A Karst Resource Inventory of the George Washington and Jefferson National Forests

Terri Brown
Virginia Karst Project
Virginia Department of Conservation
44 Sangers Lane Suite 102
Staunton, VA 24401
(540) 332-9239
tlbrown@dcr.state.va.us

Dawn Kirk
Forest Ecology Group
George Washington and Jefferson National Forest
5162 Valleypointe Pkwy
Roanoke, Virginia 24019
(540) 291-2188
dkirk@fs.fed.us

Abstract

The George Washington and Jefferson National Forests stretch across nearly 1.8 million acres in the western Virginia and eastern West Virginia portions of the Appalachian Mountains. The mountainous forestlands are fringed, and occasionally dissected, by linear bands of karst topography formed in carbonate rock of Cambrian through Mississippian age. The Virginia Speleological Survey has documented approximately 90 caves and an untold number of springs, sinkholes, and sinking streams on the Forest. The exact location, dimensions, and natural heritage value of many of these caves and karst features is not currently known by the Forest, nor actively managed to protect karst resources.

The development of a new management plan, and a grant from the Fish and Wildlife Foundation, were the catalysts that allowed the Forest Ecology Group to focus on the collection of specific information about some of the Forest's most sensitive aquatic habitats and groundwater recharge zones. Through the cooperative efforts of the Department of Conservation and Recreation's Virginia Karst Project (Natural Heritage Program) and the Karst Waters Institute, Inc., a special team of conservation-minded cavers was assembled, trained, and permitted to make observations about the aquatic (and terrestrial) habitats in targeted Forest caves. The Karst Resource Inventory Team, as the group is known, is also responsible for collecting voucher specimens of stygobitic fauna, where needed, from cave stream, epikarst, and phreatic habitats. The team will intensively gather data on the aquatic fauna of the Forest's karst for the next year, and will develop a final report on their findings with the assistance of Dr Dan Fong at American University.

Because the George Washington and Jefferson National Forest is located in a region of such high biodiversity and endemism, the Karst Resource Inventory Team has elevated expectations for the discovery of several species new to science, as well as new locations for known species. The habitat descriptions and maps generated by the Team are invaluable to the future planning process, and will be used by Forest staff to prioritize karst areas for protection from the impacts of logging and excessive recreational use.

Introduction

The George Washington and Jefferson National Forests (hereinafter referred to as the Forest) include nearly 1.8 million acres of the central and southern Appalachians in western Virginia and eastern West Virginia. For more than ten years, the U.S. Forest Service and the Virginia Department of Conservation and Recreation have cooperated in a series of on-going projects to inventory the natural heritage resources of the Forest. The natural heritage values of the Forest include the habitats of rare plant and animal species, significant natural communities, and the geologic and hydrologic features that support this biological diversity. The objective of the work has been to facilitate ecological management and monitoring strategies that preserve the integrity and viability of the Forest's most salient natural heritage resources.

Based on the results of regional and site-specific inventories, the Department of Conservation and Recreation produced a list of sites with exceptional levels of biodiversity that are proposed as candidates for Special Interest Area, Research Natural Area, or other conservation land management status (Erdle *et al*., 1996; Rawinski *et al*., 1996; Wilson, 2000). Past ecological surveys focused on targeted species and the collection of detailed vegetation and habitat information about natural communities. The current project was designed to focus on the role of the Forest as the topographic and geologic "source water area" for the watershed that sustains life beyond the Forest boundary. Specifically, this project addressed the groundwater catchment areas that are the most vulnerable to potential degradation from surrounding land use activities. Most often there are karst areas that occur along the edges of the Forest boundary. This cave fauna inventory project was initiated to augment previous inventories of the Forest's plant and wetland communities on carbonate terranes. The project was facilitated by the generous assistance of the Karst Waters Institute, the Cave Conservancy of the Virginias, and the dedicated cadre of cavers known as the Karst Resource Inventory Team.

Karst Resources of the Forest

The Forest extends across three physiographic provinces in western Virginia—from the crest of the Blue Ridge Mountains, through parts of the Valley and Ridge, and westward to the Appalachian Plateau. Much of the land is extremely mountainous, with peaks in excess of 4,000 feet (1,219 meters) in the northern section and 5,500 feet (1,676 meters) in the southern section. The mountains are typically fringed by linear bands of karst that make up less than 0.5% of the total land area of the Forest. The karst and carbonate rock areas occur at elevations ranging from around 600 feet (183 meters) to 3,700 feet (1,128 meters)(Fleming, 1999).

Average annual precipitation varies widely across the Forest, and ranges from approximately 36 inches (91 centimeters) to 50 inches (127 centimeters)(van der Leeden, 1993). Given the density of springs and caves located along the edge of the Forest, runoff and karst infiltration must constitute a substantial component of groundwater recharge both within the Forest and on adjacent lands. Forest lands overlie the headwaters areas for six of Virginia's major drainage basins, including the Big Sandy, Upper Tennessee, New, Roanoke, James, and Shenandoah-Potomac. Bedrock ranges in age from PreCambrian through Pennsylvanian, with cave-producing carbonate units occurring throughout the Cambro-Ordovician, Silurian, Devonian, and Missippian strata. Karst lands include some of the most productive sites for potential timber harvests, yet the variety of microclimates occurring in these terranes also results in exceptional ecosystem diversity that should be appropriately protected and managed by the Forest (Fleming, 1999).

Distinctive Forest Community Types on Karst

Most karst land in the Forest is mantled with sandy, acidic material derived from upgradient slopes of varying combinations of sandstone, shale, quartzite, and/or gneiss. Carbonate bedrock is exposed where soils are thin and rocky, and the substrate is rich in available calcium and magnesium. In 1997 and 1998, Department of Conservation and Recreation—Department of Natural History ecologists sampled the mineral soils and substrates of rare plant community types associated with carbonate rocks in the Forest. Sample sites were selected based on several criteria, including consistency with the Department of Conservation and Recreation—Department of Natural History 's table of limestone and dolomite indicator species. Thirty-four sample plots were classified according to topographic position, slope shape and aspect, drainage, soil/substrate characteristics, and plant associations. The following calcium-loving (calciphilic) plant communities were identified from this analysis (Fleming, 1999).

Rich Cove/Mesic Slope Forests occur in cool, sheltered locations on north- to east-facing slopes. Stands are also to be found on low carbonate ridges and rich flood plain terraces. Globally, this plant community type is cited as being among the biologically-richest systems in the world (Fleming, 1999). The typical mixed canopy of a Rich Cove/Mesic Slope Forest might be composed of *Acer saccharum* var. *saccharum* (sugar maple), *Acer nigrum* (black maple), *Tilia americana* (basswood), *Liriodendron tulipifera* (tulip poplar), *Fraxinus Americana* (white ash), *Aesculus flava* (yellow buckeye), *Ulmus rubra* (slippery elm), *Quercus rubra* (northern red oak), and *Carya Cordiformis* (bitternut hickory). The understory vegetation may include *Asimina triloba* (pawpaw), *Lindera benzoin* (spicebush), *Magnolia tripetala* (umbrella magnolia), *Cornus alternifolia* (alternate-leaved dogwood), and *Staphylea trifolia* (bladdernut), in addition to nutrient-loving herbaceous plants, such as *Trillium* spp.(trilliums), *Caulophyllum thalictroides* (blue cohosh), *Laportea canadensis* (wood nettle), *Hydrophyllum* spp.(waterleaf), and the fern species (Fleming, 1999).

Montane Seepage Wetlands occur along toe slopes and stream headwaters where groundwater discharges in the form of seeps and springs. These areas are perennially or ephemerally saturated, rarely completely flooded, and occur under both acidic and calcareous conditions. Seepage wetland communities, including bogs and calcareous fens, are rare in Virginia, and contain habitat-restricted species of plants and animals that are priorities for protection (Fleming, 1999). Montane Seepage Swamps often occur in association with slow, diffuse groundwater flows rather than the relatively fast-moving, conduit flow networks normally associated with cave systems.

Karst areas with south to west facing slopes are generally warmer, and may support Dry-Mesic and Dry Calcareous Forests on thin, rocky soils. These forests can occur where narrow bands of pure Mississippian-age limestone outcrop at higher elevations, and include populations of significant plants of global or state rarity. Some of these communities are relatively pristine due to the rugged terrain and elevations at which they occur. In these steep, rocky habitats, trees are often stunted, which diminishes the potential for future timber harvests. *Quercus muhlenbergii* (chinkapin oak) is the characteristic tree of this community type (Fleming, 1999).

Rare Calcareous Barrens and Outcrops occur on steep, dry, limestone and dolomite cliffs in the Forest where the sparse canopy allows light-demanding and lithophilic (rock-loving) plants to flourish. This community is typified by growths of shrubs and prairie-like grasslands in xeric upland openings, surrounded by *Juniperus virginia* var. *virginia* (eastern red cedar), chinkapin oak, white ash, *Fraxinus quadrangulata* (blue ash), *Frangula caroliniana* (Carolina buckthorn), *Philadelphus hirsutus* (hairy mockorange), *Rhus aromatica* var. *aromatica* (fragrant sumac), *Celtus tenuifolia* (Georgia hackberry), *Rhamnus lanceolata* ssp. *lanceolata* (lance-leaved buckthorn), and *Thuja occidentalis* (American arborvitae) (Fleming, 1999).

Cave and Karst Water Resources

The carbonate rock units with which these important plant communities are associated also contain caves of various dimensions and significance. Unpublished information from the Virginia Speleological Survey contains reports of approximately 90 caves within the Forest boundary, although the exact locations, dimensions, and natural heritage value of many of these caves are not currently known (Lucas, 1999; Kastning and Kastning, 1993). Hundreds of other caves occur along the perimeter of the Forest and on adjacent private land that could be potentially impacted by Forest management. This is particularly important where springs and surface streams originate on Forest lands, sink into the subsurface and contribute to cave streams, springs, wetlands, and public and private drinking water sources.

In addition to the more than 25 species of rare calcium-loving plants that are currently being monitored on carbonate strata in the Forest, the ecological community includes land snails and threatened species of freshwater mussels that rely on available calcium and magnesium for shell formation (Fleming, 1999; Koch, 1998). The diverse troglophilic and obligate cave fauna of the Forest includes salamander, bat, and many invertebrate species (Fleming, 1999). More than 80 species of stygobytes (aquatic cave fauna) have been identified in Virginia. In all, more than 90% of the cave-dwelling species are endemic to the central and southern Appalachians. This high level of endemism and biodiversity places the Appalachian region among the most important karst areas in the world for biological value (Culver, 1999).

Because the karst areas have been identified as a high priority for conservation, the Forest Ecology Group determined that a detailed inventory of the natural heritage value of the caves was essential for updating the Forest

Management Plan and to protect karst resources both within and outside the Forest boundary. The current project with Department of Conservation and Recreation, the Karst Waters Institute, and the Karst Resource Inventory Team was initiated to begin the inventory process by focusing on the aquatic cave fauna of the Forest.

Conducting the Cave Inventory

With funding from the National Fish and Wildlife Foundation and Cave Conservancy of the Virginias, the Forest entered into a cooperative agreement with Department of Conservation and Recreation—Department of Natural History and Karst Waters Institute to conduct the inventory in multiple phases. The first phase focused on the documentation and identification of stygobitic fauna associated with cave environments. In 1999, a Forest intern compiled the available information on known caves in the Forest (Lucas, 1999; Kastning and Kastning, 1992; Holsinger, 1975; Douglas, 1964). That information was used to assign a preliminary priority ranking to each cave, based on the age and detail of the record and the presence or absence of water. With 90 caves to inventory, the rankings were designed to highlight the caves which had not been visited, or which required more detailed descriptions.

The Department of Conservation and Recreation invited experienced cavers from around the region to form the Karst Resource Inventory Team, a special group of trained volunteers to focus on the Forest inventory project. The team collectively received the required permits to sample cave fauna in the Forest from the Department of Game and Inland Fisheries and the Virginia Cave Board. As Department of Conservation and Recreation volunteers, they signed agreements that required professional behavior while representing the state, and were covered by the Commonwealth's risk management insurance during work activities and related travel.

Grant funds covered the expense of a weekend training session for approximately 30 volunteers. The combined classroom and field training was provided by Drs David Culver, Dan Fong, and Horton Hobbs of the Karst Waters Institute, and Kevin Simon. Sessions addressed habitat types and food supplies, the major taxonomic groups in caves, relative distribution of known species, and sample collection and preservation techniques. Instruction on the collection of field data included a trip to a local stream for benthic sampling, and visits to two caves with different types of aquatic habitats. The Team was geographically divided into four subgroups that covered the twelve Ranger Districts in the Forest. The groups generally worked in the areas they were most familiar with or lived near.

Team 1 included members of the Mountain Empire and Powell Mountain Grottos, and took responsibility for the Clinch Ranger District in the furthest southwest portions of Virginia. Team 2 included members of the New River Valley and VPI Student Grottos, who covered the Mount Rogers National Recreation Area, as well as the New Castle, Wythe, and Blacksburg Ranger Districts. Team 3 consisted of Blue Ridge Grotto and NSS Virginia Region members who worked in the Glenwood, James River, and Warm Springs Ranger Districts. Team 4 included members of the TriState and Front Royal Grottos, who surveyed the Lee, Dry River, Pedlar, and Deerfield Ranger Districts in the northern part of the Forest. Each team was responsible for the inventory of 20 to 25 medium- to high-priority caves over the course of the project. Since much of the cave information was old and/or inaccurate, teams were informed that steep ridge-walking exercises and lost driving time were to be expected.

Team members documented important observations in the caves, including signs of pack rat, raccoon, and bobcat usage, historical and archaeological evidence, bat numbers and descriptions, and occurrences of troglobitic and terrestrial fauna such as cave crickets, millipedes, beetles, collembola, harvestmen, mites, spiders, salamanders, and crayfish. The teams are permitted to collect voucher specimens of stygobites, when present. They also provide detailed descriptions of cave streams, pools, and flowstone habitats (substrate, estimated flow, and the like). Collection sites were marked on cave maps when they were available. In some cases, teams surveyed caves or provided sketches in adequate detail to allow the sample sites to be revisited. Other information that was collected included ambient weather conditions, observed vandalism, encounters with adjacent landowners or Forest users, mileage and working hours, accidents, and so on. Samples are preserved in ethanol or isopropyl alcohol, properly labeled, and shipped to Dr Dan Fong at American University for subsequent identification and cataloging.

During 1999, a record drought affected access to and the availability of water in many caves, and resulted in reduced sample recovery. Where water was low or absent, Team members still noted interesting observations of troglobitic species and planned return visits to a percentage of the caves when more normal

precipitation resumed. In some cases, Team members continued to survey caves to produce maps for conservation management purposes and to correct erroneous location records. A final project report will be prepared for the National Fish and Wildlife Foundation and Forest in September 2000. The Karst Resource Inventory Team has already planned a fall meeting to finalize the first year of the project and to plan future activities to supplement the initial cave inventory.

Threats and Management Challenges

Through these inventory projects, the Forest Ecology Group is documenting the occurrence of exemplary ecological communities and species with special habitat requirements to improve ecosystem management and conservation planning practices. The portions of the Forest underlain by carbonate rock make up a relatively minor fraction of the total land area, yet present several resource management challenges. First, due to the fact that conventional hydrologic models for forestry operations do not account for surface water losses to groundwater, impacts resulting from timber harvests on karst are not adequately addressed in pre-harvest plans (Waring and Schlesinger, 1985; Brown, 1991). Second, over-visitation of caves in remote areas of the Forest, as well as those located in popular recreational areas and near private property, may conflict with conservation management principles. Third, water supplies in the Forest serve as invaluable and sometimes irreplaceable drinking water sources for rural areas.

Large-scale timber harvests and road construction on steep slopes in karst catchments pose significant potential threats to cave communities in the Forest. Soil loss from roads in the southern Appalachians can exceed 5,000 ton/ha/year on slopes of 20% or more (Waring and Schlesinger, 1985). Heavy equipment also creates excessive soil compaction, decreases infiltration, and increases runoff and erosion rates. Drainage alterations and road construction in or across the beds of sinking streams have created sedimentation impacts to caves, subsurface streams, and groundwater resources (Brown, 1991, 1999). Disposal of logging debris and slash in and around cave entrances and sinkholes can alter the natural nutrient flow associated with caves and prevent access by raccoons, bobcats, and other wildlife. Effective buffer zones are difficult to design around karst features, given the variety of habitats and foraging areas required by cave fauna, and the inherent permeability of the epikarst. The epikarst consists of the densely fractured and solution-enhanced zone of bedrock between the soil interface and the "water table." Hydrologically, the epikarst is characterized by vadose percolation, but can locally function in a water storage and transport role (Field, 1999).

Erosion from unauthorized ATV and hiking trails impact surrounding forest and plant communities, and provide opportunities for the introduction of invasive weeds (Wilson, 2000). Designated hiking trails are usually stable and well maintained, but the steep, undesignated trails leading to cave entrances create erosion and safety hazards. Such trails may actually increase cave visitation by the curious and unprepared novice. As problems with these trails are documented, recommendations for improved control, abandonment, posting, and/or repair of certain cave access trails should be considered and implemented.

The financial and environmental cost to gate all Forest caves would be prohibitive and counter-productive because gates can impede the natural nutrient transport and air flow of caves, and affect the use of caves by wildlife. In timber harvest areas, gates would not provide any protection from alterations in surface and subsurface hydrology, drying, or excessive sedimentation. Properly designed, constructed, and maintained gates have been successfully employed to eliminate over-visitation, vandalism, and disturbance of dwindling bat populations in the Forest, such as the federally endangered Indiana bat (*Myotis sodalis*). As part of this project, old or unmaintained gates will be noted and targeted for removal or replacement with secure bat-friendly gates with animal access portals, as needed.

With the recent federal emphasis on watershed and Source Water Protection (USEPA,1997), watershed groups and state drinking water programs are focussing more attention on the catchment areas in the national forests and other large expanses of public land that serve as important source areas for aquifer recharge. This is especially important in the mountainous regions with karst valley footslopes and floors. Furthermore, the Forest owns many large springs that have been historically used as public and community drinking water supplies (Brown and Ruark, 1997). Many of these springs continue to sustain consistent flows even during the prolonged drought of the late 1990s, and serve as important groundwater reservoirs for both rural domestic consumption and surface stream base flow. The Forest has Special Use Agreements with small community water systems for the use of some wells and springs, while

public access to others is relatively uncontrolled. Some of these springs are resurgences for karst systems, and provide convenient monitoring points for water quality and for cave invertebrates during periods of high flow. The protection of these large springs, as well as the smaller, biologically-significant seeps and fens, should be a conservation priority for the Forest.

Control and Use of the Data

The information collected during this project will be jointly controlled through confidential data-sharing agreements between the Virginia Speleological Survey, Department of Conservation and Recreation, and the Forest. Sensitive natural heritage resource information that could encourage removal or destruction of rare species is exempt from the Freedom of Information Act in Virginia, and will not be released to the public. The data will be used by Department of Conservation and Recreation and the Forest to develop specific management strategies for the protection of karst resources, and will serve as the cornerstone for achieving "significant" status for these caves under the Federal Cave Resources Protection Act.

The Federal Cave Resources Protection Act provides legal protection for caves on federal land that are designated as significant based on biological, cultural, geologic/mineralogic/paleontologic, hydrologic, recreational or scenic, and educational/scientific values.

The final report will be submitted as a supplement to previous reports summarizing the biologic and geologic importance of certain karst areas of the Forest (Kastning and Kastning, 1992; Erdle *et al*., 1996; Smith *et al*., 1997; Fleming, 1999; Wilson, 2000). Each of these reports recommends special U.S. Forest Service conservation designations, such as Research Natural Areas and Special Interest Areas, that would set these sites aside for additional monitoring, research, and educational purposes and to preserve their current condition from over-use or disturbance.

References

Brown, T. 1991. Notice of appeal filed pursuant to 36 CFR Part 217 of a resource management decisions in the Watauga Ranger District, Johnson County, Tenn, First Tennessee Development District, Johnson City, Tenn. Unpublished report.

Brown, T. 1999, "Karst Resource Protection and Forest Management," in *Virginia Forest Landowner Update*, Vol 13, No. 1, Virginia Tech Cooperative Extension, Blacksburg, Va.

Brown, T. and Ruark, V. 1997. "Hydrogeologic Characterization of a Karst Groundwater Supply Source to Determine Surface Water Influence," Abstract in *Karst Water Environment Symposium Proceedings*, Hotel Roanoke and Conference Center, Roanoke Va, October 30-31, 1997, Virginia Water Resources Research Center, Virginia Tech:Blacksburg, 154 pp.

Culver, D.C. 1999. Karst Resource Inventory Team training program, personal communication.

Culver, D.C. 1999. "Ecosystem and species diversity beneath our feet," pp 56-60. In T.H. Ricketts *et al*. (eds*.), Terrestrial Ecoregions of North America*. A conservation assessment. Island Press, Washington, DC.

Douglas, H.H. 1964. *Caves of Virginia*, Virginia Cave Survey, Falls Church.

Erdle, S.Y., L.R. Smith, and D.K. Howarth. 1996. Special Biological Interest Areas on the Jefferson National Forest: Candidates for Special Interest Area and Research Natural Area Designation. Natural Heritage Tech, rep. 96-14. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 270 pp plus appendices.

Field, M.S. 1999. A lexicon of cave and karst terminology with special reference to environmental karst hydrology, EPA/600/R-99/006, National Center for Environmental Assessment, US Environmental Protection Agency, Washington, DC.

Fleming, G.P. 1999. Plant Communities of Limestone, Dolomite, and other Calcareous Substrates in the George Washington and Jefferson National Forests, Virginia, Natural Heritage Technical Report 99-4, Virginia Dept. of Conservation and Recreation, Division of Natural Heritage, Richmond. Unpublished report submitted to the USDA Forest Service. 218 pp plus appendices.

Holsinger, J.R. 1975. "Descriptions of Virginia Caves*." Bulletin 85, Virginia Division of Mineral Resources*, Charlottesville, Va 450 pp.

Kastning, E.H. and Kastning, K.M. 1992. Cave and Karst Resources of the Jefferson Na-

tional Forest, West-Central and Southwestern Virginia, report of investigations and inventory to the USDA USFS, Roanoke, Va, 105 pp plus appendices.

Koch, L. 1998. US Fish and Wildlife Service, personal communication.

Smith, E.K., T. Brown, and T. Collins. 1997. Environmental Management of a Karst Resource Area in the George Washington and Jefferson National Forests, in Karst Water Environment Symposium Proceedings, Hotel Roanoke and Conference Center, Roanoke Va, October 30-31, 1997, Virginia Water Resources Research Center, Virginia Tech:Blacksburg, 154 pp.

USEPA. 1997. State Source Water Assessment and Protection Programs Guidance, Final Guidance, Office of Water, EPA 816-R-97-009.

Van der Leeden, F. 1993. *Water Atlas of Virginia—Basic Facts About Virginia's Water Resources, Tennyson Press:Lexington,VA, 46 plates.*

Waring, R.H., and Schlesinger, W.H., 1985, Forest Ecosystems: Concepts and Management, Academic Press, Inc.: Orlando, 340 pp.

Wilson, I.T. 2000. Biological Diversity Protection on the George Washington and Jefferson National Forest, First Supplement. Natural Heritage Tech. Rep. 00-11. Virginia Dept. of Conservation and Recreation, Division of Natural Heritage, Richmond, Va. Unpublished report submitted to the USDA Forest Service, 89 pp plus maps.