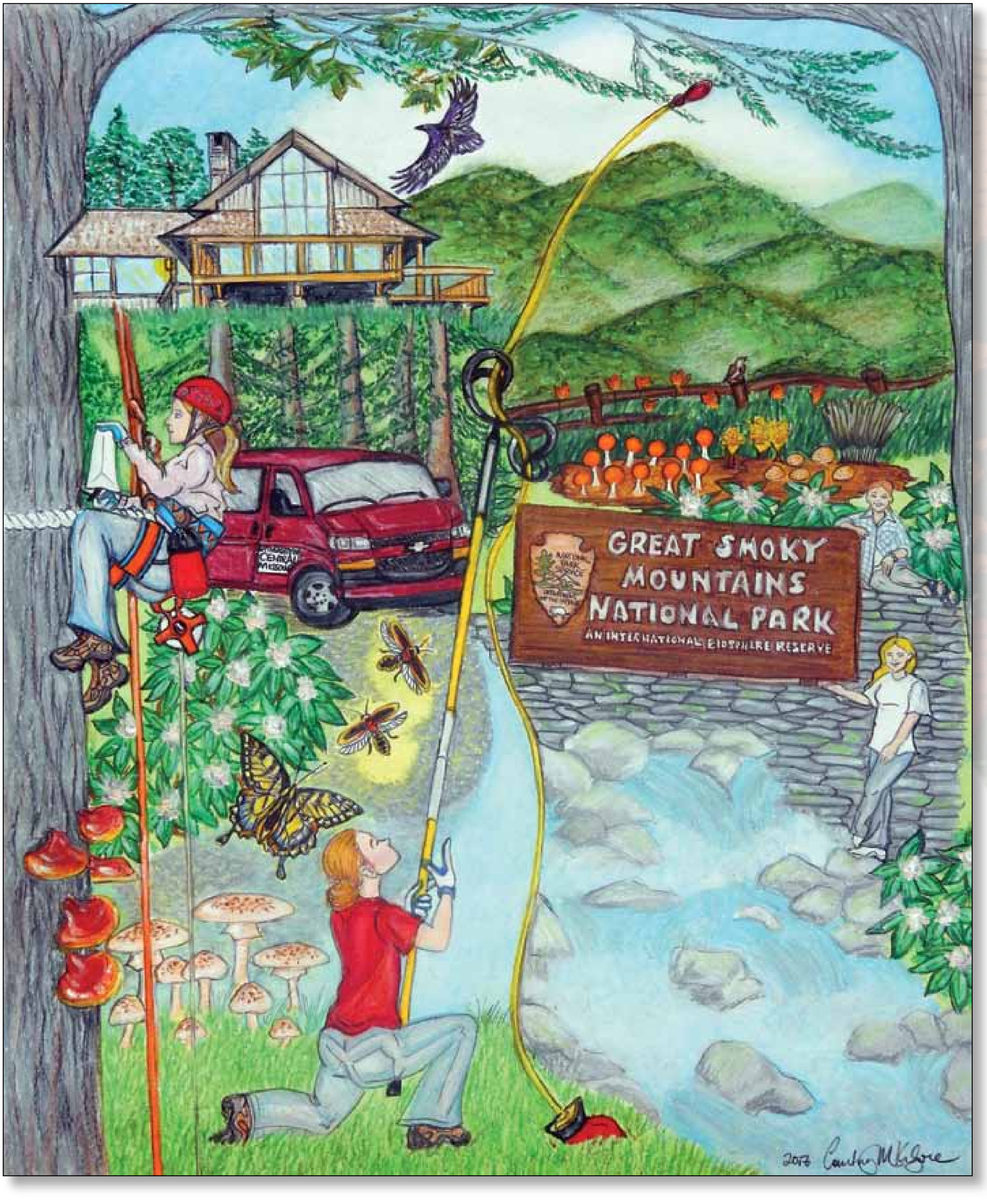

How many of the following images can you find? Appalachian Highlands Science Learning Center at 5,086 feet in Haywood County, North Carolina; panoramic view of mountain terrain; raven in the sky; hemlock trees; split rail fence with small bird (song sparrow) and flowers nearby; student climber Courtney Kilgore ascending hemlock tree above *Ganoderma tsugae* (shelf fungus); rhododendron flowering; synchronous fireflies; tiger swallowtail butterfly; *Amanita* mushrooms on ground; Courtney Kilgore shooting bigshot with throw-bag and slick line; mountain stream; park sign with Sydney Everhart above and Angela Scarborough at side; University of Central Missouri red van; decaying log with immature stalked *Physarum* sporangia, mature sporangia of *Hemitrichia stipitata*, cluster of *Stemonitis* sporangia, and *Lycogala epidendrum* developing fruiting bodies.

GREAT SMOKY MOUNTAINS NATIONAL PARK:

The People's Park

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Abstract—Early history of the park is described from the Cherokee Native Americans to the American pioneer settlers who developed their own mountain culture. Settlement of the Cades Cove area is told through the preservation, restoration, and pictures of homestead buildings. The tragic impact of the logging period and clear cutting in the early 1900s removed a significant portion of the giant trees and old- growth forest. Establishment of the park is highlighted through the efforts of different people in Tennessee and North Carolina that helped to raise money to purchase the land and create public interest in the concept of a park. Geological, physical, and natural history features of the park include the formation of mountains, streams, waterfalls, the Appalachian Trail, the appearance of autumn foliage colors, and activities of synchronous fireflies. The All Taxa Biodiversity Inventory (ATBI) organization, concept, and description of the taxonomic groups are discussed. The first tree canopy study in the park includes taxonomic groups represented by ferns, bryophytes, fungi, myxomycetes, myxobacteria, slugs and snails, and tardigrades.

Key Words—ATBI, biodiversity, BRIT, bryophytes, Cades Cove, ferns, fireflies, fungi, mollusks, Myxomycetes, lichens, tardigrades, tree canopy, waterfalls

"Shaconage" (Sha-Kon-O-Hey):
Cherokee for "land of the blue smoke"

Earliest visitors

Prehistorical archaeological sites excavated within the park indicate Native Americans were present at least 8,000 years before the present, and the earliest human occupation occurred possibly 10,000 years ago (Linzey, 2008).The Cherokee people, who called themselves *Ani-Yun-Wiya* ("The Principal People"), can trace their history back for more than a thousand years as some of the earliest visitors or inhabitants of what is now known as the Great Smoky Mountains National Park (GSMNP). Embedded in Cherokee history and culture are mythical tales and legends of the landscapes and animals found in the Smoky Mountains. The Cades Cove area (Figure 1) was part of the Cherokee Nation before the 1800s, when mostly hunting parties visited the area to hunt for elk and bison during the summertime. The Cherokees called Cades Cove *Tsiyahi* or "place of the otter." Permanent settlement would await the Europeans in the early 1800s (Brown, 2000; Shields, 1981).

Settlement and early pioneers

William Tipton and his brothers, Abraham and Thomas, are associated with the earliest land ownership (1821) in the Cades Cove area (Shields, 1981). The physical features of a flat, secluded, treeless valley with fertile soil bordered by high mountains created an isolated area well-suited for agriculture and development of Appalachian mountain culture. The population of the cove in the 1830s to 1840s listed 44 households and 271 people and by 1850 had grown to 132 households and 685 people. These numbers fluctuated slightly up and down until this area became part of the Great Smoky Mountains National Park in the 1930s (Shields, 1981).

Homesteads, buildings, and Cades Cove Visitor Center

The way of life of early pioneers that settled in the Cades Cove area has been preserved in many historic structures: log cabins, barns, fences, homes, mills, outbuildings, churches, schools, and others (more than 27 listed with the

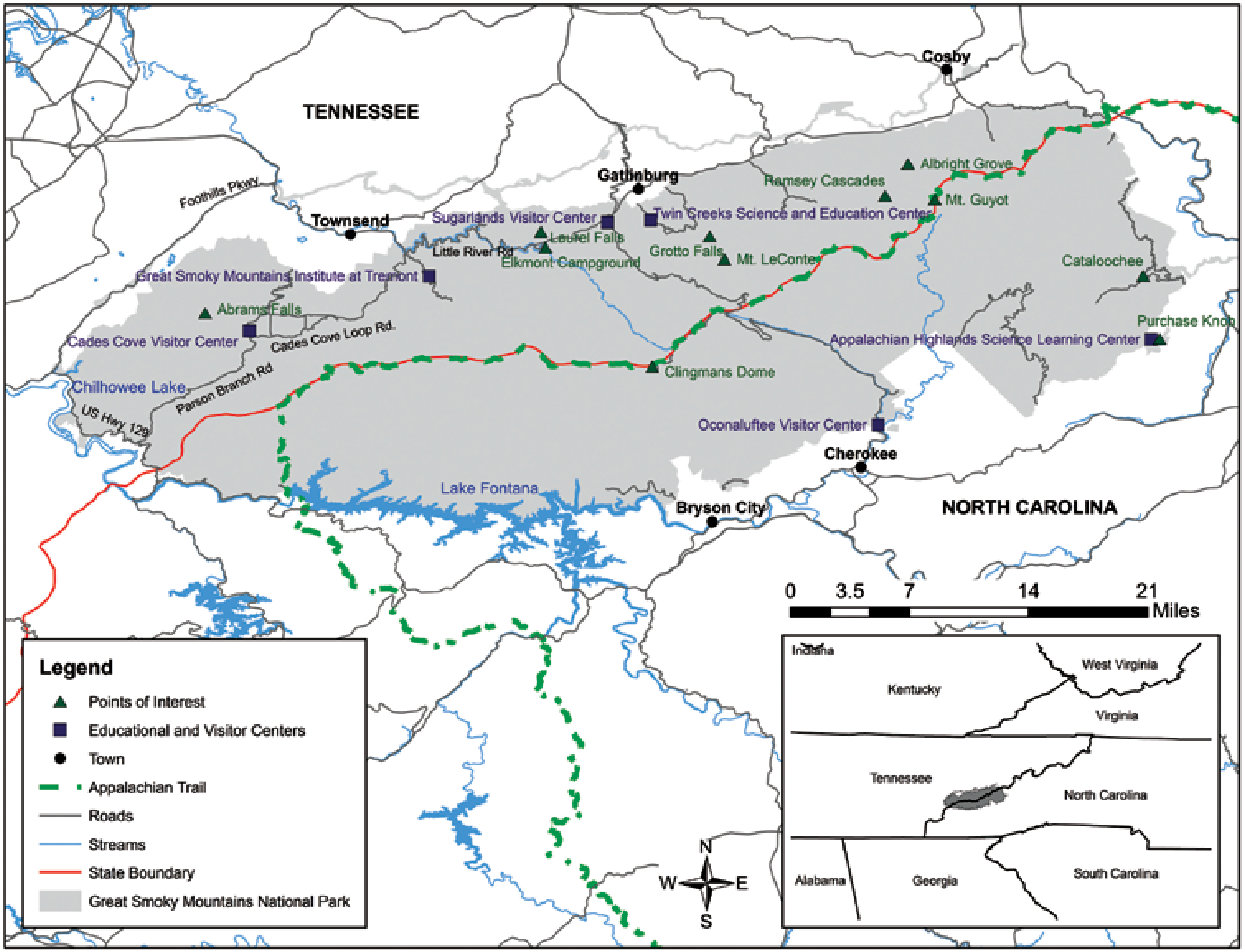


Figure 1. Great Smoky Mountains National Park map showing points of interest.

National Register of Historic Places) along the 11-mile, one-way Cades Cove Loop Road (Figure 1). One of the most photographed structures is a double cantilever barn that is a replica of an earlier one on the Tipton Place built in the early 1870s. The overhang of the roof supported a large second-story loft atop one or more log cribs that ran the entire length of the barn from front to back. Hay was stored in the loft, the cribs were used for livestock pens, and the overhang provided space for storing equipment and grooming animals. The inclined overhang protects both structure and animals by shunting rainwater away from the interior and creating an exterior drip line (GSMNP, 2017) (Figure 2).

Colonel Hamp Tipton built a two-story log cabin, carriage house, smokehouse, and woodshed at the same time and on the same site. Log cabins were constructed from native trees (usually hardwood such as *Liriodendron tulipifera*, yellow poplar) hewn into timbers or logs squared off with a broadaxe. Notches were cut in the end of each log and then interlocked to form walls. Spaces between the logs were filled with mud to keep out pests and wind and to moderate temperatures (Figure 3). A split rail fence can be seen in the foreground (GSMNP, 2017).

The John Cable Grist Mill was built in the early 1870s and was powered by water from Mill Creek. This mill still operates today grinding corn into flour, and visitors can watch the process and talk to the miller. Water is channeled to the head of the millrace where gates regulate the flow entering a 235-ft flume ending at the crest of a wooden water-wheel which rises vertically against the left side of the mill. Water from the flume continually drops onto 40-wheel-buckets, forcing the wheel to turn. This two-story mill structure consists of a small room with mill equipment hand-operated and below a room with gears that move the millstones (GSMNP, 2017) (Figure 4).

The Becky Cable House at Cades Cove Visitor Center was built in 1879 and located initially at Forge Creek Road. It is thought to be the first all-frame house in Cades Cove and was moved to its present location near the grist mill within easy walking distance (Figure 5). Rebecca Ann Cable, or "Aunt Becky" as everyone called her, purchased the home in 1887 and lived there until her death in 1940. She never married, and like so many early American pioneers, she was self-reliant and independent. She managed a farm, milled corn into flour, housed her extended family, was an exceptionally good cook (especially her apple pies made with biscuit

Figure 2. Double cantilever barn. Note wagon parked in the central open area.

Figure 3. Hamp Tipton two-story log cabin with split rail fence in foreground.

Figure 4. John Cable Grist Mill with flume and wooden water-powered wheel with 40-wheel-buckets on left side of mill and wooden walk-way to entrance.

Figure 5. Becky Cable House was the first all-frame house in Cades Cove.

dough), raised sheep, carded, spun, and dyed the wool, and wove and knitted clothing. Additional buildings remain on their original sites in other parts of the park such as Roaring Fork and the Oconaluftee Visitor Center area (GSMNP, 2017).

Figure 6. Commemorative plaque recognizing monetary gift of John D. Rockefeller.

Destructive logging phase

During the first 30 years of the 20th century, nearly two-thirds of the forested areas of the park were clear-cut, creating a barren wasteland. Everything was cut down, and though a few stumps remained, nothing was left to stop terrible erosion from silting the mountain streams. Earlier settlers in the 1830s to 1900s had used selective cutting, which did much less damage, but took from the forest the best and biggest hardwoods such as white ash, black cherry, oak, black walnut, and yellow poplar highly prized for furniture and home building. Some of these were giant trees 10–20 ft in diameter and 200 ft tall. A few remain as stately old-growth trees in Albright Grove (Houk, 1993; Linzey, 2008).

Many lumber companies were involved in logging, but one company that clear-cut the Little River watershed and the Cades Cove area was the Little River Lumber Company. It purchased 85,000 acres in 1901 for $3.00 per acre and constructed a saw mill in Townsend, Tennessee. A railroad track was built beside Little River that ran from Elkmont to Cades Cove with spurs to nearby areas and as far away as the heights of Clingmans Dome (Figure 1). Splash dams formed lakes in more inaccessible areas where logs were cut and then held until the dams were dynamited and logs floated downstream. Skidding operations were used to remove trees in more remote areas that did as much damage as the highly erosive clear-cutting. Logging continued on both the North Carolina and Tennessee sides of the park until cutting stopped in 1939 (Houk, 1993; Linzey, 2008).

Establishment of the park for the enjoyment of the people

Great Smoky Mountains National Park is the largest land and forest-protected area east of the Mississippi River. In the early 1900s, and for the next 30 years, many individuals and groups were involved in efforts to establish the park. Some of the more influential of those people were naturalists who hiked the trails, photographers who captured the scenic beauty of the place, and conservationists and politicians who all contributed to creating interest in the park or helped raise money. Many of them published books, essays, and newspaper and magazine articles that featured photographs and stories about their experiences in the park, especially the panoramic landscapes, trees, flowers, animals, and topographic features (Brown, 2000; Houk, 1993; Linzey, 2008).

One of the strongest early park enthusiasts was Horace Kephart, who wrote books based on his first-hand observations during frequent trips from his home in nearby Bryson, North Carolina. Names of others that were associated and credited with advocating to start a national park include: Paul Fink, who hiked throughout the back-country and helped

Figure 7. Scenic panoramic view of the Smoky Mountains. Note the rounded summits.

Figure 8. Park sign at the entrance located at Townsend, Tennessee.

Figure 9. Signpost at the state line between Tennessee and North Carolina.

Figure 10. Cades Cove valley as seen from the tree canopy along ridge line.

Figure 11. Ground level view of the Cades Cove valley. Note the grassy meadow surrounded by mountainous terrain on all sides.

Figure 12. Aerial view overlooking brilliantly colored, leafy, mixed tree species. October autumn colors of trees at low elevation near Gatlinburg, Tennessee.

Figure 13. Beautiful majestic Abrams Falls with access via a trailhead marker at west end of Cades Cove Loop Road. Note voluminous water flow plunging into a deep pool outlined by large boulders.

Figure 14. Grotto Falls near Gatlinburg. Walkway behind falls gives the visitor a special experience with the thunderous roar of the water flowing overhead and a cloud of misty spray all around.

establish the Appalachian Trail in the park (Figure 1); George Masa, whose stunning photographs appeared in many publications and played a major role in convincing the public that this area was worth saving; civic leader David Chapman, from Knoxville, Tennessee, who helped raise money through successful capital campaigns; Knoxville Mayor Ben Morton, who negotiated the purchase of many land acquisitions; Charles A. Webb, editor of the *Asheville Citizen-Times*, who published many editorials about the importance of the park; and the National Park Service, which supported the formation of a park in the East closer to the majority of the nation's population (Brown, 2000; GSMNP 2017).

With the words: "there is nothing else like it on the face of the earth," the U.S. Congress in December 1924 approved the concept of Great Smoky Mountain National Park but unfortunately failed to appropriate money to make the multitude of private land purchases. The states of North Carolina and Tennessee thus began to raise money themselves to buy the land. This phase of land acquisition was controversial because the logging companies did not want to give up their profitable businesses and money-making investments. In addition, residents who had owned and worked land did not want to give up their property rights. By 1931 about 5 million dollars had been raised by North Carolina, Tennessee, and the U.S. government, but this was only about half the amount needed to fund the park. John D. Rockefeller, Jr. eventually matched this dollar amount to honor his mother, and with the goal achieved, the Great Smoky Mountains National Park was officially recognized on June 15, 1934 (Figure 6). President Franklin D. Roosevelt dedicated the park at

Newfound Gap on September 2, 1940 (Brown, 2000; Linzey, 2008).

It took time, money, and the power of eminent domain to force landowners to sell their property and homes and move outside the boundaries of the new park. Only a handful of people were granted lifetime leases to stay and live out their lives. The mountain people living in the park are all gone now, but their way of life and the physical features of the park will be preserved for future generations to enjoy. Land has been added incrementally over the years through purchases, exchanges, and donations, and the park is now more than 520,000 acres in size, spanning the boundary between eastern Tennessee and western North Carolina between 35.8289° and 35.8479°N latitude (Figures 1, 9).

Geological history and natural features of the park

The Appalachian Mountains are among the oldest in the world, dating back to at least the Acadian Orogeny 380 million years ago (King et al., 1968). Several other mountain-building phases have occurred, and now this mountain chain stretches over 2,000 miles southwesterly from Maine to Georgia. Seventy miles of the world famous Appalachian Trail pass through the park (Figure 1, 17). The bedrock consists mostly of Precambrian meta-sediments that have been cut away to form majestic waterfalls such as Abrams Falls or eroded to expose limestone "windows" as in Cades Cove. The Great Smoky Mountains are the highest in the Appalachian Mountain chain, with 16 mountain tops cresting 6,000 or more ft above sea level. Total elevation ranges from 876 ft at the mouth of Abrams Creek to 6,643 feet at the summit of Clingmans Dome (Figure 1, 17), the tallest mountain in Tennessee (Houk, 1993; Linzey, 2008).

Complex geologic and climatic processes shaped these mountains and landscapes, giving rise to cliffs, steep slopes, and fertile valleys. But it is the vast forest, covering nearly 95 percent of the area, that gives the Smokies their true character (Figure 7). At lower elevations leafy deciduous hardwood trees dominate, and at higher elevations in the Clingmans Dome area needle-bearing spruce-fir conifers dominate.

During the Pleistocene Epoch of the Quaternary Period (2 million to 10,000 years ago), northern species moved southward along the spine of the Appalachians, while southern species migrated northward. The mixing of these species has formed one of the richest and most diverse biotas in the temperate regions of the world. The northeast-to-southwest orientation of the Appalachian Mountains also historically allowed species to migrate up and down the slopes. As today's climate warms, many traditionally northern species are retreating further upward and northward along the slopes, while southern species are expanding (Linzey, 2008).

Due in part to its exceptional biodiversity, the GSMNP was designated an International Biosphere Reserve October 26, 1974 and a World Heritage Site on December 6, 1983 (Figure 8). Differences in elevation and temperature ranges account for the exceptional cryptogamic or spore-producing organisms. Maritime tropical air brings in year-round moisture averaging 85 inches annually. This generous moisture, coupled with moderate temperatures that often range from 39–73°F at lower elevations, has resulted in rich plant diversity, supporting native species of southern states at lower elevations and ones from the north and Canada at higher elevations (Keller, 2004).

One area within the park that is both particularly diverse and extensively studied is Cades Cove. This area is a unique 5,000-acre valley of mostly lush, green meadows surrounded by steep, forested, low-lying mountains located at a lower elevation of approximately 269–2,205 ft at the western end of the park (Figures 10, 11). The cove's lower elevation means more moderate temperatures with an annual precipitation of 65 inches per year. A one-way, 11-mile road encircles the valley floor with two shortcut crossover roads: Sparks Lane and Hyatt Lane. But the drive can be slow-going with heavy traffic stopping often to view black bear, whitetail deer, and wild turkeys in the nearby fields. Cades Cove is visited by more than 2.5 million people each year and thus has special travel restrictions. Most of this area is reforested by trees no more than 75 years old due to heavy logging that continued until the late 1930s (Brown, 2000).

Along with this popular spot, the park's brilliant display of kaleidoscopic tree colors attracts yearly visitors during late September to early November. Early in autumn, the colors begin at the higher elevations—at the 5,000-ft zone in late September and extending to the middle of October. By that time, the lower elevations begin to explode in colors and continue into late October and early November. The foliage colors range from red, orange, yellow to gold, each from one of the more than 100 different tree species, creating a mixture of colors unmatched anywhere else in eastern United States (Figure 12). This spectacular display is short-lived—after a few short weeks all the leaves are gone, becoming part of the forest ground litter ecosystem.

Waterfalls offer breathtaking experiences in beauty and sound and are a major attraction in the park

Figure 15. Laural Falls near the Sugarlands Visitor Center. This most popular waterfall has an 80-ft drop with several cascades at different levels.

Figure 16. Synchronous flashing fireflies mating.

Figure 17. Signpost for Clingmans Dome Trail. Note Appalachian Trail nearby. These trailhead markers exist throughout the park, giving hikers distances to points of interest and intersecting trails.

Figure 18. Small stream flowing over and around rocks.

Figure 19. Larger stream after heavy storm. Heavy rain and runoff can turn a small bubbling brook into a rampaging, dangerous torrent that can wash away anything in its path. **Beware of waterways in stormy weather!**

(Morrison, 1999). There are more than 2,000 streams and creeks, punctuated by waterfalls both large and small along their pathway. Majestic Abrams Falls along Cades Cove Loop Road has the most voluminous water, flowing from Abrams Creek and falling over a sandstone base 24 ft in height and width into a picturesque deep pool. This is one of the most popular sites in the park (Figure 13). Another favorite is Grotto Falls along the Roaring Fork Motor Nature Trail near Gatlinburg. It is unique because the trail behind the falls affords the visitor an opportunity to experience a view out through the misty water spray and to hear the thunderous plunge of water over the 25-ft ledge (Figure 14).

Laurel Falls is about 3.7 miles from the Sugarlands Visitor Center. The trail to the falls is paved, making it the single most popular hiking attraction in the park. The spectacular 80-ft drop—coupled with a powerful multi-level tumbling force of water that is divided into an upper and lower section—creates a roaring sound that can be heard much before you reach the falls. A walking trail crosses over the midsection of the falls putting the visitor in the middle of the spray mist overhead before flowing into the narrow gorge below (Figure 15). The falls gets its name from the beautiful mountain laurel and rhododendron evergreen shrubs that line the trail (Morrison, 1999).

All of these falls are readily accessible from major paved roads and are easy to moderate hikes from the trailhead. Extreme caution should be exercised at all times in and around the fall spray mist area because the rocks and surrounding environs are slippery, **so watch your step and stay on the trail** (DeFoe et al., 1999; Morrison, 1999).

Synchronous fireflies

One of the spectacles in the park is the synchronous firefly display which typically occurs during the last week of May through the third week of June. There are several display areas inside and outside the park where this species displays the synchronous trait, but the largest one is at Elkmont Campground, near Gatlinburg and the Sugarlands Visitor Center. For many years, these sites and activities were not well known by the general public, but with the advent of social media, popularity of firefly viewing increased dramatically. Starting in 2006, a shuttle system to Elkmont was implemented as a way of limiting the crowds and preventing resource damage. Currently, there is a lottery system in place to select and limit the number of viewers.

The synchronous firefly is not a fly but a beetle (*Photinus carolinus*). It is the only firefly species in the park that has this synchronous display, even though there are at least 19 different firefly species that live in the park. I (HWK) was fortunate enough to observe this display during the third week of June on a road in Elkmont. It was late in the evening, about 9 or 10 pm, and it was pitch dark. There must have been millions of those beetles! They did not flash bright bursts of light, but produced a myriad of smaller light specks forming waves that progressed around me 360 degrees, then paused and started a new wave (Figure 16). This was repeated again and again, in an unforgettable and impressive sight.

What were these beetles doing? The beetle abdomen, on its underside, produces bioluminescent light, or cold light, which serves as a mating recognition signal so that males and females can find each other in darkness. Every species of firefly has its own unique flash pattern. The males of the

Figure 20. Signpost for Great Smoky Mountains Institute at Tremont.

synchronous species flash 4–8 times, then stop for 6–9 seconds, flash 5–8 times, and repeat (Faust, 2010). When large groups of males are in an area, the period of darkness becomes very synchronous, and the flashes begin to look like a wave of light. The adults only live for a couple of weeks, and during this time they mate, the female lays her eggs, and then all adults die, completing a one- to two-year life cycle.

The Dragons Run, US Highway 129

Are you ready to ride the Tail of the Dragon on US Highway 129 on the southern edge of the park in Tennessee (Figure 1)? The westernmost point of the scenic drive called Dragon's Run meets beautiful Lake Chilhowee on the south and parallels the lake in a straight stretch for about three miles. On the north are high bluffs with *Juniperus virginiana* (eastern red cedar) trees dotting the landscape. Most are stunted, growing on the rocky slopes in shallow, nutrient-poor soil, and seldom exceed more than 30 ft in total height, even though tree core samples show an age of more than 200 years (Keith Langdon, personal communication).

This scenic drive is a prelude to an 11-mile roadway going eastward that features 318 curves, many that are sharp, hairpin, and dangerous. This highway is especially hazardous during wet weather or in autumn when leaves have fallen on the roadway. The driver must concentrate on the road even with the spectacular scenery of the park on the north side along the way. The Dragon's Run is considered by many to be the most famous and exciting motorcycle and sports car road in America. There are no buildings and few turnoffs for passing so drive carefully. The roadway is like a dragon's tail whipping back and forth in a series of curves, hence the name. The road is banked, but some of the hairpin curves must be navigated at less than 15 miles per hour because of blind spots. There is a pullout and scenic overlook near the top with a panoramic view (Figure 1).

Park statistics

The park is approximately 522,427 acres (GSMNP, 2017; Jenkins, 2007) and contains the largest old-growth temperate forest in the eastern USA (98,842 acres) (Keller et al., 2004; Scarborough et al., 2009; Snell et al., 2003). It straddles the borders of eastern Tennessee and western North Carolina (Figure 9). During 2014 and 2015 the park welcomed more than 10 million visitors and set an attendance record of 11,312,785 visitors for 2016, making it the most visited of all 59 national parks (Grand Canyon, with 5.5 million visitors in 2016, is the second highest visited park) (GSMNP, 2017; NPS, 2017). In addition, this national park is readily accessible and does not require visitors to pay an entry fee. The park reported in 2016 a fiscal budget of over $18 million with about 240 permanent employees and 80 seasonal workers (GSMNP, 2017). The large number of visitors and expansive size of the park make this a unique area to protect and maintain. Park managers must work hard to carry out its mission "to conserve the scenery and the natural and historic objects and the wildlife therein … in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (GSMNP, 2017).

The park features more than 850 miles of hiking trails (Figure 17); 13 of the nation's largest trees listed on the National Register of Big Trees (Jenkins, 2007); more than 120 tree species, far more than any other temperate region of the world; 16 mountain tops above 6,000 ft—represented in part by Clingmans Dome (6,643'), Mount Guyot (6,621'), and Mount Le Conte (6,593')—730 miles of fishing streams and another 11,300 miles of tributaries (Figure 18, 19); 10 campgrounds with a total of 1,000 sites; 11 picnic areas, totaling 1,050 sites; more than 100 backcountry sites, including shelters; 384 miles of mountain roads in 800 square miles of mountainous terrain; 342 maintained structures with 97 structures preserving Southern Appalachia heritage; and approximately 550 miles of trails open to horses. The park also boasts four visitor centers—Cades Cove, Cataloochee valley (elk recently were reintroduced), Sugarlands, and Clingmans Dome—three information centers outside the park at Gatlinburg, Sevierville, and Townsend; and Great Smoky Mountains Institute at Tremont, located inside the park, which features seminars, hiking trips, and educational courses throughout the year (Figure 20).

The "Smokies" name comes from a smoke-like haze created by warm air filled with terpene vapors and mist rising in the swirling atmosphere from the lush vegetation. The Cherokees called the area *Shaconage*, or "the land of the blue smoke" (GSMNP, 2017).

All Taxa Biodiversity Inventory (ATBI)

The Great Smoky Mountains are known to support a wide diversity of plant species (Whittaker, 1956). The vegetation in this area has existed for many millions of years and provides an example of "old-growth deciduous forest" (Busing, 1998; Jenkins, 2007; Sharkey, 2001) with many of the forest ecosystems considered to be climax communities (Whittaker, 1956).

In 1998, the U.S. National Park Service and the non-profit Discover Life in America (DLIA) began the process of documenting the biodiversity located within GSMNP as part of an All Taxa Biodiversity Inventory (ATBI) (NPS, 2017). An ATBI seeks to discover, identify, and document the taxa found within a particular area; in turn this information can assist park or land managers in creating guides for stewardship of biodiversity, developing better management and data management plans, and devising ideas for sharing data among entities (Eymann et al., 2010; Janzen and Hallwachs, 1994).

Most national parks have become refuges or preserves for biodiversity due to increasing threats from human expansion (NPS BSSC, 2009), global warming, non-native organisms (White, 1982), and increased pollution levels (e.g., ozone pollution and acid rain) (GSMNP DLIA, 2001; Jenkins, 2007; Sharkey, 2001) all contribute to the rapid loss of biodiversity outside of these protected areas. However, external

Table 1. List of woody plant species that were only found in either the White (1982) publication or the ATBI database (February 28, 2017). Abundance is indicated by C = common (dominant), F = frequent, O = occasional (well distributed but not abundant), S = scarce, H = historic (documented but not seen in 50 years), I = infrequent (scattered), R =rare (small population), VR = very rare (single location), X = extirpated (not seen for 50 years), or U = unknown (ATBI did not report abundance). The elevation range indicated in the table is Lo = lower elevation (850–2,500'), Mid = middle elevation (2,500–4,500'), Lo-mid = found at lower and middle elevations (850 – 4,500'), Hi = higher elevation (4,500–6,600'), WR = wide range of elevations, HS = found near old home sites and U = unknown (ATBI did not report elevation). Origin is indicated by Na = Native (species that are endemic or indigenous) and E = Nonnative (species that are introduced).

Species	Common Name	Abundance	Elevational Range	Origin	Source
Acer floridanum	Southern Sugar Maple	U	U	Na	ATBI
Acer nigrum	Black Maple	U	U	Na	ATBI
Acer platanoides	Norway Maple	X	HS	E	White
Aesculus glabra	Ohio Buckeye	U	U	Na	ATBI
Aesculus hippocastanum	Horse Chestnut	U	U	E	ATBI
Aesculus octandra	Yellow Buckeye	U	U	Na	ATBI
Aronia arbutifolia	Hairy Chokeberry	S	WR	Na	White
Aronia x prunifolia	Purple Chokeberry	H	Lo	Na	White
Berberis vulgaris	Common Barberry	R	Lo	E	White
Berberis thunbergii	Japanese Barberry	R	Lo	E	White
Betula papyrifera	Mountain Paper Birch	R	Mid	Na	White
Betula pendula	European Weeping Birch	R	Mid	E	White
Calycanthus floridus var. *glaucus*	Eastern Sweetshrub	C	Lo-Mid	Na	White
Catalpa bignonioides	Southern Catalpa	U	U	Na	ATBI
Chaenomeles speciosa	Flowering Quince	R	HS	E	White
Crataegus calpodendron	Pear Hawthorn	S	Lo	Na	White
Crataegus pinetorum	Pineland Hawthorn	S	Lo	Na	White
Cryptomeria japonica	Japanese Cedar	U	U	E	ATBI
Cytisus scoparius	Scotch Broom	R	Hi	E	White
Diervilla lonicera	Northern Bush Honeysuckle	R	Hi	Na	White
Fagus americana	American Beech	U	U	Na	ATBI
Gymnocladus dioicus	Kentucky Coffee Tree	R	HS	Na	White
Hamamelis mollis	Witch Hazel	R	Lo	E	White
Hydrangea paniculata	Panicled Hydrangea	R	HS	E	White
Hypericum densiflorum	Bushy St. Johnswort	R	Lo	Na	White
Juglans mandshurica	Manchurian Walnut	R	HS	E	White
Juniperus chinensis	Chinese Juniper	R	Lo	E	White
Kerria japonica	Japanese Rose	R	HS	E	White
Lonicera fragrantissima	Sweet Breath of Spring	R	HS	E	White
Lonicera korolkowii	Small-leaved Honeysuckle	R	Lo	E	White
Lonicera morrowii	Morrow's Honeysuckle	S	Lo	E	White

Species	Common Name	Abundance	Elevational Range	Origin	Source
Magnolia grandiflora	Southern Magnolia	H	Lo	Na	White
Magnolia macrophylla	Bigleaf Magnolia	R	Lo	Na	White
Malus coronaria	Sweet Crab Apple	R	Hi	Na	White
Malus domestica	Paradise Apple	U	U	E	ATBI
Menziesia pilosa	Minniebush	I	Hi	Na	White
Nandina domestica	Sacred Bamboo	R	Lo	E	White
Philadelphus sharpianus	Sharp's Mock Orange	R	Lo	Na	White
Platycladus orientalis	Oriental Arborvitae	R	Lo	E	White
Poncirus trifoliata	Hardy Orange	R	HS	E	White
Populus alba	White Poplar	R	Lo	E	White
Populus nigra	Lombardy Poplar	R	HS	E	White
Populus balsamifera ssp. *balsamifera*	Balsam Poplar	R	Lo	Na	White
Populus x canescens	Gray Poplar	R	HS	E	White
Prunus munsoniana	Wild Goose Plum	R	HS	Na	White
Prunus triloba	Flowering Almond	R	HS	E	White
Prunus virginiana	Chokecherry	VR	Mid	Na	White
Ptelea trifoliata	Common Hoptree	U	U	Na	ATBI
Pyrus calleryana	Callery Pear	R	Lo	E	White
Pyrus communis	Common Pear	R	HS	E	White
Quercus michauxii	Swamp Chestnut Oak	U	U	Na	ATBI
Quercus palustris	Pin Oak	U	U	Na	ATBI
Quercus phellos	Willow Oak	R	Lo	Na	White
Rhododendron x bakeri	Cumberland Azalea	R	Hi	Na	White
Rhus aromatica	Fragrant Sumac	VR	Lo	Na	White
Rhus typhina	Staghorn Sumac	F	Lo-Mid	Na	White
Ribes aureum var. *villosum*	Golden Currant	R	HS	Na	White
Rosa arkansana	Prairie Rose	H	Mid	Na	White
Rosa canina	Dog Rose	R	HS	E	White
Rosa centifolia	Cabbage Rose	R	HS	E	White
Rosa eglanteria	Sweetbriar Rose	S	HS	E	White
Rubus alumnus	Oldfield Blackberry	O	Lo	Na	White
Rubus alumnus	Branched Blackberry	O	Lo	Na	White
Rubus trux	Lookout Mountain Blackberry	S	Lo	Na	White
Salix alba	White Willow	R	Lo	E	White
Salix caprea	Goat Willow	U	U	E	ATBI
Salix caroliniana	Coastal Plain Willow	R	Lo	Na	White
Sorbus aucuparia	European Mountain Ash	X	Hi	E	White

Species	Common Name	Abundance	Elevational Range	Origin	Source
Spiraea japonica	Japanese Meadowsweet	R	HS	E	White
Spiraea prunifolia	Bridal Wreath Spiraea	S	Lo-Mid	E	White
Spiraea virginiana	Virginia Meadowsweet	VR	Lo	Na	White
Spiraea x vanhouttei	Vanhoutte's Spiraea	R	HS	E	White
Symplocos tinctoria	Common Sweetleaf	X	Lo	Na	White
Syringa vulgaris	Common Lilac	R	HS	E	White
Taxodium distichum	Bald Cypress	U	U	Na	ATBI
Tsuga caroliniana	Carolina Hemlock	U	U	Na	ATBI
Ulmus pumila	Siberean Elm	R	HS	E	White
Viburnum plicatum	Japanese Snowball	R	Lo	E	White

Figures 21. Dead and dying red spruce trees at high elevation sites in the Clingmans Dome area.

Figure 22. Dead Fraser fir and red spruce trees as seen from Clingmans Dome Trail.

Figure 23. Clingmans Dome observation tower.

anthropogenic effects still have an impact within GSMNP as park visitors experience decreased visibility and views marred by dead trees due to air pollution, especially in the Clingmans Dome area (GSMNHA, 2001; Figures 21, 22, 23). Many of the unknown invertebrates, plants, stream algae, and fungi serve as indicator species for climate change and destructive local human activities (e.g., energy development, human expansion) (NPS BSSC, 2009). Because we can only "conserve and protect those natural resources that we are aware of" (Sharkey, 2001), conducting an in-depth ATBI has helped park managers know where the park's flora and fauna communities stand and how to move forward to conserve these precious ecosystems.

Renowned ecologist Dan Janzen conceived and attempted the first known All Taxa Biodiversity Inventory, which occurred in Costa Rica (Eymann et al., 2010). Lack of funding sank these initial efforts, but in the fall of 1997, a meeting was held to determine if a similar inventory could be completed in GSMNP (Eymann et al., 2010), the first U.S. national park to attempt an ATBI. This park was chosen based on its reputation for incredible biodiversity, especially of salamanders (it's informally recognized as the Salamander Capital of the World) (GSMNP, 2017).

Taxonomists worked in groups, known as Taxonomic Working Groups or TWiGs, identifying various life forms and accelerating the daunting process of identification (Sharkey, 2001). TWiGs were not always organized around one particular taxon and also must take into account the size and life history of particular organisms to form the group (e.g., the aquatic insect orders) (Sharkey, 2001). Rather than the species, it's taxonomic specialists themselves that are normally the limiting factor when working to identify collections, since their numbers are so few and their time is so limited (Parker and Bernard, 2006; Wilson, 1985). For example, there are 25 different TWiGs listed by Discover Life in America (DLIA, 2017), but not all of them have an assigned lead systematist or team. Recently the authors were informed that the TWiGs are no longer functional (Janet Rock, personal communication), but biodiversity inventories are still being conducted.

From these initial results from the ATBI, a "living database" was created that provides the public and science communities with information about species locations, relationships with other organisms (e.g., symbiotic, predator-prey), and genetic diversity (DLIA, 2017). The taxa listed in this database represent an accurate record of what exists within the park since the lists are continually being updated through the various biodiversity inventories that occur annually. These inventories have provided citizen scientists (including school and youth groups) an opportunity to work closely with professional scientists to collect data about all the species found within the park boundaries. The data collected have helped park officials understand and develop ideas for protecting new species and the complex ecosystems found within the park.

An updated tally of species new to the park and species new to science are posted on the DLIA homepage. From 1998 to the present, there have been 9,140 species found within the park for the first time with insects composing the largest group: Coleoptera (1,957 spp.), Diptera (1,225), and Lepidoptera (1,126). Fungi (583 spp.) and algae (566) are the next largest groups after insects (Janet Rock, personal communication). In addition, 974 species have been reported as new to science, with bacteria representing a considerable amount of these (270 spp.).

According to the DLIA database and a literature search, there are at least 700 genera of vascular plants noted within the park boundaries. This includes a large number of genera that were observed within the park but have not yet been identified to species. The top three most observed families in the park are the Sapindaceae (11.8%), Fagaceae (11.2%), and Pinaceae (10.2%). Of the top three families, the dominant growth form documented was trees (Harrington et al., 2005).

Comparing the ATBI plant data to an annotated checklist of the park flora by White (1982), it appears the top five genera within the park have seen a change in the number of species found as well as a shift in the original ranking (Table 1). The top five from the current database include *Carex* (81 reported spp.), *Viola* (26), *Solidago* (23), *Polygonum* (17), *Aster* (17), and *Dichanthelium* (16). For vascular plant families, the top five have stayed the same, but the number of reported genera has increased in all families except Rosaceae. Comparing both inventories, it appears the decrease in Rosaceae was due to two nonnative species listed by White that were not listed in the ATBI data: *Chaenomeles speciosa* (flowering quince) and *Kerria japonica* (Japanese rose). Other discrepancies between the ATBI database and White's inventory can likely be attributed to (1) a difference in man-power and resource investment, (2) some of the species have been identified as different or new genera or species (i.e., taxonomic revisions), and (3) some of the genera were only noted in one of the inventories.

Review of a small subset of plant data showed some noteworthy points. (1) The woody species that were reported within the park (i.e., trees, shrubs, and sub-shrubs) from the ATBI and White studies did not completely overlap: 15 species listed within the ATBI database are not found in White's list, and 63 were listed within the White checklist that were not found in the ATBI database. (2) Three of White's five "historic collections" (species that had been documented in the park's

Figure 24. Tree canopy fern, *Polypodium appalachianum*, showing fertile fronds with mature sori (red dots) and immature sori (pale dots) on underside. Note the thick "canopy soil" underneath the fern.

Figure 25. Colorful fungal species, *Clavaria zollingeri* (coral mushroom), growing among mosses and leaf litter trailside.

Figure 26. Building and grounds for the Appalachian Highlands Science Learning Center.

Figure 27. Backyard view of sunset after rain storm with cloud banks lingering in the valleys.

flora but were not found in at last 50 years) were not found in the ATBI (NPS website, 2017; White, 1982). These species were *Aronia* × *prunifolia* (purple chokeberry), *Magnolia grandiflora* (southern magnolia), and *Rosa arkansana* (Arkansas rose). Possible explanations include species rarity, narrow or unfortunate geographic distribution within the park, or incorrect identification in the field or from herbarium specimens on White's part. (3) A small number of species were reported by White as "very rare," occurring from one single location or from a small number of individuals. These species were *Prunus virginiana* (chokecherry), *Rhus aromatica* (fragrant sumac), and *Spiraea virginiana* (Virginia spiraea). Possible explanations, suggesting that these species are either rare but stable or are declining over time. (4) Some of the species (37) were reported by White as occurring near old home sites within the park, but 21 of these were not reported by the ATBI (see Table 1). Out of the reported 21, 18 are non-native species and were more than likely planted by settlers at those old home sites. In addition, two of the reported species—*Juglans mandshurica* (Manchu walnut) and *Prunus triloba* (flowering almond)—might be false reports or incorrect identifications since their known distribution ranges do not include Tennessee or North Carolina.

Tree canopy biodiversity, islands in the sky

Discovery of *Polypodium appalachianum* (the lithophilic rock cap fern) 140 ft up in the canopy of a giant *Liriodendron tulipifera* (yellow poplar) was an important new observation. This tree measured approximately 174 ft tall and 5.5 ft diameter at breast height, or 17 ft in circumference, and was located along the Ramsay Cascade Trail (Keller et al., 2003; Keller, 2004). There were twin trees about the same size on both sides of the trail estimated to have a life span of more than 400 years. Two more yellow poplars nearby were much larger in height and diameter. This new fern typically occurs on boulders on ground sites, but its epiphytic microhabitat in the tree canopy represented "an island in the sky" (Houk, 2015; Jourdan, 2007).

Figure 28. A rare crustose lichen, *Gomphillus americanus*, a new record for the park. Note the very unusual stalked, peltate hyphophores with conspicuous starburst tops and sharply pointed margins.

Bark samples taken at 10-ft intervals along the vertical trunk axis—to document the presence of moss and liverwort species—also failed to find any ferns until the first horizontal limb at 140 ft where a rock cap fern grew on the upper surface of a horizontal branch, extending for more than 10 ft (but could not be seen from the ground using binoculars). The fern blades had immature green and mature rusty red sori on the upper one-third of the sporophyte (Figure 24). The accumulation over time of dust, sand, and particulate matter on the branch surface created a "canopy soil" 6–8 inches thick that supported not only the fern, but also an assemblage of terrestrial mosses, an assortment of collembola (springtails), and a flightless proturan insect only known from soil and litter on the ground (Keller et al., 2003; Keller, 2004).

How did these ground-based species get high in the tree canopy? It is possible that high winds could sweep up forest litter and transport viable propagules to the upper tree canopy. Winds in excess of 80 mph associated with a deadly wildfire in the park, or weather events such as rare tornados or microbursts, could account for ground-site debris carried to tree tops. Establishment of these species over time demonstrates that entire community ecosystems can develop in tree canopies given enough time, and it will provide botanists with the opportunity to study disjunct transport mechanisms on the origin of some epiphytes.

Bryophytes (mosses and liverworts)

No new records were reported from the tree canopy out of 37 total

Figure 29. The Doubled Rope Climbing Method. Ready, set, shoot! The Big Shot sling shot enables the shooter to accurately direct a throw bag attached to a throw line 70–80 ft over a sturdy tree limb or preferably a tree crotch.

Figure 30. Courtney Kilgore strumming the throw line to release a snagged throw bag.

identified moss species (Keller, 2004) and 28 identified liverwort species (Davison and Keller, 2004). All of the bryophyte species are commonly found on ground sites, and most are common within the park. The most interesting canopy moss discovery was the light-loving *Drummondia prorepens*. This *Drummondia* was previously documented from only four sites in the park, yet it is one of the most common moss species in the upper tree canopies (Keller, 2004). Liverwort data trends indicated species of *Frullania* and *Metzgeria* are more frequent in the upper tree canopy, and of these only *F. brittoniae* and *F. eboracensis* are near-obligate epiphytes. These data were based on limited field canopy collections, therefore additional trees sampled would significantly increase the number of canopy bryophyte species (Davison and Keller, 2004).

A paradise for fungi

Great Smokies contains exceptional fungal diversity due in part to its topography, floristics, and especially the high diversity of tree species that are a source of mycorrhizal associations with many fungal species. Fungi are essential life forms that maintain the balance of ecosystems through their activities both as symbionts with trees and shrubs, providing essential nutrients, water, and acting as decomposers of organic matter. Current park records show in excess of 3,500 species of macrofungi, but vast numbers of microscopic fungi are still to be discovered. It is reasonable to estimate that more than 10,000 species of fungi may exist in the park (GSMNP, 2017).

Many mycologists have collected in the park, but two from the University of Tennessee merit special mention: Lexemuel R. Hesler and Ronald H. Petersen. Cades Cove was one of the areas where Hesler concentrated his fungal collections, resulting in more than 150 species new to science, mostly basidiomycetes. This area "… has been consistently mentioned as one of the richest locales for macrofungi in the world" (Petersen, 1979). The Tennessee side of the park is better known for fungi than the North Carolina side because of the concentration of collectors in the Cades Cove environs.

Distribution patterns of macrofungi in the park follow the same patterns

Figure 31. Courtney Kilgore collecting tree bark samples for corticolous myxomycetes cultured in moist chambers. Notice the reel-bound tape to measure height of bark sample, the climbing saddle attached to a climbing rope, and a much stronger, thicker safety rope secured around the tree trunk so that both hands are free to collect specimens.

Figure 32. Melissa Skrabal observing and collecting bark samples with stalked sporangia of a species new to science, *Diachea arboricola*, high in the canopy of a white oak tree.

as tree species where some species are indigenous, others are the southern limits of northern species at higher elevations in the spruce-fir zone, and still others are northern limits of tropical and subtropical mycotas, extending to the southern Pacific. Some of the macrofungal species in the park are also found as eastern Asia disjuncts but nowhere else in the world.

One of the strikingly beautiful violet to purple mushroom species, *Clavaria zollingeri* (coral fungus) was encountered trailside among mosses and leaf litter in an open area (Figure 25). The dichotomous branching seen here, the vivid violet-purple colors, and the brittle consistency serve to distinguish this species from other fungal species

More recent research on park mushrooms using molecular DNA profiles has found "hidden or cryptic" species that look alike but have different DNA signatures and do not interbreed. This discovery along with more careful morphological examination and comparison of type specimens from Europe indicates the same mycota names listed for the park and Europe are actually in many cases two different species. This undoubtedly will increase the number of species in the park substantially. In addition, climate change will surely continue to influence the mycota of the park, and additional collections of fungi must continue within the park to help monitor these changes over time (Petersen, personal communication).

Lichens, a partnership with cyanobacteria and algae

Fieldwork by research team members during the summer of 2000 yielded 2,008 lichen samples made from the tree canopy of 141 trees and one vine. This first canopy survey in the park resulted in 194 taxa of which 83 were presumptively identified as new records. *Gomphillus americanus* was a new record of a crustose lichen found at 49 ft on *Fraxinus americanus* (white ash). It had stalked, peltate, hyphophores 1–2 mm tall with a conspicuous starburst appearance and a marginal fringe of sharp points (Figure 28). All lichen species recorded from the tree canopy were also known from ground sites. Student climbers repeatedly observed that lichen growth and biomass increased near the top of the tree. Lichen observations made at diameter at breast height in densely shaded areas were less frequent than at higher levels on the tree trunk (Ciegler et al., 2003; Keller, 2004).

In 2004 the first Lichen Bio-Quest was held at the Great Smoky Mountains Institute at Tremont and included 30 high school teachers and students, park volunteers and staff, area residents, and professional lichenologists (Figure 20). Field forays to various park locations, resulted in 10 new lichen records. Two of these new records (*Trapeliopsis flexuosa* and *Placynthiella icmalea*) were found on an old wooden picnic table and seat encrusted with lichens on the grounds at Tremont (Keller et al., 2007).

Host tree species and different canopy heights influence species richness and distribution of lichen growth forms (Fanning et al., 2007). The foliose growth form had the greatest species richness compared to the other growth forms (crustose and foliose). The crustose and foliose growth forms were located lower to mid-canopy and nearer ground level (10–20 ft), while the fruticose forms were more prevalent on the horizontal branches and not on the trunks of the trees (Fanning et al., 2007).

Myxomycetes (plasmodial slime molds), the biological jewels of nature

The ATBI included a cryptogamic tree canopy biodiversity study that was the first to use the Doubled Rope Climbing Method to collect bark samples in the park (Figures 27–29) (Kilgore et al., 2008). A large series of papers have been published from this work, all focusing on the occurrence and distribution patterns of myxomycetes on the bark of living trees and woody vines and also on ground sites in the park (Carson, 2003; Counts et al., 2000; Everhart and Keller, 2008; Everhart et al., 2008; Everhart et al., 2009; Houk, 2015; Jourdan, 2007; Keller, 2004; Keller, 2005; Keller et al., 2004; Keller et al., 2008; Keller et al., 2009; Keller and Skrabal, 2002; Kilgore et al., 2008; Kilgore et al., 2009; Scarborough et al., 2009; Smith and Keller, 2004; Snell and Keller, 2003; Snell et al., 2003).

The Appalachian Highlands Science Learning Center served as headquarters for the tree canopy research climbing team that gave tree climbing demonstrations for the Great Smoky Mountains Association. It was the access point for bark samples collected from tree species on the North Carolina side of the park, and it was here that National Geographic Television produced a film entitled *Smoky Mountains Treetop Exploration* as part of the "Wild Chronicles" series hosted by Boyd Matson that aired on the Public Broadcasting System as Episode #318 (Figures 30, 31).

The history of collecting activities of myxomycetes in the park, species records, and previous publications are reviewed in Snell and Keller (2003) and Snell et al. (2003). Tree canopy results based on bark samples in moist chamber cultures (i.e., miniature terraria) of over 400 bark samples taken at 10-ft intervals from 25 trees representing 5 species: *Acer rubrum* (red maple), *Fraxinus americana* (white ash), *Liriodendron tulipifera* (yellow poplar), *Pinus strobus* (eastern white pine), and *Quercus alba* (white oak). Fifty-two species of corticolous myxomycetes were new records for the park. The vertical distribution patterns of myxomycete species on the bark of living trees was not restricted to the tree canopy so that bark samples taken from within easy reach at 6-ft heights for moist chamber cultures recovered the vast majority of species. Ground site myxomycetes yielded 10 additional new records, and current records for myxomycetes now stand at 220 total species for the park (Snell and Keller, 2003; Snell et al., 2003).

A myxomycete species new to science, *Diachea arboricola*, was discovered by Melissa Skrabal high in the tree canopy of a living *Quercus alba* (white oak) tree in the Cades Cove area of the park (Figure 32) (Keller, 2004; Keller, 2005; Keller and Skrabal 2002; Keller et al., 2004; Keller et al. 2008, Keller et al., 2009). Slime mold plasmodial tracks on the bark surface of the living tree extended from 30–80 ft. These tracks represented traces of plasmodial veins that excreted black waste matter along each side leaving two black lines with a white space in between that marks the bottom position of the vein (Figure 33). Observation of such plasmodial migration up to 50 ft with sporangia scattered along the way had never before been described and published (Keller et al., 2004). Stalked gold, silvery, multicolored, iridescent sporangia were collected from the crevices and fissures of the bark (Figure 34).

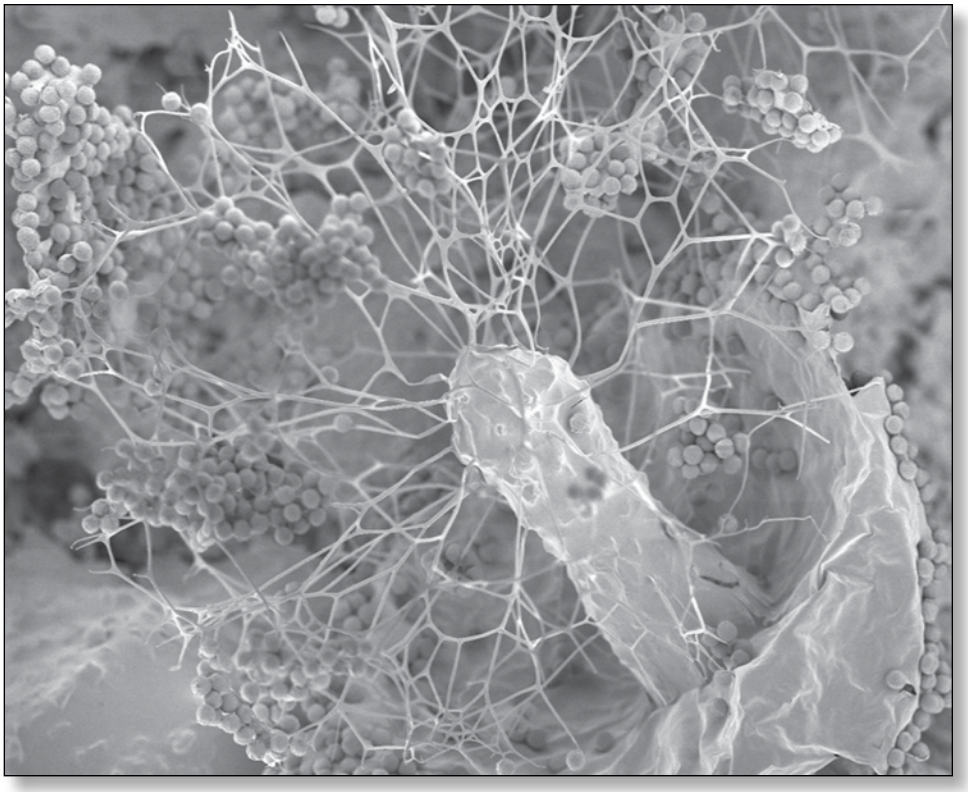
Moist chamber bark cultures yielded bright yellow phaneroplasmodia with a network of plasmodial veins (Figures 35, 36). The unique internal morphology of the stalked sporangium can be seen in scanning electron micrographs (Figures 37, 38, 39). The whole sporangium, profile of capillitium arising from the columella tip (Figure 37), stalk split open showing internal crystals (Figure

Figure 33. Network of plasmodial tracks in situ on tree canopy-collected bark.

Figure 34. Stalked sporangium with iridescent peridium showing multicolored, glittering, silvery-bluish surface.

Figure 35. Network of living plasmodial veins of phaneroplasmodium on filter paper surface in moist chamber culture.

Figure 36. Bright yellow plasmodium developing on white filter paper in moist chamber culture. Note front feeding edge and network of veins trailing behind that leave plasmodial tracks.



Figures 37–39. Scanning electron micrographs. Figure 37. Profile of capillitium arising from the tip of the columella showing pattern of branching and anastomosing.

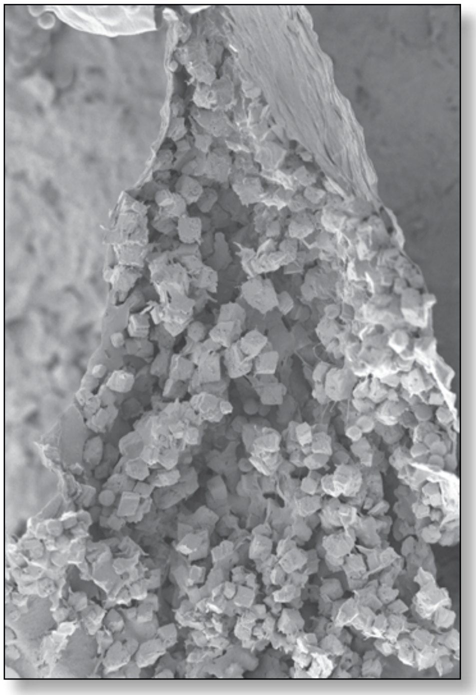


Figure 38. Fractured stalk showing individual crystals.

38), and individual calcium carbonate rhombohedron crystal (Figure 39). This crystal type had never been described before in the myxomycete literature (Keller et al., 2004).

In a review paper (Keller et al., 2009) data were assembled from a series of papers that compared myxomycete species diversity with pH and absorptive capacity of bark of different tree species (Everhart and Keller, 2008; Everhart et al., 2008; Everhart et al., 2009; Keller and Everhart, 2010; Kilgore et al., 2009; Scarborough et al., 2009). These summarized results strongly suggest that a combination of pH ranges and bark physical characteristics support species-specific myxomycete groupings. For example, *Juniperus virginiana* (eastern red cedar) had the highest species diversity of myxomycetes (54 species), far more than any other tree species. This tree bark is nearly neutral at 7.0 pH, is highly absorptive and spongy, and retains moisture over longer periods of time, providing an optimal substratum for the growth and development of the myxomycete life cycle stages (Keller, 2009).

Myxobacteria (gliding slime bacteria), a biological example of convergent evolution

Moist chamber cultures of bark from living trees and woody vines often yield the colorful fruiting bodies of myxobacteria. These organisms are bacteria with prokaryotic characteristics but still develop stalked fruiting bodies with spore-like propagating units that are elevated above the substratum. There is a life cycle phase where the individual cells developmentally glide together into an aggregative phase, eventually forming in some cases a complex, tree-like, stalked fruiting body. This stalked habit has the selective advantage for potentially disseminating airborne spore-like units. Apparently Discover Life in America taxonomists who participated in the ATBI only recorded a single species for this group of organisms from the roughly 50 species known to exist. Several species in the genera *Chondromyces* and *Stigmatella* among others were repeatedly found in bark moist chamber cultures (Figure 40) (Keller and Everhart, 2010).

Mollusks and slugs

Using the Doubled Rope Climbing Method (Kilgore et al., 2008), climbers observed and collected slugs and snails along tree trunks. Slugs (*Philomycus carolinianus* and *P. flexuolaris*) were observed up to 46 ft above ground level around a water-filled tree hole. It appeared that these slugs and snails had migrated from ground level perhaps due to the recent rain showers, producing wet conditions that enabled them to crawl higher into the canopy. The telltale presence of slime trails left behind on the bark surfaces gave evidence of their tracks. Snails with shells, for example, *Mesodon normalis* (about the size of a quarter) and *Anguispira jessica* (about the size of a dime), were found at 15 ft for the former and 79 ft for the latter (Keller and Snell, 2002; Kilgore et al., 2008).

Observations and photographs were made at night of slugs feeding on the immature sporangia of *Stemonitis axifera* (a slime mold). At night *S. axifera* developed numerous colonies of stalked sporangia with soft, milky white, spore cases and also immature and mature spore stages. Each night slugs (*Philomycus carolinianus* and *P. flexuolaris*) fed on the immature stages eating the sporangium from the top down. These observations were published in *Mycologia* (Keller and Snell, 2002), with the image of the slug eating the slime mold selected for the front cover (Figure 41).

Tardigrades (water bears or moss piglets)

These curious animals deserve special mention because of species numbers new to science (15) and new records (77) found thus far in GSMNP, which is now considered one of the best-known areas of the world for tardigrade fauna. These tiny invertebrates are usually less than 0.02 inches long but can reach 0.09 inches when fully grown. They thus fall in the category of "out of sight and out of mind" that results in an understudied and relatively little known group of life forms. The concentrated efforts of Paul Bartels and Diane Nelson have increased significantly the numbers of known tardigrade species in the park. Prior to their research, only three species were recorded from the park (Bartels and Nelson, 2006). Indeed, the park's tardigrade species diversity is probably the highest in the world, and estimates put the total number of species between 86 and 105 (Bartels and Nelson, 2007). The 80 tardigrade species known from the park represent 6.72% of the total number of species worldwide.

The name tardigrade means "slow stepper," and this group of invertebrate animals is recognized as a separate phylum, Tardigrada. Many tardigrade species are found among lichens, liverworts, or mosses, often in moist chamber cultures made from the bark of living trees. In addition, they can be found in aquatic habitats such as streambed bottoms, on periphyton (mixture of algae, cyanobacteria, heterotrophic microbes, and detritus), on moss and lichens on limestone and sandstone substrata, in caves, in bird's nests, in soil, in leaf litter, and other ground litter. Species also are known from Antarctica, the tropics, the Himalayas, and deep sea marine environments. The total number of known described tardigrade species worldwide (including species and subspecies) was 1,190 as of 15 July 2013 (Bartels et al., 2016).

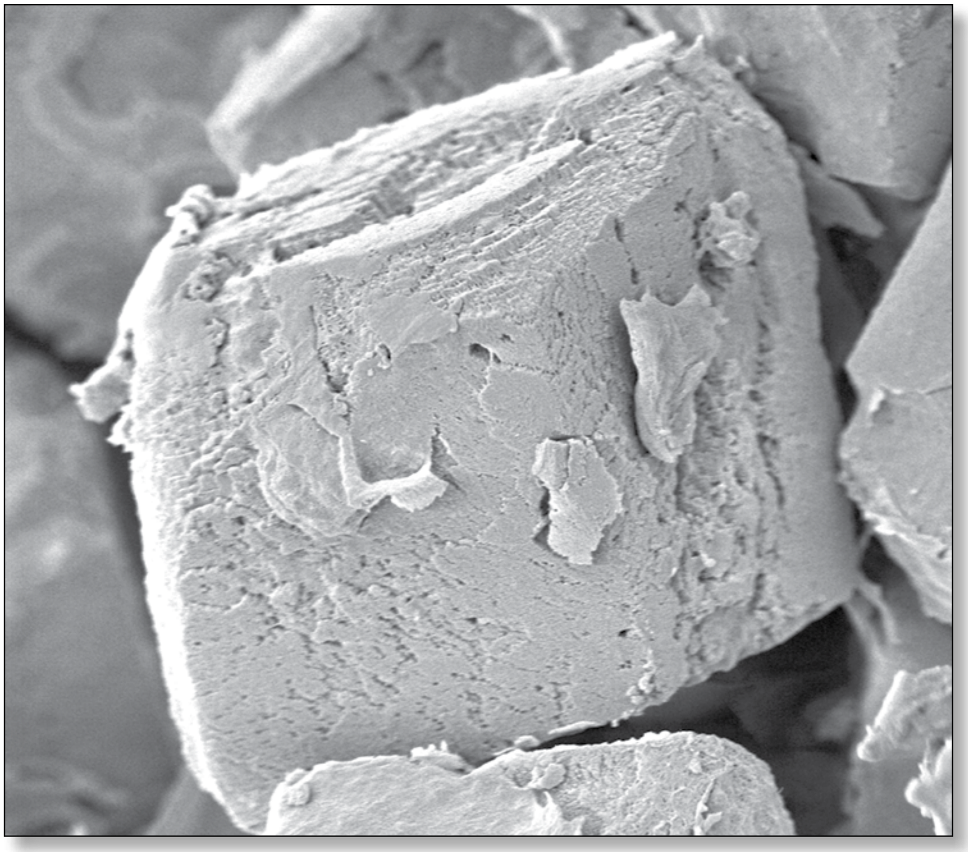


Figure 39. Unique individual calcium carbonate rhombohedron crystal.

Tardigrades walk slowly, lumbering along in a wobbly fashion on six short, stubby legs located under their bodies. The last or fourth pair of "legs" is attached posteriorly and is used for grasping or pushing the substratum, enabling the tardigrade to raise up and go through slow-motion acrobatic gyrations. Students using dissecting microscopes can easily spot their movements as the tardigrades crawl about among the mosses and lichens in moist chamber cultures. This usually generates student excitement and increases interest in observing other life forms present (Keller, 2005; Kilgore et al., 2008; Nelson and Bartels, 2007).

Tardigrades exhibit a wide variety of colors from translucent to whitish or shades of reddish-orange, brown, black, yellow, green (Figure 42), and even pink, which may be located in cells or distributed throughout the body cavity in storage cells, in the epidermal cells, or in gut content from feeding. Tardigrades feed using piercing mouth parts, sucking out the internal contents or eating whole organisms including rotifers, bacteria, algae, mosses, nematodes, and other tardigrades. One of the unique properties of tardigrades is their long-term survival in extreme conditions where they can live in a suspended state of metabolic animation or cryptobiosis for more than 30 years.

Conclusions

Future biodiversity status of life forms, species numbers, and additional counts of new species records over time will require continual monitoring, surveys, and inventories, especially of habitats rarely sampled. This should include taxa that were not included in the former ATBI years, for example, myxobacteria and other bacterial taxa, that will significantly increase the overall species numbers not previously recorded for the park. Usually the smallest taxa are the ones most difficult to find, collect, and isolate in culture and these groups will continue to challenge researchers. The current species numbers included here are based on the most recent counts as of 2017. Park habitats coupled with seasonal and phenology changes that impact certain organisms over time, especially fungi, require researchers to collect specimens and samples at the right place and time. Local citizen scientists that visit the park on a regular basis can help in this endeavor by documenting their observations. The impact of pollution and climate change on species diversity in the park should include continual observations and collections of sentinel species that are sensitive to environmental changes over time. Cooperation between the local citizenry, park officials, and the scientific

Figure 40. Bright orange fruiting body of a myxobacterium.

Figure 41. Front cover artwork selected for the 2002 issue of *Mycologia* showing a slug eating a group of immature developing myxomycete sporangia. This published paper describes the observations and photographs taken during pitch dark conditions over three successive nights.

Figure 42. *Echiniscus viridissimus*, light photomicrograph showing armored dorsal plates and bright green pigmentation inside tardigrade.

community will ensure that the ATBI continues for years to come.

EPILOGUE

The demise of the American Chestnut and possible comeback

Castanea dentata (American chestnut) at the turn of the century was still a dominant tree species in forest stands throughout the GSMNP and most of the eastern United States. It had evolved and flourished for thousands of years, representing upwards to 45% of canopy trees in the Appalachian forests (Linzey, 2008). Early settlers relied on chestnuts as a cash crop that could be easily harvested in September through October at different elevations. These delicious fruits were a favorite food roasted over the hot ashes in the fireplace, savored as sweet and tasty table fare, and also served as feed for fattening “topped off” hogs giving a special flavor to hams (Shields, 1981). Chestnuts were said to produce at least half of the annual nut crop in chestnut and oak forests in the Smokies.

These giant trees grew tall and straight up to heights of 120 ft with diameters of 14 ft and surviving for more than 400 years. Chestnut trees were highly prized by foresters as the best hardwood tree in America because the wood was straight-grained, easily worked, highly resistant to decay, exceptionally durable, and easily split to make rail fences, telephone and telegraph poles, railroad ties, shingles, and other wood products. It not only was perhaps the single most important tree in the broadleaf forest ecosystem, but it also supported the Appalachian mountain people’s way of life (Linzey, 2008).

Unfortunately, this story had a tragic ending when a parasitic fungus, *Cryphonectria parasitica* (chestnut blight), was accidentally introduced into the United States in the late 1800s from a Japanese nursery where presumably the Asian Chestnut is more resistant to the fungus. The fungal blight disease quickly spread throughout the region, eventually killing all the American chestnut trees in both the park and throughout Appalachia that lacked genetic resistance to the fungus. Though a few trees have survived in scattered localities far outside the park, stumps still remain in the park, and root sprouts give rise to second growth trees that eventually also succumb to the persistent fungus.

Attempts to save the American chestnut are ongoing. Hybrid backcrossing experiments with the Chinese chestnut aim to create an American chestnut tree resistant to the fungus that will hopefully retain all of the desirable traits associated with the native species. Some of these experiments, still undergoing field trials, are using transgenic wheat genes to confer fungal resistance (Newhouse et al., 2014).

What will this park look like 200 years from now if the re-introduction of disease-resistant American chestnuts were to restore this native tree species as towering 100-ft giants and its former dominance in the ecosystem? Time will tell!

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