,000 acre core area of forest block to have old growth structural attributes and characteristic native herbaceous understories.

Strategy 5. Define, promote and demonstrate forest management practices that favor the restoration and maintenance of the Warm Springs forest block in conjunction with the USFS, Virginia Department of Conservation and Recreation, and the Virginia Department of Forestry.

Threat Abatement or Restoration Goal 8. Restore stream banks of priority stream reaches and critical karst recharge zones in Cowpasture River

watershed, including examples of alluvial floodplain forests and native warm season grasses.

> **Strategy 8.** Promote and utilize public cost share programs and other funding sources (e.g. the Wetland Restoration Trust Fund) to restore streambanks, karst re-charge areas, and alluvial floodplain forests/grasslands. As part of this, advocate for increased funding and capacity for local Mountain Soil and Water Conservation District to more effectively deliver cost share services.

Threat Abatement or Restoration Goal 9. Reduce sulfur concentrations in atmosphere by 70% over next 10 years to stabilize and/or increase the probability for recovery of low order brook trout streams that have unnaturally low buffering capacities and forest soils that have unnaturally low base saturations.

> **Strategy 9.** Reduce emissions from out-of-state power plants by working with divisional and national TNC Government Relations staff to develop policies and strategies to 1.) provide incentives for sulfate reductions from power plants in Ohio River Valley and 2.) to affect regulatory changes in Clean Air legislation that change the sulfur concentration cap from 40% (1990 levels) to 70% or more.

Conclusion

TNC will be largely focused on the management of the newly acquired Warm Springs Mountain nature preserve over the next couple of years. Once the preserve is established, TNC plans to staff an office in the project area and begin implementing components of the designated conservation strategies at the local level, working closely with private land owners, public land management authorities and the surrounding community. Several of the strategies require implementation by national and state organizational levels within TNC. Currently, government relations capacity exists in TNC's Virginia office to do this. The key to all strategies, however, will be TNC's partnerships with public agencies, including the Forest Service, Department of Conservation and Recreation, Department of Forestry and the Department of Game and Inland Fisheries. With a comprehensive strategic conservation plan and increased leadership and capacity on-site and at large within the organization, TNC hopes to work with partners towards the successful protection and conservation of this wondrous Ridge and Valley landscape.

Table i. Description and distribution of conservation targets for the Warm Springs/Cowpasture River conservation area.

Conservation Target	**Description**	**Distribution/Conservation Significance**
Central Appalachians Mixed Hardwood Forest Matrix	These forests represent the characteristic and widespread, largely deciduous oak, hickory and maple dominated forest communities that occur across a variety of geologic strata and topographic positions, varying from more protected, north or east facing fertile coves and ravines to well drained, southwesterly facing sideslopes and broad mountain crests.	Widespread, matrix-forming community types that are common to the central and southern Appalachians. Rich cove and slope forest and calcareous forest community groups have richer, more diverse herbaceous layers and are therefore more vulnerable to invasive plant species. Hemlock communities, while common, are highly threatened by the hemlock woolly adelgid.
Pine-Oak-Heath Woodlands	Fire influenced and/or edaphically limited/drought-prone xeric vegetation consisting of variable combinations of pines and oaks with several ericaceous shrubs and a sparse herb layer. Occurs on rocky, sandy, shallow nutrient poor soils, often on southwest exposed ridges, convex sideslopes, and clifftops. Include montane pine barren community association that appears as dwarfed shrubland of the same composition.	Pine-oak/heath communities are common in the Central Appalachians but threatened throughout by fire suppression. Montane pine barren is a globally rare variant restricted to high elevations and at scattered locations in the central Appalachians primarily known from the N. Appalachians.
Alluvial Forests/Grasslands	Temporarily flooded deciduous and mixed deciduous/coniferous forest occurring in narrow floodplains along small streams and rivers in mountain valleys with well developed but variable shrub and herbaceous understory layers.	Much of these forests have been cleared and converted to agriculture and pasture. Most extant stands have been extensively invaded by exotic plant species.
Outcrops, Barrens and Acidic Woodlands	Small patch communities of open herbaceous rock outcrops, sparse woodlands, and shrublands, which are edaphically-limited. Occur on southwestern facing aspects, below 3500 ft on varying substrate from acid (shale barrens) to calcareous (limestone cliffs).	Best and largest occurrences of these globally rare communities found in conservation area w/several viable populations of globally rare plant species endemic to shale barrens such as *Arabis serotina* and *Clematis viticaulis*.
Montane Non-Alluvial Wetlands	Isolated wetland communities including seeps and ponds. Saturated deciduous forest swamps found on gentle slopes of seeps and headwater streams at various elevations with extremely acidic soils. Mountain ponds are seasonally to semi-permanently inundated wetlands found on ridge crests and benches or alluvial fans.	Seeps are uncommon, found scattered throughout the inner Piedmont and mountain ecoregions, while ponds are very rare, occurring sporadically in mountains.
Cave Invertebrate Communities	Obligate subterranean invertebrate fauna of Devonian Silurian limestone solution caves, sinkholes, epikarst, springs, intermittent streams and groundwater aquifers.	Endemic and globally rare invertebrate species occur in karst systems of Bath and Highland counties, including the Crossroads Cave beetle (*Pseudanophthalmus* intersectus) found only in Crossroads Cave close to McClung north of 39.
Bats	Several bat species including the little brown and big brown bats, pipistrels, small-footed myotis and federally endangered Indiana bat.	One significant hibernacula found in conservation area at Hupman's Saltpeter Cave with all target

Conservation Target	**Description**	**Distribution/Conservation Significance**
	Target is the wintering and foraging habitat for these species.	bat species, with collective counts of 4-5,000 bats.
Small Central Appalachian River Aquatic System	4^{th} to 5^{th} order rivers/streams in Ridge and Valley topography with watersheds dominated by Devonian shales, sandstones, and some cherty limestones. Tributaries are moderate to high gradient and flow off moderate/high elevation sandstone/shale ridges. Many tributaries are subterranean and surface flow is highly intermittent. Fish fauna is a typical Ridge and Valley warmwater assemblage with some species less tolerant of alkaline conditions.	Warm water fish community in the mainstem, including the rare and endemic roughhead shiner, is exemplary for Upper James drainage, having healthy, viable populations. Colder water tributaries provide excellent habitat for the brook trout, though are potentially imperiled by the threat of acid deposition. Outstanding water quality and lack of hydrological impediments contribute to sustaining the health of aquatic fauna.

Table ii. Ecological integrity ranks for Warm Springs Mountain/Cowpasture River conservation targets.

Target Viability	**Size**	**Condition**	**Context**	**Overall**
Central Appalachian Mixed Hardwood Forest Matrix	Very Good	Fair	Good	Good
Pine-Oak-Heath Woodlands	Good	Fair	Fair	Fair
Alluvial Forests/Grasslands	Fair	Fair	Good	Fair
Outcrops, Barrens and Acidic Woodlands	Very Good	Very Good	Good	Very Good
Montane Non-Alluvial Wetlands	Good	Good	Good	Good
Cave Invertebrate Communities	N/A	Good	Very Good	Good
Bats	Good	Good	Good	Good
Small Central Appalachian River System	Very Good	Very Good	Very Good	Very Good
Site Biodiversity Health Score				***Good***

Table iii. Threat ranks for the Warm Springs Mountain/Cowpasture River conservation targets.

Active Threats Across Systems		Mixed Hardwoods Forest Matrix	Pine-Oak-Heath Woodlands	Alluvial Forests/ Grasslands	Outcrops, Barrens and Acidic Woodlands	Bats	Small Central Appalachian River System	Cave Invertebrate Communities	Montane Non-Alluvial Wetlands	Overall Threat Rank
1	Invasive/non-native plant species	High	-	High	High	-	-	-	-	High
2	Invasive forest pests/pathogens	High	High	Medium	-	-	-	-	-	High
3	Deer management	High	Low	Medium	-	-	-	-	-	Medium
4	Fire exclusion	Medium	High	-	-	-	-	-	-	Medium
5	Rural development	Medium	Medium	Low	-	Low	Low	Low	-	Medium
6	Incompatible forestry practices	Medium	-	Medium	-	Low	Low	-	-	Medium
7	Acid deposition	Low	Low	-	Low	-	Medium	-	Low	Low
8	Incompatible confined animal feeding operations	-	-	-	-	-	Medium	Low	-	Low
9	Recreational use	-	-	-	-	Low	-	Low	Low	Low
10	Incompatible grazing	-	-	-	-	-	Low	Low	-	Low
11	Incompatible agricultural practices	-	-	-	-	-	Low	Low	-	Low
12	Mining practices	-	-	-	Low	-	-	-	-	Low
13	Inadequate cave gate design	-	-	-	-	Low	-	-	-	Low
14	Acid rock drainage	-	-	-	-	-	Low	-	-	Low
Threat Status for Targets and Site		High	High	Medium	Medium	Low	Medium	Low	Low	High

Table iv. Profile of each Warm Springs Mountain/Cowpasture River conservation area conservation strategy, the targets benefited and threats abated.

Strategy	Targets benefited by strategy	Threats abated by strategy
***Strategy 1**. Develop national and state policies that will determine ecologically sound detection and prevention measures to prohibit the introduction and slow the spread of new invasive species.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands ➢ Pine-Oak-Heath Woodlands	➢ Invasive, non-native plant species ➢ Non-native forest pests/pathogens
***Strategy 2**. Implement best available treatments to prevent and reduce impacts by problem pests or pathogens in high priority biologically significant areas.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Non-native forest pests/pathogens
***Strategy 3.1**. Implement direct control measures of targeted invasive species on Warm Springs Mountain Preserve and other publicly owned priority conservation areas.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands	➢ Invasive, non-native plant species
***Strategy 3.2.** Utilize, improve and promote publicly funded cost share programs for weed control.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands	➢ Invasive, non-native plant species
Strategy 4. *Amend state and federal deer management plans to reduce deer populations.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Deer management
***Strategy 5.** Promote and implement prescribed fire to restore and maintain Pine-Oak-Heath Woodlands and oak-hickory forests on Warm Springs Mountain Preserve and USFS lands where feasible.*	➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Fire exclusion
***Strategy 6.1**. Protect most viable occurrences of conservation targets through acquisition or conservation easement.*	➢ All Targets	➢ Inadequate cave design ➢ Incompatible agriculture ➢ Incompatible confined animal feeding operations ➢ Rural development ➢ Incompatible forestry ➢ Incompatible grazing ➢ Mining practices ➢ Recreational use
***Strategy 6.2**. Implement compatible land use planning*	➢ All Targets	➢ Incompatible agriculture

Strategy	Targets benefited by strategy	Threats abated by strategy
and zoning that will protect priority conservation areas from development or confined animal feeding operations.		➢ Incompatible confined animal feeding operations ➢ Rural development ➢ Incompatible forestry ➢ Incompatible grazing ➢ Recreational use
***Strategy 7**. Define, promote and demonstrate forest management practices that favor the restoration and maintenance of forest targets on private and public lands.*	➢ Alluvial Forests/Grasslands ➢ Bats ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands ➢ Small Central Appalachian River System	➢ Historical conversion to agriculture ➢ Historical logging ➢ Incompatible forestry
***Strategy 8**. Reduce emissions from out-of-state power plants through incentive-based policies and regulatory amendments to the Clean Air Act.*	➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Montane Non-Alluvial Wetlands ➢ Outcrops/Barrens/Acidic Woodlands ➢ Pine-Oak-Heath Woodlands ➢ Small Central Appalachian River System	➢ Acid deposition
***Strategy 9**. Promote and utilize public cost share programs and other public funding sources (i.e. the Wetland Restoration Trust Fund) to restore streambanks, karst re-charge areas, and alluvial floodplain forests/grasslands.*	➢ Alluvial Forests/Grasslands ➢ Cave Invertebrate Communities ➢ Montane Non-Alluvial Wetlands ➢ Small Central Appalachian River System	➢ Historical conversion to agriculture ➢ Incompatible agriculture ➢ Incompatible grazing

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Introduction

♦ *Site Description*

The Warm Springs Mountain/Cowpasture River (WSM/CR) conservation area is found within Alleghany, Bath and Highland counties of western Virginia in the heart of the Ridge and Valley province of the Central Appalachians and the Upper James drainage basin (Map 1). The site totals 359,500 acres (562 square miles) and includes the entirety of Warm Springs Mountain, the eastern slope of Jack Mountain, Bullpasture Mountain, the southwest portion of Shenandoah Mountain, Beards Mountain, Rough Mountain and the western slope of Mill Mountain. The Cowpasture River watershed includes the Bullpasture River and Shaw's Fork in the upper headwaters, Stuarts Run and Dry Run in the central headwaters and Mill Creek, Lick Run and Pads Creek in the lower headwaters (Map 2). Portions of the Jackson River watershed that drains off the western portion of Warm Springs Mountain are also included within the site boundary. The Jackson and the Cowpasture River merge to form the James just south of the Alleghany and Botetourt county line.

The majority of the WSM/CR landscape falls between elevations of 1,700 and 3,000 feet, ranging from the lowest point 1,341 ft in the Cowpasture River Valley to the highest, 4,400 ft at Reddish Knob at the northernmost edge of the boundary. The Ridge and Valley topography is characterized by thin, long, northeast to southwest running parallel ridges, such as Warm Springs and Bullpasture mountains, which tower over deep, long river valleys. The mountainous areas are underlain by sandstone, quartzites and shales and therefore tend to be more infertile, rocky and thin, while the river valleys are underlain by extensive limestone and dolomite bedrock, having richer, more fertile soils. Warm Springs Mountain is unique within the landscape due to the fact its geology consists of more calcareous shales and sandstones which are found on broader and gentler ridges rather than the more typically acidic substrate underlying the narrow and linear ridges found throughout the Ridge and Valley region (Ludwig et al. 1999). This is due to the erosion of the ridge crests that have exposed more of the Ordovician shales.

The climate is moderately cold in the winters with humid, mild summers. The average temperature ranges between a maximum of 63 degrees Fahrenheit and a minimum of 39.8 degrees, though elevational variability creates many localized conditions (SERCC 2002). The region is relatively dry, receiving an annual mean precipitation of between 35 inches (Covington station) and 42 inches (Hotsprings station) (SERCC 2002). Overall, this region tends to be drier and warmer than the Blue Ridge to the east or the Alleghany Mountains to the west due to a rain shadow effect created by westerly winds.

♦ *Conservation Value and Natural History*

The WSM/CP conservation area is remarkable due to the contiguous forested mountains, the unaltered condition of the Cowpasture River and the rarity and endemism of species found in local natural habitats such as shale barrens and caves. The Virginia Division of Natural Heritage tracks 53 extant species within the conservation area, 28 of which are considered globally rare, in addition to 22 natural community types (Appendix A and B).

Terrestrial Description. A diversity of contiguous forest community types sprawl across the rugged and complex topographic, moisture, climactic, and geological gradients of the WSM/CR conservation area. Roughly 90% of the conservation area is forested (USGS National Land Cover Data from 1992-94) (Table 1). Warm Springs Mountain and ridges to the east extending to the Cowpasture River comprise a 77,000-acre unfragmented, largely roadless forest block (Map 3). It is identified in the Central Appalachians Ecoregional Plan as one of 28 sites in the ecoregion that captures swaths of representative forest communities greater than 15,000 acres (TNC 2001). This is a minimum size threshold that is based on area necessary to absorb and recover from large natural disturbances while maintaining healthy, breeding populations of associated forest fauna such as interior dwelling songbirds, small mammals, reptiles and insects and spanning a diversity of community types and environmental gradients (Anderson 1999). The Nature Conservancy's (TNC) recent purchase of over 7,000 acres of Warm Springs Mountain (Map 4) means that roughly 69% of this block is in public or conservation ownership, providing a remarkable opportunity for large-scale forest conservation in the east.

Today, one finds ridgetop communities of chestnut oak, pitch pine and various species of blueberry and mountain laurel inter-grading with oak-hickory forests on crests and saddles. Richer slope and cove forests of sugar maple, hickories, red oak, and basswood or hemlock and birches are often connected to the more calcareous forests and woodlands found on convex slopes, both having species rich herbaceous understories. This landscape is considered the global epicenter of shale barrens (G. Fleming, pers. communication), which are populated with several rare plant species that are endemic to these communities, including shale-barren rock-cress (*Arabis serotina*) (G2) and Millboro leatherflower (*Clematis viticaulis*) (G2). Global rarity *Carex polymorpha* (G3), often associated with openings in oak-hickory canopies and fire maintained oak-ericad woodlands, also occurs sporadically in the landscape with several healthy populations found on Warm Springs Mountain.

The fire adapted, topographically exposed montane pine barren, is another rare natural community type found in Virginia only on Warm Springs Mountain, also near the airport. This type is a close cousin of the New Jersey pine barrens of the North Atlantic Coast and barrens found in the Alleghany Mountains of West Virginia, while also showing more distant association with the health balds found in the southern Blue Ridge of North Carolina. An occurrence of eastern hemlock forest is found with an understory of catawba rhododendron (*Rhododendron catawbiense*) on Warm Springs as well, whereas one would normally find hemlock associated with the great rhododendron (*R. maximum*) in the Ridge and Valley, making it a unique community type.

The forest communities of the present day are radically changed from a mere century ago. The most blatant of these changes is due to the chestnut blight of the 1920s and 1930s caused by a fungus (*Cryphonectria parasitica*) which resulted in the mortality of the American chestnut (*Castanea dentata*) throughout most of Appalachian forests. Forests once dominated by grand canopies of this majestic tree have now succeeded to oak and hickory or sugar maple in more mesic sites. Moreover, the forests were extensively cleared and logged in the early 20th century often followed by catastrophic slash fires. However, fire of more moderate intensity is considered an important ecological process to promote the regeneration of oak and pine species throughout the Appalachians. It has been thoroughly excluded throughout the landscape for most of the last century precluding robust oak and pine establishment and slowly changing the forest composition to more mesic, fire intolerant species.

Aquatic and Karst Description. The Cowpasture is considered a moderate gradient, moderate elevation, 4th to 5th order small Central Appalachian river system. It is underlain by Devonian shales, sandstones, and some cherty limestones, though it is not as strongly alkaline and productive as other Ridge and Valley rivers (R. Smith, pers. communication). Some tributaries are moderate to high gradient and flow off moderate to high elevation sandstone or shale ridges, while others are subterranean and surface flow is highly intermittent.

The aquatic fauna exhibit endemism to the Upper James drainage, though they are not remarkably diverse. The fish fauna is a typical Ridge and Valley warmwater assemblage with some species less tolerant of alkaline conditions. The roughhead shiner (*Notropis semperasper*) is a globally rare species (G2) that is found only in the Ridge and Valley portion of the upper James drainage (Jenkins and Burkhead 1994). Other more common James River endemics are the stripeback darter (*Percina notogramma*) and the longfin darter (*Etheostoma longimanum*). Historical records exist for the green floater (*Lasmigona subvirdis*); however, recent mussel surveys have not found extant populations of this mussel species. More common species such as the creeper mussel (*Strophitus undulatus*), the notched rainbow (*Villosa constricta*), and the triangle floater (*Alasmidonta undulata*) have healthy, viable populations in the lower watershed as do several species of crayfish (M. McGregor, pers. communication).

Solutional weathering of mostly Siluro-Devonian aged limestone along mountain flanks and valley floors has produced a karst landscape, characterized by sinkholes, caves, sinking streams, and large springs. Overall, the karst resources of this landscape may be considered in relatively undisturbed and pristine condition. 41 caves have been identified and designated as significant by the Virginia Cave Board in this conservation area. Existing available data on cave and karst biota show that Bath County and to a lesser extent, Highland County, are significant areas for obligate terrestrial cave invertebrates (Culver et al. 1999). While the communities of karst invertebrates are not exceptionally diverse, the species exhibit a high degree of endemism to individual caves. For example the Crossroads cave beetle (*Pseudonophthalmus intersectus*) is only found in the Crossroads Cave at the intersection of routes 629 and 678. Likewise, Vandel's isopod (*Caecidotea vandeli*) is only known to occur in Blowing Cave and a cave close to Falling Spring Falls in the landscape. Further inventory work of cave invertebrates may reveal more biodiversity, particularly among terrestrial cave invertebrates, than is currently known. Bats, including the little brown and big brown bats, pipistrelles, the rare small-footed myotis (eastern small-footed bat) and federally listed Indiana bat, also use caves for wintering habitat. A significant hibernacula—Hupman's Saltpeter Cave—has among the highest winter counts in the conservation area with over 4,000 bats recorded and the largest winter count in the state for the small-footed myotis (roughly 60 bats) (R. Reynolds, pers. communication).

Table 1. Land use/land cover classification of the Warm Springs Mountain/Cowpasture River conservation area (estimated from USGS NLCD).

Land Use/Land Cover Class	**Total Acres**	**% of Total Land Area**
Open Water	1403.8	0.39
Low Intensity Residential	877.2	0.24
High Intensity Residential	0.7	0.00
Commercial/Industrial/Transportation	513.7	0.14
Transitional	713.8	0.20
Deciduous Forest	232256.4	64.61
Evergreen Forest	31619.1	8.80
Mixed Forest	58496.7	16.27
Pasture/Hay	31117.1	8.66
Row Crops	1896.0	0.53
Urban/Recreational Grasses	128.3	0.04
Woody Wetlands	218.7	0.06
Emergent Herbaceous Wetlands	249.9	0.07
Total	359491.333	100.00

♦ *Defining the Ecological Boundary of a Functional Landscape*

As we embarked upon the conservation area planning process for the Warm Springs Mountain forest block, consideration was given to revising the ecological boundaries of the 77,000 forest block (Map 3). The Warm Springs/Beards Mountain area was delineated to capture only upland forests. However, these forests are inter-connected to other types of ecological systems such as aquatic and karst systems. The goal was to define a conservation area boundary that integrated the forest with the watershed and karst systems of which it is part, thereby conserving a "functional landscape". A functional landscape is an area that "seeks to conserve a large number of ecological systems, communities and species at all scales below regional"—in short, an area that conserves biodiversity at multiple scales from local to landscape (Poiani and Richter 2000).

To do this, the watersheds and sub-watersheds of which Warm Springs and Beards Mountain are part were studied. The eastern half of Warm Springs Mountain and all of Beards Mountain drain into the Cowpasture River catchment. The western half of Warm Springs Mountain drains into the Jackson River. The Cowpasture River is considered by most experts to be the most pristine river in Virginia (P. Bugas, M. Pinder, pers. communication) due to its water quality and healthy aquatic fauna, whereas the Jackson is plagued with several serious threats to its ecological health due to pollution (e.g. the Westvaco paper plant in Covington). Therefore, since the forest block mostly falls in the Cowpasture catchment and is a better example of an aquatic system similar to the Jackson, the Cowpasture watershed was integrated into the WSM/CR conservation area. The conservation area boundaries were re-drawn according to the 14-digit hydrological units for the Cowpasture watershed as delineated by Soil and Water at DCR (Map 2). The boundary still captures the western side of Warm Springs Mountain for contiguity among its terrestrial communities.

While the karst systems of this area are extensive, particularly north of highway 39, many of the subterranean basins have not been mapped or the data were inaccessible to TNC at the time of this writing. Filling this data gap with explicit karst conservation boundaries is a goal for TNC and the Division of Natural Heritage. For now, it is assumed that the surficial watershed boundary for the Cowpasture captures most of the subterranean basins comprising the karst systems and significant caves in the landscape (Wil Orndorff, pers. communication).

The combination of the terrestrial, aquatic and karst systems into one contiguous landscape defined by the western boundary of Warm Springs Mountain and the watershed boundary of the Cowpasture River is an attempt to capture multiple biological systems across various environmental gradients at multiple scales. Our hypothesis is that the boundaries of this landscape are adequate to maintain the native species and communities found throughout the different biological systems and support the ecological processes necessary for their long term persistence. Moreover, we hypothesize that conservation strategies implemented at this scale to abate threats should be optimally effective.

♦ ***Socio-Economic Characterization***

The WSM/CR conservation area is a very rural area with less than one half of one percent of the landscape classified as residential or commercial/industrial (Table 1). The human population is stable to declining within and immediately surrounding the area (Map 5). The closest population centers are Clifton Forge and Covington to the south, both of which are experiencing population declines (Table 2). The population of Bath County is roughly 5,000 people, showing only a 5% increase since the 1990 census, while Highland County is half this size, exhibiting a slight decrease in population since 1990. However, the adjacent counties to the east in the Shenandoah Valley, particularly around Harrisonburg, and north of Roanoke in Botetourt County have experienced significant population growth over the last 10-15 years.

Overall, the rural nature of the counties combined with the fact that half of the landscape is in public ownership are major contributors to the lack of development and industry in the area. The per capita incomes of Bath and Highland counties were roughly $22,000 and $20,000, respectively, according to the Bath County Bureaus of Economic Analysis, compared to the per capita income of Virginia of approximately $28,000 (based on 1998 data) (Central Shenandoah Planning District Commission 2000). The economy is driven primarily by tourism in Bath County and by agriculture in Highland County. The Homestead, a luxury resort hotel first constructed in 1766, located in Hot Springs, is a famous vacation spot for much of northern Virginia and D.C. area as well as several U.S. Presidents and other important public figures of the 20th century. It is the largest employer in Bath County and has begotten a culture of bed and breakfast inns, boutiques and other specialty shops that fuel Bath's economy. In Highland County, agriculture and forestry (including lumber) are the largest sources of employment, accounting for about 30% of the workforce. Wool is a primary agricultural commodity, along with cattle, sheep, poultry and calf production. Four locally owned and operated logging companies run in Highland County along with two lumber companies, and one corporate, industrial timber company, Westvaco, Inc. (Central Shenandoah Planning District Commission 2000).

Table 2. 1990 and 2000 population census for counties overlapping with the Warm Springs Mountain/Cowpasture River conservation area (U.S. Census Bureau 2001).

	Census Population		**Change, 1990 to 2000**	
County Name	**April 1, 1990**	**April 1, 2000**	**Number**	**Percent**
Alleghany County	13,176	12,926	-250	-1.9
Augusta County	54,677	65,615	10,938	20.0
Bath County	4,799	5,048	249	5.2
Botetourt County	24,992	30,496	5,504	22.0
Highland County	2,635	2,536	-99	-3.8
Rockbridge County	18,350	20,808	2,458	13.4
Rockingham County	57,482	67,725	10,243	17.8
Clifton Forge city	4,679	4,289	-390	-8.3
Covington city	6,991	6,303	-688	-9.8
Harrisonburg city	30,707	40,468	9,761	31.8
Staunton city	24,461	23,853	-608	-2.5
Waynesboro city	18,549	19,520	971	5.2

♦ ***Managed Lands***

Currently, roughly 55% of the land within the WSM/CR boundary is in public ownership (Table 3, Map 6). The largest portion of public land falls within George Washington-Jefferson National Forest, which is managed by the U.S.

Forest Service (USFS). Portions of three forest service districts fall within the boundary: Warm Springs Ranger District, Deerfield Ranger District and the James River Ranger District. This land is managed for multiple uses, including recreational (hunting, fishing, camping, ATV/ORV riding, etc.), timber procurement, wildlife management, viewsheds and conservation (i.e. special biological areas).

The Virginia Department of Game and Inland Fisheries (VDGIF) owns roughly 12,000 acres in the site in three separate tracts all comprising the Highland Wildlife Management Area (HWMA) in Highland County. This land is primarily managed to promote habitats for game species like turkey, deer, bear, and grouse. In addition, the Bullpasture River, which flows through the HWMA, is stocked with rainbow, brown and brook trout. Douthat State Park, a 4,500 state park, located in the southern central portion of the landscape, is managed primarily for recreational uses. Westvaco, an industrial timber corporation, owns a small tract close to Clifton Forge in Alleghany County, for timber procurement.

In April of 1999, TNC became aware of an opportunity to purchase a large tract of Warm Springs Mountain from Virginia Hot Springs, Inc. As of March 2002, the Conservancy closed on 4 separate tracts totaling 9,000 acres, the largest being the mountain proper which is over 7,000 acres (Map 4). In the past, this land has been used by the Homestead for recreational uses such as horseback riding, hiking, mountain biking and has been leased to hunt clubs for a couple of months every winter. In addition, selective harvesting has occurred on this property and much of the merchantable timber has been removed over the last two decades (L. Crowe, pers. communication). TNC plans to manage the property in accordance with the conservation strategies set forth in this plan, while also allowing for some limited recreational use and hunting leases.

Table 3. Managed lands in the Warm Springs Mountain/Cowpasture River conservation area.

Managed Area and/or Managing Agency	**Acres**	**Percent of Total Project Area**
George Washington-Jefferson National Forest—USFS	167,052	46.45
Highland Wildlife Management Area—VDGIF	12,061	3.35
The Nature Conservancy	7,400	2.06
Douthat State Park—VADCR	4,500	1.25
Westvaco	3,385	0.94
Private properties held under public conservation easements	2,960	0.82
Total	197,358	54.88%

♦ ***A Strategic Vision and Key Partners***

Overall, the Warm Springs Mountain/Cowpasture River is a very large and complex landscape and there is much that we still do not know or understand about its ecological processes and threats. To meet TNC's mission in the Warm

Springs Mountain/Cowpasture River, we need a strategic vision and plan for conservation action at the landscape scale that includes protection, aggressive ecological management and forest restoration. As always, the only means to mission success in such a vast landscape is through effective, collaborative partnerships. Key partners include the USFS, VDGIF, VDOF, planning district commissions and localities, the Homestead, Celebration Inc., and local conservation groups like the Cowpasture River Preservation Association. In the coming fiscal year, our goal is to staff an office in the project area to begin implementing the vision set forth in this plan.

Conservation Targets

♦ *Overview of Methods*

Conservation targets are the basis for all subsequent steps in the planning process and ultimately determine what conservation actions will be taken. The goal of selecting targets is to represent the biodiversity of the site and capture its "functionality"—or the ecological processes that sustain diversity. Therefore, conservation targets should occur at multiple scales across all ecological systems such that the long term functionality or collective viability of the site is ensured if they are conserved (Richter and Poiani 2000). For the WSM/CR conservation area, 8 focal targets were selected that best represent the biological diversity, uniqueness and representativeness of the area (Figure 1) (Maps 2 and 7). For each system target, several nested targets may occur. A *nested target* is a species or community found within the larger system target which has conservation significance and threats that warrant specialized attention in terms of protection and monitoring. Usually nested targets are globally rare (G1-G3 ranked), federally listed, endemic or severely declining (see Appendix B for definitions of ranking).

The ecological integrity of each conservation target is then ascertained based on an evaluation of the ecological processes and attributes necessary for the target's long term persistence. This information is crucial to establish a baseline for each target by which to analyze threats to the targets, determine conservation strategies, and ultimately, to measure success of conservation actions over time. Size, condition and landscape context are the factors used to indicate the integrity or health of a target system, community, or species. These are factors by which we infer the target's ability to persist and be resilient over the long term. They are defined as follows (TNC 2000):

- **Size**: A measure of the area or abundance of the conservation target's occurrence.
- **Condition**: An integrated measure of the composition, structure and biotic interactions that characterize an occurrence.
- **Landscape context**: An integrated measure of two factors: the dominant environmental regimes and processes that establish and maintain the target occurrence and connectivity.

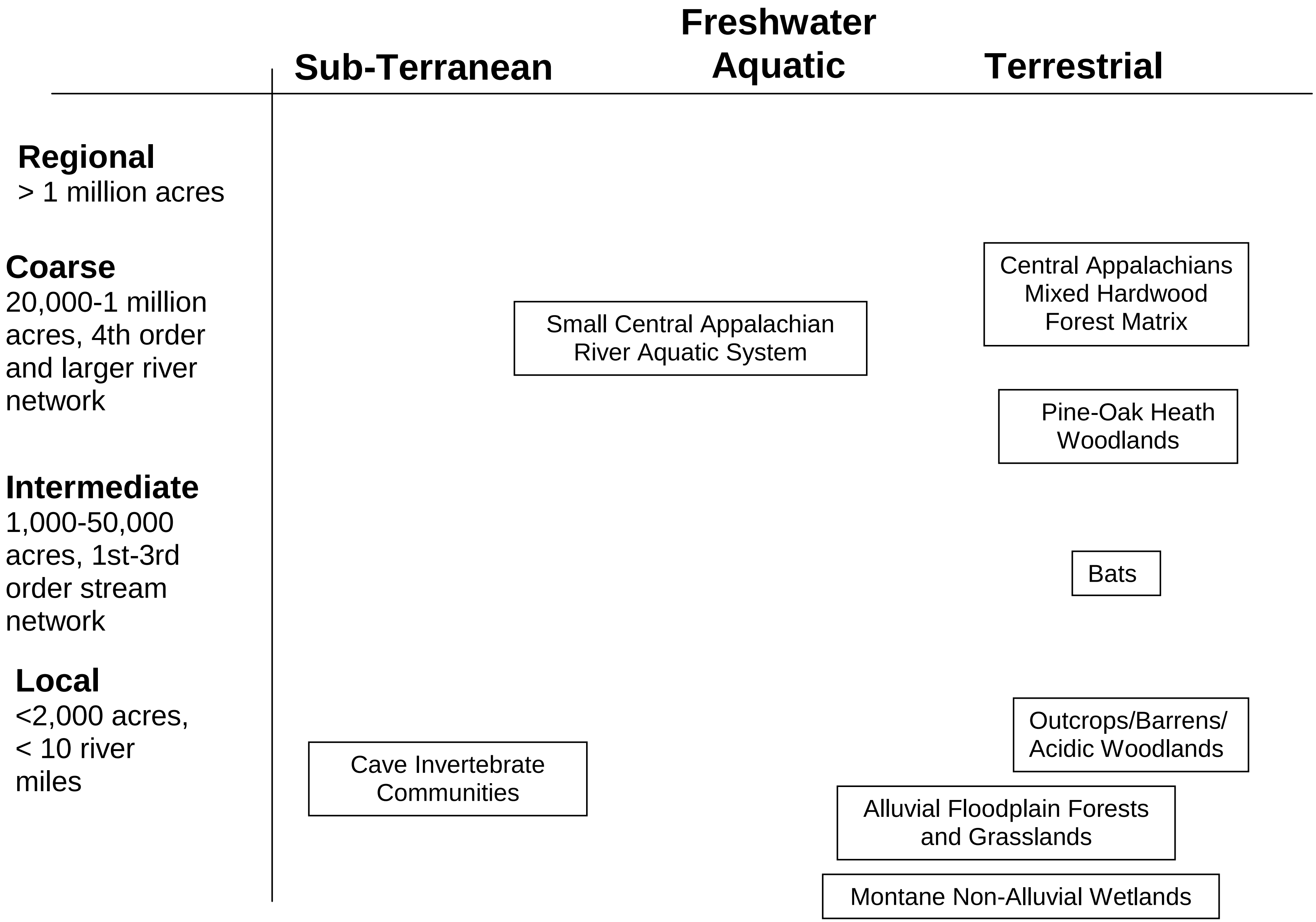
For each of the Warm Springs Mountain/Cowpasture River focal conservation targets, qualitative attributes have been developed to specifically define the target's size, condition and context. These attributes are then used to rank the target's overall ecological integrity. The ranking system consists of four general categories: "Very Good", "Good", "Fair" and "Poor". They are defined as follows:

- **Very good (or optimal integrity)**: The factor is functioning at an ecologically desirable status, and requires little human intervention.

- **Good (minimum integrity):** The factor is functioning within its natural range of variation; it may require some human intervention.
- **Fair (likely degradation):** The factor lies outside of its range of acceptable variation and requires human intervention. If unchecked, the target will be vulnerable to serious degradation.
- **Poor (imminent loss):** Allowing the factor to remain in this condition for an extended period of time will make restoration or preventing extirpation practically impossible.

For this plan, only the “good” attributes were defined for the three variables (size, condition and context) and are described for each target, serving as a measuring stick by which to rank the target. The approach of defining “good” is an attempt to describe the acceptable natural range of variation for a healthy target. With better information over time, it will be possible to have a credible definition of “very good” “fair” and “poor”. An overall ecological integrity rank per target is derived from averaging the size, condition and context ranks for all occurrences throughout the site. Individual integrity “scores” for the targets are then aggregated to develop a biodiversity health rank for the site as a whole, establishing a baseline from which to measure future success towards conserving the site.

Figure 1. Warm Springs/Cowpasture River Conservation Targets



♦ Conservation Target #1: Central Appalachians Mixed Hardwood Forest Matrix

Description (Fleming et al. 2001): This target includes the characteristic and widespread, largely deciduous mixed oak-hickory, maple or hemlock dominated forest communities occurring across a variety of geologic strata, soils, moisture regimes (excluding xeric), topographic positions, and landforms. Different forest community types are distributed as an interdigitating matrix across the landscape. Drier, less diverse oak hickory forests tend to form large patches on more acidic mountain crests, saddles, and sideslopes. Moister, more fertile and base-rich forests of sugar maple, basswood, ash and poplar with diverse and often lush herbaceous layers occur in coves and ravines. Hemlock forests are found in more acidic gorges and sheltered riparian areas often associated with dense mountain laurel and rhododendron.

Distribution and Status: Though widespread and common to areas of the central and southern Appalachians, the only occurrence of the conservation target meeting the minimum size requirement in this landscape is a 77,000 acre contiguous forest block identified through the Central Appalachians ecoregional plan (TNC 2001). Oak forests are threatened by gypsy moth invasions and lack of regeneration. Rich cove and slope forests are more threatened by non-native, invasive plants species than other forest community types included in this matrix due to the higher fertility and moisture level of soil. Many of the forests occurring on substrates weathered from dolomite and limestone have been cleared for grazing due to their position on convex, often southwest facing slopes. Eastern hemlock communities, while widespread, are by far the most highly threatened portion of the forest due to the hemlock woolly adelgid, an exotic pathogen that is currently decimating eastern hemlock stands throughout the Appalachians. An association of eastern hemlock and *Rhododendron catawbiense* is known to occur only on Warm Springs Mountain in the Central Appalachians. What makes this community unique is its association with a narrow latitudinal range in the Blue Ridge near the northern range limit of *Rhododendron catawbiense* and where *R. maximum* is inexplicably and almost altogether absent (P. Coulling, pers. communication). If truly distinct, this community is a globally rare (G1?) association.

Characteristic Ecological Groups and Associations (Fleming and Coulling 2001):

1. Acidic Oak-Hickory Forests
   - *Quercus alba - Quercus prinus - Carya glabra* / *Cornus florida* / *Vaccinium pallidum* / *Carex pensylvanica* Forest
2. Montane Oak-Hickory Forests
   - *Quercus rubra - Carya* (*glabra*, *ovata*) / *Ostrya virginiana* / *Carex pensylvanica* Forest
   - *Quercus rubra - Quercus alba - Fraxinus americana - Carya* (*ovata*, *ovalis*) / *Actaea racemosa* Forest
3. Dry-Mesic Calcareous Forests
   - *Acer saccharum - Quercus rubra – Carya (glabra, ovata) / Ageratina altissima - Bromus pubescens* Forest
4. Montane Dry Calcareous Forests and Woodlands
   - *Acer saccharum - Quercus muehlenbergii* / *Cercis canadensis* Forest
5. Rich Cove and Slope Forests
   - *Acer saccharum-Fraxinus americana-Tilia americana/ Caulophyllum thalictroides-Laportea canadensis* Forest
6. Eastern Hemlock Forests
   - *Tsuga canadensis - Betula alleghaniensis* Lower New England / Northern Piedmont Forest

Nested Targets:
Variable sedge (*Carex polymorpha*) (G3)
Swordleaf phlox *(Phlox buckleyi) (G2)*
Tsuga canadensis - (*Betula alleghaniensis, Quercus rubra*) / *Ilex montana* / *Rhododendron catawbiense* Forest (G1Q)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ >15,000 acres (Anderson 1999)	*Rank*: **Very Good** The forest matrix block captures just over 77,000 acres of contiguous forest. The size and distribution of calcareous forests has been reduced by conversion to pasturelands.
Condition	➢ Mature forest w/mixed age class structure varying from 40-150 years and canopy w/trees >150 years in age. ➢ Intact herbaceous layer composed of native species with variable abundance, depending on fertility and moisture (e.g. rich cove and slope forest should have ~80% herbaceous cover per 400 m^2 plot, while calcareous forests may be closer to 65%, mixed oak forests will have an interrupted or sporadic herb layer depending on local conditions, and hemlock forests have very sparse herb layers). <5% cover non-native, invasive species present in understory per 400 m^2 plot (G. Fleming, pers. communication, Fleming and Coulling 2001). ➢ Thick, well-developed layer of soil organic matter present on forest floor. Soils productive with base saturation remaining > 15% (Binkley et al. 1989). ➢ Coarse, large woody debris (>50 cm DBH) in density of 5-10 logs per acre present. In addition, a high density of woody debris from all age classes is present, specifically an average of 8-10% woody debris per 400 m^2 plot (M. Anderson and P. Coulling, pers. communication). ➢ Standing snags present throughout. ➢ Regeneration of dominant canopy trees robust.	*Rank*: **Fair** *Comments*: While excellent examples of all forest community types that comprise the forest matrix occur within the conservation area, forest health is suffering due to invasive species, pathogens and deer overbrowsing. Rich cove and slope forests are threatened by invasives such as garlic mustard in the understory. The gypsy moth epidemic has stressed hundreds of thousands of acres of oaks. Hemlock woolly adelgid has infested much of the hemlock population in this area, particularly the older trees, causing mortality. Dogwood (*Cornus florida*) is experiencing high levels of mortality due to the dogwood anthracnose. Oaks and hemlocks do not exhibit successful regeneration overall, attributed often to the intensity of deer browse.

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Landscape Context	➢ Low intensity fire regime with variable fire return intervals of 30-60 years for montane and acidic oak-hickory forest groups (Abrams 1992). ➢ Little to no disruption of nutrient cycling due to acid deposition. ➢ Occurrence is connected to >80% natural vegetation.	*Rank*: **Good** *Comments*: Fire has been excluded for the past century. Acid deposition is having unknown and likely deleterious impacts on the more acidic chestnut oak forest soils. Relative to other areas in Virginia, the forest matrix block is well connected within a largely rural, forested context. Cove and slope forests often abut pasturelands at toe slopes to the east and to the west. The 220 corridor is dotted with towns and residential development to the west, while north of 39 is mostly forested land and to the south I-64 and the Clifton Forge/ Covington area create a significant ecological barrier.

♦ Conservation Target #2: Pine-Oak-Heath Woodlands

Description (Fleming et al. 2001): Fire influenced and/or edaphically limited/drought-prone xerophytic vegetation consisting of variable combinations of pines (*Pinus rigida, P. pungens, P. virginiana)* and oaks (*Quercus ilicifolia, Q. montana, Q. coccinea, Q. stellata)* with several ericaceous shrubs and a sparse herb layer. Occurs on rocky, sandy, shallow nutrient poor soils, often on southwest exposed ridges, convex sideslopes, and clifftops.

Distribution: Pine-oak/heath communities are common in the Central Appalachians but threatened throughout by fire suppression and southern pine beetles. The montane pine barren is a globally rare variant of an pine barren association restricted to high elevations and primarily known from the N. Appalachians. Occurrences on Warm Springs may represent the only known locations for this community in the Virginia mountains.

Characteristic Ecological Groups and Associations (Fleming and Coulling 2001):

1. Pine-Oak/Heath Woodlands
   - *Pinus* (*pungens*, *rigida*) - *Quercus prinus* / *Quercus ilicifolia* / *Gaylussacia baccata* Woodland

Nested Target:

- Montane Pine Barren (Ludwig et al. 1999): Dwarfed shrubland (< 6 m) of dense *Rhododendron catawbiense*, *Quercus ilicifolia*, *Kalmia latifolia* and *Gaylussacia baccata* and *Vaccinium angustifolium* with scattered *Pinus rigida* occurring on exposed, xeric summits of high elevation sedimentary ridges.
- Box huckleberry *(Gaylussacia brachycera)* (G3)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	~ Large Patch (>50 acres)	*Rank*: **Good**
Condition	➢ Pitch and table mountain pine dominant in canopy. ➢ Pine regeneration robust following fires. ➢ Mix of uneven and even aged pines and uneven age hardwoods, including older age classes >150 years old. ➢ Little to minor damage by forest pathogens. ➢ Base saturation of soils > 15% (Binkley et al. 1989).	*Rank*: **Fair** *Comments*: Pine component has been significantly reduced in extent due to succession of oaks, ericads and fire retardant species in the wake of fire exclusion. Pines have also been damaged severely by the pine beetle and ice storms. Warm Springs Mountain pine barren is considered in good to very good condition, largely due to edaphic stresses that relatively favor pine regeneration.

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Context	➢ Mixed fire regime where frequent, low intensity understory fires occur (fire return interval between 2 and 10 years) in addition to infrequent stand replacement fires (fire return interval >50 years?) (Wear and Greis 2002). ➢ Area surrounding occurrence is >80% natural vegetation, i.e. a mosaic of chestnut oak forests and other sub-xeric oak forests. ➢ Little to no disruption of nutrient cycling due to acid deposition.	*Rank*: **Fair** *Comments*: While well connected to other forest types, fire has been largely excluded for the past 50 years and acid deposition is having unknown but likely deleterious impacts on the soils that may inhibit the productivity of vegetation.

♦ Conservation Target #3: Alluvial Floodplain Forests/Grasslands

Description (Fleming et al. 2001): Temporarily flooded deciduous and mixed deciduous/coniferous forest occurring in narrow floodplains along small streams and rivers in mountain valleys. Forests have variable canopy compositions ranging from associations of box elder, green ash, sycamore, black walnut and mockernut hickory (called "Piedmont/Low Mountain Forests") to types that include tulip tree, white pine, eastern hemlock, sycamore and yellow or black birch (called "Montane Alluvial Forests"). Forests have well developed but variable shrub layer (hop hornbeam and flowering dogwood dominant in the montane type and spice bush and paw-paw dominant in low mountain type) and mesophytic herbaceous understory layers. Historically, intermittent natural prairie-like openings of warm season grasses persisted within the low mountain floodplain forest along the Cowpasture River due to Native American land management practices.

Distribution: Forests and grasslands used to be common along alluvial floodplains throughout the Cowpasture River Valley, but most have been cleared and converted to pasture over the last 300 years or longer. Some of best remaining examples of successional alluvial floodplain forest in the conservation area occur in Douthat State Park.

Characteristic Ecological Groups and Associations (Fleming et al. 2001):
1. Piedmont/Low Mountain Alluvial Forests
2. Montane Alluvial Forests

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ ~Small Patch (linear > 25 acres)—Forest ➢ ~Small Patch (< 5 acres)—Grasslands	*Rank*: **Fair**
Condition	➢ Mature canopy of even to uneven aged stands with trees >150 years old. ➢ Patchwork of large patch bottomland forests with intermittent small patch grassy openings in low mountains but all forest in high gradient areas (C. Ludwig, pers. communication). ➢ Native warm season grasses abundant in grassy openings. ➢ Sycamore a constant canopy species in forests (G. Fleming, pers. communication). ➢ <25% cover non-native, invasive species present in understory. ➢ Little to minor damage by forest pathogens.	*Rank*: **Fair** *Comments*: Very few examples exist that are exemplary as most have been converted to pasturelands over the past 3+ centuries and extant examples of forests are often young and degraded. Few patches of warm season grasses persist. Invasives such as garlic mustard, multiflora rose and microstegium are well established.

Attribute Category	**Minimum Ecological Integrity Attributes (or "Good")**	**Current Rank for Ecological Integrity**
Landscape Context	➢ Area surrounding occurrence is >80% natural vegetation, i.e. intergrades with submesic oak forests, cove forests, eastern hemlock forests and shale barrens. ➢ Flooding regime and periods of inundation within natural range of variation.	*Context*: **Good** *Comments*: Flooding regime is within natural range of variation without impediments. Target is connected to forests at the base of slopes while interfacing with established human residences, and and pasturelands along the riparian corridors.

♦ Conservation Target #4: Outcrops/Barrens/Acidic Woodlands

Description (Fleming et al. 2001): Small patch communities of open herbaceous rock outcrops and prairie-like openings, sparse woodlands of chestnut oak, Virginia pine and red cedar, and shrublands which are edaphically-limited, on southwestern facing aspects, occurring below 3500 ft in elevation on varying substrate from acidic (shale barrens) to calcareous (limestone cliffs).

Distribution: Most barren community associations located in this landscape are globally rare (G3). Shale barrens are endemic to the Central Appalachians. The bulk of shale barren distribution is in Bath and Alleghany counties as well as best and largest known occurrences. Limestone outcrops (cliffs) are obscure and distribution is unknown.

Characteristic Ecological Groups and Associations (Fleming and Coulling 2001):

1. Central Appalachian Shale Barrens
   - *Pinus virginiana – Quercus prinus – Carya glabra* / *Phlox subulata – Packera antennariifolia* Woodland
   - *(Pinus virginiana, Juniperus virginiana) / Schizachyrium scoparium – Eriogonum allenii* Wooded Herbaceous Vegetation
2. Montane Acidic Woodlands
   - *Pinus virginiana – Quercus prinus* / *Quercus ilicifolia* / (*Hieracium greenii*) Woodland
   - *Quercus prinus* / *Quercus ilicifolia* / *Danthonia spicata – Solidago bicolor* Woodland
   - *Quercus prinus – Pinus virginiana – Quercus (marilandica, stellata) / Dichanthelium depauperatum* Woodland
3. Xeric Calcareous Cliffs

Nested Targets:

- Shale-barren rock-cress (*Arabis serotina)* (G2)
- Millboro leatherflower *(Clematis viticaulis)* (G2)
- Western wallflower *(Erysimum capitatum var capitatum)* (G5T5)
- Wild chess (*Bromus kalmii)* (G5, disjunct)
- Olympia marble (*Euchloe olympia*) (G4G5)
- Appalachian grizzled skipper (*Pyrgus wyandot*) (G2)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ ~Small Patch	*Rank*: **Very Good** *Comment:* High density of shale barrens throughout conservation area.

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Condition	➢ Presence of viable populations of at least 2 endemic forbs: *Arabis serotina (G2), Clematis viticaulis (G2), Clematis albicoma, Eriogonum allenii, Oenothera argillicola, Packera antennariifolius, Trifolum virginicum, Bromus kalmii,* or *Erysimum capitatum* var. *capitatum (G5T5)* (C. Ludwig, pers. communication). ➢ Warm season grasses often present (Fleming and Coulling 2001). ➢ Open physiognomy, varying from prairie-like to dwarfed woodlands (Fleming and Coulling 2001). ➢ <1% cover non-native, invasive species present (C. Ludwig, pers. communication).	*Rank*: **Very Good** *Comments*: The shale barrens in this landscape are exceptional in their native species composition, richness, presence of endemics, lack of invasives and exemplary physiognomy.
Landscape Context	➢ Area surrounding occurrence is >80% natural vegetation (2,500 to 10,000 acres), i.e. intergrades with oak-pine-heath, chestnut oak, sub-mesic oak forests and calcareous forests. ➢ Little to no disruption of nutrient cycling due to acid deposition.	*Context*: **Good** *Comments*: Found mostly on USFS land well connected to surrounding natural vegetation such as chestnut oak forests, often in clusters of occurrences. The extent to which acid deposition may be having deleterious impacts on these highly acidic communities is unknown.

♦ Conservation Target #5: Montane Non-Alluvial Wetlands

Description (Fleming et al. 2001): Includes seeps and ponds. Saturated deciduous forested seepage swamps are found on gentle slopes of headwater streams at various elevations with extremely acidic soils. Mountain ponds are seasonally to semi-permanently inundated wetlands found on ridge crests and landslide benches or alluvial fans. These seeps and ponds provide important breeding grounds for odonates and amphibians.

Distribution: Seeps are uncommon wetland communities; found scattered throughout Piedmont and mountain ecoregions. Mountain ponds are very rare communities in the Central Appalachians and other mountainous ecoregions

Characteristic Ecological Groups and Associations (Fleming and Coulling 2001):
1. Mountain Ponds
   - *Cephalanthus occidentalis* / *Dulichium arundinaceum* Shrubland
2. Mountain/Piedmont Acidic Seepage Swamps
   - *Acer rubrum – Nyssa sylvatica* / *Vaccinium fuscatum – Ilex montana* / *Osmunda cinnamomea* Forest

Nested Target:
- Northeastern bulrush *(Scirpus ancistrochaetus)* (G3, LE)

Attribute Category	**Minimum Ecological Integrity Attributes (or "Good")**	**Current Rank for Ecological Integrity**
Size	➢ Small patch	*Rank*: **Good**
Condition	➢ Seepage swamp is composed of mixed age classes including old trees (>100 years old) where blackgum is usually dominant with hummock-and-hollow topography and a well developed shrub layer, typically composed of ericaceous species (Fleming and Coulling 2001). ➢ Mountain ponds have a herbaceous and/or shrubland physiognomy with distinct zonation characterized by buttonbush (*Cephalanthus occidentalis*), three-way sedge (*Dulichium arundinaceum*) and broadleaf arrowhead (*Sagittaria latifolia*) in addition to other sedges, bulrushes, bladderworts and rushes (Fleming and Coulling 2001). ➢ Peat/organic soil accumulation is well developed.	*Rank*: **Good** *Comments*: This rank is based on very little inventory data of seeps and ponds. However, existing data indicate that these wetlands are healthy examples with characteristic composition and structure.

Attribute Category	**Minimum Ecological Integrity Attributes (or "Good")**	**Current Rank for Ecological Integrity**
Landscape Context	➢ Perennial saturation from groundwater seep within natural range of variability. ➢ Area surrounding occurrence is >80% natural vegetation (i.e. upland matrix forest such as montane oak hickory forests or basic oak hickory forests). ➢ Little to no disruption of nutrient cycling due to acid deposition.	*Context*: **Good** *Comments*: No alterations to groundwater recharge have been observed. Context is usually forested and remote with little human disturbance (i.e. logging or recreational activities). Impacts of acid deposition unknown.

♦ Conservation Target #6: Cave Invertebrate Communities

Description: Obligate subterranean invertebrate fauna of Siluro-Devonian limestone solution caves, sinkholes, epikarst, springs, intermittent streams and groundwater aquifers. Obligate cave aquatic organisms (or "stygobites") include isopods and amphipods and obligate cave terrestrial organisms (or "troglobites") include springtails, centipedes, psuedoscorpions, mites, spiders, and beetles.

Distribution: Endemic and globally rare invertebrate species occur in karst systems of Bath and Highland counties. In the Central Appalachians, Bath County is second to Greenbrier County, WVA and Lee County, VA for subterranean biodiversity, and has comparable levels of endemism.

Nested Targets:
- Crossroads cave beetle (*Pseudanophthalmus intersectus*) (G1)
- Vandel's cave isopod (*Caecidotea vandeli*) (G2)
- Burnsville Cove cave amphipod (*Stygobromus conradi*) (G2)
- Morrison's cave amphipod (*S. morrisoni*) (G2)
- Bath County cave amphipod (*S. mundus*) (G2)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ Unable to determine what constitutes healthy population sizes for individual species, communities or habitats.	*Rank*: N/A
Condition	➢ Characteristic species diversity present in relative abundance. ➢ No non-native, invasive organisms predating on cave invertebrates. ➢ Little disturbance by raccoons and other pest predators.	*Rank*: **Good** *Comments*: It is assumed that the karst invertebrates are viable due to the good condition of their habitat; however, a current and comprehensive inventory should be conducted to state condition with confidence.
Landscape Context	➢ Autogenic (epikarst) and allogenic (surface) water inputs to basin fall within the ecological range of variability, determined by nutrient inputs, dissolved solids, temperature, turbidity, dissolved oxygen, and organic matter as well as quantity and timing of flow (D. Culver, pers. communication). ➢ Uninhibited flow of terrestrial transitory organic matter in and out of cave entrance (D. Culver, pers. communication).	*Rank:* **Good** *Comments*: The karst areas of this landscape are considered to be in tact and functioning though more monitoring needs to be conducted to determine impacts of grazing and agriculture on water quality. In addition, cave gates may adversely be impacting food sources for invertebrate communities.

♦ Conservation Target #7: Bats

Description: Bat species that winter and forage in the conservation area, including the little brown bats (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), pipistrels (*Pipistrellus subflavus*), the small-footed myotis (*Myotis leibii*), and the federally-listed Indiana bat (*Myotis sodalis*).

Distribution (R. Reynolds, pers. communication and W. Orndorff, pers. commuincation):
Overall, moderate winter counts of bats are distributed throughout many cave openings in the conservation area, though no maternity colonies have been identified in forest habitats. Hupman's Saltpeter Cave is the most significant known hibernacula, having over 4,000 bats, including the highest winter counts of the small-footed myotis in Virginia. Clark's, Breathing, and Witheros caves have winter counts of over 1,000 bats. The Cowpasture watershed represents the easternmost edge of the Indiana bats' range. The world's largest hibernaculum for the Virginia big-eared bat lies just to the north in Hellhole Cave, Pendleton County, WV. The caves of the Warm Springs/Cowpasture River Landscape may provide an important refuge for these bats should something happen to Hellhole, which is being encroached upon by an active limestone quarry.

Nested Targets:
- Indiana bat (*Myotis sodalis*) (G2, LE)
- Eastern small-footed myotis (*Myotis leibii*) (G3, SOC)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ Relative winter counts of individual bat species[1] remain stable or increase in caves.	*Rank*: **Good** *Comments***:** Bats in most caves that are monitored by VDGIF appear to maintain consistent numbers, though cave gate may enable better predator access (e.g. snakes).
Condition	➢ Stable temperature (>0-4 º C for M. leibii, 4-8 º C degrees for Indiana/little brown bats, pipistrelles withstand up to 12º C) (R. Reynolds, pers. communication). ➢ Stable humidity levels (>65%) (R. Reynolds, pers. communication). ➢ Good ventilation and air flow in cave. ➢ No sources of extraordinary predation.	*Rank*: **Good** *Comments*: Habitat condition overall is stable.

[1] Please note that since summering habitat may fall outside of the conservation area, a change in wintering counts will not be necessarily attributable to the decline or degradation of wintering habitat. Therefore, conservation strategies to conserve the bats will need to be regional in scope, addressing all phases of the bats' life histories.

Landscape Context	➢ Adequate forested buffer to protect microclimates within cave and prevent excessive erosion. ➢ No disturbances by humans for recreation, visitation, research, etc. ➢ Large, dead snags for roosting throughout forest (e.g. shagbark hickories).	*Rank*: **Good** *Comments*: Context for cave is largely forested with little visitation or disturbance due to gate. However, debris collecting at gate may alter temperature, air flow and humidity of cave microclimate.

♦ Conservation Target #8: Small Central Appalachian River Aquatic System

Description: Higher order rivers/streams and lower order tributaries in Ridge and Valley topography with watershed dominated by Devonian shales, sandstones, and some cherty limestones. The Cowpasture is not as strongly alkaline and productive as other Ridge and Valley rivers. Low gradient channels occur in moderate elevation shales. Tributaries are moderate to high gradient and flow off moderate/high elevation sandstone/shales ridges. Flow is augmented by good connection to karst groundwater. Many tributaries are subterranean and surface flow is highly intermittent. Fish fauna is a typical Ridge and Valley warmwater assemblage with some species less tolerant of alkaline conditions.

Distribution (P. Bugas, M. Pinder, R. Smith, pers. communication):
This aquatic system type occurs in the New, James, and Potomac River drainages in Virginia and has a high level of endemism. The Cowpasture River is the best remaining example of a small central Appalachian river in the James River Drainage. It is one of the most pristine rivers in the state, with high water quality and healthy, diverse aquatic fauna, including viable populations of three James River endemic fishes: the roughhead shiner (*Notropis semperasper*), stripeback darter (*Percina notogramma*), longfin darter (*Etheostoma longimanum*), and a species restricted in distribution to the Potomac and James drainages, the Potomac sculpin (*Cottus bairdi*). In the tributaries, a significant assemblage of fish occur, the most notable being the brook trout (*Salvelinus fontinalis*), including the blacknose dace (*Rhinichthys atratulus*), mottled sculpin (*Cottus bairdi*), torrent sucker (*Thoburnia rhothoeca*), mountain redbelly dace (*Phoxinus oreas*), and the creek chub (*Semotilus atromaculatus*). These lower order, high gradient tributaries are more sensitive to the effects of acid deposition due to the fact they flow over more acid substrate with much lower buffering capacity than the more alkaline waters flowing through the valleys at lower elevations.

Nested Targets:
Tributary aquatic system types:
- Moderate/high elevation, gradient, alkaline Ridge and Valley streams
- Moderate/high elevation, gradient, acidic Ridge and Valley streams

Fishes:
- Roughhead shiner (*Notropis semperasper*) (G2)
- Brook trout (*Salvelinus fontinalis*)

Mussels (viability is questionable):
- Virginia pigtoe (*Lexingtonia subplana)* (G1Q)
- Green floater (*Lasmigona subviridis*) (G3)

Attribute Category	Minimum Ecological Integrity Attributes (or "Good")	Current Rank for Ecological Integrity
Size	➢ Fish and mussel communities occur intact (i.e., with all representative species present in normal relative abundance, especially roughhead shiner) in more than 80% of its historical range within the watershed.	*Rank*: **Very good** *Comments*: Based on recent VDGIF surveys, fish communities are intact in most available habitat.
Condition	➢ Fish IBI[2] "Good" or "Very Good". ➢ Late summer presence of juveniles of rare and representative fishes. ➢ Benthic macroinvertebrate EPT[3] index or multimetric index "high". ➢ Presence of native mussels in natural densities and size class distribution. ➢ Endemic fish species (longfin darter, roughhead shiner) present with viable populations.	*Rank*: **Very good** *Comments*: Recent surveys by VDGIF indicate characteristic viable populations of native fishes, including endemic species. Telescope shiner is present as well but should not out-compete the roughhead shiner unless water quality declines.
Landscape Context	➢ Habitat – gravel and cobble substrate embedded in less than 20% fines in riffles, pool tails; median substrate particle size within natural range in riffles, runs, pool tails; bank sloughing in less than 10% of channel; no major changes in stream-bed elevation and channel shape at transects in key fish spawning habitats, along agricultural fields and grazing areas; 125 to 300 pieces of large woody debris (LWD) per stream mile in low order cold water streams and 75-200 pieces of LWD per stream mile in higher order streams (USFS 1993). ➢ Water quality – natural pH with acid-neutralization capacity > 50 µeq/L in low order streams (Bulger et al. 2000); nutrient levels (P, N) naturally low; and DO > 7 ppm (USFS 1993); low levels of agricultural and industrial toxins; very low turbidity; maximum temperature in low order cold water streams = 69ºF and in higher order warm water streams temperature is within 2ºF of the ambient (USFS 1993). ➢ Flow – dry season base flows and peak flood flows within natural range of variation. ➢ Connectivity – no migration inhibiting low-flow culverts bridges and low-head dams, no large dams.	*Context*: **Very good** *Comments*: Cowpasture and tributaries is considered most pristine river in Virginia with exceptional water quality and a lack of impediments to the flow regime.

[2] IBI = Index of Biotic Integrity
[3] EPT Index = Percent composition of Ephemeroptera (mayfly order), Plecoptera (stonefly order), and Trichoptera (stonefly order) present in a given stream reach.

♦ *Site Biodiversity Health Score*

The overall biodiversity health score is ranked as "good" (Table 4). The ranks for *landscape context* vary from "good" to "very good" for all targets, reflecting the fact that the WSM/CP conservation area is a predominately rural landscape with large contiguous forested habitat, a free flowing river system, and an undisturbed karst network. However, while the context may be optimal overall, the *condition* of the forest targets is on average "fair", indicating the decline in forest health and integrity due to invasive non-native plant species and forest pathogens, poor air quality, fire suppression and a long history of intensive logging. The exact nature of the decline in forest health has yet to be determined. It likely involves a loss of genetic diversity and decline in soil quality that reduces forests' resiliency to natural disturbance and causes a myriad of cascading effects in the trophic structure of forest organisms. Therefore, while the biodiversity health score of the conservation area is good, this may obscure the fact that the forest systems are severely ailing; however, we do not have enough information to better assess the loss of ecological integrity in these systems.

Table 4. Ecological integrity ranks for Warm Springs Mountain/Cowpasture River conservation targets.

Target Viability	Size	Condition	Context	Overall
Central Appalachian Mixed Hardwood Forest Matrix	Very Good	Fair	Good	Good
Pine-Oak-Heath Woodlands	Good	Fair	Fair	Fair
Alluvial Forests/Grasslands	Fair	Fair	Good	Fair
Outcrops, Barrens and Acidic Woodlands	Very Good	Very Good	Good	Very Good
Montane Non-Alluvial Wetlands	Good	Good	Good	Good
Cave Invertebrate Communities	N/A	Good	Very Good	Good
Bats	Good	Good	Good	Good
Small Central Appalachian River System	Very Good	Very Good	Very Good	Very Good
Site Biodiversity Health Score				***Good***

♦ *Desired Future Condition*

As we attempt to describe what the attributes of ecological integrity are for a given target and consider how to rank its current status, it is also important to articulate what our desired future condition is for the target. Desired future condition can also be defined as the ecological goals of the conservation area. The overarching goal is to improve or restore the target's ecological integrity to "good" as defined by its attributes. If all three factors—size, condition, and context—are ranked as "good", the goal is to maintain these targets as such. Specifically defining desired future condition for a given target is by nature controversial since there is often little conclusive evidence that can help to illustrate exactly what the landscape looked like or how it functioned pre-settlement. Moreover, making pre-settlement conditions the goal is problematic as well given that nature is dynamic and today's climate and ecological communities are quite different than they were 400 years ago due to a mixture of anthropogenic and natural causes.

It is generally agreed upon however that European settlers have altered the biological diversity and structure of most terrestrial and aquatic habitats in the Central Appalachians at large in ways that have imperiled the ability of certain species, natural communities and ecological systems to persist in the long term. Desired future condition, therefore, is based on the best evidence that exists to describe conditions necessary to support, maintain and restore the diversity of organisms in the Warm Springs Mountain/Cowpasture River conservation area. It is a sketch of what a healthy landscape might look like in the future as a result of conservation efforts. Defining desired future condition is inherently fraught with information gaps and assumptions, but is intended to be iterative. Below is a summary of the ecological goals or desired future conditions for each of the targets.

Central Appalachians Mixed Hardwood Forest Matrix

1. 80,000 acre forest block is maintained in a contiguous, relatively unfragmented condition, with no major changes to land use.
2. A core forested area of up to 50,000 acres within the forest block is maintained, consisting of native species with <5% relative cover of non-native, invasive plant species in the herb layer of a 400 m^2 sample plot and likewise <5% relative cover of invasive species in the canopy. No new non-native, invasive species are introduced to this forested ecosystem.
3. Core forest area is structurally diverse, including a continuum of age classes with trees >150 years old predominating. Periodic regeneration occurs through light gaps caused by local natural disturbances, but otherwise there is continuous canopy cover. Moreover, standing dead trees are present throughout and coarse woody debris (>50 cm dbh) in a density of 5-10 logs per acre occurs along with roughly 8-10% cover of woody debris in all size classes per 400 m^2 plot.
4. Remaining 30,000 acre forest surrounding the core area is managed in compliance with 3rd party certified sustainable forestry methods, promoting excellent stand development of uneven aged, native, Central Appalachian forest tree species.
5. Soil organic matter and pit and mound topography are well developed throughout most of the forest block; soils remain productive in high elevation acidic areas with base saturations of > 15%.
6. The natural fire regime is restored through a mixture of wildland and prescribed burning.

Pine-Oak-Heath Woodlands

1. Between 5 and 10 >50 acre occurrences are protected and managed.
2. Mix of even and uneven aged pine species (pitch pine and table mountain pine) dominant in canopy with saplings present. Oak species present throughout but minor canopy components.

3. The natural fire regime is restored through a mixture of wildland and prescribed burning[4].
4. Dwarf vegetation physiognomy of montane pine barren maintained through use of fire every 35+ years.
5. Soils remain productive in high elevation acidic areas with base saturations of > 15% except where base saturation is naturally low.
6. Known populations of box huckleberry *(Gaylussacia brachycera)* are maintained.
7. Pine-oak-heath woodland occurrences are embedded in 80,000+ acres of Central Appalachians mixed hardwood forest matrix.

Alluvial Floodplain Forests/Grasslands

1. Multiple examples of 25 acre patches of alluvial forests with intermittently occurring 1-5 acre patches of native warm season grasses are restored.
2. Alluvial forest consists of native riparian woody species and < 25% cover non-native, invasive species in understory per 400 m^2 plot. Grasslands consist of native warm season grass species and <25% cover non-native, invasive species.
3. Flooding regime and periods of inundation remain within natural range of variation.
4. Area surrounding occurrence is >80% natural vegetation, i.e. intergrades with Central Appalachian mixed hardwood matrix forest.

Outcrops/Barrens/Acidic Woodlands

1. All high quality examples of shale barrens in study area that fall on public lands are appropriately protected.
2. Characteristic native species composition and structure of barren communities is maintained with < 1% relative cover of non-native, invasive species present in a sample 400 m^2 plot.
3. Healthy populations of shale-barren rock-cress (*Arabis serotina*), Millboro leatherflower (*Clematis viticaulis*), wild chess (*Bromus kalmii*) and the western wallflower (*Erysimum capitatum* var *capitatum*) are maintained at current levels of abundance as are populations of the Lepidoptera species Olympia marble (*Euchloe Olympia*) and the Appalachian grizzled skipper (*Pyrgus wyandot*).

Montane Non-Alluvial Wetlands

1. All known examples of mountain ponds and seepage swamps are protected in the conservation area.
2. Acidic seepage swamp is composed of mixed age classes including old trees (>100 years old) (where blackgum is usually dominant) with hummock-and-hollow topography and a well developed shrub layer, typically composed of ericaceous species.

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[4] A fire history study will commence in the spring of 2003 being conducted by the University of Tennessee in Knoxville and the University of Texas in Austin to better determine what the fire regime and return intervals should be to restore the pine-oak-heath communities.

3. Mountain ponds have an herbaceous and/or shrubland physiognomy with distinct zonation characterized by shrubs, forbs, sedges, bulrushes, bladderworts and rushes.
4. Non-native and/or invasive species relative cover is <1% on average in a given 400 m^2 plot.
5. Seeps are fed by groundwater with flow rates and levels of inundation fluctuating within the groundwater's natural range of variability.
6. Peat/organic soil accumulation is well developed.

Cave Invertebrate Communities

1. Cave openings are protected and managed to restrict access where significant communities of cave invertebrates occur. Cave gates are designed to enable the uninhibited flow of organic material into and out of cave opening.
2. Characteristic species composition and abundance is maintained in known significant cave invertebrate community locations.
3. Autogenic (epikarst) and allogenic (surface) water inputs to basin fall within the ecological range of variability.

Bats

1. Caves with known hibernacula are protected and restricted to recreational uses through cave gates.
2. Typical bat species continue to hibernate in caves within landscape.
3. Indiana bats and small-footed myotis present in stable or increasing numbers year to year.
4. Stable temperature, humidity and air flow necessary for hibernation are maintained in protected cave entrances during winter months.

Small Ridge and Valley Rivers

1. Characteristic fish, mollusks, and aquatic insect communities are maintained within at least 80% of their known historical range within the Cowpasture watershed, and all representative species are present within historic ranges of relative abundance.
2. Roughhead shiner maintains current distribution and abundance in Cowpasture.
3. Brook trout populations maintain current distribution and abundance in headwater streams of Cowpasture.
4. Acid neutralizing capacity of low order, cold water streams is maintained at > 50 µeq/L.
5. Habitat structure of low order cold water streams includes 125 to 300 pieces of large woody debris (LWD) per stream mile and 75-200 pieces of LWD per stream mile in 4^{th} and 5^{th} order warmer water streams.
6. Low base flows during normal and drought years, regularly recurring high flows and the rise and fall rates of flood flows stay within their natural range of variation. Any water management projects take into account these parameters and manage water sources accordingly.

7. 80% of riparian habitat is restored along the Cowpasture River and tributaries.
8. The connectivity of aquatic habitat is maintained throughout the watershed.
9. Land use surrounding the Cowpasture remains in pasture or forest with very limited development.

Stresses and Sources of Stress

♦ ***Overview of Methods***

A threat is defined as a combination of the stress on the target and the source(s) of stress. A stress is an “impairment or degradation of the size, condition, and landscape context of a conservation target, and results in reduced viability of the target” (TNC 2000). Stresses are identified and ranked for each conservation target based on the *severity* of damage to the target and the *scope* or scale of damage expected over the next 10 years. Consideration of a given target’s viability attributes and ranks informs the process of identifying and ranking stresses. For instance, a target with “fair viability” indicates that there are severe and widespread stresses to the target having deleterious effects on its size, condition and context.

Each stress is attributed to one or more source for a given target (Table 5). A source of stress is defined as “an extraneous factor, either human or biological, that infringes upon a conservation target in a way that results in stress” (TNC 2000). Sources may be cited as historical or active. A historical source is currently inactive, but its past impacts remain persistent today (e.g. historical clearing of upland terrestrial forest for conversion to agriculture that continues to contribute to the flashiness of water flow during storm events). An active source contributes to the stresses on a target presently and into the future (e.g. development contributes to habitat fragmentation and loss). Sources are ranked based on both their degree of contribution to the stresses and the irreversibility of impacts over the next 10 years.

Stresses and sources of stress are ranked as “very high”, “high”, “medium” or “low”. The active and historical threats are ranked for all targets both individually (Appendix C) and collectively across the site (Table 6).

♦ ***Definition of Stresses***

The following stresses have been identified for the Warm Springs Mountain/Cowpasture River conservation targets:

1. **Altered fire regime**: Disruption of natural, historical fire return intervals, fire intensity, severity and extent in vegetation communities that changes the composition, structure and abundance of characteristic, fire-influenced species and communities.
2. **Alteration of energy flow regime**: The increase or decrease in allogenic inputs to a karst system via epikarstic water (i.e. rainwater bringing in dissolved organic matter), sinkholes (i.e. leaves, twigs, other soil organic matter) and cave entrances (i.e. “transitory organic matter” such as crickets, guano eggs, leaves, etc.). For example, a cave gate can interrupt the flow of transitory organic matter into a cave entrance by filtering out leaves, soil, crickets and other sources of food and energy for obligate cave fauna.
3. **Altered hydrologic regime**: A significant change to a river that simplifies the natural seasonal variability in baseflow (i.e. higher average minimum baseflows or lower average peak baseflows), reduces periods of inundation in alluvial communities, and may involve total overall reduction in flow volume.

4. **Acidication**: Artificial lowering of pH in water or soil that is outside the natural range of variation for natural pH.
5. **Excessive herbivory**: Consumption of vegetation by herbivores beyond the vegetation's natural ability to rejuvenate with the same diversity, composition and structure.
6. **Extraordinary competition for resources**: The process by which predominately non-native, invasive species out-compete native species and communities for resources such as light, nutrients, and water, thereby displacing the native vegetation.
7. **Extraordinary parasitism/disease**: The weakening and often eventual mortality of an organism (e.g. *Tsuga canadensis*) due to a pest, pathogen or disease (e.g. the hemlock woolly adelgid) that imperils the species viability.
8. **Habitat alteration**: A change or disturbance to the physical habitat structure that degrades its quality and function which in turn has a deleterious impact on the conservation target (e.g. the loss of large woody debris in low order streams).
9. **Habitat disturbance**: This includes a spectrum of disturbance varying from minor negative impacts such as trampling or other recreational uses to more severe impacts such as bank sloughing by cattle herds to large scale alterations of composition and structure due to clearcutting or channel dredging.
10. **Loss of soil nutrients**: The loss of exchangeable base cations (or lowered base saturation) such as calcium and magnesium associated with the loss of soil organic matter due to logging activity or acid deposition.
11. **Nutrient loading**: Addition of excessive nutrients such as nitrogen and phosphorus to cave/surface streams and rivers via sinkholes or overland flow during rain or flood events. Excess nutrients cause eutrophication of river and stream channels that lead to reduced diversity of aquatic and karst organisms.
12. **Sedimentation**: The addition of soil, sand, silt and other substrate to water bodies via overland flow during rain or flood events often resulting from erosion/disturbance of upland habitat.
13. **Toxins/contaminants**: Refers to pesticides and other organic chemicals, heavy metals or toxins used for farming, lawn care or industry that degrade water quality. Also includes aluminum toxicity due to acid deposition or road cuts that leach hydrogen sulfate in surface waters.

Table 5. Stresses and sources of stress to conservation targets in the Warm Springs Mountain/Cowpasture River conservation area. The matrix below illustrates the various sources for a given stress to a conservation target in the project area.

SOURCES of Stress	*Acidification*	*Altered fire regime*	*Altered hydrologic regime*	*Alteration of energy flow regime (in caves)*	*Extraordinary competition for resources*	*Excessive herbivory*	*Extraordinary parasitism/disease*	*Habitat loss*	*Habitat alteration*	*Habitat disturbance*	*Habitat fragmentation*	*Nutrient loading*	*Loss of soil nutrients*	*Sedimentation*	*Toxins/contaminants*
Acid deposition	**X**												**X**		**X**
Acid rock drainage	**X**													**X**	**X**
Alteration of natural fire regime		**X**													
Dams or reservoirs			**X**						**X**		**X**				
Deer management					**X**	**X**									
Historical conversion to agriculture/pasture								**X**			**X**				
Historical logging					**X**					**X**	**X**		**X**		
Inadequate cave gate design				**X**					**X**						
Incompatible agricultural practices				**X**								**X**		**X**	**X**
Incompatible confined animal feeding operations												**X**			**X**
Incompatible forestry practices				**X**	**X**			**X**		**X**	**X**		**X**	**X**	
Incompatible grazing				**X**					**X**			**X**		**X**	**X**
Invasive forest pests/pathogens							**X**								
Invasive/non-native species (plants and fish)		**X**			**X**										
Loss of chestnut									**X**	**X**					
Mining practices	**X**							**X**							**X**
Recreational use				**X**					**X**	**X**				**X**	
Rural development		**X**		**X**				**X**			**X**	**X**		**X**	

♦ ***Sources of Stress***

Each source of stress is listed below along with total conservation targets affected and descriptive information defining the source. Each active source of stress is presented below in order of its overall threat rank, from highest to lowest, followed by historical sources of stress. An *active* source contributes to the stresses on a target presently and into the future (e.g. invasive species, development) (Table 6). A *historical* source is currently inactive, but its past impacts remain persistent today (e.g. historical logging caused a tremendous loss to soil structure, nutrients and organic matter from which forests are still recovering) (Table 7). Please see Appendix C for rankings of threats for individual conservation targets.

A. Sources of Stress with High Threat Ranks

1. Invasive Forest Pests/Pathogens:

- *Total targets affected*: 3 (Alluvial Floodplain Forests and Grasslands Central Appalachians Mixed Hardwood Forest Matrix, Pine-Oak-Heath Woodlands)
- *Comments***:** Forests pests and pathogens are considered the most insidious threat besides invasive plants and acid rain currently degrading the health of the forest targets in this landscape and throughout the Central Appalachian ecoregion at large.

Present and active pests and pathogens include the following:

- **Hemlock woolly adelgid (*Pseudoscymnus tsugae*)**. This aphid sucks on the sap in twigs of hemlock trees (*Tsuga* spp.), reducing the tree's vigor and causing a loss of needles and twigs that often leads to mortality. The adelgid was introduced from Asia into the Pacific Northwest in the 1920's and was first observed in Richmond, Virginia in the 1950s (Salom 1999). However, it was not until the 1980s that the adelgid's attack on the hemlock exploded, causing mass mortality of hemlock trees in Virginia and the northeast. The present range of the pest is North Carolina to Massachusetts and it is spreading at a rate of 15 miles per year (Salom 1999). A large portion of Virginia's hemlocks and hemlock communities have been decimated over the last 10-15 years, particularly along the Blue Ridge Parkway.
- **Gypsy moth *(Lymantria dispar*).** Gypsy moth larvae defoliate many deciduous tree species, most commonly oaks (*Quercus* spp.). Multiple successive seasons of defoliation can stress these trees to the point of mortality, especially when trees are already stressed by additional factors, such as drought. Gypsy moths were introduced in Boston, Massachusetts from Europe around 1868. Gypsy moth arrived in Virginia around 1980 and has spread to the south and west of over two thirds of the state since then (Ravlin and Stein 2001). It is predicted that the hardwood forests of every county in Virginia will experience the impacts of gypsy moths by 2010 (Ravlin and Stein 2001). Outbreaks of this pest are episodic and

depend on moisture conditions (i.e. outbreaks more likely during a drought). In 2001, 130,000 acres were defoliated by the gypsy moth in Bath County, yet only 5,000 acres was defoliated in Bath County in 2002 (P. Sheridan and P. Sellers, pers. communication). While this significantly stresses the trees making them vulnerable to other diseases and pests, defoliation does not necessarily lead to mortality. Overall, the impacts of gypsy moth are much less acute than those of the hemlock woolly adelgid, which almost invariably causes tree mortality.

- **Dogwood anthracnose (*Discula destructiva*).** Dogwood anthracnose (*Discula destructiva*) is a destructive fungus that infects the leaves of flowering dogwoods (*Cornus florida*), spreading through the petioles to twigs, branches and finally the trunk. Symptoms include lesions or blotches on leaves, dead leaves, twig and lower branch die-off, epicormic shoots, cankers and girdling of tree trunks, all of which lead to tree mortality (Anderson et al. 1994). Considered exotic but of unknown origin, this disease was first documented in New York and Connecticut in 1978 and has since quickly proliferated throughout eastern forests, spreading to Virginia by the mid-1980s and continuing into North Carolina, Tennessee, Georgia much of the southeast in the 1990s. It favors understory dogwoods found in moist, cool, protected areas often on northeast facing aspects. In addition, it favors younger trees and rates of infection are higher during the spring and fall when conditions are more wet. Anthracnose also suppresses the fruit production of trees. This combined with susceptibility of seedlings and smaller trees greatly imperils the ability of the species to recruit new reproductive trees and regenerate (Carr and Banas 2000). Dogwoods contribute high levels of calcium to the nutrient budget of forest soils. Losing this species could be a threat to the health of forest communities where it is a significant understory species (P. Coulling, pers. communication).
- **Chestnut blight (*Cryphonectria parasitica*)**. The chestnut blight was introduced to North America in 1904 via an Asian chestnut species that was imported to the Bronx Zoological Park in New York. The blight quickly spread throughout the chestnut's native range and infected all trees by the 1940s. The blight is a fungus that enters the tree through cracks in the bark when the tree is young, then feeds on the cambium and phloem of the tree creating girdling cankers that kill the tree within a decade. Because the root system is not affected, chestnut stumps resprout but saplings are continuously re-infected with the blight once their bark begins to furrow. Currently, chestnut persists as a common understory tree throughout the s. Appalachians, including the Warm Springs landscape, as does the blight which continues to suppress the maturity of these trees (American Chestnut Cooperators' Foundation 2002).

Potential new pests and pathogens include:

- **Beech bark disease**. Beech bark disease refers to a canker-forming fungal pathogen *Nectria coccinea* var. *faginata* that infects the bark of the American beech tree (*Fagus grandifolia*) via the activities of an exotic scale (*Cryptococcus fagisuga*). The beech scale, introduced from western Europe to Nova Scotia at the turn of the 20th century, creates wounds in the bark through its feeding, facilitating the invasion of the nectria fungus that then creates cankers in the bark (Houston and O'Brien 2002). The trees can persist for years with beech bark disease or the cankers eventually girdle and kill the trees. This "deadly duo" of forest pathogens is distributed throughout New England and has now spread to northwestern Virginia. While it has not spread to the WSM/CR landscape yet, its spread is inevitable and should be monitored closely.
- **Asian long-horned beetle (*Anoplophora glabripennis).*** This species makes its way into U.S. ports from China via wooden cargo crating. It was first observed in Chicago in 1996 and in New York City in 1998. It bores into trees and tunnels into branches and tree trunks, eventually killing the tree. Its primary host trees appear to be maples (*Acer* spp.) and buckeyes (*Aesculus* spp.), but it will feed on a wide variety of hardwoods. Its natural rate of dispersal is very slow due to limited flying ability, and its reproduction is cryptic, laying few eggs in low density among many trees; however, its prevalence in wooden cargo as larvae is extremely problematic. Already, it has been found in roughly 30 port sites and inland warehouses in a dozen states (Canadian Food Inspection Agency 2001). There is no known evidence of the beetle in Virginia at this point.

2. Invasive/non-native plant species

- *Total targets affected*: 3 (Central Appalachians Mixed Hardwood Forest Matrix, Alluvial Floodplain Forests and Grasslands, Outcrops/Barrens/Acidic Woodlands)
- *Comments***:** Invasive, non-native plants are not nearly as widespread in the WSM/CR landscape as in forests of the Piedmont or the Coastal Plain due to the high percentage of contiguous forest cover. However, four significant species are locally abundant throughout the landscape: multiflora rose (*Rosa multiflora*) in pastures and alluvial floodplains, garlic mustard (*Alliaria petiolata*), oriental bittersweet (*Celastrus obiculatus*) and Japanese grass (*Microstegium vimineum*) which all favor rich, moist soils of rich forest understories. Garlic mustard, a shade-loving biennial, is found in the understory of more mesic oak forests, alluvial floodplain forests, and calcareous forests. It invades the forest understory following disturbances such as road building or logging, and creates huge monocultures, eliminating native understory herbaceous species. Oriental bittersweet is a woody, deciduous vine that can invade sunny open sites such as forest edges in addition to forest interiors. It out-competes native vegetation by growing over it and preventing photosynthesis. Japanese grass is found mostly exclusively in floodplain forests, preferring more

hydric soils. It is ubiquitous along most riparian areas in the valleys of the WSM/CR landscape, forming dense green carpet-like mats that cover the substrate, displacing most native species. Other species which could potentially pose a future problem to forest composition in this conservation area are tree-of-heaven (*Ailanthus altissima*) and honeysuckle (*Lonicera japonica*). Spotted knapweed (*Centaurea maculosa*) and *Bromus sterilus* are both problematic invasives to shale barren endemic plant species and communities in other states such as Maryland and West Virginia; however, neither of these plants is yet known to occur yet on Virginia shale barrens in the WSM/CR conservation area.

B. Sources of Stress with Medium Threat Ranks

3. Deer Management

- *Total targets affected*: 3 (Central Appalachians Mixed Hardwood Forest Matrix, Pine-Oak-Heath Woodlands, Alluvial Floodplain Forests and Grasslands)
- *Comments***:** The rise in white-tailed deer density since the turn of the century underscored by cultural hunting and management practices that favor doe recruitment has led to an increase in deer herbivory in the understories of eastern deciduous forests (Tilghman 1989). The impacts of this are to reduce herbaceous understory diversity and density while additionally inhibiting oak and hemlock regeneration. Deer eat both the oak saplings in addition to consuming the acorns, preventing both oak seedling establishment and recruitment (P. Coulling, personal communication). Deer browse on hemlock saplings further jeopardizes the survival and recovery of the eastern hemlock that is currently being lost to the hemlock woolly adelgid. Deer may also influence tree regeneration indirectly by selectively browsing on herbs, particularly native herbs, and thus altering herbaceous composition in favor of invasive native or non-natives species. For example, the herb layers dominated by broad-leaved ferns such as the native *Dennstaedtia punctilobula* which are widespread in contemporary mesic oak forests undoubtedly reflect heavy deer browse and may significantly impede oak regeneration (P. Coulling, personal communication). While much anecdotal evidence suggests deer are having an adverse impact on oak and hemlock regeneration and other understory species in the WSM/CR conservation area, no studies or data exist that determine the extent or scope to which deer browse is affecting forest understory richness or abundance in the landscape. It is clear though that deer browse is contributing to a complex interplay of several stresses leading to a decline in oak regeneration and overall understory health.

4. Fire exclusion

- *Total targets affected*: 2 (Central Appalachians Mixed Hardwood Forest Matrix, Pine-Oak-Heath Woodlands).

- *Comments*: Fire exclusion is considered another contributor to the lack of oak regeneration in the montane and acidic oak-hickory forests found in the Central Appalachians Mixed Hardwood Forest Matrix (Abrams 1992). In addition, fire exclusion prevents the germination of fire-dependent pitch pines and table mountain pines in the Pine-Oak-Heath Woodlands (Williams 1998). Oaks are fire-adapted, having thick bark and the ability to sprout from stumps and roots, and this gives oak species a competitive advantage over other more mesophytic species such as beech, red maple and birch. In the absence of fire, oaks lose this advantage and other mesophytic, fire-intolerant species become dominant in the canopy. In addition, since vulnerability to fire is in large part a size-related phenomenon, a sufficient period of fire exclusion may allow these mesophytic trees to reach a size at which they are no longer susceptible and are somewhat fire-retardant. Thus, the simple reintroduction of fire may not be sufficient to restore forest composition and structure to those characteristic of unaltered fire regimes (P. Coulling, personal communication). In Pine-Oak-Heath Forests, since table mountain and pitch pines require fire to release seeds from serotinous cones, the exclusion of fire leads to competitive displacement and succession by chestnut oaks and red maple. In the montane pine barren, fire is important for maintaining the barren physiognomy though the productivity of the community is limited primarily by edaphic factors. Historically, fire has played an important role in maintaining these forests, and without it, the forests are exhibiting changes in canopy composition and abundance of understory density. However, much controversy and equivocal data exists regarding the frequency of fire return intervals, intensity and duration in forest of the Central Appalachians.

5. Rural development

- *Total targets affected*: 6 (Central Appalachians Mixed Hardwood Forest Matrix, Pine-Oak-Heath Woodlands, Alluvial Floodplain Forests and Grasslands, Bats, Small Central Appalachian River System, Cave Invertebrate Communities)
- *Comments*: Rural development refers to second homes, trailer homes and other residential developments that are incompatible with conservation target persistence. The most immediate threat of residential development is on the western slope of Warm Springs Mountain where a several second homes have been built over the last few years. Additionally, Virginia Hot Springs, Inc. sold a 3,500 acre tract to Celebration Associates, Inc., a corporation that seeks to integrate the development of communities with natural amenities. The tract is located along highway 220 close to the town Warm Springs, just outside the western boundary of the WSM/CR conservation area. Second home development is a more negligible threat throughout the Cowpasture River Valley. New trailer homes are a greater threat due to the accompanying septic systems that can contaminate groundwater streams and in turn

impact subterranean invertebrate fauna. However, predicting their future distribution is very difficult. Overall, the fact that the small, rural populations of Bath and Highland County are growing so little indicates that the likelihood of primary residences such as trailers, trailer parks or subdivisions is relatively low.

6. **Incompatible forestry practices**
   - *Total targets affected*: 4 (Central Appalachians Mixed Hardwood Forest Matrix, Alluvial Floodplain Forests and Grasslands, Small Central Appalachian River System, Bats)
   - *Comments***:** Incompatible forestry practices may include methods such as high grading, shelterwood cutting, and clear cutting forests as well as the secondary effects of these harvesting methods, including erosion and siltation of streams and creeks. The USFS uses modified shelterwood cuts for its timber sales. The number of timber sales per year and the volume cut varies greatly among the three districts in the USFS. Warm Springs Ranger District has had only one sale per year for the last five years. Along the Cowpasture River valley south of 39, private landowners rarely harvest land for timber as most of the privately held lands have been cleared for agriculture for the last two centuries. In fact, many landowners have been allowing portions of their pastures to revert back to forests (P. Sheridan, pers. communication). North of 39 more private harvesting of timber takes place. One motivating factor behind many of the private and public timber sales is salvage cutting of forests that have been damaged by gypsy moth or hemlock woolly adelgid. In addition, incompatible forestry includes private landowners who cut standing snags that may be ideal habitat for bats such as the shagbark hickory for Indiana bats.

C. Sources of Stress with Low Threat Ranks

7. **Acid deposition**
   - *Total targets affected*: 5 (Central Appalachians Mixed Hardwood Forest Matrix, Pine-Oak-Heath Woodlands, Outcrops/Barrens/Acidic Woodlands, Montane Non-Alluvial Wetlands, and Small Central Appalachian River System)
   - *Comments***:** Acid deposition originates west of the Appalachians in the Ohio Valley, Tennessee Valley and in West Virginia from industrial power plants and vehicular emissions. Western Virginia and West Virginia are considered to be exposed to among the highest acidic deposition levels in the United States (Webb 2002). It affects both low order streams in the Cowpasture watershed and forest soils at high elevations where soils are thinner and naturally acidic. It is hypothesized that acid deposition has caused the elevated sulfate concentrations and decreasing anion buffering capacities in low order brook trout streams found on the flank of Warm Springs Mountain and throughout the Central Appalachians (R. Webb,

personal communication and unpublished data). The acidification of these streams leads to the extirpation of brook trout and other fish species.

Higher soil acidity also contributes to the leaching of exchangeable base cations and produces toxic levels of aluminum in the soil. Both of these stresses can lead to the mortality of trees and shrubs in higher elevation forests, particularly chestnut oak and pine-oak-heath forests which occur on naturally acidic, poor, thin soils. At this point in time, little data exist to determine how acid deposition affects the forests of the WSM/CR landscape, though it is considered to be one of the most severe potential threats to Appalachian forests over the next 50 years (P. Coulling, pers. communication, and R. Webb, pers. communication). Please see Appendix D entitled “Supplemental Material on Acidic Deposition and the Warm Springs Mountain/Cowpasture River conservation area” for more information on this threat as well as all unpublished data.

8. Incompatible confined animal feeding operations

- *Total targets affected*: 2 (Small Central Appalachian River System, Cave Invertebrate Communities)
- *Comments***:** The poultry industry has a stronghold in the adjacent Shenandoah Valley and is expanding operations into the Potomac watershed north of the Cowpasture. However, new poultry facilities have been observed in the towns of Head Waters along Shaw’s Fork, a tributary of the Cowpasture, and in McDowell along the Bullpasture (P. Bugas, pers. communication). It is uncertain whether this trend will continue as it depends highly on landowner interest and economic incentive. If it were to continue, though, it could seriously jeopardize both surface and groundwater quality. However, a recent and devastating outbreak of avian flu in the Shenandoah Valley may be a deterrent to local interest in attracting the poultry industry to this landscape.

9. Recreational use

- *Total targets affected*: 3 (Montane Non-Alluvial Wetlands, Bats, Cave Invertebrate Communities)
- *Comments***:** In regards to wetlands, recreational use includes ATV and ORV traffic through wet areas that causes erosion, altered hydrology and other disturbances to the habitat. However, ATV and ORV use and traffic in the remote area in which mountain ponds and seepage swamps occur is negligible. Recreation use also refers to caving activities that disturb cave invertebrates and wintering bats. Caving is very popular sport in Virginia, and members of the Virginia Speleological Society (VSS) frequent many of the caves in this landscape. While many cavers are conscientious, the slightest trampling may adversely impact invertebrates. In addition, caving activities can disrupt or interfere with the flow of organic matter into the caves. Hibernating bats are also very sensitive to

disturbance by humans at the cave entrance; however, many of the significant caves with bats in the conservation area have been gated.

10. Incompatible agricultural practices/ Incompatible grazing practices

- *Overall threat rank*: Low
- *Total targets affected*: 2 (Small Central Appalachian River System, Cave Invertebrate Communities)
- *Comments***:** Cattle grazing is the largest agricultural use of the land in this landscape and has been for hundreds of years. Crops such as corn are grown exclusively for feeding cattle. The stresses caused by grazing include erosion in waters and nutrient loading resulting in eutrophication in the Cowpasture River, its tributaries and groundwater streams via sinkholes. Many landowners do not implement best management practices (BMPs) such as fencing or vegetated riparian buffers, and BMPs do not exist for sinkholes/groundwater. Moreover, many landowners remove large woody debris from the river channel to make cattle access to drinking water easier or to prevent destruction of their water gap fences. In many cases, removing woody debris is an issue of aesthetics for farmers and landowners who prefer the river channel to look clear and clean. The net loss of woody debris is hypothesized to have changed the habitat structure and flow regime of the Cowpasture and its tributaries for the native fish populations through simplifying stream structure and increasing the speed of stream flow that leads to more erosion of channels and riparian zones and sediment transport (Kappasser 1999). Overall though, However, the cattle and agricultural industry is small scale in the Cowpasture watershed and impacts on the river or groundwater systems are considered low.

11. Mining practices

- *Total targets affected*: 1 (Outcrops/Barrens/Acidic Woodlands)
- *Comments***:** This refers to the practice of gravel mining for shale from shale barrens for roads and driveways. This is a very localized threat that occurs on private property. However, it can be very destructive to shale barren communities as well as contributing to acid drainage into streams.

12. Inadequate cave gate design

- *Total targets affected*: 2 (Cave Invertebrate Communities, Bats)
- *Comments***:** Cave gates prevent cavers from trespassing into cave entrances and disturbing bat hibernacula. However, their construction often blocks the flow of organic matter into the cave that is necessary to support the ecology of invertebrates. The cave gates are usually horizontal bars that act like large sieves, collecting woody debris and other detritus at the cave entrance which in turn builds up, creating a dam that blocks energy flow in and out of the cave. The extent to which this is a problem for cave invertebrates for gated caves in this landscape is unknown and should be further investigated.

13. Acid rock drainage

- *Total targets affected*: 1 (Small Central Appalachian River System)
- *Comments***:** Acid rock drainage is the local acidification of streams and rivers due road cuts in to the highly acidic shale characteristic of the WSM/CR landscape. The increased acidity caused by this phenomenon releases excessive iron and manganese that leads to and increase in hydrogen sulfate which can potentially cause die-offs of fish and other aquatic fauna (Wil Orndorff, pers. communication). At this point, little is known about acid rock drainage and its potential effects on aquatic life in a highly alkaline watershed such as the Cowpasture.

14. Non-native, invasive fish species

- *Total targets affected*: 1 (Small Central Appalachian River System)
- *Comments*: As in virtually every drainage basin across the country, several non-native fish have naturalized in the Cowpasture watershed such as the muskellunge, the rainbow and brown trouts, and the small-mouthed bass. The wild brook trout populations are threatened by the brown trout which continue to be stocked by VDGIF at Coursey Springs Fish Hatchery on the Cowpasture south of Williamsville. Brown trout work their way up to the low order, high gradient cold water streams from the mainstem and dominate the deep pools, hybridize with the brook trout (the offspring of such a union is called a “tiger trout”), and prey on juvenile brook trout. However, wild brook trout populations are considered to be healthy at present.

  The telescope shiner, a species introduced through bait bucket dumping, could pose a substantial threat to the viability of the roughhead shiner if sedimentation and turbidity increase in the Cowpasture in the future. The telescope occupies a similar ecological niche as the roughhead and is much less sensitive to the degradation of water quality than the roughhead. If water quality is degraded, the telescope can gain a competitive advantage over the roughhead and displace the rare species from its habitat. However, as long as water quality remains high, the telescope shiner will be a negligible threat to the roughhead shiner (P. Bugas, pers. communication).

D. Historical Sources of Stress

1. Historical conversion to agriculture/pasture

- *Overall threat rank*: Very High
- *Total targets affected*: 2 (Central Appalachians Mixed Hardwood Forest Matrix, Alluvial Floodplain Forests and Grasslands)
- *Comments*: The majority of alluvial forests found in the Cowpasture River valley and the forests sloping down into the floodplains were converted to pasturelands by European settlers beginning in the mid-eighteenth

century. Native Americans created and maintained pasture or prairies throughout the valley for agricultural and hunting purposes for centuries by using fire; however, the widespread mechanical clearing of forests for cattle or sheep grazing has been far more destructive and far-reaching in scope to native forests. Examples of high quality alluvial floodplain forests and native grasslands are rare in the Cowpasture River valley. While restoration is possible, the conversion of forests to pastureland has left few examples of high quality, viable alluvial or slope forests to serve as "sources" (i.e. seed stock, genetic diversity, and sufficient core area) for forest regeneration. Dry montane calcareous forests and woodlands have also been decimated by conversion to pastureland though more high quality examples remain that provide models for restoration.

2. Historical logging

- *Overall threat rank*: Medium
- *Total targets affected*: 2 (Central Appalachians Mixed Hardwood Forest Matrix, Alluvial Floodplain Forests and Grasslands)
- *Comments*: The majority of logging in this region took place at the turn of the century with the advent of the railroad. Almost all accessible timber was cut during this period, while the slash was often burned. Since this coincided with the loss of the American chestnut, the logging changed the structure and composition of the forests radically, producing a new forest that has no true historical analog (P. Coulling pers. communication). Many of the "biological legacies" which signify a healthy forest ecosystem such as older age classes of trees, standing dead snags and plentiful downed woody debris are missing from the landscape today. Moreover, the logging practices employed and the associated catastrophic fires caused the erosion and destruction of soil organic matter and soil nutrients that had been accumulating for thousands of years. Finally, one of the lasting relics of historical logging is the ubiquitous presence of logging roads throughout the mountains within the conservation area. These roads create abundant edge effects and corridors for invasive species, predators and other disruptions to forest ecology, while also imposing unnatural fire breaks, thus contributing to fire exclusion.

3. Loss of chestnut

- *Overall threat rank*: Low
- *Total targets affected*: 2 (Central Appalachians Mixed Hardwood Forest Matrix, Small Central Appalachian River System)
- *Comments***:** The loss of the American chestnut (*Castanea dentata*) from the forest canopy in the early half of the twentieth century was a catastrophic ecological disturbance. It was caused by the chestnut blight (*Cryphonectria parasitica*), an exotic pathogen introduced from Asia that spread to the Central Appalachians. Historically the chestnut was the dominant tree, composing at least 40% of the forest canopy. Forests once dominated by grand canopies of this majestic tree have now succeeded to

oak and hickory community types or sugar maple in more mesic sites. On one hand, it is thought that present day forests have recovered from this devastating loss and have reached a new dynamic equilibrium. On the other, it is postulated that the forest has been fundamentally destabilized due to this event and there are cascades of effects that continue to contribute to the decline in forest health today.

For example, since the chestnut was the keystone species for mast production in the forest, its disappearance led to crashes and extirpations of small mammal populations. It is unknown the extent to which the loss of these mammals has affected forest dynamics, or for those species remaining, how the adaptation to oak mast is changing the forest for the future. For example, mice primary eat acorns, whereas chestnuts used to be their preferred food source pre-blight. In addition, mice prey upon gypsy moth larvae. It is hypothesized that fluctuations in mice populations are related to the outbreaks of gypsy moth in oak forests (Elkinton et al. 1996). Since oaks produce acorns biennially as opposed to annually like the chestnut, the mice experience a population crash every 1.5 to 2 years which in turn leads to a gypsy moth outbreak (Ostfeld et al. 1996). Would gypsy moth outbreaks be as destructive if chestnut were still a canopy dominant and mice had a consistent source of food? This is just one of many questions regarding the persistent stresses to forest health related to the loss of chestnut.

The loss of the chestnut has also meant a loss of woody debris in rivers and tributaries since the wood of oaks, hickories and other current day dominant canopy species do not persist as well in water as that of chestnut. Chestnut debris in the stream channels is in its final stages of decay and large flood events will often wash out these remaining chestnut structures that have served as sediment storage, unleashing and delivering large sediment plumes downstream. Without new sources of chestnut, the primary supply of large woody debris has been lost in the Appalachian streams, impeding stream channel recovery from historical and current logging events (Kappesser 1999).

♦ ***Overall Conservation Area Threat Rank***

Overall, the active threat rank for the Warm Springs Mountain/Cowpasture River conservation area is high for the terrestrial targets and low for the subterranean and aquatic targets (Tables 6 and 7). The higher threat rank for terrestrial targets reflects the insidious combination of multiple invasive pathogens and plant species amplified by historical impacts of logging and land conversion. Unlike most conservation areas in Virginia where the highest ranked threat is often development, forest pathogens and invasive plant species are driving the decline of forests here. These threats are highly intractable and difficult to control once they have established a presence. The karst and aquatic targets are threatened to a much lesser extent than the forest targets due to a lack of industrial land uses, confined animal feeding operations, high density residential development or alterations to hydrologic regime such as dams or reservoirs. Relative to other conservation areas, there are few *local* threats to the targets at this time. Rather, the most problematic threats are *regional* in scope such as invasive pathogens and plant species, deer management, acid deposition and fire exclusion.

Table 6. Active threats and ranks across Warm Springs Mountain/Cowpasture River conservation targets.

	Active Threats Across Conservation Targets	Mixed Hardwoods Forest Matrix	Pine-Oak-Heath Woodlands	Alluvial Forests/ Grasslands	Outcrops, Barrens and Acidic Woodlands	Bats	Small Central Appalachian River System	Cave Invertebrate Communities	Montane Non-Alluvial Wetlands	Overall Threat Rank
1	Invasive/non-native plant species	High	-	High	High	-	-	-	-	High
2	Invasive forest pests/pathogens	High	High	Medium	-	-	-	-	-	High
3	Deer management	High	Low	Medium	-	-	-	-	-	Medium
4	Fire exclusion	Medium	High	-	-	-	-	-	-	Medium
5	Rural development	Medium	Medium	Low	-	Low	Low	Low	-	Medium
6	Incompatible forestry practices	Medium	-	Medium	-	Low	Low	-	-	Medium
7	Acid deposition	Low	Low	-	Low	-	Medium	-	Low	Low
8	Incompatible confined animal feeding operations	-	-	-	-	-	Medium	Low	-	Low
9	Recreational use	-	-	-	-	Low	-	Low	Low	Low
10	Incompatible grazing	-	-	-	-	-	Low	Low	-	Low
11	Incompatible agricultural practices	-	-	-	-	-	Low	Low	-	Low
12	Mining practices	-	-	-	Low	-	-	-	-	Low
13	Inadequate cave gate design	-	-	-	-	Low	-	-	-	Low
14	Acid rock drainage	-	-	-	-	-	Low	-	-	Low
Threat Status for Targets and Site		High	High	Medium	Medium	Low	Medium	Low	Low	High

Table 7. Historical threats and ranks across Warm Springs Mountain/Cowpasture River conservation targets.

Historical Sources Across Systems		Mixed Hardwoods Forest Matrix	Pine-Oak-Heath Woodlands	Alluvial Forests/ Grasslands	Outcrops, Barrens and Acidic Woodlands	Bats	Small Central Appalachian River System	Cave Invertebrate Communities	Montane Non-Alluvial Wetlands	Overall Threat Rank
1	Historical conversion to agriculture	Low	-	High	-	-	-	-	-	Medium
2	Loss of chestnut	High	-	-	-	-	Low	-	-	Medium
3	Historical logging	Medium	-	Medium	-	-	-	-	-	Medium
Historical Source Status for Targets and Site		Medium	-	Medium	-	-	Low	-	-	High

Conservation Strategies

♦ ***Overview of Methods***

The next step in the conservation area planning process is to decide how best to protect and conserve the conservation targets, given the analyses of their ecological integrity and threats. The objectives of the conservation area plan are to improve the health of targets and abate their threats in order to achieve the desired future condition for each given target over time as described in the "Conservation Targets" chapter of this document. Specific objectives are presented that describe how a threat is to be abated or a target's health restored. Based on these *threat abatement and restoration goals*, the planning team has developed conservation strategies to fulfill conservation and threat abatement goals for the Warm Springs Mountain/Cowpasture River landscape (Table 8). Goals and strategies are prioritized based on abatement of highest ranked threats to lowest ranked threats. Please note some low ranked threats do not have associated strategies due to their low priority.

For each conservation strategy, a list of *action steps* necessary to implement a given strategy are present that will be incorporated in the TNC-VA annual strategic plan and staff goals and objectives. In addition, key partners and key constituencies for successful implementation are noted. A *key constituency* is either a decision-making body (e.g. the Virginia General Assembly or a local jurisdiction) or a stakeholder (e.g. a private land owner or the Farm Bureau) that has the power or political will to strongly influence and determine the outcome and success of a given strategy. TNC must address what will motivate these entities to support a strategy. A *key partner* is an organization or group such as the Division of Natural Heritage or the Cowpasture River Preservation Association with which TNC works closely, having similar goals and missions in a particular conservation area (Table 9). Sometimes a key constituency can also be a key partner. For example, TNC may work in partnership with the Warm Springs District of the George Washington National Forest, but will need to influence higher organizational levels within the USFS such as the Southeast Region or national level. Finally, *information and research needs* are identified for a goal/strategy where necessary for successful implementation.

Strategies were also evaluated for their *benefits* to the target in terms of threat abatement or restoration, overall *feasibility* of implementation (a function of both institutional and leadership capacity to carry out the strategy as well as the complexity involved in achieving the desired results), and the financial *cost* associated with the strategy (Table 10). While the results of this evaluation are not necessarily used to assign priority to the conservation strategies, they are helpful in deciphering and taking into full consideration the realistic constraints involved with implementation.

♦ ***Threat Abatement and Restoration Goals, Conservation Strategies, Key Constituencies, Key Partners and Information/Research Needs***

Threat Abatement and Restoration Goal 1. Prevent new introduced, non-native, invasive pests/pathogens and plant species from spreading into landscape.

Strategy 1. *Develop national and state policies that will determine ecologically sound detection and prevention measures to prohibit the introduction and slow the spread of new invasive species.*

Action Steps*:*

1. Participate as member of the Invasive Species Advisory Committee to the National Invasive Species Council (NISC), broadly influencing U.S. agency policies.
2. Support legislation to authorize NISC, which was established by Executive Order.
3. In cooperation with the University of Richmond, introduce invasive species legislation to the General Assembly that will establish an Invasive Species Council in Virginia and (2) prohibit state agencies from introducing *new* invasive species.
4. Work with Virginia Department of Agricultural and Consumer Services (VDACS) to anticipate and place new invasive, non-native species on state noxious weed list.
5. Develop native vegetation ordinances in localities that promote the use of native plants in landscaping and new developments while eliminating the use of non-native, invasive species in these activities. As part of this, seek endorsement of local nursery associations to promote sale of native plants and limit introduction and sale of invasive, non-native plants.
6. Support U.S. Forest Service (USFS) to develop and implement frequent (every 5 years or less) forest inventory programs to inventory and monitor forest composition and structure, invasive species and incidences of forest pests/pathogens.

Key Constituencies: Global Invasive Species Programme (GISP), NISC, U.S. Congress, U.S. Department of Agriculture, U.S. Department of Commerce, U.S. Department of Interior, VDACS, and the Virginia General Assembly

Key Partners: National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), USFS, University of Richmond, Virginia Department of Conservation and Recreation (DCR)—Division of Natural Heritage (DNH), and Virginia Department of Forestry (VDOF).

Threat Abatement and Restoration Goal 2. Control the most threatening established pests and pathogens (i.e. hemlock woolly adelgid, gypsy moth and dogwood anthracnose) in priority areas on Warm Springs Mountain Preserve.

Strategy 2. *Implement best available treatments to prevent and reduce impacts by problem pests or pathogens in high priority biologically significant areas.*

Action Steps:

1. Implement localized systemic insecticide treatments of hemlock woolly adelgid on Warm Springs Mountain (WSM) and other high priority small patch hemlock sites.
2. Consider the use of the lady beetle bio-control on selected hemlock stands to prevent infestation by hemlock woolly adelgid.
3. Use best available controls for gypsy moth when necessary. Develop a decisions analysis tree to decide how and when to do treatment for gypsy moth.
4. Once blight-resistant genetic stock for American chestnut is available, conduct research trials in partnership with USFS, DOF, NPS and ACF to establish chestnut in select areas.
5. Consider introducing anthracnose resistant cultivar of the flowering dogwood to select areas where dogwood mortality is highest.

Key Constituencies: The Homestead
Key partners: NPS, USFS, VDOF
Information and Research Needs:

- Work with state and federal agencies to secure grants to study new controls methods, including biocontrol, for landscape scale abatement of forest pests/pathogen.

Threat Abatement and Restoration Goal 3. Control most threatening invasive, exotic weeds on priority tracts in conservation area.
Strategy 3.1. *Implement direct control measures of targeted invasive species on Warm Springs Mountain Preserve and publicly-owned priority conservation areas.*

Action Steps:

1. Designate "weed control zones" (i.e. the areas most vulnerable to future weed infestation) on TNC property, USFS special designation areas, and other significant conservation tracts within the project area.
2. Collaborate with partners to assess the full array of weed management tools and methods, including bio-controls and use those found to be the most effective.
3. Work at national level to have USFS categorically excluded from NEPA regulations requiring an EIA to use herbicides for invasive species control.
4. Lobby for higher allocation of USFS funds for invasive plant control programs via the Southeast Region for the George Washington and Jefferson National Forest.
5. Recruit volunteer weed watchers to survey weed control zones on priority tracts on both TNC preserves and publicly owned lands.

Key Constituencies: Congress, EPA, USDA, USFS
Key Partners: DCR-DNH, NPS, USFS, Virginia Department of Game and Inland Fisheries (VDGIF), VDOF
Information and Research Needs:

1. Conduct surveys to map the full extent of infestation and threat posed by problem weed species (e.g. garlic mustard) to designate weed control zones (Action Step 1).
2. Find examples of landscape scale weed control projects and methods for prioritizing areas for treatment.
3. Track current research being conducted on biocontrols for garlic mustard.

Strategy 3.2. *Utilize, improve and promote publicly funded cost share programs for weed control.*

Action Steps:

1. Expand or amend existing cost share programs such as Conservation Reserve Enhancement Program (CREP), Forest Land Enhancement Program (FLEP), or the Wildlife Habitat Incentive Program (WHIP) to provide sufficient funds that enable land owners to control problem weeds.
2. Demonstrate the cost of invasive weeds to land owners through economic analysis.
3. Collaborate with Mountain Soil and Water Conservation District to demonstrate weed control methods on private lands.
4. Develop literature on weed control methods to distribute to private landowners that own significant tracts of alluvial floodplain habitat.

Key constituencies: Agriculture Research Services, Farm Service Agency, Farm Bureau, National Resources Conservation Service (NRCS), private land owners and VDACS.
Key Partners: DCR-DNH, Mountain Soil and Water Conservation District (MSWCD), Virginia Native Plant Society (VNPS), and Virginia Tech Co-operative Extension

Threat Abatement and Restoration Goal 4. Reduce deer populations to biological carrying capacity of landscape.

Strategy 6. *Amend state and federal deer management plans to reduce deer populations.*

Action Steps:

1. Change VDGIF policies to promote doe hunting through increasing the doe bag limit, adding special doe hunting days to regular season, and educating hunters on deer browsing problem (e.g. distribute literature when license is purchased).
2. Work with federal district rangers to permit additional doe hunting days to regular hunting season.

Key Constituencies: Local hunt clubs, USFS, and VDGIF
Key Partners: USFS, VDGIF
Information and Research Needs:

- Determine the biological carrying capacity of deer for the Cowpasture Watershed and set goals for population reductions.

Threat Abatement and Restoration Goal 5. Restore historic fire regime for Pine-Oak-Heath Forests on Warm Springs Mountain Preserve and USFS lands within forest block for 5-10 examples greater than 50 acres. Where possible, restore historic fire regime for the montane and acidic oak-hickory forest types found in the Central Appalachians Mixed Hardwood Forest Matrix.

Strategy 4. *Promote and implement prescribed fire to restore and maintain Pine-Oak-Heath Woodlands and oak-hickory forests on Warm Springs Mountain Preserve and USFS lands where feasible.*

Action Steps:

1. Write and implement a fire management plan for Warm Springs Mountain Preserve.
2. Work with USFS to prioritize areas for prescribed burning and develop fire management plans and burn prescriptions.
3. Promote expansion of USFS fire management programs in order to increase acreage burned annually in priority areas.
4. Publicly support the use of prescribed burning by the USFS as a tool for ecological management, restoration and conservation.
5. Apply for funds from the National Fire Plan to reduce fuel loading near the urban-wilderness interface; use funds for prescribed burning and for public education.
6. Design and implement fire effects monitoring program in conjunction with the USFS for all prescribed burning activities.

Key Constituencies: The Homestead, Bath County, local citizens

Key Partners: DCR-DNH, University of Tennessee, University of Texas, USFS, VDOF, and VDGIF

Information and Research Needs:

- Contract with universities to conduct a fire history study of Pine-Oak-Heath Woodlands on Warm Springs Mountain to determine the fire return intervals (or fire frequency) and fire intensity.

Threat Abatement or Restoration Goal 6. Protect all priority conservation areas within the WSM/CR landscape.

Strategy 6.1. *Protect viable occurrences of conservation targets through acquisition or conservation easement.*

Action Steps:

1. Acquire Warm Springs Mountain from Virginia Hot Springs, Inc.
2. Designate TNC/Heritage priority conservation areas (a.k.a. standard portfolio sites or Natural Heritage sites) as Research Natural Areas in revision of George Washington National Forest Management Plan.
3. Work with the Valley Conservation Council (VCC), Virginia Outdoors Foundation (VOF), and local land trusts to secure conservation easements on private properties through donation or public funds.
4. Secure conservation easements of high quality forest targets through the Forest Legacy Program.

5. Secure easements to prohibit concentrated animal husbandry in critical karst conservation areas and aquatic sites.
6. Assist DCR-DNH and VDGIF in the protection of Hupman's Saltpeter Cave.
7. Nominate publicly owned caves (e.g. Butler's Cave, Breathing Cave) for protection under the Federal Cave Resource Protection Act.
8. Work with partners to obtain easements on shale mining where high priority shale barrens occur, while promoting incentives for landowners to find alternative sources of road fill.

Key Constituencies: Local private landowners, U.S. Congress, Celebration, Inc., The Homestead, Virginia General Assembly
Key Partners: Cowpasture River Preservation Association (CRPA), DCR-DNH, USFS, VCC, VDGIF, VDOF, VOF, and Virginia Department of Mines, Minerals and Energy (DMME)
Information and Research Needs:

1. Develop a protection priority map (i.e. collect tax parcel data for project area and overlay with distributional data for conservation targets to determine best potential protection opportunities).
2. Develop cave and karst management plans to protect target invertebrate communities and bats.
3. Identify critical shale barrens on private land where mining potentially occurs.

Strategy 6.2: *Implement compatible land use planning and zoning that will protect priority conservation areas from development or confined animal feeding operations.*

Action Steps:

1. Recommend that local jurisdictions consider the protection of conservation targets in their county comprehensive plans.
2. Conduct assessment of county and landowner interest in the poultry business and identify other economic growth options; based on this information, work with local jurisdictions to encourage alternative options for economic development that ensure the protection of conservation targets.
3. Support the Chesapeake Bay Foundation (CBF) and other partners to work with the Virginia Department of Environmental Quality (DEQ) and DCR to improve existing regulations (e.g. Virginia Pollution Abatement permitting process) to prohibit spreading of poultry waste in critical karst areas and in close proximity to aquatic sites.

Key Constituencies: Farm Bureau, Bath and Highland County Board of Supervisors, Central Shenandoah Planning District Commission (CSPDC), The Homestead, Celebration, Inc., local landowners
Key Partners: CRPA, CBF, DCR-DNH, DMME, VDGIF
Information and Research Needs:

1. Review county comprehensive plans for Bath and Highland County.

2. Analyze and compare the cost versus the benefits of various compatible economic growth options and the poultry industry.

Threat Abatement or Restoration Goal 7. Restore and maintain up to a 50,000 acre core area of forest block to have old growth structural attributes and characteristic native herbaceous understories.

Strategy 7. *Define, promote and demonstrate forest management practices that favor the restoration and maintenance of forest targets on private and public lands.*

Action Steps:

1. Demonstrate silvicultural techniques that will restore forest matrix to desired future condition at a landscape scale.
2. Recommend forest management practices in matrix forest blocks for public (via planning) and private lands (via VDOF and private consultants).
3. Work with USFS to designate forest block as a Research Natural Area in the upcoming revision of the George Washington National Forest Management Plan.

Key Constituencies: Private landowners, USFS, VDGIF

Key Partners: CRPA, private forestry consultants, USFS, Virginia Tech, VDOF

Information and Research Needs:

1. Investigate and determine silvicultural techniques that will best promote the restoration and ecological management of matrix forests.
2. Further refine and research the attributes of matrix forest system health and ecological integrity (aka "desired future condition").

Threat Abatement or Restoration Goal 8. Restore stream banks of priority stream reaches and critical karst recharge zones in Cowpasture River watershed, including examples of alluvial floodplain forests and native warm season grasses.

Strategy 8. *Promote and utilize public cost share programs and other public funding sources (e.g. the Wetland Restoration Trust Fund) to restore streambanks, karst re-charge areas, and alluvial floodplain forests/grasslands.*

Action Steps:

1. Work with DCR-DNH and VDOF to prioritize places for Alluvial Floodplain Forest/Grasslands restoration and develop restoration plans.
2. Work with NRCS agents, MSWCD, CRPA, VCC, and the Farm Bureau to educate and encourage priority landowners to participate in cost share programs, especially those located in priority conservation areas.
3. Help the Mountain Soil and Water Conservation District to identify funding sources to increase their capacity to hold donated conservation easements for riparian areas.
4. Collaborate with Mountain Soil and Water Conservation District to demonstrate the value of planting native vegetation along riparian buffers to prevent stream bank erosion.

Key Constituencies: Private land owners

Key Partners: CRPA, CSPDC, DCR-DNH, DMME, Farm Bureau, MSWCD, NRCS, USFS, VCC, VSS

Information and Research Needs:

- Identify potential restoration sites through GIS analysis of tax parcel data and riparian buffers.

<u>Threat Abatement or Restoration Goal 9</u>. Reduce sulfur concentrations in atmosphere by 70% over next 10 years to stabilize and/or increase the probability for recovery of low order brook trout streams that have unnaturally low buffering capacities and forest soils that have unnaturally low base saturations.

Strategy 9. *Reduce emissions from out-of-state power plants through incentive-based policies and regulatory amendments to the Clean Air Act.*

<u>Action Steps:</u>

1. Work with divisional and national Government Relations staff to affect regulatory changes in Clean Air legislation to change the sulfur concentration cap from 40% of 1990 levels to 70% or more.
2. Advocate to maintain the EPA's the new source review process in place for the evaluation and regulation of older power plants grandfathered by the Clean Air Act.

Key Constituencies: U.S. Congress, VA General Assembly, power plants

Key Partners: Isaac Walton League, Southern Environmental Law Center (SELC), and the University of Virginia

Information and Research Needs:

- Track changes in the biogeochemical properties of streams and soils associated with forested mountain watersheds in streams and headwaters running off shale and sandstone within the conservation area.

Table 8. Profile of each Warm Springs Mountain/Cowpasture River conservation area conservation strategy, the targets benefited and threats abated.

Strategy	Targets benefited by strategy	Threats abated by strategy
***Strategy 1**. Develop national and state policies that will determine ecologically sound detection and prevention measures to prohibit the introduction and slow the spread of new invasive species.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands ➢ Pine-Oak-Heath Woodlands	➢ Invasive, non-native plant species ➢ Non-native forest pests/pathogens
***Strategy 2**. Implement best available treatments to prevent and reduce impacts by problem pests or pathogens in high priority biologically significant areas.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Non-native forest pests/pathogens
***Strategy 3.1**. Implement direct control measures of targeted invasive species on Warm Springs Mountain Preserve and other publicly owned priority conservation areas.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands	➢ Invasive, non-native plant species
***Strategy 3.2.** Utilize, improve and promote publicly funded cost share programs for weed control.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Outcrops/Barrens/Acidic Woodlands	➢ Invasive, non-native plant species
Strategy 4. A*mend state and federal deer management plans to reduce deer populations.*	➢ Alluvial Forests/Grasslands ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Deer management
***Strategy 5.** Promote and implement prescribed fire to restore and maintain Pine-Oak-Heath Woodlands and oak-hickory forests on Warm Springs Mountain Preserve and USFS lands where feasible.*	➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands	➢ Fire exclusion
***Strategy 6.1**. Protect most viable occurrences of conservation targets through acquisition or conservation easement.*	➢ All Targets	➢ Inadequate cave design ➢ Incompatible agriculture ➢ Incompatible confined animal feeding operations ➢ Rural development ➢ Incompatible forestry ➢ Incompatible grazing ➢ Mining practices ➢ Recreational use
***Strategy 6.2**. Implement compatible land use planning and zoning that will protect priority conservation areas from development or confined animal feeding operations.*	➢ All Targets	➢ Incompatible agriculture ➢ Incompatible confined animal feeding operations

Strategy	Targets benefited by strategy	Threats abated by strategy
		➢ Rural development ➢ Incompatible forestry ➢ Incompatible grazing ➢ Recreational use
***Strategy 7**. Define, promote and demonstrate forest management practices that favor the restoration and maintenance of forest targets on private and public lands.*	➢ Alluvial Forests/Grasslands ➢ Bats ➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Pine-Oak-Heath Woodlands ➢ Small Central Appalachian River System	➢ Historical conversion to agriculture ➢ Historical logging ➢ Incompatible forestry
***Strategy 8**. Reduce emissions from out-of-state power plants through incentive-based policies and regulatory amendments to the Clean Air Act.*	➢ Central Appalachians Mixed Hardwood Forest Matrix ➢ Montane Non-Alluvial Wetlands ➢ Outcrops/Barrens/Acidic Woodlands ➢ Pine-Oak-Heath Woodlands ➢ Small Central Appalachian River System	➢ Acid deposition
***Strategy 9**. Promote and utilize public cost share programs and other public funding sources (i.e. the Wetland Restoration Trust Fund) to restore streambanks, karst re-charge areas, and alluvial floodplain forests/grasslands.*	➢ Alluvial Forests/Grasslands ➢ Cave Invertebrate Communities ➢ Montane Non-Alluvial Wetlands ➢ Small Central Appalachian River System	➢ Historical conversion to agriculture ➢ Incompatible agriculture ➢ Incompatible grazing

Table 9. Key partners for implementing conservation strategies on in the Warm Springs Mountain/Cowpasture River conservation area.

Federal Agencies:
- United States Department of Agriculture—Forest Service (USFS)
- National Park Service (NPS)
- National Resources Conservation Service (NRCS)
- United States Department of Interior--United States Fish and Wildlife Service (USFWS)

State Agencies:
- Virginia Department of Conservation and Recreation--Division of Natural Heritage (DCR-DNH)
- Virginia Department of Conservation and Recreation--Division of Soil and Water Conservation (DCR-SWC)
- Virginia Department of Conservation and Recreation—State Parks
- Virginia Department of Forestry (VDOF)
- Virginia Department of Game and Inland Fisheries (VDGIF)
- Virginia Department of Mines, Minerals and Energy (DMME)

Local Government:
- Bath County
- Central Shenandoah Planning District Commission (CSPDC)
- Highland County
- Mountain Soil and Water Conservation District (MSWCD)

Non-Governmental Organizations:
- American Chestnut Foundation (ACF)
- Chesapeake Bay Foundation (CBF)
- Cowpasture River Preservation Association (CRPA)
- Isaac Walton League
- Southern Environmental Law Center (SELC)
- The Homestead
- University of Richmond
- University of Tennessee
- University of Texas
- University of Virginia
- Valley Conservation Council (VCC)
- Virginia Native Plants Society (VNPS)
- Virginia Outdoors Foundation (VOF)
- Virginia Speleological Society (VSS)
- Virginia Tech—Cooperative Extension

Table 10. Evaluation of Warm Springs Mountain/Cowpasture River conservation strategies in terms of benefits to conservation targets, feasibility and cost of implementation.

Strategies for Threat Abatement and Restoration	**Benefits**			**Feasibility**			**Cost**	**Overall**
	Threat Abate-ment Benefit	Leverage (default = Low)	Overall Benefits	Lead Individual/ Institution	Ease of Implement-ation	Overall Feasibility	Overall Cost *	Overall Strategy Rank
***Strategy 1.** Develop national and state policies that will determine ecologically sound detection and prevention measures to prohibit the introduction and slow the spread of new invasive species*.	High	High	High	Low	Medium	Low	Medium	Medium
***Strategy 2**. Implement best available treatments to prevent and reduce impacts by problem pests or pathogens in high priority biologically significant areas*	High	Medium	High	Low	Medium	Medium	High	Medium
***Strategy 3.1**. Implement direct control measures of targeted invasive species on Warm Springs Mountain Preserve and other publicly-owned priority conservation areas.*	High	Medium	High	Medium	Medium	Medium	Medium	Medium
***Strategy 3.2**. Utilize, improve and promote publicly funded cost share programs for weed control.*	High	High	High	Low	Medium	Medium	Medium	Medium
***Strategy 4**. Amend the state and federal deer management plans to reduce deer populations.*	Medium	Medium	Medium	Medium	Medium	Medium	Low	High
***Strategy 5.** Promote and implement prescribed fire to restore and maintain Pine-Oak -Heath Woodlands and oak-hickory forests on Warm Springs Mountain Preserve and USFS lands where feasible.*	Medium	Very High	High	Medium	High	Medium	High	Medium
***Strategy 6.1.** Protect viable occurrences of conservation targets through acquisition or conservation easement.*	Medium	Very High	High	Very High	Very High	Very High	Very High	High
***Strategy 6.2**. Implement compatible land use planning and zoning that will protect priority conservation areas from development or confined animal feeding operations.*	Low	High	Medium	Low	Medium	Low	Medium	Low
***Strategy 7**. Define, promote and demonstrate forest management practices that favor the restoration and maintenance of forest targets on private and public lands.*	Medium	High	Medium	Low	Medium	Low	High	-
***Strategy 8**. Reduce emissions from out-of-state power plants, either through incentive-based policies or regulatory amendments to the Clean Air Act.*	Low	Very High	Medium	Low	Low	Low	High	-

Strategies for Threat Abatement and Restoration	**Benefits**			**Feasibility**			**Cost**	**Overall**
	Threat Abatement Benefit	Leverage (default = Low)	Overall Benefits	Lead Individual/ Institution	Ease of Implementation	Overall Feasibility	Overall Cost *	Overall Strategy Rank
***Strategy 9**. Promote and utilize public cost share programs and other public funding sources (i.e. the Wetland Restoration Trust Fund) to restore streambanks, karst re-charge areas, and alluvial floodplain forests/grasslands.*	High	High	High	Medium	High	Medium	Medium	High

Conclusion

TNC will be largely focused on the management of the newly acquired Warm Springs Mountain nature preserve over the next couple of years (Map 4). Once the preserve is established, TNC plans to open an office in Hot Springs, hire a conservation area program director and begin implementing components of the conservation strategies presented in this plan at the local level, working closely with private land owners, public land management authorities and the surrounding community. Several of the strategies require implementation by national and state organizational levels within TNC, particularly by the government relations staff. Currently, government relations capacity exists in TNC's Virginia office to carry out such strategies. The key to all strategies, however, will be TNC's partnerships with public agencies, including the USFS, DCR, VDGIF, and VDOF. With a comprehensive strategic conservation plan and increased leadership and capacity on-site and at large within the organization, TNC hopes to work with partners towards the successful protection and conservation of this wondrous Ridge and Valley landscape.

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APPENDIX A. SPECIES AND COMMUNITY DATA

Appendix A. I. Natural species elements that are inventoried and tracked by the Department of Conservation and Recreation's Division of Natural Heritage (DCR-NHP), including global rank, state rank, and federal and state protection status. Please note that Appendix B contains definitions of global/state ranks and federal/state protection status abbreviations. In addition, tracked elements that are conservation targets in the Central Appalachians Ecoregional Plan are indicated in the column "CAP Target".

Major Taxa Group	***Scientific name***	**Common name**	**Global Rank**	**State Rank**	**Federal Status**	**State Status**	**CAP Target**
AB	*Lanius ludovicianus*	Loggerhead shrike	G5	S2		LT	
AM	*Myotis leibii*	Eastern small-footed bat	G3	S1	SOC		Yes
AM	*Myotis sodalis*	Indiana bat	G2	S1	LE	LE	Yes
AR	*Eumeces anthracinus*	Coal skink	G5	S2			
IC	*Caecidotea holsingeri*	Greenbriar valley cave isopod	G3	S1	SOC		Yes
IC	*Caecidotea vandeli*	Vandel's cave isopod	G2G3	S1S2	SOC		
IC	*Stygobromus conradi*	Burnsville cove cave amphipod	G1G3	S1S2	SOC		Yes
IC	*Stygobromus morrisoni*	Morrison's cave amphipod	G2G3	S1S2	SOC	SC	Yes
IC	*Stygobromus mundus*	Bath county cave amphipod	G2G3	S1S2	SOC	SC	
II	*Aeshna tuberculifera*	Black-tipped darner	G4	S2			
II	*Aplectoides condita*	A noctuid moth	G4	S1S3			
II	*Arrhopalites carolynae*	A cave springtail	G2G3	S1	SOC		
II	*Arrhopalites sacer*	A cave springtail	G1G2	S1	SOC		
II	*Catocala herodias gerhardi*	Herodias underwing	G3T3	S2S3	SOC		
II	*Cicindela ancocisconensis*	A tiger beetle	G3	S2	SOC		
II	*Cicindela splendida*	Splendid tiger beetle	G5	S2			
II	*Cordulia shurtleffi*	American emerald	G5	S2			
II	*Euchlaena milnei*	Milne's euchlaena	G2G4	S1S2	SOC		
II	*Gomphus descriptus*	Harpoon clubtail	G4	S1			
II	*Hydraecia stramentosa*	Figwort borer	G4	S2S4			
II	*Hydraena maureenae*	Maureen's shale stream beetle	G1G3	S1S3	SOC		
II	*Lanthus parvulus*	Northern pygmy clubtail	G4	S2			
II	*Lestes disjunctus disjunctus*	Northern common spreadwing	G5T5	S1			
II	*Lytrosis permagnaria*	A looper moth	GU	S1S3			
II	*Papaipema astuta*	Stoneroot borer moth	G4?	S1S3			
II	*Papaipema duplicata*	Stoneroot borer	GU	S1S3			
II	*Pseudanophthalmus intersectus*	Crossroads cave beetle	G1	S1	SOC		Yes
II	*Sinella hoffmani*	Hoffman's springtail	G4G5	S2S3			
II	*Speyeria atlantis*	Atlantis fritillary	G5	S2			
IL	*Anthrobia*	A cave spider	G3G4	S1	SOC		

	monmouthia						
IL	*Rhagidia varia*	A cave mite	G3	S2?	SOC		
IM	*Lasmigona subviridis*	Green floater	G3	S2	SOC	SC	Yes
IT	*Nampabius turbator*	A cave centipede	G1G2	S1	SOC		
IT	*Trichopetalum weyeriensis*	A millipede	G3Q	S2	SOC		
IT	*Trichopetalum whitei*	A millipede	G2G3 Q	S2	SOC		
PD	*Arabis serotina*	Shale-barren rockcress	G2	S2	LE	LE	Yes
PD	*Clematis viticaulis*	Millboro leatherflower	G2	S2	SOC		Yes
PD	*Cornus canadensis*	Bunchberry	G5	S1			
PD	*Crataegus pruinosa*	A hawthorn	G5	S1			
PD	*Erysimum capitatum var capitatum*	Western wallflower	G5T5	S2			Yes
PD	*Gaylussacia brachycera*	Box huckleberry	G2G3	S2	SOC		Yes
PD	*Iliamna remota*	Kankakee globe-mallow	G1Q	S1	SOC		Yes
PD	*Phlox buckleyi*	Sword-leaved phlox	G2	S2	SOC		Yes
PD	*Populus tremuloides*	Quaking aspen	G5	S2			
PD	*Sida hermaphrodita*	Virginia mallow	G2	S1	SOC		Yes
PD	*Triadenum fraseri*	Fraser's marsh st. John's-wort	G4G5	S1			
PD	*Vitis rupestris*	Sand grape	G3G4	S1?	SOC		
PG	*Juniperus communis var depressa*	Ground juniper	G5T5	S1			
PM	*Bromus kalmii*	Wild chess	G5	S1			
PM	*Carex polymorpha*	Variable sedge	G3	S2	SOC	LE	Yes
PM	*Carex vesicaria*	Inflated sedge	G5	S1S2			
PM	*Elymus trachycaulus ssp trachycaulus*	Slender wheatgrass	G5T5	S2			

Appendix A.2. Data compiled from Culver et al. 1999 (courtesy of the Karst Waters Institute).

Genus	**species**	**Common Name**	**G Rank**	**Target?**
Stygobitic Organisms				
Caecidotea	*holsingeri*	Holsinger's isopod	G3G4	Y
Caecidotea	*vandeli*	Vandel's isopod	G3	
Stygobromus	*conradi*	Conrad's amphipod	G3	
Stygobromus	*morrisoni*	Morrison's amphipod	G3G4	
Stygobromus	*mundus*	an amphipod	G3	
Troglobitic Organisms				
Anthrobia	***mammouthia***	a cave spider	G4G5	
Apochthonius	*holsingeri*	Holsinger's pseudoscorpion	G3	
Arrhopalites	*caedus*	a cave springtail	G3	
Arrhopalites	*carolynae*	a cave spingtail	G3	
Arrhopalites	*marshalli*	a cave spingtail	G3	

Genus	species	Common Name	G Rank	Target?
Arrhopalites	*sacer*	a cave spingtail	G3	
Arrhopalites	*silvus*	a cave spingtail	G3	
Arrhopalites	*silvus*	a cave spingtail	G3	
Hesperochernes	*mirabilis*	a cave pseudoscorpion	G4G5	
Kleptochthonius	*anophthalmus*	a cave pseudoscorpion	G1G2	
Nesticus	*tennesseensis*	a cave spider	G4G5	
Phanetta	*subterranea*	a cave spider	G4G5	
Porrhomma	*cavernicola*	a cave spider	G4G5	
Pseudanophthalmus	*intersectus*	Crossroad's Cave beetle	G1G2	Y
Pseudanophthalmus	*potomaca potomaca*	Potomac cave beetle	G3G4T3T4	Y
Pseudosinella	*orba*	a cave beetle	G4G5	
Rhagidia	*varia*	a cave mite	G3G4	
Schaefferia	*hubbardi*	a cave springtail	G3	
Sinella	*hoffmani*	a cave springtail	G4G5	
Trichopetalum	*weyeriensis*		G3G4	

Appendix A.3. Collections data for fishes and mussels of the Cowpasture River Watershed from Virginia Department of Game and Inland Fisheries. Please note that 3 species historically native to the Cowpasture are now extirpated: American Eel (*Anguilla rostrata*), American shad (*Alosa sapidissima*), and banded killifish (*Fundulus diaphanus*).

Common Name	*Scientific Name*	Native in Upper James Watershed
Fish		
Bass, largemouth	*Micropterus salmoides*	No
Bass, rock	*Ambloplites rupestris*	No
Bass, smallmouth	*Micropterus dolomieu*	No
Bluegill	*Lepomis macrochirus*	No
Bullhead, brown	*Ameiurus nebulosus*	
Bullhead, yellow	*Ameiurus natalis*	
Carp, common	*Cyprinus carpio*	No
Carp, grass	*Ctenopharyngoden idella*	No
Chub, bluehead	*Nocomis leptocephalus*	
Chub, bull	*Nocomis raneyi*	
Chub, creek	*Semotilus atromaculatus*	
Chub, river	*Nocomis micropogon*	
Chubsucker, creek	*Erimyzon oblongus*	
Crappie, black	*Pomoxis nigromaculatus*	
Dace, blacknose	*Rhinichthys atratulus*	
Dace, longnose	*Rhinichthys cataractae*	
Dace, mountain redbelly	*Phoxinus oreas*	
Dace, rosyside	*Clinostomus funduloides*	
Darter, fantail	*Etheostoma flabellare*	
Darter, johnny	*Etheostoma nigrum*	
Darter, longfin	*Etheostoma longimanum*	
Darter, Roanoke	*Percina roanoka*	No

Common Name	***Scientific Name***	**Native in Upper James Watershed**
Darter, shield	*Percina peltata*	
Darter, stripeback	*Percina notogramma*	
Fallfish	*Semotilus corporalis*	
Hogsucker, northern	*Hypentelium nigricans*	
Jumprock, black	*Moxostoma cervinum*	
Madtom, orangefin	*Noturus gilberti*	No
Madtom, margined	*Noturus insignis*	
Minnow, bluntnose	*Pimephales notatus*	
Minnow, cutlips	*Exoglossum maxillingua*	
Minnow, eastern silvery	*Hybognathus regius*	
Muskellunge	*Esox masquinongy*	No
Pickerel, chain	*Esox niger*	
Pumpkinseed	*Lepomis gibbosus*	
Sculpin, mottled	*Cottus bairdi*	
Sculpin, Potomac	*Cottus girardi*	
Shiner, comely	*Notropis amoenus*	
Shiner, common	*Luxilus cornutus*	
Shiner, crescent	*Luxilus cerasinus*	No (?)
Shiner, mimic	*Notropis volucellus*	
Shiner, rosefin	*Lythrurus ardens*	
Shiner, rosyface	*Notropis rubellus*	
Shiner, roughhead	*Notropis semperasper*	
Shiner, satinfin	*Cyprinella analostamas*	
Shiner, spottail	*Notropis hudsonius*	
Shiner, swallowtail	*Notropis procne*	
Shiner, telescope	*Notropis telescopus*	No
Stoneroller, central	*Campostoma anomalum*	
Sucker, torrent	*Moxostoma rhothoecum*	
Sucker, white	*Catostomus commersoni*	
Sunfish, redbreast	*Lepomis auritus*	
Trout, brook	*Salvelinus fontinalis*	
Trout, brown	*Salmo trutta*	No
Trout, rainbow	*Oncorhynchus mykiss*	No
Mussels		
Mussel, creeper	*Strophitus undulatus*	
Mussel, green floater	*Lasmigona subviridis*	
Mussel, notched rainbow	*Villosa constricta*	
Mussel, yellow lance	*Elliptio lanceolata*	

APPENDIX B. KEY TO GLOBAL RANK DEFINITIONS AND FEDERAL ENDANGERMENT ABBREVIATIONS

Appendix B: Key to Global Rank Definitions and Federal Endangerment Abbreviations

Table B.1. Global Heritage Status Rank Definitions. State status ranks are the same definitions, using a "S" rather than a "G", but applicable only to a given state, in this case Virginia, rather than the total global distribution of a species or community. Please note that these ranks should **not** be interpreted as legal designations.

Rank	Definition
GX	**Presumed Extinct** (species)—Believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. **Eliminated** (ecological communities)—Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.
GH	**Possibly Extinct** (species)—Known from only historical occurrences, but may nevertheless still be extant; further searching needed. **Presumed Eliminated** (Historic, ecological communities)—Presumed eliminated throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration, for example, American Chestnut (Forest).
G1	**Critically Imperiled**—Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2	**Imperiled**—Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3	**Vulnerable**—Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	**Apparently Secure**—Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5	**Secure**—Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

* Acreage and distance measures for global ranking of ecological communities consider typical spatial pattern knowledge of long-term trends in relative extent. Acreage and distance estimates listed in the table above refer to G1 and G2 communities that typically occur as discrete patches on the landscape. Communities may occur today with acreage or distance greater than when originally recorded; these occurrences are still ranked G1 or G2 because of strong decline in extent or condition.

Variant Global Ranks

Rank	Definition
G#G#	**Range Rank**—A numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4).
GU	**Unrankable**—-Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. NOTE: Whenever possible, the most likely rank is assigned and the question mark qualifier is added (e.g., G2?) to express uncertainty, or a range rank (e.g., G2G3) is used to delineate the limits (range) of uncertainty.
G?	**Unranked**—Global rank not yet assessed.
HYB	**Hybrid**—(species elements only) Element not ranked because it represents an interspecific hybrid and not a species. (Note, however, that hybrid-derived species are ranked as species, not as hybrids.)

Rank Qualifiers

Rank	Definition
?	**Inexact Numeric Rank**—Denotes inexact numeric rank
Q	**Questionable taxonomy that may reduce conservation priority**— Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank.
C	**Captive or Cultivated Only**—Taxon at present is extant only in captivity or cultivation, or as a reintroduced population not yet established.

Infraspecific Taxon Ranks

Infraspecific taxon ranks apply to species only, these ranks do not apply to ecological communities.

Rank	Definition
T#	**Infraspecific Taxon** (trinomial)—The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T subrank cannot imply the subspecies or variety is more abundant than the species, for example, a G1T2 subrank should not occur. A vertebrate animal population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T-rank to denote the taxon's informal taxonomic status.

Table B.2. Standard abbreviations used for Federal endangerment developed by the U.S. Fish and Wildlife Service, Division of Endangered Species and Habitat Conservation.

LE - Listed Endangered	**LT** - Listed Threatened	**PE** - Proposed Endangered	**PT** - Proposed Threatened
C - Candidate (formerly C1 - Candidate category 1)	**E(S/A)** - treat as endangered because of similarity of appearance	**T(S/A)** - treat as threatened because of similarity of appearance	**SOC** - Species of Concern species that merit special concern **(not a regulatory category)**

Table B.3. Standard abbreviations used for endangerment status in Virginia.

LE - Listed Endangered	**PE** - Proposed Endangered	**SC** - Special Concern - animals that merit special concern according to VDGIF (**not a regulatory category**)
LT - Listed Threatened	**PT** - Proposed Threatened	**C** - Candidate

APPENDIX C. WARM SPRINGS MOUNTAIN/ COWPASTURE RIVER CONSERVATION AREA 5-S EXCEL WORKBOOK TABLES

APPENDIX D. SUPPLEMENTAL MATERIAL ON ACIDIC DEPOSITION

Appendix D: Supplemental Material on Acidic Deposition and the Warm Springs Mountain/Cowpasture River conservation area

Prepared by: Rick Webb, Department of Environmental Sciences, University of Virginia
Date: September 1, 2002

Note: The information presented here was mainly obtained through the coordinated Shenandoah Watershed Study and the Virginia Trout Stream Sensitivity Study (SWAS/VTSSS) research and monitoring program. The SWAS/VTSSS program is maintained with funding support from the National Park Service and the U.S. Environmental Protection Agency. Logistical support, including assistance with sample collection, is provided by the USDA Forest Service, the Virginia Department of Game and Inland Fisheries, and Trout Unlimited.

A. Susceptibility of low-order versus high-order streams in the WSM/CR conservation area.

Susceptibility to acidification is determined by differences in watershed bedrock and soil. The forested mountain watersheds in Virginia's Valley and Ridge physiographic province are underlain by siliceous, argillaceous, and carbonate bedrock. Watersheds underlain by siliceous bedrock commonly have base-poor soils and more-acidic streams than watersheds underlain by argillaceous or carbonate bedrock. The higher-order streams of the WSM/CR drainage network are probably all influenced by carbonate rock and thus all should have high acid-neutralization capacity (ANC). The lower-order streams in the drainage network vary with respect to watershed bedrock and thus vary with respect to ANC. Many are associated with siliceous bedrock and thus have low ANC.

B. The presence of acid-sensitive streams in the WSM/CR conservation area.

Stream water composition data obtained through the SWAS/VTSSS program confirms the presence of acid-sensitive low-order surface waters in the WSM/CR conservation area. In addition to regional synoptic surveys of native brook trout streams in 1987 and 2000, the SWAS/VTSSS program has maintained a quarterly sampling program since 1988, including eight streams in the Cowpasture River drainage. Table 1 indicates the distribution of ANC values for these eight streams relative to ANC criteria for brook trout response (Bulger et al., 2000). Based on this classification:

- For streams with ANC values $\leq$ 20 μeq/L: sub-lethal and/or lethal effects on brook trout are possible.
- For streams with ANC values $\leq$ 50 μeq/L: brook trout response is variable.
- For streams with ANC values > 50 μeq/L: reproducing brook trout populations are expected where habitat is suitable

Table 1. Percentage distributions of ANC for brook trout streams sampled quarterly in the WSM/CR conservation area: 1988-2000.

Stream Name	Site Elev	Area	n	ANC (µeq/L)		USGS 7.5 Min Quad. Map
				≤ 20	≤ 50	
Laurel Run	2380	3.45	54	44%	94%	Burnsville
Mare Run	2030	6.02	54	35%	100%	Warm Springs
Panther Run	2030	4.04	54	2%	4%	Warm Springs
Bear Hole	2000	2.61	27	0%	2%	Bath Alum.
Little Wilson Creek	1860	3.27	49	43%	96%	Healing Springs.
Porters Creek	1980	2.12	51	45%	100%	Healing Springs
N. Br. Simpson Creek	1400	7.65	52	37%	100%	Longdale Furnace
Blue Suck Branch	1280	6.04	25	0%	4%	Longdale Furnace

Notes: site elevations are given in feet; Area = watershed area above sampling sites given in km^2; n = number of samples collected; sampling of Bear Hole and Blue Suck Branch was discontinued in 1994

As indicated in Table 1, five of the eight study streams in the WSM/CR conservation area commonly have ANC values in the ranges in which adverse impacts on brook trout populations are likely. It should also be noted that brook trout are comparatively acid tolerant. Adverse effects on other fish species should be expected at even higher ANC values.

C. Evidence for acidification of low-order streams in the WSM/CR conservation area.

Stream water acidification is indicated by a loss of ANC. Table 2 provides the results of trend analysis conducted for ANC concentrations in the six WSM/CR conservation area streams for which 12 years of quarterly sample data are available.

Statistically significant negative trends in ANC occurred in the 1988-2000 period for four of the five streams with ANC values commonly in the range of adverse impacts for brook trout populations. Over this 12-year period, ANC losses for these streams ranged from 7.2-10.8 µeq/L, indicating a biologically significant degree of acidification. Application of predictive models (e.g., Bulger et al., 2000) indicates that acidification of Virginia's brook trout streams is likely to continue into the future despite current air pollution control programs.

Table 2. Trend statistics for brook trout streams sampled quarterly in the WSM/CR conservation area: 1988-2000.

Stream name	ANC	
	ρ value	Trend μeq/L/yr
Laurel Run	**0.08**	**-0.60**
Mare Run	**0.004**	**-0.73**
Panther Run	0.4	-0.58
Little Wilson Creek	**0.01**	**-0.87**
Porters Creek	0.6	+0.08
N. Br. Simpson Creek	**0.001**	**-0.90**

Notes: trend analysis was conducted using the nonparametric Seasonal Kendall test (Hirsch and Slack, 1984); values are given in bold for trends that are significant at $\rho < 0.1$

Further examination of SWAS/VTSSS data indicates that sulfate concentrations in Virginia's brook trout streams, including those in the WSM/CR conservation area, are two to six times greater than estimated pre-industrial values. Sulfur is the primary determinant of precipitation acidity and sulfate is the dominant acid anion associated with acidic streams in the Appalachian region. Sulfate in now the most-concentrated solute in many Virginia brook trout streams –a major change in the chemical environment. The coincidence of elevated sulfate concentrations and decreasing ANC provides strong evidence of stream water acidification due to acidic deposition.

D. Effects of acidification on the biological integrity of low-order streams.

The threat of acidic deposition to the biological integrity of Virginia's brook trout streams, including those in the WSM/CR conservation area, is dependent upon landscape properties, primarily bedrock type, and varies between a very high threat and little or no threat. Research conducted in Shenandoah National Park (SNP) has shown a strong relationship between the ANC of streams and both the number of fish species (Bulger et al., 1999) and the number of aquatic macroinvertebrate species (Moeykins and Voshell, 2002). This relationship suggests that the more-sensitive species have disappeared in the past from acidifying streams and that additional species will disappear in the future if acidification continues. The SWAS/VTSSS research team is presently compiling fisheries data for Virginia brook trout streams that will provide additional perspective on the impact of acidification on the biological integrity of brook trout streams throughout western Virginia, including the brook trout streams in the WSM/CR conservation area.

E. Susceptibility of forest soils in the WSM/CR conservation area to effects of acidification.

There may be no data currently available to assess the nutrient and acid-base status of soils associated with the forested ridges in the WSM/CR conservation area. However, based on bedrock distribution patterns, it is probable that many of the forest soils in the WSM/CR conservation area share characteristics with base-poor soils in SNP. Detailed soil sampling surveys conducted for SNP through the SWAS/VTSSS program indicate that base saturation levels for many SNP soils are less than 15%. Base saturation levels in this range are associated with both mobilization of toxic aluminum and nutrient deficiency in both forest soils and low-order streams.

An analysis by Lawrence and Huntington (1999) shows that base supplies in forest soils associated with siliceous bedrock in a number of southeastern areas, including parts of SNP, are already insufficient to support complete forest regeneration after timber harvest. In addition, calcium levels in many SNP streams, which ultimately depend on calcium availability in soils, are already marginal for fish survival (Bulger et al., 1999). Similar conditions are certainly present in parts of the WSM/CR conservation area.

Degradation of both terrestrial and aquatic systems can only increase as base cations (mainly calcium and magnesium) are leeched from forest soils by continuing acidic deposition. The specific severity of this threat within the WSM/CR conservation area has not been determined.

F. Collection of baseline data and initiation of long-term monitoring for soils and low-order streams in the WSM/CR conservation area.

As indicated above, stream water composition data have been collected for native brook trout streams in the WSM/CR conservation area. However, these streams are only a fraction of the total number of low-order streams draining the forested ridges of the area. Although broad-scale regionalization is possible based on known relationships between bedrock and water quality, the strength of the relationships is not sufficient to support prediction of individual stream conditions. This is mainly due to the scale of available geologic mapping, which in many cases does not adequately reveal the presence or absence of spatially minor, but geochemically important, carbonate inclusions. A detailed water quality survey of low-order streams is thus needed to support a comprehensive and appropriately scaled assessment of headwater streams in the WSM/CR conservation area.

Similarly, the information available for assessment of soil conditions in the WSM/CR conservation area is very limited. As indicated above, it is probable that there is no data of the type required to assess the nutrient and acid-base status of soils associated with the forested ridges. Any available soils information that has been obtained for agricultural purposes is not adequate in this respect and certainly will not address the variance in soil conditions that occurs on the forested ridges due to differences in parent material, slope position, vegetative cover, and past landuse. Thus, a detailed sampling survey of soils on the ridges is a prerequisite of an informed assessment of soil status and relationships between soil, forest, and stream conditions.

A project to assess the current status and track changes in both the low-order streams and the soils associated with the forested ridges could proceed in phases. A first phase could involve design and execution of sampling programs to establish baseline water quality and soil conditions and improve understanding of the landscape properties that determine variation in these conditions. A second phase could involve selection of watersheds for intensive long-term monitoring. These watersheds should represent the major geochemical classes in the area and provide a framework for co-location and integration of additional ecosystem monitoring and research.

The SWAS/VTSSS monitoring system could provide a basis for more-intensive watershed monitoring in WSM/CR conservation area. The SWAS/VTSSS program involves a data collection system whereby stream water composition is measured at different temporal scales among a range of designated watershed classes.

It should be noted that while acidic deposition has provided a primary reason for development of the SWAS/VTSSS program, it is certainly not the only reason for stream monitoring. The solute composition of stream waters represents an integration of complex hydrologic and biogeochemical processes and conditions in watershed systems. Change in the composition of stream waters thus provides a measurable indication of ecosystem changes occurring on a landscape scale.

Figure 1 depicts the hierarchical framework of the SWAS/VTSSS monitoring system. As indicated in Figure 1, the monitoring system involves seasonal or quarterly sampling of 62 streams representing five geologically defined watershed classes. The watershed classification scheme accounts for differences in biogeochemical factors that determine ecosystem conditions and govern response to agents of change. The selection of sample streams was based on representation of the geologic classes, geographic distribution, site accessibility, and prospects for long-term watershed protection. Sample stream selection was also intended to avoid the more-direct human disturbance factors that would confound detection and understanding of changes in watershed biogeochemistry related to air pollution, forest regeneration, insect disturbance, climate change, etc.

As also indicated in Figure 1, more intensive data collection has been conducted for a subset of the study watersheds located in the Blue Ridge Mountain physiographic province (all within SNP). Streams representing the three watershed classes in the Blue Ridge Mountain province were selected for weekly sampling, and one stream in each class was selected for continuous discharge gauging and automated high-frequency sampling during high-runoff conditions. The more-intensive components of the program maximize our capacity to detect long-term changes, provide the temporal resolution necessary for interpretation of short-term changes and identification of episodic extremes, and allow quantification of watershed export and retention of nutrients and acid-base constituents. In addition, the more-intensive data collection in the SNP watersheds has provided a framework of hydrochemical information in support of a broad range of ecological research.

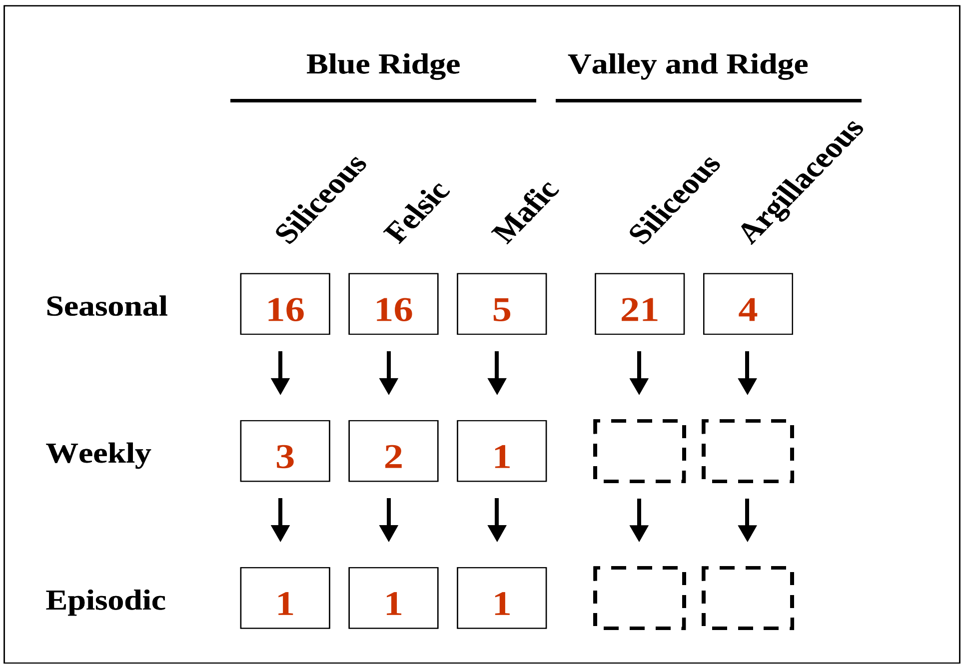

Figure 1. The hierarchical framework of the SWAS/VTSSS monitoring system, indicating numbers of study watersheds and stream water sampling frequencies for watersheds classified by physiographic province and bedrock geology.

Ideally, the SWAS/VTSSS program could be further developed to include more-intensive study watersheds within the WSM/CR conservation area. This development could include:

- <u>A detailed synoptic survey of stream water composition for low-order streams associated with the forested mountain ridges in the area.</u> This survey could be modeled after the 1987 and 2000 surveys conducted through the SWAS/VTSSS program, although not restricted to brook trout streams.

- A sampling survey to determine acid-base and nutrient properties of soils associated with the forested mountain ridges in the area. This survey could be modeled after soil sampling in SNP that involved selection of sites based on bedrock type, slope position, vegetative cover, and past landuse.

- Selection of watersheds sites for long-term monitoring on a quarterly basis. These sites should provide geographic coverage and replication of information obtained for the more-intensively studied sites. Selection of these sites would involve evaluation of the existing SWAS/VTSSS study watersheds in relation to new information obtained through the stream and soil surveys. The potential for contribution to other ecosystem management and research objectives for the WSM/CR conservation area should also be considered.

- Selection of watersheds for long-term intensive monitoring. These sites should: (1) complete the SWAS/VTSSS watershed monitoring framework by providing temporally intensive monitoring within the watershed classes defined for the Valley and Ridge province; (2) provide a sensitive basis for detecting and understanding biogeochemical change within the WSM/CR conservation area; and (3) provide a hydrochemical framework for watershed-oriented ecological research. These sites would be selected as a subset of the quarterly monitoring sites, with additional selection criteria related to suitability for discharge gauging and other watershed instrumentation.

- Promotion and use of the study watersheds for co-location of other ecosystem research and monitoring. This should include monitoring of soil properties, aquatic biota, and atmospheric deposition. In addition, the hydrochemical framework provided by the monitoring program should attract and support a range of research. The study watersheds in SNP, for example, have provided the locale for many research projects conducted by graduate students and various agency scientists, all of which have contributed to improved understanding of SNP watershed ecosystems.

- Promotion and use of the study watersheds for purposes of environmental education and community participation in ecological preservation. Programs could be developed to involve the local and regional public in the scientific activities conducted at the study watersheds. Educational material and publicity developed for the WSM/CR conservation area could highlight the work conducted in the study watersheds. Hands-on public involvement could include field trips, student research projects, and assistance with surveys and other data collection. A primary objective could be promotion of informed and dedicated community-based stewardship of the unique WSM/CR conservation area.

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