INTERIM REPORT EVALUATING IMPLEMENTION OF THE POST-DELISTING MONITORING PLAN FOR THE WEST VIRGINIA NORTHERN FLYING SQUIRREL (*Glaucomys sabrinus fuscus*)

(Photo by Larry Master)

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I. INTRODUCTION

The Post-delisting Monitoring Plan (PDMP) for the West Virginia Northern Flying Squirrel (*Glaucomys sabrinus fuscus*) (WVNFS) established a framework to monitor the status of the WVNFS and its habitat for 10 years after delisting to verify that the subspecies remains secure from risk of extinction after removal from the protections of the Endangered Species Act (ESA). This interim report constitutes a mid-point evaluation by the U.S. Fish and Wildlife Service (USFWS) of implementing the PDMP, covering the period from March 4, 2013 through March 4, 2018.[1] While this report focuses on actions during this 5-year period, in some cases we used data prior to 2013 in order to better analyze trends. Whereas section 4(g)(1) of the ESA requires monitoring the status of delisted species for a minimum of 5 years, the USFWS determined a longer time frame was needed to document that the WVNFS remains secure, given consideration of practicable monitoring methods for this difficult to detect animal and the need to establish trends spanning multiple generations (USFWS 2007).

As specified in national guidance for post-delisting monitoring plans, this interim evaluation of data collected on the WVNFS appraises the status of the delisted species, and identifies any potential problems in data collection protocols and/or consistency of implementation (USFWS and National Marine Fisheries Service 2008). As specified in the PDMP for the WVNFS, in this report we analyze habitat status and trends, progress made implementing management plans and agreements, and distribution and persistence of the WVNFS (USFWS 2007). We also determine if the monitoring thresholds in the PDMP have been met or exceeded. Such an occurrence at any stage during the post-delisting monitoring period would require the USFWS to investigate causes of the declines and determine if the WVNFS warrants expanded monitoring, additional research, additional habitat protection, and/or relisting under the ESA.

II. HABITAT STATUS AND TRENDS

To analyze habitat status and trends, we established a baseline map of WVNFS habitat and acreage. We also established a baseline geospatial layer of fragmentation for future use in analyzing trends in habitat patch sizes and connectivity. In addition, we estimated habitat losses and gains since delisting in 2013, and reviewed new literature on the health of the red spruce/northern hardwood ecosystem.

[1] The period for post-delisting monitoring began on March 4, 2013, following the conclusion of a lawsuit and appeal process. By way of background, the USFWS determined the WVNFS was a recovered subspecies and removed it from the protections of the ESA in 2008 (73 FR 50226). The Friends of Blackwater sued the USFWS in the District Court of Columbia, and while legal proceedings were underway, the court ordered re-instatement of the ESA protections in 2011 (76 FR 35349). The U.S. Department of Justice, acting on behalf of the USFWS, successfully appealed the District Court decision and the ESA restrictions were removed a second time on March 4, 2013 (78 FR 14022).

A. Baseline Habitat Map and Acreage

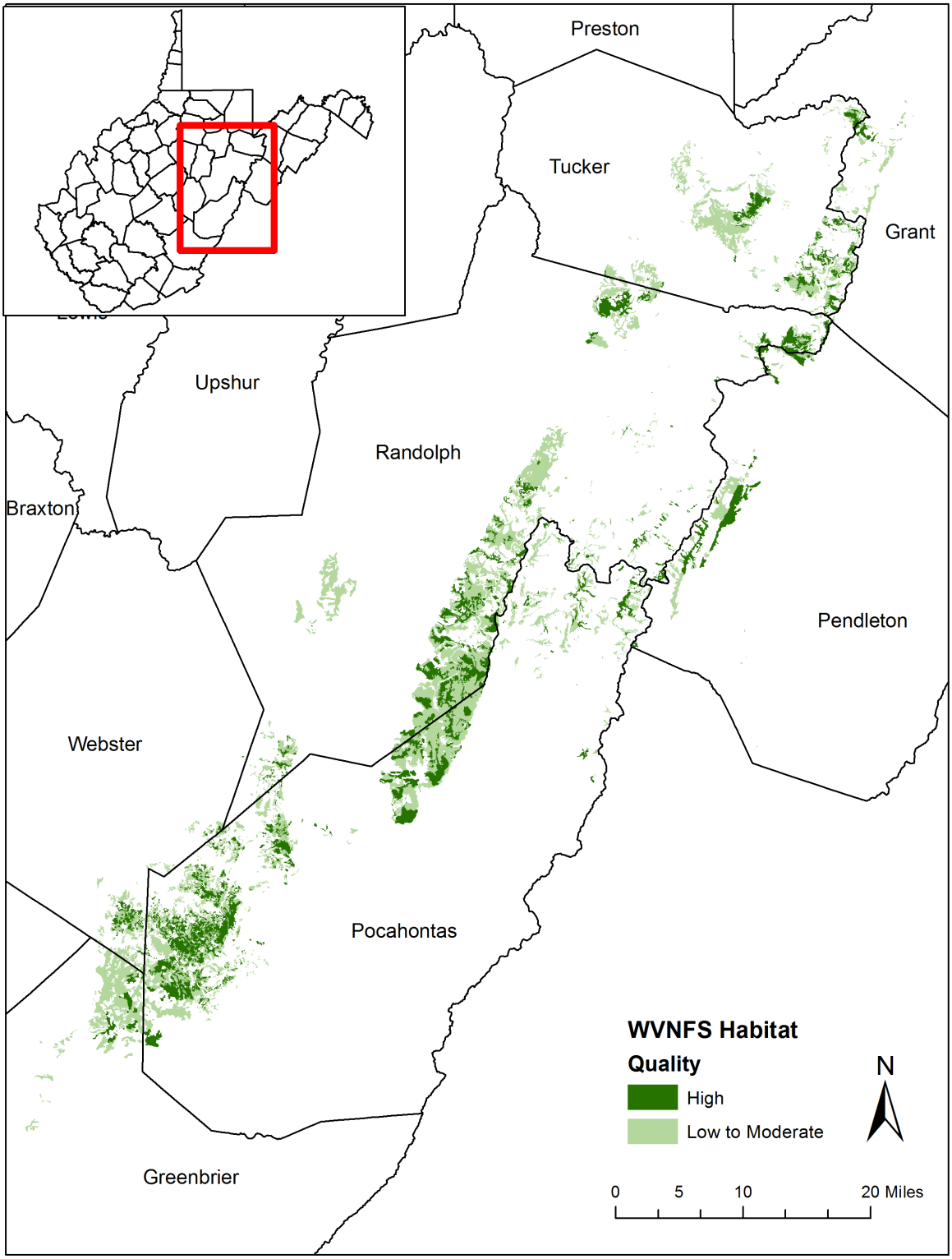
The PDMP specified that WVNFS habitat changes would be tracked range-wide by interpretation of remote-sensed imagery obtained at or near the time of delisting (baseline) compared to the end of the 10-year-long post-delisting monitoring period. Data would be validated by a subsample of stand data and field checks.

A map of red spruce/northern hardwood cover in West Virginia was completed in late 2013 as a collaborative effort by the West Virginia Division of Natural Resources (WVDNR), USFWS, Monongahela National Forest (MNF), and Appalachian Forest Heritage Area AmeriCorps members shared between the agencies (Byers et al. 2013). The team had initiated an effort to map the red spruce/northern hardwood ecosystem in 2010 and completed it shortly after the WVNFS was delisted in 2013. The idea for starting early on the map arose during discussions among members of the Central Appalachian Spruce Restoration Initiative (CASRI), a group of private, state, federal, and non-governmental organizations collaborating on conservation and restoration of the red spruce-northern hardwood ecosystem. CASRI members identified the map as an objective in their strategic plan, to help with planning conservation and restoration actions, and to track changes in the size and configuration of spruce and spruce-northern hardwood forest over time (CASRI 2010).

To obtain a forest cover map as close to 2013 as possible, it was necessary to use multiple sets of imagery and ground-truth data points to validate interpretation of imagery. The team used 2011 satellite imagery for the base map but supplemented it with other available photography (primarily from 2010-2013) to aid in interpretation of the imagery. Despite its age, the 1996-1997 color-infrared leaf-off imagery was important to verify interpretation of more recent imagery as it is the only leaf-off imagery available in West Virginia and helps distinguish coniferous from deciduous trees (Elizabeth Byers, WVDEP, pers. comm. 2017). Image interpretation also was aided by mining of existing data sets to retrieve 4,000 ground-truth data points and 18,000 stand polygons on the MNF 1990 to 2013 (the most current data available), 1,200 WVNFS habitat points, and 100 stands in the Kumbrabow State Forest (CASRI 2013). To supplement these data, the team identified high-priority areas needing validation and collected an additional 1,600 ground-truth validation points in these areas from 2010-2013. Ultimately, the team validated 15,490 Geographic Information System (GIS) polygons covering 1.3 million acres in the Allegheny Mountains of West Virginia.

Using the red spruce/northern hardwood cover map, the USFWS created a baseline map of WVNFS habitat in West Virginia (Figure 1). We assigned and quantified habitat into two categories: high quality habitat (53,308 acres) and low to moderate quality habitat (114,174 acres), for a total of 167,482 acres of WVNFS habitat in West Virginia in 2013. High quality WVNFS habitat was defined as > 50 percent red spruce cover. A model of the importance of conifers in WVNFS habitat predicts a 90 percent chance of WVNFS occupancy in habitat containing > 50 percent conifer cover (Ford et al. 2004). This mapping category consists

Figure 1. Baseline map of West Virginia northern flying squirrel habitat at the start of the 10-year monitoring period established in the PDMP.



primarily of mature spruce forest. It also includes older (40+ years) red spruce plantations, and a few polygons of densely regenerating "doghair" spruce.

Low to moderate quality WVNFS habitat was defined as 10-50 percent red spruce cover. Most polygons in this category consist of northern hardwood forest with a moderate spruce component or young red spruce regenerating under a hardwood canopy. At the lower end of the scale, there a small (5 percent probability of WVNFS occurrence in habitat with 1 percent conifer cover.

In classifying red spruce communities, Byers et al. (2010) defined them as having at least 15 percent total cover of red spruce in the canopy, based on different vegetation communities starting at this break point (Elizabeth Byers, WVDEP, pers. comm. 2018). However the spruce mapping team used 10 percent red spruce cover as the boundary of the moderate cover attribute for practical reasons, to be consistent with the way forest plot data were collected. Since there is little difference in predicted occupancy of WVNFS at conifer cover of 10 percent or 15 perrcent, we chose not to modify the categories for the baseline WVNFS habitat map.

Byers et al. (2013) mapped a third category called trace red spruce cover, defined as < 10 percent spruce. The amount of trace red spruce is 184,848 acres[2]. Most polygons in this category represent sparse young red spruce regeneration. A few polygons include northern hardwood stands with widely scattered red spruce canopy trees. While some WVNFS habitat may be found in trace red spruce cover, the probability of it being occupied by WVNFS is < 2 percent (Ford et al. 2004). Because the chance of occupancy is so low, the USFWS decided not to include this category in the baseline acreage of WVNFS habitat.

In addition, the George Washington and Jefferson National Forests (GWJNF) estimated an additional 6,268 acres of WVNFS habitat in the Laurel Fork area in Highland County, Virginia in 2014 (USFS 2014a). This habitat was not classified as to quality.

Combining the two states, the amount of baseline habitat for the WVNFS rangewide is 173,750 acres (Table 1). This is less than the 242,000 acres of habitat predicted by the USFWS in its 2008 final rule based on habitat modelling that had not been validated by ground-truthing at the time (73 Federal Register 50229). The model tended to underestimate high quality habitat and overestimate low quality habitat, especially at the 50 percent probability of occurrence threshold (Ford 2007). The difference in acreages between the model and baseline map is due to methodology and not due to significant habitat loss between 2008 and 2013, when the WVNFS was first delisted, relisted following the lawsuit and appeal process, and then delisted the second time.

[2] The attribute information originally described by Byers et al. (2013) and posted to the GIS Data Clearinghouse inadvertently reversed the acreages for the 10-50 percent and <10 percent spruce cover categories. Since then this error has been corrected at http://wvgis.wvu.edu/data/dataset.php?ID=455.

Table 1. Baseline acreage of WVNFS habitat rangewide at the start of the 10-year monitoring period established in the PDMP.

Habitat Type	West Virginia	Virginia	Total Acres
High quality	53,308		53,308
Low to moderate quality	114,174		114,174
Unclassified		6,268	6,268
Total	167,482	6,268	173,750

B. Baseline Habitat Patch Sizes and Connectivity

The PDMP specified that at the end of the monitoring period, the USFWS would include in the final report an analysis of 10-year trend in habitat patch sizes and connectivity compared to baseline conditions near the time of delisting. To facilitate this later analysis, we created a preliminary baseline GIS layer of WVNFS habitat patch sizes in West Virginia. We plan to work with the USFS on a more detailed analysis of patch sizes and connectivity for the final report at the end of the post-delisting monitoring period. For now, we simply overlaid the WVNFS baseline habitat map (GIS layer) on top of a statewide forest fragmentation map (Strager and Maxwell 2012), and excluded data that were outside the area of mapped WVNFS habitat. For preliminary purposes, we did not change the general-purpose 100-meter (328-foot) edge width utilized by Strager and Maxwell (2012).

Within the boundaries of WVNFS baseline habitat, we categorized and quantified forest patches into seven attributes (Table 2). Roughly 94 percent of baseline habitat consists of core habitat (156,509 acres), defined as interior forest patches not degraded from edge effects. Of this core habitat, over 99 percent is comprised of patches > 500 acres in size. Approximately 5 percent of baseline habitat is perforated (9,026 acres), consisting of forest along the inside edges of small forest openings. Less than 1 percent of baseline habitat consists of edge habitat (1,448 acres), defined as forest along the outside edge of a forest patch. Only 22 acres of habitat were attributed to small patches of forest that are entirely degraded by edge effects (patch habitat).

Large, medium, and small core areas could support multiple WVNFS individuals with significantly overlapping home ranges. Preliminary data from a pre-treatment study of commercial spruce restoration in the Upper Greenbrier North project show 4 to 5 WVNFS occupying overlapping home ranges totaling approximately 15 acres, or a density of roughly 0.3 WVNFS/acre. However, density may vary with habitat quality across the landscape. WVNFS are highly mobile and can sometimes have individual home ranges as small as 7 to 12 acres, and sometimes as large as or greater than 49 acres (Ford et al. 2007, Menzel et al. 2006), Diggins and Ford 2017). Thus absent additional information on habitat quality of each mapped polygon forest

Table 2. Baseline forest patch conditions in WVNFS habitat.

Attribute	Sum of area (acres)	# Patches
Large core: >500 acres)	156,176	38
Medium core: 250-500 acres	48[3]	1
Small core: < 250 acres	285	82
Perforated	9,026	576
Edge	1,488	45
Patch	22	13
Other	337	
Total:	167,482	755

patches less than 7 acres likely are too small to support a pair of WVNFS and would be considered a habitat remnant.

A study of northern flying squirrels (*G. sabrinus,* NFS*)* in southern Canada showed that mature forest amount was the primary predictor of patch occupancy by NFS (Ritchie et al. 2009). NFS occupancy was not strongly correlated with patch size or edge contrast. However, the width of canopy gaps can be important to flying squirrel movement between patches (Smith et al. 2013). Food availability within dispersal corridors also may be important to successful dispersal. Trapp et al. (2017) found that stand age and structure might be more important to WVNFS diet availability than habitat type (pure spruce stands, other conifer stands, mixed conifer and hardwood stands, and pure hardwood stands).

Because the width of edge effects varies by species, we may decide to change the edge width or incorporate other factors, such as gap distance, into the final report to be completed at the end of the post-delisting monitoring period. As a general rule of thumb, gliding mammals are expected to avoid crossing large gaps because they favor gliding from tall trees to running on the ground. In a study in southern Canada, 69 percent of NFS translocated across canopy gaps of 50 to 960 meters (164 to 3,149 feet) took the forested route home and avoided crossing gaps (Smith et al. 2013). NFS were much more likely to take forested routes home than to cross open canopy gaps even when the direct distance was 6.8 times shorter, suggesting that NFS make cost-benefit decisions regarding predation risks or assess the energetic costs of moving across versus circumnavigating clearcuts. While the maximum recorded gliding distance of flying squirrels is 30 meters (98 feet), NFS crossed gaps up to 436 meters (1,430 feet) when the detour efficiency was less than 55 percent (distance to return home across the gap divided by the forested detour distance). NFSs took between 1 and 624 hours to return home; however, all NFSs translocated across gaps of 331 meters (1,086 feet) or less returned home in one night (n = 25). Based on the time to return home, the authors noted that recent clearcuts and young conifer plantations > 300

[3] The one patch classified as medium core forest (250-500 acres) appears to be highly perforated as the 48-acre summed area excludes perforations (forest along the inside edge of a patch).

m (984 feet) wide might be substantial barriers to NFS. They suggest that irregular shaped clearcuts with several gap distances < 100 m (328 feet) should provide adequate gap crossing and therefore higher functional connectivity for NFS. These types of considerations and other new information may be useful to analysis of WVNFS habitat connectivity at the end of the post-delisting monitoring period.

C. Habitat Loss Trends

The PDMP specified the USFWS was to track WVNFS habitat loss on public and private lands annually, including reports of proposed or actual habitat loss submitted through receipt of Environmental Impact Statements, Environmental Assessments, project reviews, and from other sources. This task is ongoing and will continue for the duration of the 10-year post-delisting monitoring period.

During the first 5 years of the monitoring period, approximately 285 acres of WVNFS habitat loss was documented (Table 3). The majority of habitat loss occurred in low quality habitat, and the greatest extent of habitat loss was associated with construction of the Corridor H Highway project between the towns of Davis and Bismarck, West Virginia. Of the thousands of project reviews conducted by the USFWS over this time, only a few occurred in WVNFS habitat and impacts were minimized and mitigated. As shown later in this report, the amount of WVNFS habitat protection, creation, and restoration greatly exceeded habitat losses during this time.

As an illustration of agency due diligence in project reviews, we highlight below each of the projects named in Table 3.

Housing development has not had a significant impact on WVNFS habitat since delisting. In 2013, the WVFO reviewed a project for the construction of a home on a 2,900 square-foot lot in the North West Ridge development near Snowshoe Ski Resort (USFWS 2013). The landowner agreed to reduce impacts to WVNFS habitat by eliminating a driveway or parking area, and minimizing tree clearing and ground disturbance to the footprint of the house: 900 square feet. This project resulted in the loss of approximately 0.02 acre of low quality WVNFS habitat. This subdivision has been under development since the 1970s and has not seen increased home construction since delisting of the WVNFS (Ed Galford, Snowshoe Resort, pers. comm. 2019). In fact, only one new home has been built there since 2013. Other proposed housing developments (known at the time of delisting) also have not been completed. The developers of the Tuscan Ridge development near the town of Davis filed for bankruptcy and did not complete the project. Similarly, Allegheny Wood Products has not completed a habitat conservation plan for logging and housing development on its lands in the Blackwater Canyon.

Table 3. Documented WVNFS habitat loss by core area from March 2013 to March 2018.

				Acres of Habitat	
Land Owner	Project	Project Proponent	WVNFS Core Area	Low to Moderate Quality	High Quality
Private	Home construction	Private landowner	Cheat Mountain	0.02	
MNF	Atlantic Coast Pipeline	Dominion Energy	Cheat Mountain	1.2*	
MNF	WB Xpress Pipeline	Columbia Gas	Cheat Mountain	0.9	
MNF	Big Mountain	Monongahela National Forest (MNF)	Spruce Knob/Laurel Fork	1.5**	
Multiple landowners, Right-of-Way leased by WVDOH	Corridor H, Davis to Bismarck	WV Division of Highways (WVDOH)	Blackwater Canyon/Dolly Sods	221.7	59.8
Total:				225.3	59.8

*Construction of the Atlantic Coast Pipeline has been halted because of a lawsuit; thus, these impacts have not yet occurred.

**1.5 acres and an unquantified number of individual trees.

Natural gas pipeline development also has not had significant impacts to WVNFS habitat since delisting, despite widespread activity in the state. During 2017 and 2018, the USFS issued two Special Use Permits for multi-state natural gas pipeline projects within the range of WVNFS on the MNF. However, the USFS, with support from the USFWS and WVDNR, was successful in greatly reducing potential impacts to WVNFS habitat from both projects, in large part because the USFS treated the WVNFS as a regional forester sensitive species. Thus, the protective standards and guidelines for the WVNFS and its habitat contained in the MNF Land and Resource Management Plan were applied (USFS 2006).

As proposed, the 524.5-mile long Atlantic Coast Pipeline project crossed 5 miles of land managed by the MNF in Pocahontas County, West Virginia. The original proposed route was moved to avoid major impacts to WVNFS habitat and red spruce restoration areas in the heart of WVNFS range on Cheat Mountain (USFS 2016a). As a result, impacts to WVNFS habitat were limited to 1.2 acres of low quality habitat in one stand largely dominated by hardwoods, with scattered red spruce and hemlock (FERC 2017a). Conservation measures included: (1) retaining mature spruce and hemlock trees by side-trimming the trees instead of removing them; (2) limiting the widening of an existing access road in this area; (3) realigning a segment of new

access road to minimize clearing of regenerating red spruce; (4) transplanting red spruce and hemlock saplings from the access corridor to unaffected areas; and (5) replanting temporary workspaces and the edge of the construction right-of-way with native tree and shrub seedlings. Thus, impacts were significantly avoided, minimized and mitigated.

Likewise, impacts from another major pipeline project were reduced and mitigated. As proposed, the WB Xpress Pipeline was 29.3-miles long, crossing 11.4 miles of the MNF in Randolph and Pendleton Counties, West Virginia. Tree-clearing impacts were reduced from 31.9 acres (August 2016 project workspace boundaries) to 0.87 acre of predominantly low quality WVNFS habitat, based on the Byers et al. (2013) red spruce cover map (FERC 2017b, USFS 2017). A USFS biologist went into the field with the project engineer to view potential WVNFS habitat and flag trees that would need to be cut. Mature red spruce trees were avoided. All spruce saplings between 1 and 5 feet tall in the construction area were transplanted into adjacent undisturbed habitat ahead of time (approximately 431 trees). In addition, 1.5 red spruce seedlings were planted for every tree lost. Thus, the balance favored the WVNFS and future red spruce habitat in the area. Additional conservation measures included seasonal tree clearing restrictions to avoid impacts to WVNFS during the nesting and lactation period; temporary work stoppages if an individual WVNFS or nest is seen during construction activity; establishing 10 nest boxes in sub-optimal habitat and monitoring them for 3 years; and prohibiting aerial herbicide application in suitable habitat. The project developer committed to monitor trees planted or relocated for 3 years to evaluate mitigation success, and if tree plantings and relocations are deemed unsuccessful, then to implement additional measures after consultation with the MNF (USFS 2017). At last check, the transplanted saplings were doing well (Cathy Johnson, pers. comm. 2018).

The USFS also minimized impacts of one of its own projects (USFS 2016d, 2016e). As proposed, the Big Mountain Project on the MNF included timber harvest, prescribed fire, road construction, upland wildlife habitat creation, and stream and riparian habitat restoration. The USFS reviewed information on potential and known distribution of the WVNFS within the action area and developed a map of suitable habitat. Activities such as prescribed fire and timber harvest for this project would not occur in suitable WVNFS habitat. Although some activities involving limited amounts of tree removal would occur in suitable habitat, design features to minimize impacts to WVNFS were incorporated into the project. Up to 1.5 acres total ground disturbance could occur at aquatic passage projects. Because of the highly variable nature of the work, other impacts from large woody debris placement projects and road deconstruction could not be accurately estimated. Therefore, design features to reduce risk and impacts to WVNFS were incorporated into projects in WVNFS habitat. These included: retaining all hardwood trees > 6" diameter-at-breast-height (dbh) with a visible cavity and all conifers (especially spruce) > 10" dbh to avoid disturbing WVNFS leaf nests; and if this is not possible, then restricting tree clearing to September 15 to March 31 when immobile young WVNFS are not likely present.

Construction of the 16.5-mile long Davis to Bismarck section of the Appalachian Corridor H highway has had the greatest impact to WVNFS habitat during the first 5 years of the post-delisting monitoring period. This project was anticipated and the potential impacts were analyzed in the USFWS's biological opinion (USFWS 2008). A total of 381 acres of suitable to highly suitable WVNFS habitat was predicted to be lost from this project and was considered in the delisting rule (73 FR 50242-50243). Post-construction analysis documented 351.4 acres of clearing by WVDOH for the project, of which the majority (291.6 acres) was classified as suitable habitat (i.e. low to moderate quality) and 59.8 acres as highly suitable habitat (i.e. high quality). The WVDOH cleared approximately 69.9 acres of trees in 2011 and 2012 before the start of the post-delisting period in 2013; this loss has already been accounted for in the baseline habitat acreage. The remaining 281.5 acres of WVNFS habitat were cleared for Corridor H between 2013 and 2016. Clearing occurred between September 15 and April 1 to avoid effects to immobile young.

As part of the project, WVDOH funded installation and monitoring of 82 WVNFS nest boxes intended as alternate artificial den sites for displaced WVNFS. During 7 years of monitoring, WVNFS were not found using the boxes, perhaps because suitable den trees remained nearby. In addition, WVDOH funded a radio-telemetry study to evaluate response of WVNFS to disturbances in the area. In its biological opinion, the USFWS had predicted WVNFS would move away from sources of disturbance (USFWS 2008).

From 2011 to 2017, a total of 24 WVNFS were trapped in the project right-of-way site and 1 to 3 were fitted with radio-transmitters each year (Mountain State Biosurveys 2011, 2012, 2013, 2014, 2015, 2016, 2017). Nine WVNFS (4 males; 5 females) were tracked to a total of 13 den trees, all in the capture vicinity. These individuals denned in hardwood trees surrounded by rhododendron. Whereas 5 radioed individuals remained near capture locations, the majority moved away from capture locations; however, it is unclear whether they moved in response to disturbances in the area or simply returned to natural den sites located distant from capture locations. Eleven individuals (8 males; 3 females) moved up the mountain into dense rhododendron. Several of these individuals returned to trap sites but then moved back up the mountain. Due to dense, impenetrable rhododendron thickets, their den locations could not be located despite multiple attempts to find them. Interestingly, a few individuals of the Carolina NFS (*G. s. carolinus*) recently were documented using atypical den sites located underground in dense rhododendron cover where cavity trees were not abundant (Diggins et. al. 2015).

In addition, as part of this project, the Federal Highway Administration and WVDOH established a $762,000 conservation fund for habitat protection, restoration, and research to benefit the WVNFS. The USFWS solicited grant proposals and a team of biologists from USFWS and WVDNR reviewed, ranked, and selected projects for funding. The team awarded four grants totaling $761,047. Ninety percent of the money went toward the purchase of 115 acres of fee title and 1,110 acres of conservation easements protecting WVNFS habitat near Mount Porte Crayon

(Thunderstruck property) and Pharis Knob (Gandy Ranch property). (See The Nature Conservancy header in the Habitat Management and Agreements section for more details). A portion of the funds supported red spruce seed collection for use in propagating trees for restoration projects. A fourth grant supported research on microhabitat use of the WVNFS. The remaining $953 will be used during the second half of the post-delisting monitoring period, likely to purchase trees for planting, or acoustic detectors for use by the WVDNR in improving detectability of WVNFS at nest box monitoring sites.

The objective of the research study was to determine variables that influence within-stand microhabitat selection by WVNFS for the purpose of better understanding potential impacts to WVNFS from spruce restoration actions using canopy cap creation to release single or small groups of trees (Diggins and Ford 2017). Researchers used points obtained from radio telemetry surveys and randomly generated points within each WVNFS's home range to compare microhabitat variables for 13 individuals. Researchers found that WVNFS preferentially selected plots with conifer-dominant overstory and deep soil horizons. Researchers also opportunistically searched for WVNFS food sources (hypogeal fungi) at telemetry points and found three species of *Elaphomyces* during surveys. Results support the idea that efforts to restore red spruce where hardwoods dominate in the central Appalachians may improve the connectivity and extent of habitat of WVNFS.

Thus, despite delisting of the WVNFS, habitat losses have been minimal to date, amounting to only 0.2 percent of baseline habitat. Moreover, agency project reviews have resulted in avoiding and minimizing impacts of projects on WVNFS habitat, and mitigating residual effects to predominantly low quality habitat.

D. Health of the Central Appalachian Red Spruce/Northern Hardwood Ecosystem

In addition to tracking habitat losses, the PDMP specified that at the end of the 10-year monitoring period, the USFWS would compile and review new research and reports indicating any significant residual or new emerging threats to WVNFS habitat. To facilitate this upcoming task, we compiled and reviewed relevant new literature since 2013 and summarize it here.

Published papers continue to show that currently the red spruce/northern hardwood ecosystem used by the WVNFS appears to be expanding on the landscape to reoccupy available suitable conditions for tree growth (Butler-Leopold et al. 2015). Stand and landscape level dynamics indicate that red spruce currently is regenerating, increasing in abundance, and slowly occupying a greater share of the landscape in the central Appalachians.

Moreover, others have reported improved growth rates of red spruce since passage of the Clean Air Act. Mathias and Thomas (2018) examined the effects of acidic air pollution, atmospheric carbon dioxide, and climate change on recent growth of red spruce in the Central Appalachian

Mountains. The study area encompassed red spruce along a north-to-south transect of 100 kilometers (62 miles) in West Virginia. The study sites overlapped WVNFS populations in three core areas of their range: the McGowan Mountain study site in the Stuart Knob core area, the Span Oak Run study site in the Cheat Mountain core area, and the Cranberry Glades study site in the Cranberry/Upper Williams core area. The study focused on tree ring chronology from 1940 to 2014, which is after the growth release of saplings following logging in the early 1900s. Between 1940 and 1989 there was a 49-year period of declining red spruce tree growth at these study sites associated with high levels of acid rain. Whereas red spruce tree growth declined 49 percent between 1940 and 1989, it increased 106 percent in the 25-year period from 1989 to 2014. By looking at multiple environmental factors, the authors concluded that this recovery resulted from the interaction of three primary factors: 1) reduced acidic sulfur air pollution and nitrogen deposition following passage of the Clean Air Act in 1970, 2) a fertilization effect of increased atmospheric carbon dioxide, and 3) a positive influence of warmer early spring temperatures. The authors note that while higher temperatures currently are benefitting red spruce, it remains unclear how long the increases in growth of these red spruce stands will be sustained. They note that plant available nitrogen will likely be important to maintain this increased productivity, however, nitrogen inputs from man-made sources are declining.

Notably, separate papers reached similar conclusions for red spruce in the northeastern U.S. Kosiba et al. (2013, 2018) showed recovery of red spruce growth in New England linked to a decrease in acid deposition and an increase in temperature. Changes in climate, particularly a lengthening of the growing season and higher temperatures outside the traditional growing season (i.e. fall, winter and spring) simultaneously reduced the likelihood of winter foliar injury, while reductions in air pollution alleviated a stressor that contributed to past declines of red spruce in New England.

Despite optimism about the short- and mid-term, researchers caution that the long-term (100-year) prognosis for the red spruce/northern hardwood ecosystem remains uncertain due to climate change. Best-case climate change scenarios project little impact to red spruce whereas worst-case scenarios project significant impacts. Butler-Leopold et al. (2015) analyzed the vulnerability of the spruce/fir and Appalachian (hemlock)/northern hardwood forest types to climate change using downscaled climate models. They concluded that projected (worst case) increases in average temperature and decreases in summer and fall precipitation may exceed ecological tolerances of red spruce, balsam fir, and eastern hemlock; however, a major transition in forest composition across the landscape could take 100 years or more in the absence of major disturbances. They note that seedlings would be more vulnerable than mature trees to changes in temperature and moisture, whereas adult red spruce would likely persist at high elevations even after their ability to reproduce diminishes.

It should be noted that modeling regional effects of climate change in the mountains of West Virginia remains especially difficult because complex topography provides cool, wet pockets of

habitat where red spruce would be likely to persist. In fact, Anderson et al. (2012, 2016) scored the mountainous areas of the state as above average in terms of resilience to climate change. They noted that high elevation areas may not follow regional climate trends and may be resistant to climate change with thermal inversions and cloud fog as possible mitigating factors. Seidel et al. (2009) first noted a growing body of evidence suggesting considerable variability in climate trends among mountain ranges. Moreover, early century increases in red spruce due to succession and planting efforts may help the species do better than worst case models project in the short term. Therefore, restoring red spruce and achieving greater resilience in the face of climate change seems like a viable strategy.

Genetic resiliency of red spruce is another important consideration in the long-term health of this ecosystem. Through multiple genetic analyses, Keller and Trott (2017) studied the diversity of red spruce in Central Appalachia to assess population health of this tree species, which is an important component of WVNFS habitat. They reached three main conclusions. First, genetic diversity of red spruce in Central Appalachia is low, as determined by the low levels of allelic richness within stands and the low population size required for a successful community. Second, current effective population size of red spruce in Central Appalachia (322) is near or slightly below the minimum effective population size that is generally accepted for a working population (500). Third, the genetic connectivity of red spruce is high in Central Appalachia, but there are isolated pockets due to climatic barriers caused by varying amounts of precipitation. They noted that the most important environmental factor for red spruce genetic structure is the amount of precipitation during the warmest part of the year. Thus, the current trend of increased precipitation during the growing season is good for maintaining red spruce genetic structure.

As an adaptation measure to climate change, Keller and Trott (2017) recommended that restoration practices include diverse seed stock from within the region to incorporate allelic differences into the gene pool. This will increase the effective population size, which makes the population more resilient and less susceptible to the deleterious effects of inbreeding and disturbance. Fortunately, CASRI partners recognized the importance of a diverse seed stock, and from the outset of tree planting, they have collected red spruce seeds for propagation from many different locations. In addition, scientists are investigating whether different populations of red spruce might respond to climate change in different ways, depending on their locations and genetics (Harvey 2019). If so, forest managers could choose to plant the most resilient varieties in future restoration projects

On a local level, we note that a small amount WVNFS habitat has been affected by the decline of eastern hemlock (*Tsuga canadensis*) since 2013. In the delisting rule, the USFWS recognized that mortality of hemlock from an insect pest, the hemlock wooly adelgid (*Adelges tsugae* Annand), could remove a conifer component at less than 10 percent of known WVNFS capture locations (73 Federal Register 50246). Because most or all of these sites are in close proximity to red-spruce/northern hardwood forests, the USFWS concluded that future hemlock mortality was

not considered significant to WVNFS and was not expected to create barriers to movement by WVNFS. Nevertheless, the public raised concerns about hemlock loss, particularly in Blackwater Canyon. Therefore, we assessed the status of hemlock health in WVNFS habitat, especially in Blackwater Canyon.

The Plant Industries Division of the West Virginia Department of Agriculture (WVDPI) has been conducting studies of hemlock stands across the state. These studies show that hemlock wooly adelgid currently occurs in all counties where WVNFS habitat occurs (Limbu et al. 2018). However, the greatest areas of hemlock mortality have been outside of the range of WVNFS, in the eastern panhandle where hemlock wooly adelgid was first detected in the state (Kristen Carrington, WVDPI, pers. comm. 2019). Treatments of hemlock trees with imidacloprid, an insecticide injected into the tree stem or soil around the base of the tree, appear to be working but are labor and cost-prohibitive on a wide scale. Predatory beetle release also is being used in an attempt to control the adelgid.

A preliminary report by WVDPI (2019) for Blackwater Falls State Park shows that 76 percent of hemlock trees examined in 2014 were showing needle loss, 11 percent were dead, and 14 percent were healthy. WVDPI concluded that virtually the entire hemlock canopy in the park is likely to succumb to the adelgid infestation over time; however, the length of time this takes will depend on the intensity of the infestation, if it is slowed by severe winter temperatures, and if the hemlocks are stressed during months of low precipitation during the growing season. They predicted the hemlock canopy gaps in the park will likely be replaced by nearby spruce, birch, maples, and other species. In addition, over half of the seedling regeneration in the survey area was red spruce, indicating a gradual shift from a hemlock-dominated forest to a spruce dominated forest as openings occur in the park canopy. The WVDPI plans to assist Blackwater Falls State Park in planting trees in canopy gaps created by hemlock mortality. The USWS concludes that despite the impacts to hemlock trees in Blackwater Falls State Park, the area is likely to remain WVNFS habitat dominated by spruce and hardwoods. The small canopy gaps created by loss of sparse hemlocks should not be barriers to WVNFS movement.

III. HABITAT MANAGEMENT PLANS AND AGREEMENTS

The PDMP indicated that key habitat management components for the WVNFS would be reviewed during the 10-year post-delisting monitoring period. A longer than normal monitoring period was chosen in part because of the need to assess long-term trends in implementation of land management plans and commitments. However, since land managers signed the spruce MOU in December 2006 and January 2007 (USFWS et al. 2007), for the purposes of this interim post-delisting assessment, we analyzed accomplishments from late 2006 to spring 2018 to establish a longer-term trend (11.3 years) than 5 years.

To compile accomplishments by land manager, we extracted data from annual accomplishment reports on: (1) acres of red spruce/northern hardwoods protected through fee title purchase or

conservation easements; (2) number and acres of red spruce and native trees planted; (3) acres of understory red spruce released from hardwood-dominated canopy; (4) acres of invasive plants removed or otherwise restored in the ecosystem; (5) and miles of road decommissioned and replanted to red spruce (CASRI 2011, 2012, 2013, 2014, 2015, 2016, 2017). When only the number of trees planted was reported, we converted to acres using a typical tree planting density of 250 to 300 trees/acre.

By way of background, in late 2006/early 2007 seven partners initially developed and signed a Memorandum of Understanding (MOU) for coordinating actions and laying out a vision of the landscape scale restoration of the red spruce/northern hardwood ecosystem. Since establishing the MOU, the group adopted the name CASRI and has grown to 22 partners including federal and state agencies, non-governmental organizations, and private landowners. CASRI is a science-based partnership representing diverse interests with a common goal of protecting, enhancing, and restoring the red spruce-northern hardwood ecosystem across the high elevation landscapes of central Appalachia. In 2010, the CASRI partners developed a strategic plan to guide restoration efforts over the next 10 years, with the majority of effort geared toward on-the-ground conservation efforts such as tree planting, understory release, and collection and propagation of native plant materials for restoration work and other ecosystem enhancement activities in key locations (CASRI 2010). CASRI identified three priority areas for restoring connectivity: Upper Greenbrier North, the Cheat Mountain area, and Canaan Valley. Collectively to date, CASRI partners have planted hundreds of thousands of trees and restored over 7,245 acres (11.3 square miles) of the red spruce/northern hardwood ecosystem (CASRI 2017). Of this total, 5,745 acres (79 percent) were restored between 2013 and 2017. Below we analyze implementation of land management plans and commitments by the six land managers named in Table 3 of the PDMP.

A. Monongahela National Forest

The MNF finalized the Land and Resource Management Plan (or Forest Plan) revision in September 2006 (USFS 2006) and signed the spruce MOU in December of that year. The Forest Plan contains direction in the form of management goals, objectives, guidelines, and standards that protect and conserve the red spruce /northern hardwood ecosystem, including habitat for the WVNFS. Because the MNF still considers the WVNFS as a regional forester sensitive species and a management indicator species, these management goals, objectives, guidelines, and standards still apply. The PDMP identifies two key WVNFS habitat management components to be reviewed for implementation during the post-delisting monitoring period: (1) active management of red spruce/northern hardwood forest following the direction under Management prescription 4.1 (Spruce and Spruce-Hardwood Ecosystem Management); and (2) passive management of wilderness, proposed wilderness, backcountry recreation areas, and special areas under management prescriptions 5.1, 6.2, and 8.0. Success is measured as an assessment of progress toward meeting objectives for vegetation composition and structure, and restoring habitat patch size and connectivity.

1. Active Management

A key objective of management prescription 4.1 is to conduct approximately 1,000 to 5,000 acres of species composition and habitat structure enhancement every decade, with a focus on restoring habitat connectivity, increasing the size of existing habitats, and providing travel corridors between existing habitats (Objective 4107). During the first 10 years of implementing the Forest Plan revision (late 2006 through late 2016), the MNF met this objective by working with others to restore 5,001 acres of the red spruce/northern hardwood ecosystem in priority focus areas. This included planting 109,342 red spruce seedlings and 70,641 other native plants on approximately 854 acres, releasing 2,124 acres of red spruce from the understory, controlling invasive plants on 2,023 acres, and planting red spruce on over 32 miles of decommissioned roads.

Since the delisting of the WVNFS, the pace of habitat restoration by the MNF has increased dramatically over time. From September 2006 through February 2013 (the 6.5-year period when the status of the WVNFS changed from listed to unlisted to listed again during the lawsuit and appeal process), the MNF restored a total of 681 acres of red spruce/northern hardwoods, which equates to an average of 105 acres/year. During the 5-year period following the second delisting (March 2013 to March 2018), the MNF restored a total of 4,961 acres or an average of 992 acres/year. This 9-fold increase likely was influenced by several factors: 1) time needed to complete restoration project design, environmental review, and public comment under the National Environmental Policy Act; 2) time needed to grow nursery stock for planting; and 3) a hesitancy by Forest Service staff to pursue spruce restoration while the WVNFS was still listed. The second 10-year cycle for restoration objectives began in 2017 and we anticipate that the MNF will continue to show a commitment to achieve another 1,000 to 5,000 acres of tree species composition and structural enhancement work during the second cycle by completing ongoing multi-year projects (Upper Greenbrier North and the Mower Tract). We describe these two priority projects below to better illustrate efforts by the MNF to improve habitat connectivity, increase forest patch sizes, and provide travel corridors for WVNFS.

a. Upper Greenbrier North

The MNF identified the Upper Greenbrier North project as a priority to encourage red spruce regeneration and provide an important connector between 100,000 acres of existing blocks of red spruce-northern hardwoods in the Cheat Mountain-Shavers Mountain area and the Sinks of Gandy-Elk Mountain area. The project was designed to connect existing stands of overstory red spruce by planting trees in critical corridors that currently have low densities of red spruce seedlings and saplings. It also was designed to enhance red spruce in this area through 3,161 acres of silvicultural manipulation to create conditions to encourage red spruce regeneration, release suppressed spruce in the understory/midstory, accelerate the presence of red spruce in the overstory, and increase the structural diversity of the stands (Table 4). Approximately half of the

site-specific projects were designed to improve red spruce patch sizes and half were designed to connect red spruce patches.

Table 4. Summary of Upper Greenbrier North restoration activities.

Activities	Estimated acres	Source
Commercial thinning of hardwood for spruce release	863	USFS (2012, 2015b)
Commercial thinning of red pine plantations for spruce release	223	USFS (2015b)
Commercial clear-cut for spruce/hardwood regeneration	17	USFS (2015b)
Total commercial restoration:	1,103	
Non-commercial spruce release	1,425*	USFS (2012)
Non-commercial timber stand improvement with spruce emphasis	633	USFS (2012)
Total non-commercial restoration:	2,058	
Total spruce restoration:	3,161	

*In addition to releasing spruce, snags are to be created on 800 of the 1,425 acres.

The primary objective of the Greenbrier North project is to accelerate the presence of red spruce in the overstory where overstory spruce currently does not exist. This objective is to be achieved two ways: (1) in commercial thinning, by selectively thinning hardwood overstory trees around young spruce trees, while retaining other mature hardwoods in the stand to provide habitat and structure; and (2) in non-commercial spruce release, by controlling hardwood competition. Herbicide treatments may occur in all acres of commercial thinning areas for diseased beech, striped maple, and other undesirable species that could outcompete the spruce. Non-commercial treatments include using herbicides, chainsaws, and/or hand tools to kill or cut down overtopping hardwood saplings, and scattered mature hardwoods, red pine (*Picea resinosa*), and nonnative Norway spruce (*Picea abies*). This would release understory red spruce and create snags.

Initiated in 2016, the project is expected to be completed within 10 years. During 2016 and 2017, 2,240 acres of red spruce were released in this area. (CASRI 2016, 2017). In addition, contractors and volunteers planted 51,852 red spruce and 60,630 native hardwood seedlings across 227 acres, and decommissioned over 18 miles of road, which were replanted with red spruce.

As this was the first commercial spruce restoration project proposed on the MNF, it attracted considerable attention and underwent a long and deliberative planning process. Proposed restoration sites were in areas adjacent to suitable occupied WVNFS habitat and in red pine plantations with advanced spruce regeneration in the understory. Whereas preliminary research

on red spruce restoration had shown single-tree gap creation techniques as promising methods to release understory spruce, questions remained about short-term effects to WVNFS individuals from nearby habitat manipulations. Forest Plan Standard TE64 requires that on lands determined to be suitable habitat for WVNFS, vegetation management initially would be limited to research or administrative studies to determine effective habitat enhancement techniques for the WVNFS (USFS 2006). After such studies have demonstrated effective techniques, vegetation management to enhance habitat for WVNFS or other threatened, endangered, or protected species could occur on a larger scale.

Because of these issues, the project planning process took over 6 years to complete. During this time, issues were deliberated through coordination with the USFWS, other members of CASRI, and the Friends of Blackwater. As a result, the size of the project was greatly reduced in response to public comments (U.S. Forest Service 2012, 2015). This resulted in smaller acreages of commercial and non-commercial spruce restoration, less herbicide use than originally proposed, and monitoring WVNFS to determine how treatments affect WVNFS in the short-term.

Using acoustic technology, research scientists from Virginia Tech have begun monitoring WVNFS occupancy before, during, and after vegetative treatments (USFS 2015). In addition, during 2016 the MNF collaborated with Purdue University, the USFS's Northern Research Station, and Friends of Blackwater to collect hair samples from WVNFS in an attempt by Purdue University to extract DNA and estimate the local population size before and after vegetation treatments (USFS 2015). However, they had difficulty getting an adequate sample size for the genetic analysis and sampling is expected to continue (Shane Jones, USFS, pers. comm. 2018). Years ago, King and Eackles (2003) also had problems extracting sufficient DNA from hair samples. Despite collection of 300 hair samples by the WVDNR, researchers in 2003 were not successful in developing microsatellite markers in WVNFS for the objective of identifying population structure, the extent of metapopulations, and evolutionary lineages. With improvements in DNA extraction and analysis techniques since 2003, it is hoped that information on local population size can be obtained.

b. <u>The Mower Tract</u>

The USFS identified restoration of the Mower Tract as a priority project to reconnect habitat north to south and to connect elevation gradients on Cheat Mountain. Cheat Mountain lies within the center of the range of the WVNFS and was identified by CASRI partners as a key red spruce corridor and a top priority for conservation. When completed, the Mower project will create a nearly 2,600-acre contiguous habitat corridor for multiple species dependent on the red spruce ecosystem (Figure 2). In addition, the project will restore 971 acres of previously restored mine

Figure 2: Aerial view of the Lambert South section of the Mower restoration project (USFS 2014b).

lands and release 6,360 acres of surrounding red spruce. Spruce release would encourage growth, and increase structural diversity within the stands (USFS 2016b, 2016c).

Historically, the 40,000-acre Mower Tract was a red spruce influenced old growth ecosystem. Approximately 2,500 acres of the tract was mined for coal during the 1970s and 1980s, then reclaimed and planted following restoration practices of that era, which included heavily compacting the soils and planting non-native grasses, red pine, and Norway spruce plantations to control soil erosion. After 30+ years, few trees have successfully seeded into the area; however, the area does contain immature hardwood dominated forests with varying levels of red spruce, and dense thickets of young red spruce. Because the surrounding area is a 50 to 100 year old forest, restoring these lands to red spruce/northern hardwoods will create an important habitat corridor and increase the quantity and quality of WVNFS habitat in the area.

Restoration of the Mower Tract started in 2010 with the approximately 90-acre Barton Bench pilot project, designed to test soil ripping techniques and wetland creation to restore hydrology.

Approximately 135 wetlands were created, and 27,000 native plants were planted, including a large red spruce component. Over 90 percent of these trees survived.

This initial success led to starting the Lambert Run project in 2012. This project consists of an array of activities across 2,667 acres including: 573 acres of timber stand improvement (hardwood thinning for spruce release), and 11 miles of road decommissioning with red spruce plantings. Collectively, through 2017, over 200,000 native tree and shrub species (about 50 percent red spruce) have been planted on over 584 acres of reclaimed land at the Mower Tract and over 700 vernal pool wetlands have been created. In addition, over 8 miles of roads have been decommissioned and planted to red spruce, and 353 acres of invasive plant control have been implemented.

The USFS plans to complete the entire Mower Tract project by 2024. While the area currently is predominantly mid-successional habitat (20-120 years), progress is being made to move the forest toward a functioning late successional red spruce dominated forest over the long term (Figure 3).

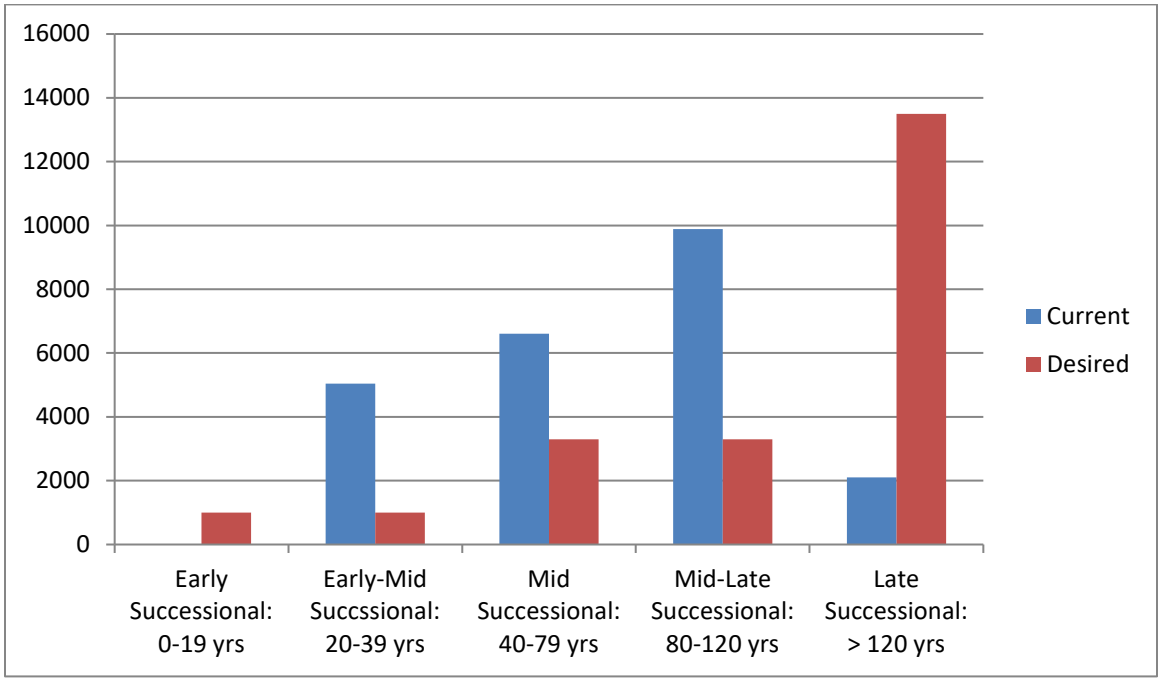


Figure 3. Acres of current and desired age classes for spruce and spruce-hardwood forests in the Mower Tract project area (adapted from USFS 2016b).

2. Passive Management

Management prescriptions 5.1, 6.2, and 8.0 in the MNF Land and Resource Management Plan protect WVNFS habitat through passive management in wilderness, proposed wilderness, backcountry recreation areas, and special areas. Management activities are low to non-existent in in these areas, allowing ecological processes to dominate, with exception made for invasive plant control in these areas. During the first 5 years of the post-delisting monitoring period, forests in theses area were passively managed to allow them to mature; there was no timber harvest, facility construction, road construction, oil and gas development, or other adverse activities in WVNFS habitat within these areas.

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3. Feasibility of Meeting Goals and Desired Conditions for Vegetative Composition and Structure

During the first 10 years of implementing Management Prescription 4.1, the MNF has implemented projects addressing all goals for this area (Table 5), thus moving the forest gradually toward desired vegetation conditions within restoration areas. The Forest Plan states that during the early decades of the 50+ year planning period, restoration focuses on advancing spruce and spruce-hardwood species composition in the overstory, and establishing vertical habitat structure in early-mid, mid, and mid-late successional stands (USFS 2006).

During the first 10 years of implementing Management Prescriptions 5.0, 6.2, and 8.0, the MNF has passively managed designated wilderness, backcountry wilderness, and special areas consistent with the overall goal in these areas to allow natural processes to dominate (USFS 2006). Thus, natural succession is slowly moving trees in these areas toward dominance by late successional stands where gaps form from natural disturbances as trees age.

Whereas the Forest Plan expressed desired vegetation conditions only in general terms for passive management areas (Management Prescriptions 5.0, 6.2, and 8.0), it quantified desired age class distributions within active restoration areas in Management Prescription 4.1 (Forest Service 2006). Table 6 displays the long-term desired condition in spruce and spruce-hardwood restoration areas within Management Prescription 4.1. This includes 3-8 percent of the of the restoration areas in classes with long-term goals ranging from 3-15 percent (13-38 percent if summed) of the total restoration area. The long-term goal for the oldest seral stage ($\geq$120 years) is 60-80 percent of the total restoration area. Because the mid-late and late successional age classes include stands that are trending toward multi-aged conditions that are the result of active restoration and natural succession, the 80-120 and 120+ ages refer to the time elapsed since the last stand replacing disturbance, and not necessarily to the ages of individual trees.

Table 5. Vegetation management goals for the spruce and spruce-hardwood ecosystem (management prescription 4.1) in the Forest Plan for the Monongahela National Forest (USFS 2006).

Goal #	Direction Description	Project
4101	Maintain or enhance the spruce component within mixed spruce-hardwood communities. Maintain a hardwood component in mixed stands as well as to provide mast, nesting habitat, and species diversity.	Upper Greenbrier North, Mower Tract
4102	Restore a spruce component to stands that contain understory spruce or scattered overstory spruce.	Upper Greenbrier North, Mower Tract
4103	Restore multi-age ecosystem structure in areas where spruce is being restored, enhanced, or maintained.	Upper Greenbrier North, Mower Tract
4104	Work the with Fernow Research Work Unit of the Northern Research Station, academia, USFWS, or state and private researchers on designing and monitoring spruce restoration efforts.	Upper Greenbrier North
4105	Restore Norway spruce and red pine plantations to native red spruce and mixed hardwood communities	Upper Greenbrier North

Table 6. WVNFS habitat objectives as they relate to current, desired, and modeled vegetation conditions by age class in spruce and spruce-hardwood restoration areas within Management Prescription area 4.1 (USFS 2006).

	Percent by Age Class				
	Early Successional (0-19 yrs.)	Early-Mid Successional (20-39 yrs.)	Mid Successional (40-79 yrs.)	Mid-late Successional (80-119 yrs.)	Late Successional (≥ 120 yrs.)
Current condition in Management Prescription 4.1 area	7	11	40	32	10
		83 summed across all mid-seral stages of 20 to 119 years			
Desired condition in Restoration Areas	3-8	3-8	5-15	5-15	60-80
		13-38 summed across all mid-seral stages			
Modeled condition in Management Prescription 4.1 area after 100 years	About 0.2 for all scenarios	38-50 for all scenarios, summed across all mid-seral stages			50-59 for all scenarios
WVNFS habitat objectives				Maintain at least 20,000 acres of mid-late and late successional (> 80 years old) spruce forest, with a long-term objective of increasing this to at least 40,000 acres to provide optimum habitat for WVNFS	

To answer questions about the ability to achieve landscape-scale restoration of red spruce while protecting the WVNFS, Thomas-Van Gundy and Sturtevant (2014) used a landscape model to simulate red spruce ecosystem response to management scenarios for 100 years. The patch cuts modeled were designed to be close to intended restoration actions. Only one type of harvest was modeled, and restoration scenarios differed in management of "potential habitat"[4] for WVNFS: 1) No Restrictions--harvest in stands regardless of WVNFS habitat; 2) Protect Habitat--no harvest in areas of high probability WVNFS habitat; 3) Protect Spruce--harvest in all areas with the exclusion of stands with existing mature red spruce in the overstory; and 4) No Harvest--natural succession only.

When all age classes were combined, active management with protections for existing red spruce stands resulted in a greater area dominated by red spruce than did larger, area-wide protections. However, protecting larger areas of low quality WVNFS habitat potentially increased these areas' suitability for the species.

Compared to active management, passive restoration resulted in a greater amount of red spruce developing in open areas determined to have no potential for WVNFS habitat at the start of the modeling period. The authors noted that while passive restoration approaches can delay progress in advancing toward late seral stages, at the end of the model period, 59 percent of the area was in this age class, which comes close to the lower end of the MNF Plan goal of 60-80 percent of forest types in this age class.

Notably, the authors concluded that the harvests, as modeled for 100 years, would not meet some seral stage targets (future conditions) when measured against the entire area of Management Prescription 4.1. The No Harvest scenario came the closest to meeting desired future conditions for the mid-seral and late successional stages (Table 6). All model scenarios resulted in an early successional stage below 3 to 8 percent of the landscape at year 100 (Table 6). Whereas young trees are important to sustaining a constant supply of older red spruce over the long term, WVNFS use of openings and early successional stages is likely limited to dispersal across such areas to reach mature forest.

Moreover, the authors concluded that the restoration goals in the Forest Plan may be unrealistic, and that alternative strategies should be considered, including more tree planting, larger areas harvested or treated and even-aged harvests. However, it is important to note the authors are using the term "goal" to refer to desired future conditions at a broad landscape level, and for purposes of analysis, they constrained the time modeled to 100 years. Unlike other active management prescriptions in the Forest Plan, desired conditions for Management Prescription 4.1 are expressed in terms of age class distributions within the restoration area, rather than at the landscape level (USFS 2006). Moreover, there is no clearly articulated timeline in the Forest

[4] The term "potential habitat" as used in the paper is a bit of a misnomer as it is habitat with a low to moderate probability of occurrence of WVNFS occurrence.

Plan by which broad goals and desired vegetation conditions for Management Prescription 4.1 are to be achieved. Rather, the timeless overarching intent of goals in the Forest Plan is to move the forest toward desired conditions, in an incremental manner measured by objectives (1,000 to 5,000 acres per decade), and constrained by standards and guidelines.

More importantly, it appears that it is feasible to meet habitat objectives on the MNF for WVNFS within 100 years. The Forest Plan set a habitat objective for WVNFS to maintain 20,000 acres of mid-late and late successional spruce forest ($\geq$ 80 years old), with a long-term objective of increasing this to at least 40,000 acres to provide optimum habitat for WVNFS (U.S. Forest Service 2006, page D-1, Management Indictor Species). Under all scenarios, the model projected over 76,000 acres of late successional spruce forest ($\geq$120 years) by year 100 (Thomas-Van Gundy and Sturtevant 2014). Thus, the long-term objective of at least 40,000 acres of optimum WVNFS habitat would be met under all scenarios, and this does not even account for mid-late successional forest (80-119 years old) by year 100, which was not presented in the paper.

B. The Nature Conservancy

The Nature Conservancy (TNC) signed the spruce MOU in December 2006 and committed to restoring red spruce/northern hardwood forest to TNC preserves and easements, and working with private landowners to improve habitat connectivity through voluntary fee title purchase, conservation easements, and management agreements. Although not mentioned in the MOU, TNC subsequently expanded its reach by collaborating with others to implement red spruce restoration on public lands.

From 2007-2017, TNC reported planting a total of 46,500 red spruce trees on its preserves and easements, as well as 175,800 red spruce trees and 25,600 other native plants on private lands to improve habitat connectivity. TNC has planted red spruce on all of its preserves and easements. In total, red spruce were planted on over 459 acres, including private lands. As TNC did not report acres of trees planted for many of these projects, this acreage is an underestimate. Using a typical tree planting density of 250 to 300 trees/acre, the total acres of red spruce planted on TNC preserves, easements, and with private land partners is likely closer to 826 to 992 acres during this 11-year period.

TNC placed an emphasis on restoring connectivity across large blocks of rangeland separating WVNFS occurrences in the Spruce Knob-Seneca Rocks Recreation Area from suitable habitat in the Laurel Fork Wilderness Area. In 2013 and 2015, TNC acquired permanent conservation easements totaling 1,110 acres on two key private land parcels targeted for establishing connectivity on and around Pharis Knob in the Sinks of Gandy area. This corridor connects an estimated 50,000 acres of red spruce. Cumulatively in this corridor, TNC released 944 acres of red spruce on the higher elevations, planted over 76,000 red spruce and northern hardwood seedlings (331 acres) in the pastures on side slopes, and fenced 7,000 acres to protect the

seedlings and restrict cattle grazing. This work was facilitated in part by a $470,000 grant from the WVNFS Conservation fund for purchase of a 555-acre conservation easement on Gandy Ranch and restoration of 331 acres of red spruce/northern hardwood forest.

TNC also placed emphasis on protecting critical red spruce forest and facilitating additional spruce restoration at the 2000-acre Thunderstruck property at the base of Mt. Porte Crayon. Since 2007, TNC, the MNF, USFWS, and others had worked together to permanently protect the Thunderstruck Tract near Mt. Porte Crayon. By connecting high elevation forests to the valley floor, the property provides a protective buffer to over 100,000 acres of forest in the remote Roaring Plains and Dolly Sods wilderness areas of the MNF. The property also creates a north/south link within the Canaan Valley/Dolly Sods landscape to the adjoining Cheat/Spruce Mountain landscape. By 2011, TNC had protected 1,355 acres through conservation easement and sold the property to the MNF. In early 2013, TNC was awarded $218,500 from the WVNFS Conservation fund to reimburse its prior purchase of fee title to 115 acres of high quality WVNFS habitat and to donate the parcel to the MNF. The remaining parcels were purchased by the MNF (300 acres) and TNC (290 acres) in 2013 and 2014. In 2013, TNC and CASRI partners planted 34,000 red spruce trees across 239 acres on the Thunderstruck Tract to increase the amount of habitat, patch sizes, and connectivity for WVNFS and Cheat Mountain salamander (*Plethodon nettingi*).

In addition, TNC placed emphasis on protecting spruce forest and restoring connectivity in the Dolly Sods and Canaan Valley area. In early 2018, TNC announced it had acquired 1,143 acres bordering its 477-acre Bear Rocks Preserve, adjacent to the Dolly Sods Wilderness Area. The purchase significantly increased the size of the TNC preserve and helps to buffer the preserve and conserve habitat. The tract lies at the heart of a narrow corridor along the Allegheny Front that can serve to interlock biologically diverse and resilient forests together.

In addition to working on its own lands and assisting private landowners, TNC has significantly aided CASRI by serving as a contractor for red spruce restoration projects and invasive plant control. For example, in 2014, TNC signed an agreement to release red spruce on the MNF in an area covering 4,754 acres. Funded by the USFS, this work is being accomplished by TNC's Ecological Restoration Team composed of AmeriCorps members. For purposes of this PDMP report, we credited this work on federal lands toward the restoration goals of the MNF.

In addition, working as contractor for the Potomac Highlands Cooperative Weed and Pest Management Area (CWPMA), TNC removed invasive plants in and around red spruce forest from approximately 1,600 acres during the first 5 years of the PDM period. Most of this work was done on USFS lands and when it was reported to occur on the MNF was credited there for tracking purposes. The CWPMA is a partnership between federal, state, and local agencies, community associations, non-profit organizations, and private landowners aimed at coordinating efforts and programs for addressing the threat of invasive species in the headwaters region of the South Branch of the Potomac River in West Virginia and Virginia.

C. **Canaan Valley National Wildlife Refuge**

The Canaan Valley National Wildlife Refuge signed the spruce MOU in December 2006, committing to implement goals and objectives for the WVNFS and its habitat on the refuge and adjacent private lands as determined through completion of a comprehensive conservation plan (CCP). Completed in February 2011, the CCP identified the WVNFS as a priority species for protection and management. One of the CCP goals is to perpetuate the ecological integrity of the northern hardwood-conifer forest to sustain species of conservation concern, to develop late-successional forest characteristics, and to perpetuate the biological diversity and integrity of upland forest ecosystems on the refuge.

Objectives 2.3, 2.4, and 2.5 contain elements relevant to WVNFS (USFWS 2011). These include three key habitat management objectives: (1) advance late-successional characteristics on 214 acres of existing coniferous and mixed coniferous forest on the refuge to maximize breeding and foraging habitat for WVNFS; (2) expand the areal extent of understory and canopy spruce by at least 25 percent (approximately 53 acres) in conifer and hardwood dominant forests to increase the potential future spruce-dominated forest; and (3) improve the size and connectivity of red spruce forest on the refuge and across refuge boundaries.

The CCP notes that achieving desired habitat conditions will require a longer period than the 15-year planning window of this document but that the refuge will make incremental progress toward meeting habitat objectives. To advance toward these goals while the CCP was being was being completed, the refuge purchased 334 acres of red spruce communities, of which 90 acres was suitable for red spruce restoration. During 2007-2010, the refuge planted 25 acres of red spruce, 3 acres of balsam fir, and over 1,790 other native tress on refuge lands. After the CCP was completed (2011 through 2017), the refuge and its partners advanced late successional forest on the refuge by releasing 13.2 acres of young red spruce from hardwood dominated canopy and conducting 3 acres of beech brush control. In addition, the refuge expanded the areal extent, patch size, and connectivity of red spruce forest in key areas on and off refuge by planting 33,740 red spruce seedlings on 262 acres of refuge land, and planting 1,110 red spruce seedlings on 87 acres adjacent to the refuge. This amount of regeneration planting (an average of 37 acres of red spruce seedlings planted on the refuge annually) exceeds the CCP target strategy of planting at least 20 acres of red spruce seedlings a year (USFWS 2011). Moreover, to improve plant diversity of these restored areas, the refuge also planted 24 acres of other native plant species (3,850+ individual trees and shrubs) on the refuge. Thus, the refuge is exceeding expectations for spruce regeneration on refuge, and making incremental progress toward advancing late-stage forest succession on refuge and improving habitat connectivity off refuge.

D. West Virginia Division of Natural Resources

In signing the spruce MOU in December 2006, the WVDNR committed to manage or enhance red spruce habitat on wildlife management areas and state parks. While not yet reporting any red

spruce planting on wildlife management areas since signing the MOU, the WVDNR has worked with state parks and other partners to plant 14,400 red spruce in state parks and forests in WV. This has included planting 9,900 red spruce at Blackwater Falls State Park in areas impacted by hemlock wooly adelgid and beech bark disease; 1,500 red spruce at Watoga State Park and the adjoining Seneca State Forest; 1,000 red spruce at Canaan Valley State Park; and 2,000 red spruce at unnamed state parks in West Virginia (CASRI 2012, 2013, 2016, 2017).

WVDNR also committed in the MOU to benefitting red spruce restoration by supporting spruce mapping, completing classification of vegetation communities within the red spruce ecosystem, and soliciting and funding research proposals related to red spruce communities. As previously mentioned, WVDNR initiated and oversaw the multi-agency effort to map the red spruce ecosystem. WVDNR also completed classification of vegetation communities in this ecosystem in 2010 using Natural Heritage methodology to assess upland red spruce habitats (Byers et al. 2010). Five vegetation associations were classified, peer-reviewed, and published in the U.S. National Vegetation Classification. Red spruce forest and woodland associations were all ranked as high state and global conservation priorities. This report complemented an assessment of high elevation wetland communities within the Allegheny Mountains of West Virginia (Byers et al. 2007), and together these two reports completed the classification of red spruce communities in West Virginia.

With regard to research, since signing the MOU, WVDNR has solicited and funded two studies relevant to management of the red spruce ecosystem: forest fragmentation (Strager 2011) and a genetic assessment of the red spruce population (Stephan 2017). As mentioned earlier, the USFWS used the results of the statewide study of forest fragmentation to establish baseline conditions of forest fragmentation within WVNFS habitat.

Although not related to habitat management, WVDNR also continued monitoring WVNFS nest boxes, coordinating the effort with other agencies, and summarizing WVNFS captures in its annual ESA section 6 reports (WVDNR 2013, 2014, 2015, 2016, and 2017). Results of the next box monitoring are summarized in part IV of this post-delisting monitoring report. WVDNR continues to maintain a database of WVNFS captures and other rare plant and animal species in the red spruce ecosystem.

E. West Virginia Division of Forestry

The West Virginia Division of Forestry (WVDOF) signed the MOU for the Conservation of the Spruce Ecosystem in January 2007, committing to maintaining red spruce habitat on state forest lands (primarily Kumbrabow State Forest), and providing technical and financial assistance to private landowners to manage and restore red spruce and related habitat. Since signing the MOU, the WVDOF has planted 4,000 red spruce seedlings on Kumbrabow State Forest, released 100 acres of understory red spruce from a hardwood dominated canopy, and removed invasive plants from 23.5 acres and along 4 miles of road in this state forest (CASRI 2015, 2016, 2017). With

regard to private landowners, WVDOF has provided technical and labor assistance resulting in 550 red spruce seedlings planted on six different private properties in Pendleton County, 6 acres of red spruce canopy release on private lands, and 180 acres of invasive plant control on privately owned red spruce-northern hardwood forests. These projects received cost sharing from the Natural Resources Conservation Service (Barbara Breshock, WVDOH, pers. comm. 2018). In addition, the WVDOF State Nursery has grown native plant seedlings for use by CASRI partners in spruce ecosystem restoration (CASRI 2012, 2013).

Since signing the MOU, the WVDOF also has participated in research related to effects of hardwood thinning and canopy release on red spruce. In 2014, the WVDOF established four permanent red spruce research plots in the Morgan Camp project area on the Kumbrabow State Forest and collected pre-harvest data for each plot. In addition, from 2005 to 2013, WVDOF collaborated with the USFS-Northern Research Station and West Virginia University on a regional study of the response of red spruce-northern hardwood stands to thinning at Kumbrabow State Forest, Canaan Valley NWR, and the Gauley Ranger District. This understory red spruce release experiment was conducted in hardwood-dominated stands with a small component of understory spruce. Overlapping hardwood trees were treated with herbicide using a stem injection technique. Treatment levels varied by the amount of basal area removal of overtopping hardwoods. Pre-treatment data were collected in 2005 and post-treatment data were collected from 2007 to 2013. The high treatment level ($\geq$90 percent removal of basal area of overtopping hardwood trees) provided significantly greater 6-year red spruce growth (diameter and height) than the control and other treatment levels. Based on these results. Rentch et al. (2016) proposed that a tree-centered release approach using small canopy gaps emulating the historical gap-phase disturbance regime provides a good strategy for red spruce restoration in hardwood forests where overstory spruce are virtually absent and largely relegated to the understory.

F. George Washington National Forest

In 2006, the joint administrator of the GWJNF opted to delay signing the spruce MOU for the Central Appalachians because it was about to begin public scoping associated with revising the 1997 Land and Resource Management plan (or forest plan) for the GWNF, and the administrator preferred to sign the MOU once the plan revision was complete.

In 2018, staff expressed interest in signing the MOU through a site-specific cooperator agreement, and including the JNF since both the delisted WVNFS and the threatened Carolina NFS are in Virginia and the two national forests are combined administratively (Carol Croy, GWJNF, pers. comm. 2018a). It has been proposed that the West Virginia Field Office of the USFWS would sign the Cooperator Agreement as a sponsor of the GWJNF, and other partners may sign as well describing their roles and responsibilities. This action might also serve as a springboard for developing a separate multi-agency, multi-species ecosystem restoration MOU among partners already collaborating under the Southern Appalachian Spruce Restoration

Initiative (SASRI), and could facilitate grants and invigorate SASRI to begin larger scale restoration efforts similar to the path followed by CASRI. Discussions regarding this are continuing.

A small, disjunctive population of WVNFS occurs on the GWNF in Highland County Virginia on approximately 6,268 acres of mixed spruce and northern hardwood habitat in the 10,000-acre Laurel Fork Special Biological Area. Under the 2014 revised Forest Plan for the GWNF, known occurrences of the WVNFS are to be managed to protect and maintain populations and surrounding habitat conditions (USFS 2014c).

During the first 5 years of implementing the WVNFS PDM Plan, the GWNF has avoided impacts to WVNFS and its habitat. As the forest ages, the number of acres in early successional stages is decreasing and the amount of old growth is increasing. The GWJNF found that the 2008 to 2014 trend in spruce-northern hardwood old growth forest type for this area was stable to increasing (USFS 2014a). Since 2014, the GWNF has initiated planning processes for restoration projects benefitting WVNFS that it anticipates implementing during coming years (Carol Croy, GWJNF, pers. comm. 2018b). These include efforts to improve habitat quality for WVNFS by removal of unoccupied red pine plantations in the Laurel Fork Special Biological Area and replanting with red spruce and other native vegetation.

IV. DISTRIBUTION AND PERSISTENCE

To determine if WVNFS continue to persist throughout their extant distribution following delisting, the PDMP called for continued nest box monitoring and live trapping to document WVNFS presence/absence. Persistence was defined as continuing captures of WVNFS over multiple generations at previously documented sites, assuming an average generation span of roughly 1.5 years for WVNFS (USFWS 2007). An example of persistence would be capture of two or more WVNFS at a site across a monitoring period of three or more years (two or more generations). Sites were to be categorized as not persistent if they were visited annually for 5 consecutive years and there was no detection of WVNFS. The PDMP provided additional persistence criteria and examples.

Multiple entities monitored WVNFS at 33 sites in West Virginia from 2013 to 2017, including sites in all 7 core areas of the range. The WVDNR monitored 12-13 sets of nest boxes annually. Other partners supplemented this effort, including WVNFS monitoring by the MNF[5], and

[5]The PDMP indicated the MNF would focus its monitoring efforts on a few sites centered primarily in the Cheat Mountain core area, sampled more intensively during the post-delisting monitoring period as an ancillary effort to determine population trend. The USFWS did not consider this ancillary effort to be essential to determining persistence trends per the PDM plan. From 2013 to 2016, the MNF continued its long-term monitoring of nest box grids across the forest (20 grids, 500 nest boxes) in an effort to assess occupancy patterns and potential changes resulting from local and range-wide habitat changes or other stressors. However, biannual checking of the grids resulted in highly variable results and in 2017, the

WVNFS monitored as part of research studies on hair snare detection (Trapp and Flaherty 2017a), micro-habitat (Diggins and Ford 2017), and diet (Trapp et al. 2017b) by faculty and students from Purdue University and Virginia Tech. The WVDNR incorporated capture data from all partners into its long-term database of WVNFS captures.

A. Distribution

During the first 5 years of the post-delisting monitoring period, the WVNFS remained well distributed across its range along the spine of the Allegheny Plateau from Helmick Run, Grant County, West Virginia (in the northeast), to Briery Knob, Greenbrier County, West Virginia (in the southwest). From 2013 to 2017, the WVDNR and its partners captured and/or confirmed hair from 161 individual WVNFS[6] at 25 sites distributed across the range (Table 7). This brings the cumulative total of captures to 1,601 WVNFS individuals at 113 sites dispersed across all 7 core areas. Notably, during 2013-2017, individuals were found at new, expanded[7], and historic locations including: three new sites in the Spruce Knob/Laurel Fork core area, one new site in the Cheat Mountain core area, two expanded sites in the Blackwater Canyon/Dolly Sods core area, and two historic sites in the Cranberry/Upper Williams core area. The records of WVNFS at existing, new, and expanded locations provide evidence of an increasing distribution within the historic range.

B. Persistence

In addition, the records show WVNFS populations continue to persist across their range. During the first 5 years of implementing the PDMP, the persistence criteria were met at 20 of 27 previously known occupied sites (74 percent) that were monitored for a long enough period (5 years) to determine if the criteria were met (Table 7). Seven sites (26 percent) were categorized as not meeting the persistence criteria. Notably, one of these sites (#10, Blister Run) was checked 6 years in a row because it is a long-term monitoring site checked annually. WVNFS were detected at the site only in the 6th year (2018), and they had young of the year, providing

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MNF determined the level of effort required to generate sufficient data for demographic analysis would be time- and cost-prohibitive (Cathy Johnson, MNF, personal communication, 2018). Instead of continuing to intensively monitor the grid, the MNF decided to focus efforts on assisting the WVDNR with checking several sites on the MNF, establishing nest boxes in active spruce restoration sites, and exploring use of camera traps, acoustic monitoring, and hair snares to supplement nest box checks as a means of documenting WVNFS persistence across the forest.

[6] The 161 individuals include 42 single captures of WVNFS at 9 sites using live-traps modified to collect hair (Trapp and Flaherty 2017). This new method uses hair morphology to identify WVNFS presence and greatly improves the chance of detecting WVNFS compared to traditional nest box checks.

[7] The WVDNR defines a new site as a location that is greater than 0.5 miles from another previously known location of WVNFS. Sites can be expanded by capture of a WVNFS within 0.5 mile of a known location.

Table 7. Sites meeting WVNFS persistence criteria during 2013 to 2017 in West Virginia.

Core Area	Site #	Capture or Hair Evidence	Persistence Criteria at Sites with Sufficient Monitoring		Sites with Sufficient Monitoring	Sites Needing Additional Monitoring
			Met	Not Met		
Blackwater Canyon/ Dolly Sods	1	Both	X		X	
	78	Hair	X		X	
	92	Both	X		X	
	101	Capture	X		X	
Stuart Knob	2	None		X	X	
	3	Capture	X		X	
Kumbrabow/Mead Westvaco Experimental Research Forest	99	Capture	X		X	
Cheat Mountain	7	None		X	X	
	8	Hair	X		X	
	10	None		X	X	
	35	None		X	X	
	60	Capture	X		X	
	82	Capture	X		X	
	91	Capture				X
	96	Capture	X		X	
	110	Capture				X (new site)
Spruce Knob/Laurel Fork	5	Capture	X		X	
	6	None		X	X	
	55	None		X	X	
	33	Capture	X		X	
	39	Both	X		X	
	68	Both	X		X	
	69	Both	X		X	
	111	Capture				X (new site)
	112	Hair				X (new site)
	113	Hair				X (new site)
Gauley Mountain	87	Capture	X		X	
Cranberry /Upper Williams	25	Capture	X		X	
	26	None		X	X	
	27	Capture	X		X	
	29	Capture	X		X	
	31	None				X
	51	Capture	X		X	
Total	33 sites		20	7	27	6

evidence of reproduction. This shows that non-detection of WVNFS for 5 years in a row does not definitively equate to non-persistence. Yet even when strictly applying the persistence criteria, the threshold for concern was not met ($\geq$ 35 percent or more of previously known occupied sites not meeting the persistence criteria).

Moreover, multiple WVNFS were found at two historic sites, demonstrating continuing captures over many generations. These sites had not been monitored for a long period. Lingebach and Perrygo caught a female WVNFS at historic site #25 in 1936, preserving her as the type locality for the subspecies (specimen # 260420 in the U.S. National Museum). Seventy-seven years later, the WVDNR caught 3 adults there in 2013 (51 generations later). Likewise, a male WVNFS was caught at historic site #27 in 1951, and an adult female and 2 juvenile WVNFS were caught there in 2017, (64 years or 41 generations later). Continuing captures of multiple WVNFS at historic sites provide evidence of persistence over multiple generations.

V. POPULATION INDEX

Although not required by the PDMP, we conducted additional analysis in response to concerns raised by the Friends of Blackwater about a "downward trend" in the number of WVNFS caught in the past 5 years at nest box sites, and a request for "hard data" on population numbers (Friends of Blackwater 2018). While we do not agree the number of WVNFS caught is cause for concern, we took a hard look at the literature to determine if available data could be used to create a population index.

First, we note that the raw numbers of WVNFS caught do not reflect population trends as the level of effort varied considerably the last 5 years. As would be expected, the greatest number of WVNFS were caught in years when researchers were live-trapping WVNFS (Diggins' work in 2013 and 2014, and Trapp's work in 2015 and 2016).[8] WVNFS more readily enter live traps than use nest boxes. Once those studies ended, the number of WVNFS caught per year declined. Thus, reduced effort should not be interpreted as a population decline.

Second, population fluctuations are to be expected for WVNFS. Stihler (1995) noted annual variability in WVNFS captures before delisting. Like many species of small mammals, there is substantial evidence that NFS exhibit density-dependent population growth (Fryxell et al. 1998, Lehmkuhl et al. 2006, Weigl 2007). The longest study from 1952 to 1995, in the province of Ontario, Canada, showed NFS populations fluctuating in recurrent wave-like form from high to low numbers at approximately 4- to 5-year intervals, and provided strong evidence that the rate of population growth was density-dependent (Fryxell et al. 1998). In density dependent populations, we would expect the rate of population growth to decline as population size

[8] It should be noted that the summary tables of WVNFS captures in WVDNR monitoring reports for 2015 and 2016 do not include numbers of WVNFS trapped and detected through hair collection, since the ability to accurately identify WVNFS from hair samples was still under development at the time (WVDNR 2015, 2016).

increases because increasing densities of individuals begin competing with each other or other species for resources.

We looked to the literature to see if there was a way to make use of existing data to analyze population trend in a data set that cannot be readily corrected for varying level of effort. We found a model developed by Smith and Person (2007) which fit the need. Since the model relies upon proportions and average values as population statistics, and not upon the number of individuals caught, the annual variation in level of effort is not a problem.

The model estimates average per capita rate of increase (r) of NFS, which is the rate at which population size changes per individual in the population. This is a simple birth (b) minus death (d) model:

$r = b - d,$

where b = the proportion of females in the population x the proportion of females reproducing x average litter size, and d = the proportion of the total population dying annually. A population is growing when $r > 0$, constant when $r = 0$, and declining when $r < 1$.

Ideally, this growth rate is determined by the birth, death, emigration, and immigration rates in the population. However, since we lack information on emigration and immigration rates in West Virginia, our estimate of r serves as an index of trend, representing potential growth rates of the WVNFS populations in isolation without influences of immigration/emigration.

We used nest box and live trapping data from 1988 to 2017 in West Virginia to look for changes in average per capita rates of increase across 5-year increments corresponding to expected population cycles. Pooling data across years is appropriate since we are not interested in normal annual variation, but want to know if cycling populations on average are growing, constant, or declining. Pooling data across each 5-year increment, we estimated means for litter sizes, annual proportions of females in the population, and proportions of females breeding in the spring (peak breeding season).[9] Because we lacked data on the annual mortality rate of all age classes, we used the range of values reported for NFS in the literature: approximately 0.3 to 0.5 (Sullivan et al. 2017, Smith and Pearson 2007, Lehmkuhl et al. 2006).

Applying the parameters in Table 8 for WVNFS to the birth minus death model, the WVNFS per capita rate of increase was positive during all 5-year periods, ranging between 0.11 and 0.70 during 2013 to 2017, which is indicative of potential for a slowly growing population. The rate was relatively constant from 1988 to 2002, increased from 2003 to 2012, and dropped during

[9] To be consistent with the methods of Smith and Pearson (2007), we used the proportion of females breeding in the spring rather than year round. A small number of females breed in the summer and fall in West Virginia.

2013 to 2017 but was within the range of earlier periods. Since r-values were consistently above zero, this reflects positive potential population growth over the long term.

By comparison, WVNFS populations appear to have higher rates of increase than NFS in Alaska, perhaps because litter sizes and proportion of females in the population are higher in West Virginia than Alaska. Smith and Pearson (2007) calculated 0.01 and 0.14 per capita rates of increase for NFS in the poorest and highest quality habitats, respectively, in southeast Alaska during 1999 to 2001. Using the comparable 0.5 death rate, the per capita rate of increase for WVNFS in West Virginia was 0.28 for the overlapping period of 1998 to 2002. For five of six periods, per capita rates of increase in West Virginia were two to three 3 times greater than the highest rate in Alaska, and approximately equal for one period.

Table 8. Estimates of average per capita rates of increase, r, for WVNFS in West Virginia from 1988 to 2017, based on a birth (b) minus death (d) model, in the absence of immigration and emigration.

Parameters	1988 to 1992	1993 to 1997	1998 to 2002	2003 to 2007	2008 to 2012	2013 to 2017
Avg. litter size (range)	3.1 (1-6)	2.4 (1-4)	2.4 (2-3)	2.4 (1-4)	2.7 (1-4)	2.4 (1-4)
Proportion of females in the population	0.46	0.51	0.56	0.58	0.45	0.56
Proportion of females reproductive in the spring	0.51	0.51	0.58	0.72	0.81	0.58
b, avg. annual birth rate per female	0.73	0.61	0.78	1.00	0.98	0.78
d, est. avg. annual mortality rate across all age classes	0.3 to 0.5	0.3 to 0.5	0.3 to 0.5	0.3 to 0.5	0.3 to 0.5	0.3 to 0.5
r = b - d						
r (when d = 0.3)	0.43	0.31	0.48	0.7	0.68	0.48
r (when d = 0.5)	0.23	0.11	0.28	0.5	0.48	0.28

VI. MONITORING THRESHOLDS

The PDMP established monitoring thresholds for habitat, distribution, and persistence of the WVNFS. If declines are detected equaling or exceeding these thresholds, the USFWS, in combination with participants, will investigate causes of these declines, including consideration of habitat changes, low birth rates, deaths or emigration, weather, trap shyness, competition for nest sites, or any other significant evidence. The result of this investigation will be to determine if the WVNFS warrants expanded monitoring, additional research, additional habitat protection, and/or resumption of Federal protection under the ESA.

As described below, none of the thresholds has been met or exceeded during the first 5 years of implementing the PDMP.

- The first threshold is a 10 percent or greater net reduction in baseline acres of WVNFS habitat, which is equivalent to a net reduction of 17,375 acres of WVNFS habitat. This threshold has not been reached because the amount of habitat created (983 acres planted) and restored (4,762 acres) greatly exceeds the amount of habitat lost (285 acres) from 2013 to 2017.
- The second threshold is a significant reduction in distribution of WVNFS as indicated by lack of detection for 5 years in one or more of the 7 general core habitat areas. This threshold has not been reached because WVNFS were detected in all 7 cores areas during the 5-year period from 2013 to 2017.
- The third threshold is a lack of WVNFS persistence during the PDM period at 35 percent or more of the previously known occupied sites. Midway through the 10-year monitoring period, at sites with sufficient monitoring to determine persistence, 26 percent of the previously known occupied sites were classified as not persistent. Therefore, this threshold has not been reached.

Because none of the thresholds have been met or exceeded, there currently is no need to investigate if the WVNFS warrants expanded monitoring, additional research, additional habitat protection, and/or relisting under the ESA.

VII. CONCLUSIONS

Despite removal of the protections of the ESA, there is reason for optimism about the status of the WVNFS mid-way into the 10-year post-delisting monitoring period. Habitat status is stable to improving, good progress has been made implementing management plans and agreements, and the WVNFS persists throughout its historic range.

At the start of the post-delisting monitoring period, there was an estimated 173,750 acres of baseline WVNFS habitat, of which 94 percent was interior forest not degraded by edge effects, and over 53,000 acres was high quality habitat. Habitat losses have been minimal following delisting (285 acres). Due to natural succession, tree planting and restoration, habitat currently is

expanding on the landscape to reoccupy space with favorable conditions for tree growth. During the first 5 years of the post-delisting monitoring period, there has been 26 times more habitat protection, creation, and restoration than habitat loss.

Collectively, land management agencies appear to be on track to meet goals and objectives for WVNFS, its habitat, and the red spruce northern-hardwood ecosystem. Restoration has focused on helping red spruce reach advanced age more quickly, and increasing forest patch sizes and connectivity. The partnership initiated by the spruce MOU signed in 2006 has grown from 7 to 22 partners who collectively have restored over 7,245 acres in 11 years, of which almost 80 percent has been accomplished in the last 5 years. Most notably, the MNF (the landowner responsible for the majority of WVNFS habitat) has met the upper end of Forest Plan objectives to restore 1,000 to 5,000 acres per decade and is advancing the forest toward long-term desired age classes. With assistance from TNC and others, the MNF appears to be committed to continue this trend. Modeling suggests it is feasible to meet long-term habitat objectives on the MNF to create at least 40,000 acres of WVNFS habitat $\geq$ 80 years old within 100 years.

Mirroring habitat trends, the WVNFS continues to persist across its historic range. Despite being difficult to survey, the WVNFS remains well distributed across all 7 core areas and continues to be found at new, expanded, and historic sites. Persistence criteria were satisfied at 74 percent of previously known occupied sites monitored for a long enough period to determine persistence. Moreover, the per capita rate of population growth was positive during 2013-2017, and comparable to past 5-year periods, indicative of long-term potential for a slowly growing population.

VII. RECOMMENDATIONS

Members of CASRI have made significant progress to date working together to conserve and restore the red spruce-northern hardwood ecosystem. During the remaining years of implementing the PDMP and beyond, we encourage CASRI to continue this great work, especially planting trees and restoring the red spruce/northern hardwood ecosystem in priority areas, moving toward the goals of increasing the amount of young forest, advancing development of mature forest, and increasing habitat patch sizes and connectivity. We also recommend that USFWS and the GWJNF complete and sign a cooperator agreement pursuant to the spruce MOU, formally recognizing the GWJNF as a member of CASRI.

With respect to improving data collection and consistency of implementation during the remaining portion of the monitoring period, we recommend that:

- CASRI annual reports consistently report acres of trees planted and acres restored for all projects, rather than simply the number of trees planted.
- CASRI partners work together to create a map of tree planting and restoration areas, which would facilitate standardized calculation of acres of habitat created, restored, and connected.

- The USFWS work with the GWJNF to ensure the next revision to the spruce cover map identifies the amount and quality of WVNFS habitat in Virginia at the start and end of the 10-year monitoring period, using methodology similar to that for creating the baseline habitat map for West Virginia.
- The USFWS, WVDNR, and MNF work closely on site selection for WVNFS monitoring to maximize monitoring of highest priority sites across core areas. Sites identified as having met the persistence criteria in Table 7 of this report do not need to be monitored again during the remainder of the post-delisting monitoring period (unless part of a research project).
- The WVDNR, USFWS, and MNF incorporate acoustic technology and/or hair snares into WVNFS monitoring to improve detectability. In particular, these new techniques should improve efficiency in data collection at sites previously determined to be persistent prior to delisting, where detection of only one WVNFS individual is needed to confirm continued persistence, consistent with the criteria in the PDMP (USFWS 2007).

The final report for the 10-year PDMP will be prepared after the monitoring period ends on March 4, 2023. To facilitate preparation of the final report, we recommend:

- CASRI partners begin gathering aerial photos, data sources, and other GIS layers that will be useful to creating the 2023 red spruce-northern hardwood cover map and analyzing habitat changes since 2013. While aerial photos as close to 2023 should be used to produce the map, other resources may aid interpretation of the 2023 aerial photos.
- The USFWS convene a meeting with representatives from the MNF and other interested CASRI members to discuss methodology and identify who can help to analyze 10-year trend in patch size and habitat connectivity for WVNFS between 2013 and 2023. Likewise, this group should begin gathering data needed for the analysis.

LITERATURE CITED

Anderson, M.G., M. Clark, and A,O, Sheldon. 2012. Resilient sites for terrestrial conservation in the Northeast and Mid-Atlantic region. The Nature Conservancy. https://rcngrants.org/sites/default/files/final_reports/Resilient-Sites-for-Species-Conservation(1).pdf

Anderson, M.G.,A. Barnett, M. Clark, C, Ferree, Sheldon, A.O., and J Pierce. 2016. Resilient sites for terrestrial conservation in eastern North America. The Nature Conservancy. http://climatechange.lta.org/resilient-sites-ne/

Butler, Patricia R.; Iverson, Louis; Thompson, Frank R., III; Brandt, Leslie; Handler, Stephen; Janowiak, Maria; Shannon, P. Danielle; Swanston, Chris; Karriker, Kent; Bartig, Jarel; Connolly, Stephanie; Dijak, William; Bearer, Scott; Blatt, Steve; Brandon, Andrea; Byers, Elizabeth; Coon, Cheryl; Culbreth, Tim; Daly, Jad; Dorsey, Wade; Ede, David; Euler, Chris; Gillies, Neil; Hix, David M.; Johnson, Catherine; Lyte, Latasha; Matthews, Stephen; McCarthy, Dawn; Minney, Dave; Murphy, Daniel; O'Dea, Claire; Orwan, Rachel; Peters, Matthew; Prasad, Anantha; Randall, Cotton; Reed, Jason; Sandeno, Cynthia; Schuler, Tom; Sneddon, Lesley; Stanley, Bill; Steele, Al; Stout, Susan; Swaty, Randy; Teets, Jason; Tomon, Tim; Vanderhorst, Jim; Whatley, John; Zegre, Nicholas. 2015. Central Appalachians forest ecosystem vulnerability assessment and synthesis: a report from the Central Appalachians Climate Change Response Framework project. Gen. Tech. Rep. NRS-146. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs146.pdf

Byers, E.A., K.C. Love, K.R. Hiader, E.J. Burks, and J. Rowan. 2013. Red spruce (*Picea rubens*) cover in West Virginia. Version 1.0. http://wvgis.wvu.edu/data/dataset.php?ID=455

Byers, E. A., J. P. Vanderhorst, and B. P. Streets. 2007. Classification and conservation assessment of high elevation wetland communities in the Allegheny Mountains of West Virginia. West Virginia Natural Heritage Program, WVDNR. Elkins, WV.

Byers, E.A., J.P. Vanderhorst, and B.P. Streets. 2010. Classification and conservation assessment of upland red spruce communities in West Virginia. West Virginia Natural Heritage Program, WVDNR. Elkins, WV.
http://www.wvdnr.gov/publications/PDFFiles/RedSpruceUplands-web.pdf

Central Appalachian Spruce Restoration Initiative Strategy Committee. 2010. Action plan of the Central Appalachian Spruce Restoration Initiative.
http://applcc.org/Members/casri/resources/action-plan/casri-action-plan/at_download/file

Central Appalachian Spruce Restoration Initiative. 2011. Year-end report for the Central Appalachian Spruce Restoration Initiative (covering years 2006 -2011).
http://www.restoreredspruce.org/category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2012. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2013. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2014. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2015. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2016. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Central Appalachian Spruce Restoration Initiative. 2017. Year-end report for the Central Appalachian Spruce Restoration Initiative. http://www.restoreredspruce.org/ category/red-spruce/publications/

Diggins, C.A. and W.M. Ford. 2017. Microhabitat selection of the Virginia northern flying squirrel (*Galucomys sabrinus fuscus* Miller) in the central Appalachians. Northeastern Naturalist 24:173-190. http://www.bioone.org/doi/full/10.1656/045.024.0209

Diggins. C.A., C.A. Kelly, and W.M. Ford, 2015. Atypical den use Carolina northern flying squirrels in the southern Appalachians. Southeastern Naturalist 14LN44-N49.

Federal Energy Regulatory Commission. 2017a. Atlantic Coast Pipeline and Supply Header Project. Final Environmental Impact Statement. Volume I. Prepared by the Office of Energy Projects, Washington, D.C. https://www.ferc.gov/industries/gas/enviro/eis/2017/07-21-17-FEIS/volume-I.pdf

Federal Energy Regulatory Commission. 2017b. WB XPress Project. Environmental Assessment. Prepared by the Office of Energy Projects, Washington, D.C.

Ford, W.M., S.L. Stephenson, J.M. Menzel, D.R. Black, and J.W. Edwards. 2004. Habitat characteristics of the endangered Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) in the central Appalachian Mountains. American Midland Naturalist 152:430-438.

Ford, W.M., K,N, Mertz, J.M. Menzel, and K.K. Sturm. 2007. Winter home range and habitat use of the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*). Research paper NRS-4, Northern Research Station, U.S. Forest Service, Newtown Square, PA.

Friends of Blackwater. 2018. Endangered species are clinging to life. June newsletter, Thomas, WV.

Fryxell, J.M., J.B. Falls, E.A. Falls, and R.J. Brooks. 1998. Long-term dynamics of small-mammal populations in Ontario. Ecology 74:213-225.

Harvey, C. 2019. Red spruce sprout atop coal mines that helped kill them. Published April 3, 2019 in E & E News. https://www.eenews.net/climatewire/2019/04/03/stories/1060140777

Keller, S.R. and R. Trott. 2017. A genetic assessment of the population health and connectivity of a keystone species in high elevation Appalachian forest ecosystems: red spruce (*Picea rubens* Sarg.). Prepared for the West Virginia Division of Natural Resources, Operations Office, Elkins, WV.

King, T.L. and Michael Eackles. 2003. Final report. Microsatellite DNA marker development in the federally endangered northern flying squirrel (*Glaucomys sabrinus fuscus*): identification of population structure, metapopulation extent, and evolutionarily significant lineages. In appendix I, West Virginia Division of Natural Resources, federal assistance performance report, endangered species, project E-6-HP (1 October 2002 to 30 September 2003).

Kosiba, A.M., P.G. Schaberg, G.J. Hawley, and C.F. Hansen. 2013. Quantifying the legacy of foliar winter injury on woody aboveground carbon sequestration of red spruce trees. Forest Ecology Management 302:363-371. https://www.nrs.fs.fed.us/pubs/43459

Kosiba, A.M., P.G. Schaberg, S.A. Rayback, and G.J. Hawley. 2018. The surprising recovery of red spruce growth shows links to decreased acid deposition and elevated temperature. Science of the Total Environment 637-638:1480-1491. https://www.fs.fed.us/nrs/pubs/jrnl/2018/nrs_2018_kosiba_001.pdf

Lehmkuhl, J.F., K.D. Kistler, J.S. Begley, and J. Boulanger. 2006. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584-600.

Limbu, S., M.A. Keena, and M.C. Whitmore. 2018. Hemlock wooly adelgid (Hemiptera: Adelgidae): a non-native pest of hemlocks in eastern North America. Journal of Integrated Pest Management 9:1-16.

Mathias, J.M. and R.B. Thomas. 2018. Disentangling the effects of acidic air pollution, atmospheric CO_2, and climate change on recent growth of red spruce in the central Appalachian Mountains. Global Change Biology 2018;00:1-16. https://doi.org/10.1111/gcb.14273

Menzel, J.M., W.M. Ford, J.W. Edwards, and T.M. Terry. 2006. Home range and habitat use of the vulnerable Virginia northern flying squirrel *Glaucomys sabrinus fuscus* in the Central Appalachian Mountains, USA. Oryx 40:204-210.

Mountain State Biosurveys, LLC. 2011. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2012. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2013. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2014. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2015. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2016. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern con

Mountain State Biosurveys, LLC. 2017. Annual report, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Mountain State Biosurveys, LLC. 2019. Executive summary, West Virginia northern flying squirrel (Glaucomys sabrinus fuscus) study for the Appalachian Corridor H, Davis to Bismarck eastern construction project. Prepared for the West Virginia Division of Highways, Charleston, WV.

Rentch, J.S., W.M. Ford, T.S. Schuler, J Palmer, and C.A. Diggins. 2016. Release of suppressed red spruce using canopy gap creation—ecological restoration in the Central Appalachians. Natural Areas Journal 36:29-37. http://www.bioone.org/doi/full/10.3375/043.036.0108

Ritchie, L.E., M.G. Betts, G. Forbes, and K. Vernes. 2009. Effects of landscape composition and configuration on northern flying squirrels. Forest Ecology and Management 257:1920-1929.

Seidel, T.M., D.M. Wehrauch, K.D. Kimball, A.A.P. Pszenny, R. Soboleski, E. Crete, and G. Murray. 2009. Evidence of climate-change declines with elevation based on temperature and snow records from 1930s to 2006 on Mount Washington, New Hampshire, U.S.A. Arctic Antarctic Alpine Research 41:362-372. http://www.bioone.org/doi/full/10.1657/1938-4246-41.3.362

Smith, M.J., G.J. Forbes, and M.G. Betts. 2013. Landscape configuration influences gap-crossing decisions of northern flying squirrel (*Glaucomys sabrinus*). Biological Conservation 168:176-183.

Smith, W.P. and D.K. Pearson, 2007. Estimated persistence of northern flying squirrel populations in temperate rain forest fragments of southeast Alaska. Biological Conservation 137:626-636.

Stihler, C.W., J.L. Wallace, E.D. Michael, and H. Pawelczyk. 1995. Range of *Glaucomys sabrinus fuscus*, a federally endangered subspecies of the northern flying squirrel in West Virginia. Proceedings of the West Virginia Academy of Science 67:13-20.

Strager, M. 2011. Forest fragmentation of West Virginia. http://wvgis.wvu.edu/data/dataset.php?ID=453

Strager, M. and A. Maxwell. 2012. NRAC415: West Virginia wetland inventory and modeling project phase III.

Sullivan, T.P., D.B. Ransome, D.S. Sullivan, P.M.F. Lindgren, and W. Klenner. 2017. Tree squirrel abundance and demography in managed coniferous forests of British Columbia are within the range of natural fluctuations of old-growth stands. Canadian Journal of Forestry Research 47:565-582.

Thomas-Van Gundy, M.A. and B.R. Sturtevant. 2014. Using scenario modeling for red spruce restoration planning in West Virginia. Journal of Forestry 112:457-466.

Trapp, S.E. and E.A. Flaherty. 2017a. Noninvasive and cost-effective trapping method for monitoring sensitive mammal populations. Wildlife Society Bulletin 41:770-775.\

Trapp, S.E., W.P. Smith, and E.A. Flaherty. 2017b. Diet and food availability of the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*): implications for dispersal in a fragmented landscape.

U.S. Fish and Wildlife Service. 2007. Post-delisting monitoring plan for the West Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*). Prepared by the West Virginia Field office, Elkins, WV.

U.S. Fish and Wildlife Service and National Marine Fisheries Services. 2008. Post-delisting monitoring plan guidance under the Endangered Species Act. Dated August 2018 (section 6.1.2 updated July 2018).

U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Department of Agriculture Northern Research Station. West Virginia Division of Natural Resources, West Virginia Division of Forestry, and The Nature Conservancy. 2007. Memorandum of understanding for the conservation and management of the red spruce-northern hardwood ecosystem.

U.S. Fish and Wildlife Service. 2008. Biological opinion on the Appalachian Corridor H highway project from Davis to Bismarck; formal consultation. Letter and enclosure dated Feb. 13, 2008 from Tom Chapman, U.S. Fish and Wildlife Service to Henry Compton, Federal Highway Administration confirming and transmitting the final biological opinion.

U.S. Fish and Wildlife Service. 2011. Canaan Valley National Wildlife Refuge Comprehensive Conservation Plan. Prepar5ed by CVNWR, Davis, WV.

U.S. Fish and Wildlife Service. 2013. Letter from John Schmidt, Acting Field Supervisor, USFWS, West Virginia Field Office, dated May 17, 2013 to Travis Kidd, regarding construction of West Ridge lot 21.

U.S. Forest Service. 2006 (updated 2011). Land and resource management plan for the Monongahela National Forest. Prepared by the Supervisor's Office, Elkins, WV.

U.S. Forest Service. 2012. Upper Greenbrier North decision notice and finding of no significant impact #2. Issued November 21, 2012 by District Ranger, Greenbrier Ranger District, Monongahela National Forest.

U.S. Forest Service. 2014a. Appendix G –Management Indicator Species population trends. Monitoring and evaluation report for fiscal year 2008 through fiscal year 2014, for the 1993 George Washington National Forest Land and Resource Management Plan, and the 2004 Jefferson National Forest Land and Resource Management Plan. Prepared by the Supervisor's Office, Roanoke, Virginia.
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd611923.pdf

U.S. Forest Service. 2014b. Mower Tract ecological restoration, final report 2012-14. Prepared by staff of the Greenbrier Ranger District, Bartow, WV.

U.S. Forest Service. 2014c. Revised land and resource management plan for the George Washington National Forest. Prepared by the Supervisor's Office, Roanoke, VA.

U.S. Forest Service. 2015. Upper Greenbrier North decision notice and finding of no significant impact #4. Issued May 14, 2015 by District Ranger, Greenbrier Ranger District, Monongahela National Forest.

U.S. Forest Service. 2016a. Letter from Kathleen Atkinson, USFS to Leslie Hartz, Atlantic Coast Pipeline, LLC) dated Jan. 19, 2016, regarding the proposed route across Cheat Mountain.

U.S. Forest Service. 2016b. Mower Tract restoration and recreational enhancement project. Environmental Assessment. Prepared by the Greenbrier Ranger District Office, Monongahela National Forest, Randolph and Pendleton Counties, WV.

U.S. Forest Service. 2016c. Mower Tract Restoration Project. Decision notice and finding of no significant impact, dated September 2016. Prepared by the Greenbrier Ranger District Office, Bartow, WV.

U.S. Forest Service. 2016d. Big Mountain Project Environmental Assessment, dat6ed December 2016. Prepared by the Potomac Ranger District. Monongahela National Forest, WV.

U.S. Forest Service. 2016e. Biological assessment/evaluation of sensitive species for the Big Mountain project, dated January 2016. Prepared by the Potomac Ranger District. Monongahela National Forest, WV.

U.S. Forest Service. 2017. Biological evaluation prepared by the Monongahela National Forest for the Columbia Gas Transmission, LLC WB Xpress Project, for regional Forester's sensitive species, rare, threatened and endangered species, and birds of concern. Contained in appendix G of the Federal Energy Regulatory Commission's March 2017 Environmental Assessment for the WB Xpress project.

Weigl, P.D. 2007. The northern flying squirrel (*Glaucomys sabrinus*): a conservation challenge. Journal of Mammalogy 88:897-907.

West Virginia Division of Plant Industries. 2019. Draft report. Blackwater Falls State park hemlock survey. Prepared for Blackwater Falls State Park, Davis, WV.

West Virginia Division of Natural Resources. 2013. Performance report, West Virginia endangered animal species. Annual report on West Virginia northern flying squirrel monitoring, management, and life history studies, for the period from 1 October 2012 through 30 September 2013, submitted by WVDNR to Federal Aid, Northeast Region 5, U.S. Fish and Wildlife Service.

West Virginia Division of Natural Resources. 2014. Performance report, West Virginia endangered animal species. Annual report on West Virginia northern flying squirrel monitoring, management, and life history studies, for the period from 1 October 2013 through 30 September

2014, submitted by WVDNR to Federal Aid, Northeast Region 5, U.S. Fish and Wildlife Service.

West Virginia Division of Natural Resources. 2015. Performance report, West Virginia endangered animal species. Annual report on West Virginia northern flying squirrel monitoring, management, and life history studies, for the period from 1 October 2014 through 30 September 2015 submitted by WVDNR to Federal Aid, Northeast Region 5, U.S. Fish and Wildlife Service.

West Virginia Division of Natural Resources. 2016. Performance report, West Virginia endangered animal species. Annual report on West Virginia northern flying squirrel monitoring, management, and life history studies, for the period from 1 October 2015 through 30 September 2016, submitted by WVDNR to Federal Aid, Northeast Region 5, U.S. Fish and Wildlife Service.

West Virginia Division of Natural Resources. 2017. Performance report, West Virginia endangered animal species. Annual report on West Virginia northern flying squirrel monitoring, management, and life history studies, for the period from 1 October 2016 through 30 September 2017 submitted by WVDNR to Federal Aid, Northeast Region 5, U.S. Fish and Wildlife Service.

VIII. PERSONAL COMMUNICATIONS

Breshock, Barbara, West Virginia Division of Forestry. 2018. E-mail to Laura Hill, U.S. Fish and Wildlife Service, dated April 18, 2018, regarding West Virginia Division of Forestry work with private landowners on red spruce restoration.

Byers, Elizabeth, West Virginia Department of Environmental Protection, 2017. E-mail to Laura Hill, U.S. Fish and Wildlife Service, dated Nov. 29, 2017, clarifying dates of aerial imagery used for creating the red spruce cover type map of West Virginia.

Carrington, Kristen, West Virginia Department of Agriculture. 2019. E-mail to Laura Hill, U.S. Fish and Wildlife Service, dated March 19, 2019, regarding eastern hemlock health in West Virginia.

Croy, Carol, U.S. Forest Service. 2018a. Response to an e-mail from Laura Hill, U.S. Fish and Wildlife Service, on Jan. 10, 2018 referring to the status of red spruce restoration projects being planned by the George Washington National Forest, as relayed during a Central Appalachian Spruce Restoration Initiative conference call on Jan. 9, 2018.

Croy, Carol, U.S. Forest Service. 2018b. E-mail to Susan Cameron and Laura Hill, U.S. Fish and Wildlife Service, dated Feb. 13. 2018, regarding a desire by the George Washington National Forest to sign the spruce MOU.

Galford, Ed, Snowshoe Intrawest. 2019. Record of a phone conversation with Laura Hill, U.S. Fish and Wildlife Service, on May 1, 2019, regarding the status of the West Ridge subdivision.

Johnson, Catherine, U.S. Forest Service. 2018. E-mail to Laura Hill, U.S. Fish and Wildlife Service, dated Oct. 2, 2018, seeking clarification on acreage discrepancies in the environmental assessment for the WB Xpress Project.

Jones, Shane. U.S. Forest Service. 2018. E-mail to Laura Hill, U.S. Fish and Wildlife Service, dated November 15, 2018, clarifying research being conducted on the West Virginia northern flying squirrel related to the Upper Greenbrier North project.

INTERIM REPORT EVALUATING IMPLEMENTATION OF THE POST-DELISTING MONITORING PLAN FOR THE WEST VIRGINIA NORTHERN FLYING SQUIRREL (*Glaucomys sabrinus fuscus*)

November 2019

Lead Field Office Approval:

Approved: _____ Date: 11/20/2019

Project Leader, West Virginia Field Office