Threats Template Matrix -- Hemlock

1. **Threat**: Non-native species threats to Eastern hemlock, including hemlock woolly adelgid (HWA) and elongate hemlock scale (EHS), jeopardizing the ability of hemlock forests to protect riparian areas & water quality, provide wildlife habitat/thermal cover, and recreational opportunities. A native pathogen, Fabrella tsugae needle blight, can also add stress to hemlock particularly during drought; however this has not been detected on the ANF. Scirococcus tip blight, another pathogen, has been identified on the ANF, but has not normally cause high levels of stress or decline. The combination of all these stressors may produce faster decline and mortality rates than previously seen in other areas of northern and central PA.

2. **Location**: Hemlock is widespread throughout the ANF, and is dense in many locations (Figure 1), especially higher gradient stream corridors. Hemlock woolly adelgid has been identified in various locations at low population levels both on the ANF and adjacent to ANF land, including at Cook Forest State Park and Millstone township to the south, Tionesta centrally located (HWA has not been found since cold winters of 13-14 and 14-15), and along the Allegheny River near the Kinzua Dam and at Webbs Ferry (though the Webbs Ferry infestation was not located again following cold winters). Elongate hemlock scale has not been found yet in any county that contains ANF land, the furthest point west that it has been positively identified thus far is around Clinton County directly west and in the Pittsburgh area to the south. High priority hemlock conservation areas have already been identified on the ANF (Figure 2).

3. **Impact or Severity:** The impact of HWA, and HWA in conjunction with EHS, could be severe to the ANF's hemlocks. In other parts of hemlock's range, especially to the east and south, mortality has been very high, and occurs on a time scale anywhere from about 5 to about 20 years with HWA alone. Hemlock on the ANF have more "climatic protection" at this point, since very cold winters keep the adelgid in check, however the impacts of climate change and potential HWA adaptation are unknown. It can be speculated that climate will not be a significant check on the population indefinitely into the future, and therefore once HWA and EHS are widespread, it is possible that a very high percentage of the ANF's hemlock will experience mortality within the next 2 decades.

4. **Desired Outcome:** Protect at least some populations of eastern hemlock in priority areas from the impacts of non-native insects into the future, so as to protect riparian areas and old-growth forest ecosystems, maintain recreational opportunities (provide aesthetics) and to serve as future seed sources. Ecosystem function in priority riparian areas should be maintained, through treatment of hemlock to protect against pests, or mitigation of the impacts of hemlock mortality by enhancing resiliency of understory responses to disturbance by promoting natural regeneration, preventing or controlling invasive plants, and/or re-planting.

Threats Template Matrix -- Hemlock

5. **Strategies to Achieve the Desired Outcome**

Strategy 1: Preventative chemical treatment of priority hemlock conservation areas (see Figure 2); and EDRR/rapid response treatments in other critical habitat or recreation areas where a small outbreak may be detected (see Monitoring section)

When: Once HWA is detected in a priority area/stand/management unit, treatments could begin. Spring is the best time for treatment, but Fall is also possible and especially desirable if flowering understory plants are present in Spring and treatments would pose a risk to pollinators. Treatments are technically possible any time of year as long as adequate soil moisture is present. Imidacloprid is very cost-effective for HWA, but once EHS shows up, dinotefuran (Safari) will be necessary. Figure 3 shows treatment areas for 2016-2017.

Who: Contractual crews and/or Forest Service employees potentially with volunteer assistance (volunteers have been used with many hemlock treatment programs, in PA and other states)

Cost: Anywhere from probably $0.75 to $1.50 per diameter inch treated for imidacloprid contract, and at least ~$2/inch for dinotefuran, maybe more. Can be as low at ~$0.50 per inch for imidacloprid materials with in-house labor.

Strategy 2: Use of biocontrols may be another treatment option. This could be done in the same areas as chemical treatments, or other places.

May be useful in priority areas where the beetles are easy to release, collect, and where small hemlocks (planted as a hedgerow) could serve as "future insectaries". *Sasajiscymnus tsugae* was released widely in PA and other states. State and federal agencies are no longer releasing this beetle in PA though, because it is not as well-adapted to the climate conditions as other predatory beetle species (and one species of silver fly, collected in the Pacific NW; currently has been released and is being tested in the Finger Lakes area of NY by Dr. Mark Whitmore). There are two species of *Laricobius* that are more appropriate in PA, *L. nigrinus* and *L. osakensis*. Ln is capable of being reared in field insectaries (although also knocked back by cold winters), and Ln and Lo are also both available in small numbers for release on public lands from Forest Service-funded rearing labs.

The numbers of insects (thousands) and the amount of time needed for success may make this option more prohibitive. This is a long-term solution, as it may take as much as 2 or more decades for biocontrols alone to "save" hemlock trees.

When: Biocontrols may be released once there is a suitable amount of HWA present for them to feed on. Thus far only one location on the ANF is known to have enough HWA for a release, near the Kinzua Dam along the Allegheny River. Biocontrols have also been released in Cook Forest State Park. Biocontrols should be released as often as possible in a limited number of locations, to allow populations to build.

Who: Forest service employees and PA DCNR Bureau of Forestry employees

Cost: Cost for lab-reared beetles already covered by federal funding for those labs, and beetles from field insectaries require the staff time spent to collect, transport and release.

Threats Template Matrix -- Hemlock

Strategy 3: Maintaining/enhancing resiliency of understory to HWA disturbance: including monitoring and control of invasive plants and re-planting/underplanting in priority stands with a mix of native or eastern hemlock, evergreen shrubs such as rhododendron and mountain laurel, and "surrogate conifer species," depending on what regeneration is already present at a given site and the site characteristics. Priority areas would include along a headwater drainage, where gaps are created in the overstory by HWA or some other natural or human disturbance- particularly near riparian corridors, or areas where HWA treatment isn't practical. Replanting of eastern hemlock, especially resistant hemlock, would be preferred. Potential surrogate species include native conifers such as tamarack, red and white spruces, balsam firs, cedars (appropriate for larger headwaters), and possibly white pine. Riparian hardwoods such as red maple, yellow birch, serviceberry, or tulip poplar are other choices. Group consensus is that Norway spruce not recommended. For some species, seedling protective measures from browsing, such as fencing or cribs, will be needed.

When: Planting could begin now in openings where there is no natural regeneration of hemlock, but should be deferred in areas where there is adequate hemlock regeneration or where shade is prohibitive to seedling establishment (see Monitoring strategy 4 to determine where these locations exist within the priority hemlock conservation areas).

Who: Forest Service staff and volunteers (would be good activity for school and youth groups)

Cost: DCNR can provide free hemlock seedlings, other seedling costs; fencing costs?

Considerations/ Information needed: Debate exists about whether replanting should be limited to just eastern hemlock. More testing needs to be done to develop resistant hemlock. Western hemlock has been proposed for evaluation as a species to replant. It is more resistant to the adelgid but may not be adapted to the region. Selection of replacement species might also consider potential climate change and range shifts for some species.

6. Monitoring Strategies

Strategy 1: Volunteers in adopted priority areas

When/Frequency: Nov – March during "wool-up," once yearly

Who: Volunteers – examples include Friends of Allegheny Wilderness members, Kinzua Fish & Wildlife Association, concerned citizens. Also train school and youth groups to help with monitoring

Cost: Administrative hours for someone to send reminders to volunteers, collect reports, and possibly provide training

Threats Template Matrix -- Hemlock
Strategy 2: State/federal personnel in priority areas **When/Frequency**: Nov – March during "wool-up" once yearly **Who**: DCNR BOF employees, ANF staff/interns **Cost:** Hourly wage for interns/salary & benefits for BOF Forest Health staff (not covered by ANF), estimated one week for each of 2 or 3 BOF staff?
Strategy 3: Permanent Hemlock Condition Monitoring plot re-measurement **When/Frequency**: Plots are established (2016), could be re-measured every other year **Who**: Contract crew (initially established and measured by Forecon, Inc.) **Cost**: Estimated at ~$15,000
Strategy 4: Monitoring should begin now to indicate the need for underplanting in: 1) high priority hemlock conservation areas, 2) in other areas where there is a lack of regeneration, and 3) where there are openings already in critical riparian areas. **When/Frequency**: Do simultaneously with HWA monitoring **Who**: ANF **Cost**:

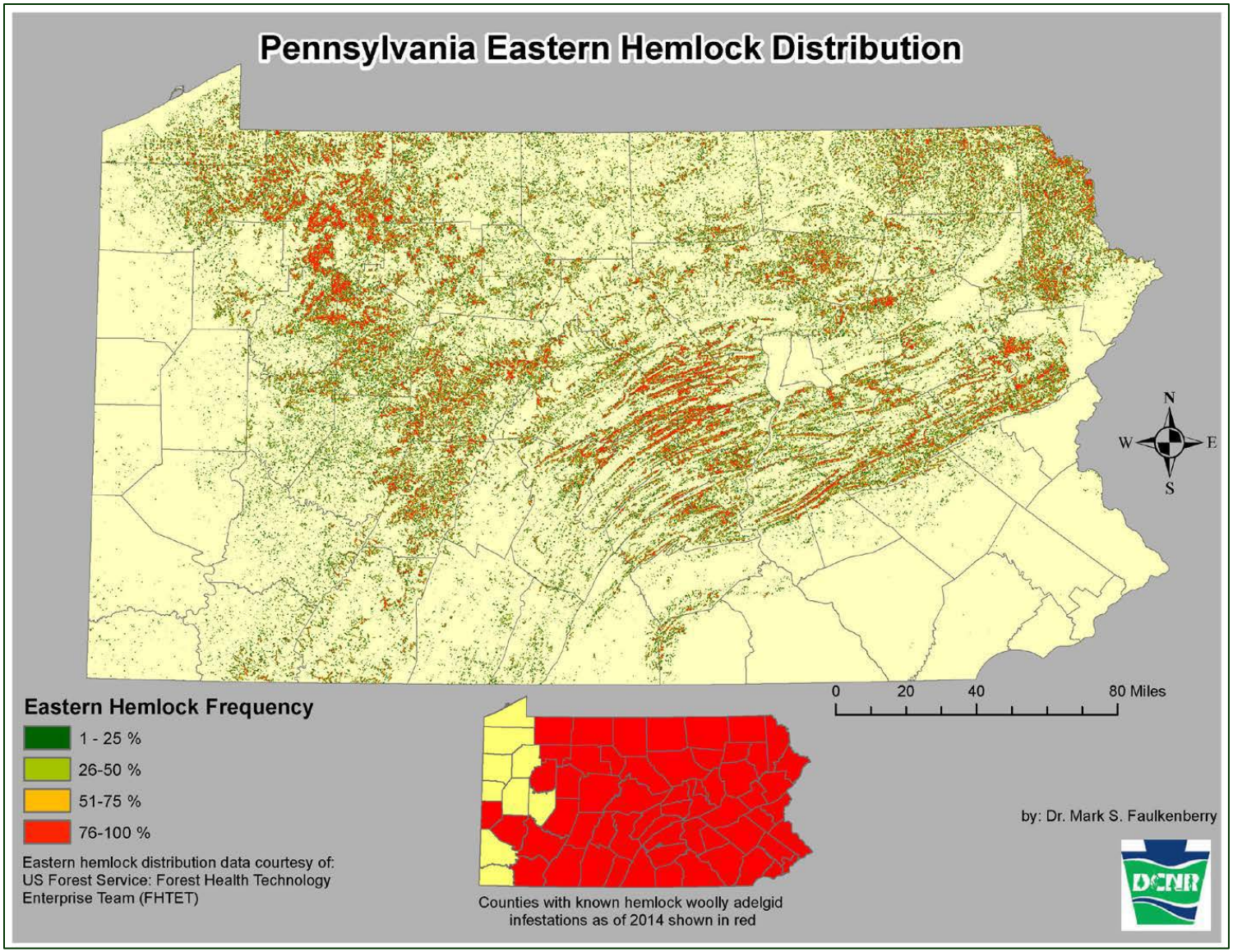

Figure 1. Hemlock distribution throughout Pennsylvania

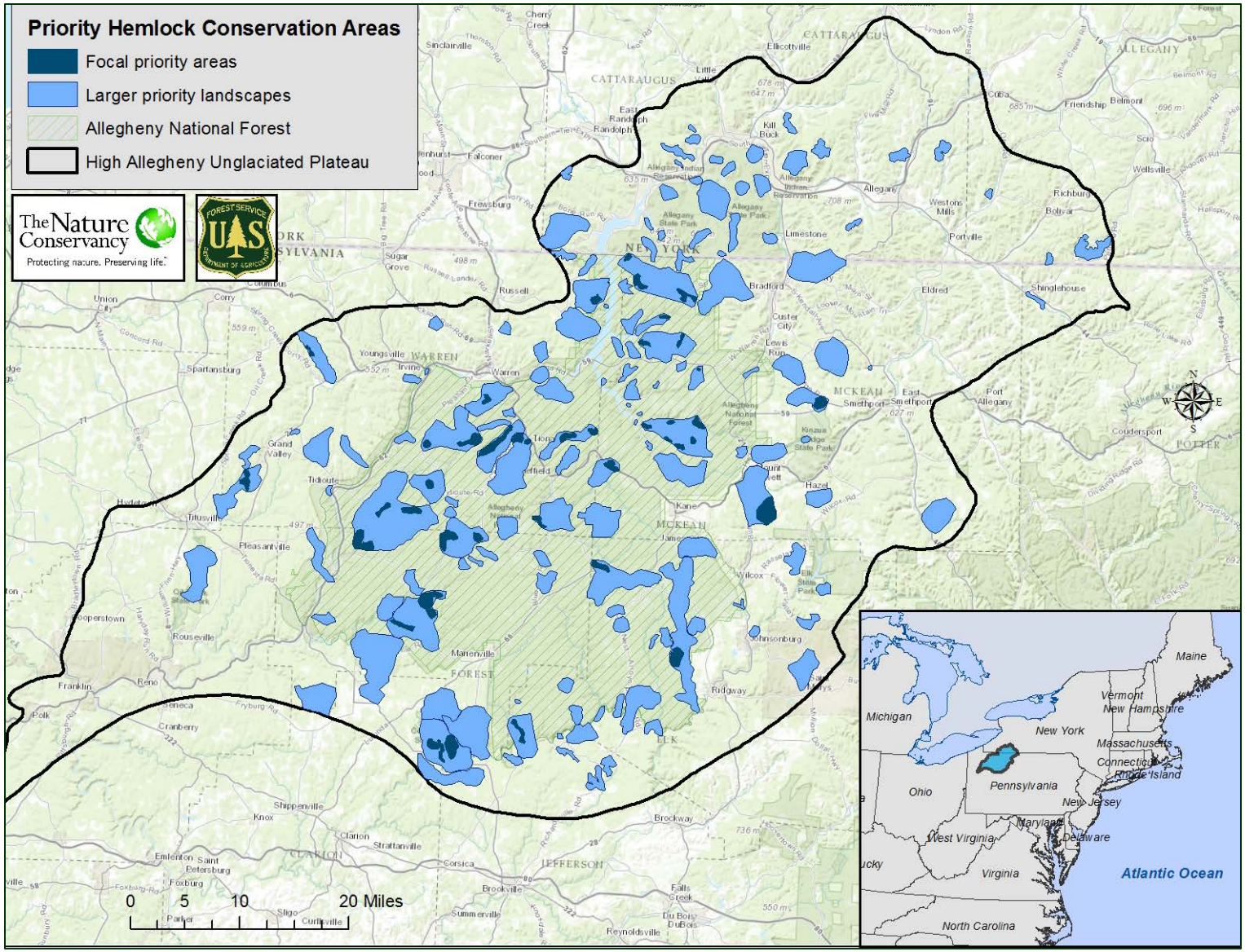

Figure 2. Priority areas for Hemlock conservation.

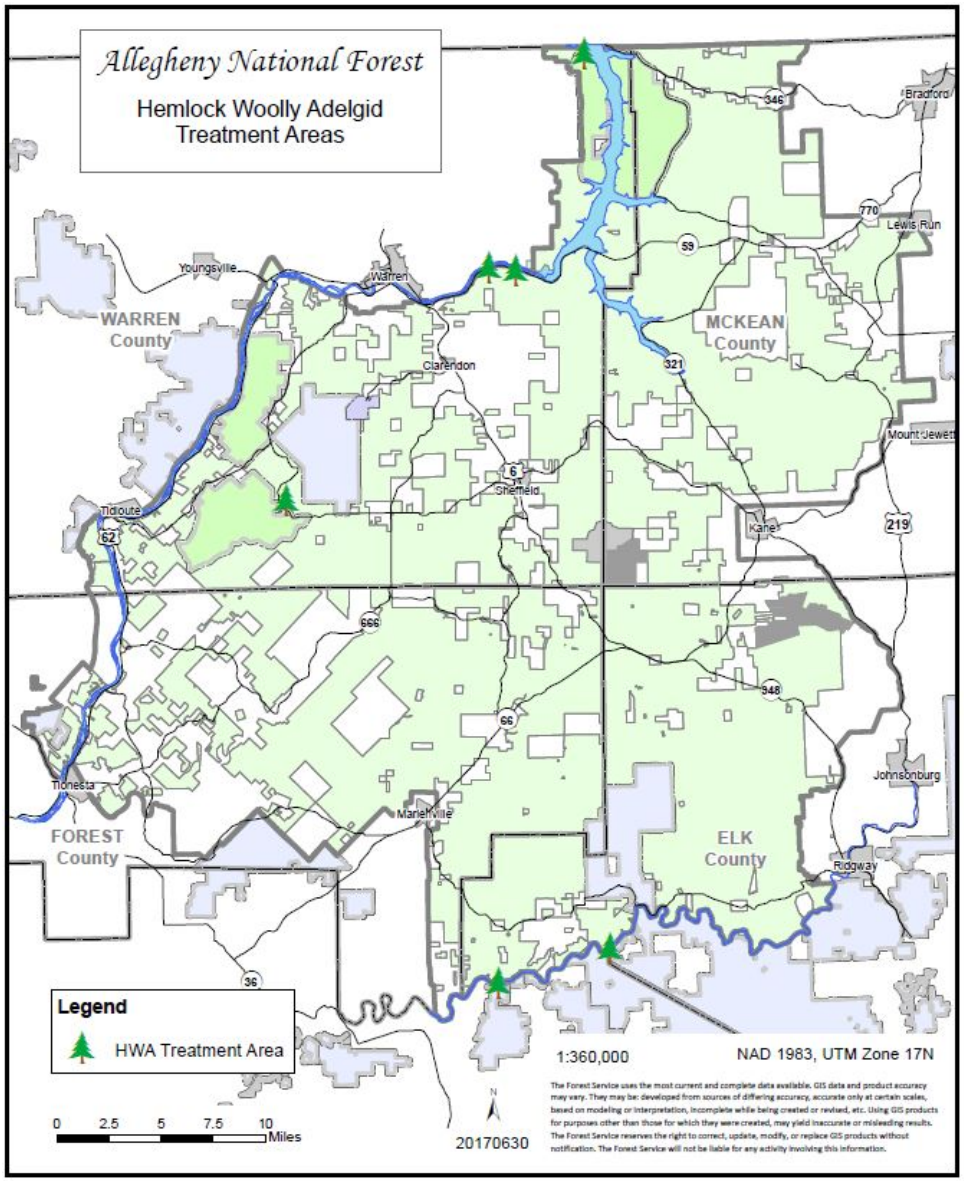

Figure 3. HWA treatment areas for 2016-2017

Table 1. **Species Considerations for Conifer Planting on the ANF**[i]

Species	Habitat Characteristics	Present Distribution*	Site Requirements	Shade Tolerance/ Growth	Deer Palatability/ Browse Tolerance	Pest / Disease/ Pollution Considerations	Other Considerations/Climate Change Projections
Red Spruce *Picea rubens*	Lacking lower limb structure and thermal characteristics of hemlock. Best replacement species for northern flying squirrel, as it supports lichens (bryoria fremontii) required by northern flying squirrel for food and nesting material.	North of PA, and higher elevations in northern Appalachian mountains. Specimens in McKean County	Higher elevation, good moisture regime. Grows well on poor sites, acidic and shallow soils preferred.	Tolerant-Very Tolerant. Long-lived (350-400 years), slow growing.	Browsing occurs, but not preferred browse.	Spruce budworm, eastern spruce beetle, eastern dwarf mistletoe. Potentially sensitive to pollution (sulphur dioxide, nitrogen oxides and ozone).	Suitable habitat projected to occur north of ANF region in climate change models.
White Spruce *Picea glauca*	Retains lower limbs.	North of PA with specimens in a few counties south of the ANF. Planted on the ANF in the past.	Tolerant of wide range of sites in northern North America, from moist to dry, alkaline and acidic.	Intermediate shade tolerance. Long lived (250-300 years)	Not preferred as browse.	Can be susceptible to frost heaving. Seedlings can be damaged by rodents. Spruce budworm. European spruce needleminer. Tomentosus root disease. Various bark and wood boring beetles.	Considered a hardy tree. Strong affinity to local environments. Suitable habitat projected to occur in northern New York state and New England in climate change models.

Species	Habitat Characteristics	Present Distribution*	Site Requirements	Shade Tolerance/ Growth	Deer Palatability/ Browse Tolerance	Pest / Disease/ Pollution Considerations	Other Considerations/Climate Change Projections
Black Spruce *Picea mariana*	Small dbh at maturity, retains lower limbs, shallow rooting.	North of PA with specimens in Tioga County	Moisture regime important, prefers dark brown peat, boggy areas and wet organic soils. Common in swamps or bogs. Pioneer species.	Tolerant. 200 year lifespan typical.	Not preferred as browse.	Eastern dwarf mistletoe, spruce budworm, bud and needle rusts.	Not a large tree, usually planted in pure stands. Suitable habitat projected to occur north of Canadian border in climate change models.
Balsam Fir *Abies balsamea*	Retains Lower Limbs, Fairly small crown area. Provides food and cover for wildlife. Second best species for northern flying squirrel.	Generally north of PA, and higher elevations in Appalachian mountains. Specimens in Warren County	Abundant moisture required, slightly acidic sites.	Very Tolerant. Slow growing, 80 year lifespan typical.	Browsing occurs, but not preferred browse.	Balsam wooly adelgid. Intermediate sensitivity to sulphur dioxide and tolerant of ozone.	Suitable habitat projected to occur north of ANF region in climate change models.
Pitch Pine *Pinus rigida*	Lacking lower limb structure and thermal characteristics of hemlock.	Native to ANF and surrounding counties.	Dry, low quality sites- poor sandy soils. Mineral soil seedbed essential for regeneration. Pioneer species.	Intolerant. 200 year lifespan typical.	Limited to seedlings and sprouts.	Syrix wood wasp and various wood boring bark beetles.	Very good at surviving injury, has the ability to "green up" after fire or pests. Suited habitat not projected to migrate northward as much as other species in climate change models.

Species	Habitat Characteristics	Present Distribution*	Site Requirements	Shade Tolerance/ Growth	Deer Palatability/ Browse Tolerance	Pest / Disease/ Pollution Considerations	Other Considerations/Climate Change Projections
Virginia Pine *Pinus virginiana*	Lacking lower limb structure and thermal characteristics of hemlock.	Generally south of ANF and northern PA. Specimens in Potter County.	Requires well drained sites, prefers poor sandy soils. Mineral soil seedbed essential for regeneration.	Intolerant. 100 year lifespan typical.	Not preferred as browse.	Syrix wood wasp and various wood boring bark beetles. Sensitive to air pollution (ozone). Meadow mouse girdling.	Grows well in old fields, pioneer species, successful competitor. Suitable habitat projected to migrate northward into ANF region in climate change models.
Eastern Redcedar *Juniperus virginiana*	General Bush-like appearance, may lose lower limbs in forest grown areas.	Widely distributed through eastern and Midwestern U.S. Specimens in Forest County, but separate from ANF.	Can grow on a wide variety of conditions, prefers deep, moist, well drained sites. Prefers calacareous soils.	Intolerant-Very Intolerant. 150 year lifespan typical.	Intermediate preference/ Tolerant	Cedar gall. Tolerant of air pollution (sulphur dioxide and hydrogen fluoride).	Pioneer species. Can tolerate drought and temperature extremes. Suitable habitat projected to migrate northward into ANF region in climate change models.
Red Pine *Pinus resinosa*	Lacking lower limb structure and thermal characteristics of hemlock.	Planted already on ANF, McKean County population. Generally native to counties east of ANF.	Dry sites but will grow on wetter sites.	Intolerant to very-intolerant. 200 year lifespan typical.	Not preferred/ Tolerant	Syrix wood wasp and various wood boring bark beetles. Sensitive to sulphur dioxide but tolerant of ozone.	Pioneer. Usually planted in pure stands. Suitable habitat projected to occur north of ANF region in climate change models.

Species	Habitat Characteristics	Present Distribution*	Site Requirements	Shade Tolerance/ Growth	Deer Palatability/ Browse Tolerance	Pest / Disease/ Pollution Considerations	Other Considerations/Climate Change Projections
Northern white-cedar *Thuja occidentalis*	General Bush-like appearance, may lose lower limbs in forest grown areas. Provides an abundance of food in cover for wildlife, especially in winter.	North of PA, mostly into Canada and Northern New England area.	Moist, nutrient rich sites, such as those along streams. Prefers calacareous soils.	Tolerant. Slow-growing, persistent. 300 year lifespan typical.	Preferred/ \ Not Tolerant	Carpenter ants/ Leafminers. Tolerant of sulphur dioxide and ozone.	Can withstand suppression for long time periods. Suitable habitat projected to occur north of Canadian border in climate change models.
Eastern White Pine *Pinus strobus*	Lacking lower limb structure and thermal characteristics of hemlock.	Native to ANF and surrounding states.	Well drained, drier sites, with coarse textured soils.	Intermediate. 200 year lifespan typical, but can be long-lived (450 years).	Preferred/ Not tolerant.	White pine weevil, syrix wood wasp, white pine blister rust. Sensitive to ozone and sulphur dioxide.	Grows rapidly and is considered an excellent tree for reforestation projects. Suitable habitat projected to migrate northward but still remain ANF region in climate change models (could consider more southerly genotypes).
Shortleaf pine *Pinus echinata*	Lacking lower limb structure and thermal characteristics of hemlock.	South of ANF. Native to ridge and valley region of southeastern PA.	Wide range of sites from dry sites to deep well-drained soils.	Intolerant. 200 year lifespan typical.	Limited to seedlings and sprouts	Syrix wood wasp and various wood boring bark beetles. Intermediate air pollution sensitivity.	Pioneer- competes better on dry sites. Suitable habitat projected to migrate northward into ANF region in climate change models.

Species	Habitat Characteristics	Present Distribution*	Site Requirements	Shade Tolerance/ Growth	Deer Palatability/ Browse Tolerance	Pest / Disease/ Pollution Considerations	Other Considerations/Climate Change Projections
Norway spruce *Picea abies*	Conical crown in young trees changing over to a columnar shape with age. Drooping, pendulous branches. Its drooping branching structure make it a potential candidate for planting in areas where the maintenance of shade is highly important such as excellent value streams, riparian areas, and known brook trout streams.	Not considered native to the United States, but widely distributed through plantings across the Eastern and Midwestern United States.	Grows best in cool, humid climates on rich soils but grows well on almost all types of soils. Not suited for dry or nutrient deficient soils or those that are permanently waterlogged	Tolerant. 200 year lifespan but can live up to 300 - 400 years	Not preferred		Can withstand suppression for long time periods. Widely used in reforestation programs in the eastern US. Has shallow rooting system similar to eastern hemlock. Norway spruce needle litter has a similar decay rate to eastern hemlock, possibly preserving some of the ecosystem function of the site.

*Note: Distribution column requires further work to separate indigenous from naturalized species.

[i] References include:

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USDA Natural Resources Conservation Service Plants Database (website: http://plants.usda.gov/java/)

USDA Forest Service Climate Change Tree Atlas. Anantha M Prasad, Louis R Iverson, Steve Matthews, Matt Peters. NRS-4151, USDA Forest Service, Northern Research Station, Delaware, Ohio (website: http://www.nrs.fs.fed.us/atlas/tree/tree_atlas.html)