U.S. Fish & Wildlife Service
ECOS: Environmental Conservation Online System
TORREYA TAXIFOLIA "Recovery Plan Ad Hoc Report results"

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*Note: On **9 February 2023**, Connie Barlow copied the items of interest to TORREYA GUARDIANS that she found in this tabular report. Here the items are arranged in numerical order, with some bolding added by Barlow. This document is intended to make it easier for Torreya Guardians to understand t**he history of the official recovery actions**. It is also intended as an **archive**, just in case some of the history is lost when the report is updated in the future.*

ACTION 12: **Determine protection strategies for habitat outside preserves**

2019-2020. The **Torreya Keepers** received funding in 2019 and 2020 from Section 6 and FEMA, respectively, to 1) seek out property owners within the predicted range of the species; 2) survey for Florida torreya trees once landowner permission has been obtained; 3) collect genetic material for analysis and propagation; 4) set up and monitor seed trials on private lands; 5) utilize and advise on best management practices, and 6) work with conservation partners to monitor trees and provide educational opportunities for students and volunteers. The TK intend to use some areas on their private lands as experimental plots to study different environmental perimeters on growth and survival. They have fenced several trees to prevent deer rubbing and damage from falling limbs and trunks of other tree species. Mr. Bill Boothe (FL private landowner) has a property with Torreya and has identified GPS locations for over 100 trees. His observations included other nearby properties comprised of about 40-50 trees of 6-15 feet tall. He would like to use private lands as experimental plots ¿ opening up the canopy, using smoke for pest control to limit die off. In general, Ms Anderson and Mr. Boothe are going to try to fence the trees to prevent against deer rubbing, and will continue to record measurements for the trees. They are willing to form the Torreya Conservation Commission at Crooked Creek, FL (see section IV, action 6).

ACTION 21: **Identify pathogen(s) responsible for the decline**

This is an ongoing action that goes back to 1967. 2020: An ongoing project at ABG is focused on determining whether the fungal pathogen (see 2011, 2013 Smith & collaborators findings) has infected outplanted material at Vogel State Park and Smithgall Woods State Park, GA and if it has moved into surrounding trees. **A preliminary inspection of trees at Vogel State Park revealed fungal cankers on outplanted T. taxifolia material, and fungal infections on surrounding Tsuga caroliniana and Carya sp. Fungal material from these trees has yet to be sequenced to determine if the species infecting these trees is Fusarium torreyae.** 2019: Kumarihamy et al. (2019) investigated endophytic fungi isolated from a diseased leaf of cultivated T. taxifolia; compounds isolated showed potent in vitro activity against P. falciparum D6 and W2 strains (protozoan parasite that causes malaria). 2013: A systematic survey (soil-borne pathogen survey of roots, soil and plant litter associated with T. taxifolia) was conducted from three sites at TSP, Florida, and one site in Decatur, Georgia. About 102 fungi were isolated: 27 isolates (26%) were from TSP and 75 (74%) from Georgia. **All T. taxifolia trees sampled showed moderate to severe levels of decline; 48 % had root necrosis and stem cankers.** Composition of fungal community included plant pathogens, lignin and cellulose decomposers, endophytes and saprophytes. **2011, 2013: Smith et al. (2011) conducted an above-ground plant pathogen study. They isolated numerous fungi from cankers and consistently found Fusarium torreyae (Aoki et al. 2013), as possible etiological agent.** According to the studies, when Torreya plants were inoculated with F. torreyae, it leads to canker development, lesions, and mortality. Dr. Smith's lab identified F. circinatum in a canker on one of the lower branches of a permanently planted individual at the Bok Tower Garden (Bok Garden; P. Lynch, Bok Garden, 6/03/2020, pers. comm.).

ACTION 22: **Experiments in disease management in mature cultivated specimens**

As of this update status of this task is unknown although there has been some work conducted in this area.

ACTION 221: **Conduct tests of culture regimens**

Conduct integrated scientific tests of the effectiveness of various culture regimes J. Smith and collaborators (2011, 2013) conducted independent fungicides tests for stem canker. In addition, **the ABG has an ongoing study to determine whether the pathogen has infected outplanted material, Vogel State Park and Smithgall Woods State Park, and if it has moved into surrounding trees.** J. Smith proposes to assess the potential use of mycoviruses to reduce virulence of Fusarium torreyae (J. Smith, UF, 06/26/2019 comm. to Torreya Tree Conservation project) and its applicability to Torreya trees

ACTION 222: **Investigate mychorrhizal relations**

Dr. Melissa McCormick (Smithsonian Environmental Research Center) final report of research into the mycorrhizal associations of Torreya taxifolia within its native range along the Apalachicola River in northern Florida and extreme southern Georgia and in several explants from northern Georgia into North Carolina determined that **Torreya forms mycorrhizal associations with arbuscular mycorrhizal (AM) fungi. Nearly all AM fungi identified in this study belonged to the Glomus genus. Many species in this genus are known to have a role in protecting host trees against root pathogens.** They found a similar diversity of AM fungi associated with native and explanted trees, suggesting that native populations have sufficient diversity of mycorrhizal fungi available to support healthy tree growth. They found that the abundance of mycorrhizal fungi in tree roots (including non-Torreya roots) was higher in garden explants (Atlanta Botanical Garden and Biltmore Gardens) than in native or forest explanted trees. This relationship was likely driven by light available to garden-planted trees to support photosynthetic fixation of carbon, which could then be used to support associations with mycorrhizal fungi. Within each habitat type (garden, forest explant, native), they found that Torreya roots were more heavily colonized by mycorrhizal hyphae than the roots of surrounding trees, suggesting **Torreya are strongly dependent on mycorrhizal fungi**.

ACTION 23: **Develop protocol for blight control experiments on seedlings and cuttings**

Arnold Arboretum collected 2,000 cuttings from ofver 166 tress at 14 sites. Atlanta Botantical Gardens has also collected seedlings from Torreya State Park and TNC Bluffs and Ravines Perserve. However, they have not published any protocol.

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ACTION 331: **Establish program to obtain cuttings**

In September 2016, Atlanta Botanical Gardens hired a part time conservation horticulture assistant to assist with completing an updated inventory of the ex situ tree collection, propagate ex situ accessions and prepare material for exchange. Additionally in **October 2016, ABG staff visited ex situ collections of Torreya taxifolia that were established by the Georgia Plant Conservation Alliance at the University of Georgia, Georgia Mountain Research and Education Center in Blairsville, GA (http://gmrec.uga.edu/). A portion of the seeds collected were established in a safeguarding bed at Atlanta Botanical Garden. A portion of the seeds were sent to three conservation partners so that they could also establish safeguarding beds for Torreya taxifolia.** The ultimate goal would be for all participating institutions to curate well documented ex situ collections of trees as assurance populations and seed sources for restoring trees in to protected natural habitats. 2015 FL State Park: Expand surveys into TNC property, to increase understanding of current range and collect additional cuttings for safeguarding of the species.

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ACTION 332: **Establish cuttings**

The ABG is currently safeguarding 584 individual's ex-situ (ABG 2019); of the total trees, 189 cuttings were collected post Hurricane Michael, representing individuals not currently housed in ex-situ; unfortunately, 20 did not survive the first 6 months. As part of the Center for Plant Conservation program, **2,622 stem cuttings were collected from 166 trees at 14 sites in the late 1980s to the early 90s. Rooted cuttings were sent to 10 institutions (including the Bok Tower Garden, Lake Wales, Florida) for safeguarding but this material posed several challenges: could carry unknown pathogens responsible for the decline of this species; and the cuttings were mainly**

collected from lateral branches and in cultivation they often display plageotropic architecture (they have dominant lateral growth and end up looking like shrubs). The ABG has switched to propagating cuttings made from ¿leaders¿- the rapidly growing apex (top) of a tree. This process forms upright plants of about two-feet tall in about two years.

The Bok Tower Garden (BTG) received 97 plants from Arnold Arboretum on 1991. BTG staff actively propagated clones and annually reported growth and mortality data to Mercer Arboretum, Arnold Arboretum and to the Center for Population Biology. At present, BTG has 15 plants located on the Garden grounds as permanent plantings.

The ABG has been propagating T. taxifolia in its conservation collection for more than 20 years and has increased the number of trees in its collection to more than 1200 stems. This is the largest ex-situ collection of Florida Torreya outside the natural range of the species (and potentially as large as the remaining wild population). **After more than 20 years since the ex situ collections were established at ABG, they have the first reproductive offspring.** 2012: The efforts to date have resulted in 67 new cuttings added to the safeguarding collection in cultivation at the Atlanta Botanical Garden. The cuttings are currently being rooted on the mist bench in the greenhouse at the Garden. 2013: 82 new cuttings added to the safeguarding collection in cultivation at the Atlanta Botanical Garden. The cuttings are currently being rooted on the mist bench in the greenhouse at the Garden. Activities during this project period have resulted in propagation of cuttings from wild genotypes for safeguarding and eventual seedling production in cultivation. **The Atlanta Botanical Garden conservation nursery in Gainesville, GA now holds 125 Torreya trees that originated from wild material.** This material is documented and indexed in the accession records of the Garden. The material serves as a safeguarding population for the wild populations. **The greenhouses at the Atlanta Botanical Garden now hold 244 accessioned Torreya taxifolia trees.** This material originated from cuttings of wild material it is documented and indexed as part of the ex situ conservation collection. The plants will propagated and grown as safeguarding material.

ACTION 3111: **Locate seed-bearing cultivated trees**

Seed-bearing trees are rare; most of the wild population persists as stump sprouts. Currently, in wild populations there are six plants producing cones. **Several botanical gardens have seed-bearing trees (Atlanta Botanical Garden (ABG), GA; Callaway Garden, GA; Biltmore Gardens, NC). After 10 years in cultivation as part of the conservation collection at ABG, a large proportion (>60) of the Torreya trees began producing reproductive cones. Seedlings from these mature plants also became reproductive within 10 years.** According to R. Determann (Conservation Director, Atlanta Bot Garden), the Callaway Garden has a partial duplicate set of ABG cutting inventory trees that had produced seeds, however, they are in decline.

ACTION 3112: **Protect seed from frugivores**

Task duration: 2-10 yrs. Most trees do not produce cones in the wild population. In ex situ collections, cones on female seed bearing trees are caged at the Atlanta Bot Garden and at one of the safeguarding locations at Georgia Department of Natural Resources Smithgall Woods/Dukes Creek Conservation Area to protect seeds and facilitate collection for propagation.

ACTION 3121: **Search for seed bearing wild trees**

Most of the wild population persists as stump sprouts, so seed-bearing trees are rare. 2010 to present: about 15 plants were observed coning in the wild: three female cone bearing plants at TSP; one female cone bearing tree at Corps' property; and three male plants on private lands; locations of the other 8 plants are unknown. Several botanical gardens have seed-bearing trees (Atlanta Botanical Garden (ABG), GA; Callaway Garden, GA; Biltmore Gardens, NC). In cultivation, a large proportion (>60) of the Torreya trees in the conservation collection at ABG began producing reproductive cones. Seedlings from these mature plants also became reproductive within 10 years. **The Callaway Garden has a partial duplicate set of ABG cutting inventory trees that had produced seeds, however, they are in decline.**

ACTION 3122: **Harvest seed from wild trees**

The ABG has the largest collection of seed-bearing plants. Seeds have been collected from 15-20 trees and been propagated and shared with conservation or research partners, and **ABG holds approximately 70 female trees in conservation collections**.

ACTION 321: **Arrange seed exchange**

According to R. Determann (Director Conservation, Atlanta Bot Garden), ABG has 500-600 seeds in some years that they propagate and grow in the conservation collection at the garden, and in some cases disseminate to other botanical gardens, to universities for study, use for outreach (display), and long-term storage. The Biltmore Gardens harvested 300 seeds in 2009 and were distributed to interested parties (http://www.torreyaguardians.org/2009-seeds.html).

ACTION 322: **Establish seedling production programs**

The ABG has the largest collection of seed bearing plants. About 60-65 trees have produced seeds that have been propagated, shared with our conservation or research partners. Jerry Pullman (Georgia Institute of Technology) in collaboration with ABG is working on **somatic embryogenesis**, important for producing disease-free seedlings/trees.

ACTION 34: **Conduct grafting experiments**

The recovery plan suggests grafting [asexual propagation where the tissues (vascular cambium) of one plant are fused with those of another] with T. californica. However, **T. californica is exhibiting some issues with cankers caused by pathogens with a different Fusarium species which is killing the cambium.**

ACTION 42: **Evaluate the native habitat**

In-situ conditions for T. taxifolia and its habitat were dramatically altered by **Hurricane Michael in late 2018**, thus the ABG efforts shifted from tree monitoring to search and rescue. They were able to **uncover 292 trees from fallen debris. As of 2019 more than 650 trees have been georeferenced and baseline data on the individuals recorded across the range**. Since 2008, the ABG in collaboration with TSP and University of Florida have conducted an updated survey of habitat conditions and population status with the natural range if T. taxifolia. They have georeferenced and collected information on approximately 150 trees from locations throughout the natural range of T. taxifolia. Future efforts should evaluate the success of habitat management experiments in improving the health of in situ trees. Nov 1, 2010 to Oct 31, 2011: 205 new trees were found. A total of 242 trees were visited, including 41 re-visits of trees that were found and tagged in previous years. Of these trees, 61 were caged to protect them from deer damage. 2012: Of the 292 trees visited, 192 were found and assessed for the first time, 94 were re-visits to trees that had been visited once and 6 were trees that were visited for the third time. The number of trees visited represents a huge proportion, perhaps 20-30%, of the suspected population. These tree visits are important for gathering information regarding the status and health of the population. Average height of trees visited during the grant period was 121.8 cm with a basal diameter of 1.87 cm. Of the trees revisited (plus some data collected outside the grant period) 32.4% showed stem dieback and loss of stem length averaging 52.67 cm. The remaining trees (67.6%) did not lose stems and showed positive growth averaging 12.51 cm per year. Of all the trees visited during the grant period 61.9% showed signs of stem canker, 59.8% showed signs of deer rub. Damage to stems that were rubbed by deer averaged 46.1% of stem circumference. 2013: a total of 380 Torreya trees were surveyed or 60% of the total known documented wild population. The survey work took place primarily at Torreya State Park. Of the 380 trees surveyed, 211 were found and assessed for the first time, 124 were reassessments of trees that had been assessed once before, and 16 were trees that were assessed for a third time, and 30 were included as part of an ecological experiment.

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ACTION 44: **Study population dynamics**

Current status surveys conducted between 2008 ¿ 2010 in collaboration between the ABG, TSP, and the University of Florida have documented the health and size of several trees. All of the plants were stem sprouts and none of the plants had reached reproductive maturity. No seeds or seedlings were found. No demographic studies have been done. 2013: ABG documented two seedlings were during, both were observed at the base of the same female tree, but were observed in separate years. The first was observed in the winter of 2011, but the seedling disappeared a few months later. The second was observed in July of 2012 and was fencing to protect it from damage or browse.

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ACTION 5: **Establish experimental collections outside native habitat**

Georgia: **The ABG and the Georgia Department of Natural Resources outplanted 19 individuals of T. taxifolia at the Smithgall Woods** in White County in north Georgia. The purpose of the Smithgall Woods collection and **two additional off-site plantings (Blairesville, GA and Vogel State Park)** were to establish safeguarding populations of Torreya to conserve material that had been propagated at the ABG in backup collections at more than one location. The material planted at Smithgall Woods was propagated from all Georgia source population material (Army Corps. Of Engineers, site at Woodruff Dam, Lake Seminole, in Georgia). **The trees have grown quite large and are now reproductively mature producing male and female cones annually. Most of the plants were placed in full sun and they are quite healthy.** The trees at **Vogel State park** are smaller than those at **Smithgall Woods** and have not yet reached reproductive maturity. North Carolina: **In 1939 nearly a dozen specimens of T. taxifolia were planted at the Biltmore Gardens; 31 seedlings were planted in 2008 at two locations near Waynesville; and 10 seedlings were planted at Bt. Highlands and Franklin** (http://www.torreyaguardians.org/north-carolina.html).

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ACTION 7: **Reestablish Torreya in its native habitat**

In 2002, the ABG in collaboration with Florida State Park Service reintroduced seedlings propagated from seed produced from the cuttings collected by the Arnold Arboretum of Harvard University in 1989. The

cuttings were obtained from the wild population at TSP. The plants were **reintroduced into ravines** where T. taxifolia had been extirpated. **Sixty seedlings** were subjected to four different treatments (fungicide, fertilizer only, fertilizer and lime, and control) for determining the optimum reintroduction techniques for this species. **Only 34.5 % survived after one year post planting.** No further information is available.