Torreya taxifolia
Florida torreya

5-Year Review:
Summary and Evaluation

Sweetwater Creek, Liberty County, Florida. Photo by Vivian Negron-Ortiz

U.S. Fish and Wildlife Service
Southeast Region
Panama City Field Office
Panama City, Florida

5-YEAR REVIEW
Torreya taxifolia (Florida Torreya)

I. GENERAL INFORMATION

A. Methodology used to complete the review

This review was accomplished using information obtained from the Recovery Plan of September 1986, unpublished field survey results, reports of current research projects, peer-reviewed scientific publications, unpublished field observations by Service, State and other experienced biologists, and personal communications. These documents used in the completion of this review are on file at the Panama City Field Office. In addition, a Working Recovery Group meeting, including those individuals working on and knowledgeable about the natural history of Florida torreya, was held on May 11, 2010 to discuss past, current, and planned activities and their relationship to the recovery actions stipulated in the Recovery plan. Information from that meeting, including progress on certain recovery actions, new scientific data, management, has been incorporated into this 5-year status review. A *Federal Register* notice announcing the review and requesting information was published on April 9, 2009 (74 FR 16230). Two replies were received and the information from these has been incorporated into this document. No part of this review was contracted to an outside party. Comments and suggestions from peer reviewers were incorporated as appropriate (see Appendix A). This review was completed by the Service's lead Recovery botanist for this species in the Panama City Field Office, Florida.

B. Reviewers

Lead Field Office: Dr. Vivian Negrón-Ortiz, Panama City Field Office, 850-769-0552 ext. 231

Lead Region: Southeast Region: Kelly Bibb, 404-679-7132

Peer reviewers:

Dr. Jenny Cruse Sanders, Director of Research and Conservation, Atlanta Botanical Garden, Atlanta, GA
Dr. Lydia Rivera, Professor, University of Puerto Rico, Mayagüez, PR
Dr. Jason Smith, Assistant Professor, University of Florida, Gainesville, FL
Ms. Tova Spector, Environmental Specialist II, Florida Park Service, FL

C. Background

1. Federal Register Notice citation announcing initiation of this review

74 FR 16230 (April 9, 2009): Endangered and threatened wildlife and plants: 5-Year Status Reviews of 13 Southeastern Plant Species

2. Species status: Decreasing (Recovery Data Call 2009). See section II.C.1.a. for current information.

3. Recovery achieved: 2 (26-50% recovery objectives achieved); see section II.B.3 for details on recovery criterion and actions, and how each action has or has not been met.

4. Listing history

Original Listing
FR notice: 49 FR 2783
Date listed: February 22, 1984
Entity listed: species
Classification: endangered

5. Associated rulemakings

Not applicable.

6. Review History: A previous 5-year review for this species was noticed on November 6, l991 (56 FR 56882). In this review, the status of many species was simultaneously evaluated with no in-depth assessment of the five factors, threats, etc. as they pertained to the individual species. The notices summarily listed these species and stated that no changes in the designation of these species were warranted at that time. In particular, no changes were proposed for the status of the species in this review.

Final Recovery Plan - 1986

Recovery Data Call – 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, and 1998.

7. Species' Recovery Priority Number at start of review (48 FR 43098):

The Florida torreya is assigned a recovery priority of 5 because the degree of threat is high, and it is a species that has a low recovery potential.

8. Recovery Plan

Name of plan: Florida Torreya Recovery Plan
Date issued: September 9, 1986

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

The Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish or wildlife. Because *T.*

taxifolia is a plant, the DPS policy is not applicable and not addressed further in this review.

B. Recovery Criteria

1. Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes. The recovery plan included two recovery objectives: 1) production of a collection of sexually mature, healthy trees in cultivation representing the gene pool of the plants from the field; these plants will serve as stock for possible reintroduction into the native habitat; and 2) maintain the integrity of the torreya's native habitat. The Recovery Plan projected that downlisting could potentially be done when 5 populations with sexually mature offspring (viable or reproducing individuals) are established in secure portions of its native range. Delisting could be considered if 15 self-sustaining populations are established in separate ravine systems. The minimum population size and minimum land area for each population must be determined.

2. Adequacy of recovery criteria.

a. Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?

No. The recovery criteria were based on the available data at the time the plan was published 24 years ago.

b. Are all of the 5 listing factors[1] that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

No. The recovery plan only addressed factors A and C. See sections II.B.3 and II.C.2 for description of current information and threats.

3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. For threats-related recovery criteria, please note which of the 5 listing factors are addressed by that criterion. If any of the 5-listing factors are not relevant to this species, please note that here.

The recovery criteria address factors A and C. Factor B is not addressed. Factor D, although relevant to this species, was not addressed by the Recovery Plan.

Evaluation of Criteria:

[1] A)Present or threatened destruction, modification or curtailment of its habitat or range;
B) Overutilization for commercial, recreational, scientific, or educational purposes;
C) Disease or predation;
D) Inadequacy of existing regulatory mechanisms;
E) Other natural or manmade factors affecting its continued existence.

1. Ensure the preservation and appropriate management of Torreya's native habitat to allow for reintroduction.

   Management is an ongoing action at The Nature Conservancy's Apalachicola Ravines and Bluffs Preserve (TNC), the Torreya State Park (TSP), and the Army Corps of Engineers' (Corps) Lake Seminole, GA, and to some extent by a few private landowners.

2. Produce cultivated plants of *Torreya* and conduct empirical investigations of methods to control the decline in cultivated plants.

   Propagation of the species has been conducted by several botanical gardens (see Recovery action 3 for details).

   Several investigations have been undertaken but they have not provided the information for controlling this species' decline. See Recovery action 2.

3. Investigate the decline to determine its cause and, if possible to find a cure. Research into the cause of the decline is ongoing. See Recovery action 2 for details.

4. Introduce cultivated plants into secure habitat within its former range See Recovery action 7 for details.

We summarize our progress under existing recovery actions below.

Recovery Action 1: Protect the existing habitat
This is an ongoing action.

Protect the existing habitat

Management of existing biological preserves

Management is an ongoing action conducted by TNC, TSP, and the Corps. Ms. Pamela Anderson (volunteer) has mulched plants at the Gregory House (TSP). She is monitoring 400+ trees and has gone back several times to each plant collecting data related to stem length and width. According to her results, she has noticed an apparent decline since 2000.

Management plans have been developed and implemented by TSP. Management includes constructing enclosures to prevent damage from deer, restoring adjacent uplands, preventing erosion in the sandhill and slope forests, and exotic species control. The Corps has no written management plan and we do not have information for the TNC population.

Determine protection strategies for *Torreya* habitat outside of preserves

Ms. Anderson on her property planted a few seedlings and used oak leaves as compost and the seedlings have grown faster.

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).

The *Torreya* guardians, created in 2004, translocated seedlings of *T. taxifolia* outside of the species native habitat (two sites in North Carolina mountains). One of the identified goals of their intentional assisted migration was to save *T. taxifolia* from extinction (http://www.torreyaguardians.org/save.html).

Recovery Action 2: Control the torreya decline

This is an ongoing action.

Identify pathogen(s) responsible for the decline

This is an ongoing action that goes back to 1967 (Alfieri et al. 1967). The authors observed that the stem and needle blight disease of *T. taxifolia* appears to be incited by a fungus causal agent implicating *Physalospora* and *Macrophoma*. Alfieri et al. (1987) isolated six other fungi from leaves and stems of *T. taxifolia*. Lee et al. (1995) isolated more than 30 different endophytic fungi, but consistently, *Pestalotiopsis microspora* (a fungus that resides in the inner bark of symptomless *T. taxifolia* trees) was found on diseased trees. They concluded that the pathological activity of this fungus could be triggered by physiological and/or environmental stress.

Herman and Schwartz (1997) studied the pathogenicity of *Scytalidum* sp. They inoculated both needles and stems causing needle spots and necrosis, but couldn't provide evidence that it was the cause of the original decline of *T. taxifolia.*

Soil-borne pathogens, such as *Phytophthora* sp., *Pythium* sp., *Rhizoctonia solani* and *Sclerotium rolfsii* have been reported on *T. taxifolia*. At present, Dr. Lydia Rivera (Univ. of Puerto Rico, 2009) is conducting a soil-borne pathogen survey, emphasizing the detection of *Phytophthora* spp. She isolated 102 fungi from TSP, FL, and Corps property, GA. Of the trees surveyed, 48 % had root necrosis and stem cankers. She is designing a pathogenicity test associated with potential disease outbreaks.

Dr. Jason Smith (Univ. of Florida) is conducting an above-ground plant pathogen study. He isolated numerous fungi from cankers and consistently found an undescribed *Fusarium* sp.; he is working with a specialist in Japan to describe the new *Fusarium* species. According to Smith (2010, pers. comm.), "inoculation experiments with seedlings and larger potted torreyas have provided ample evidence that *Fusarium* is the causal agent" for the current population decline; the

cause of the initial decline remains unknown. When plants are inoculated with *Fusarium*, it leads to canker development, lesions, and mortality (Smith 2010, pers. comm.). He proposes to elucidate the disease biology, as well as conductive epidemiological factors and treatment. Aaron Trulock is a graduate student under Smith and will be doing his research on the biology of canker disease of the *T. taxifolia*.

Conduct empirical experiments into disease management in mature cultivated specimens

Conduct integrated scientific tests of the effectiveness of various culture regimes

J. Smith and collaborators will be conducting independent fungicides tests for stem canker; they might also use lime, varying pH on clonally propagated material.

Investigate mycorrhizal relations of *Torreya*

Dr. Melissa McCormick (Smithsonian Environmental Research Center) proposed to investigate the type of mycorrhizal association formed by *T. taxifolia*, identify the fungi forming the association, and quantify the degree of colonization. This investigation will be initiated in September 2010.

Develop a protocol for experiments on seedlings and cuttings

See action 3, sections *establish seedling production programs* and *propagate from cuttings.*

Recovery Action 3: Produce seedlings and cuttings

This is an ongoing action

Locate seed-bearing 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: TSP has two female cone bearing plants (Spector 2010, pers. comm.); the Corps' property has only female cone bearing tree (Negron-Ortiz 2009, per. observ.); and three male plants have been observed coning on a private site (P. Anderson 2010, pers. comm.).

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, ABG), the Callaway Garden has a partial duplicate set of ABG cutting inventory trees that had produced seeds, however, they are in decline.

Protect seed from frugivores

This action has not been initiated, but concerns were raised related to seed predation by squirrels (Spector, 2010, pers. comm.). Most trees do not produce

cones in the wild population. In *ex situ* collections, cones on female seed bearing trees are caged at the ABG and at one of the safeguarding locations at Georgia Department of Natural Resources Smithgall Woods/Dukes Creek Conservation Area (Smithgall Woods) to protect seeds and facilitate collection for propagation (Cruse-Sanders, 2010, pers. comm.).

Disseminate and propagate seeds

According to R. Determann (2010, per. comm.), 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).

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, including with Dr. Jerry Pullman (Georgia Institute of Technology; Cruse-Sanders 2010, pers. comm.).

Jerry Pullman in collaboration with ABG is working on somatic embryogenesis, important for producing disease-free trees. The process takes embryos out of full-term seeds; the tissue is de-contaminated of fungi that may be present, and whole plants are generated from these embryos. They have 100-200 early stage embryos for use in studies. The material can be stored in liquid nitrogen as a library/bank for future use. A manuscript describing this method has been developed, X. Ma, K. Bucalo, R. Determann, J. Cruse-Sanders and G. S. Pullman. 2010. Can somatic embryogenesis help save *Torreya taxifolia*, a highly endangered coniferous species?

Propagate from cuttings

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 (Cruse-Sanders 2010, pers. comm.). 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 (C. Peterson, Manager, Rare Plant Conservation Program, BTG 2009, pers. comm.).

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 (Cruse-Sanders 2010, pers. comm.). 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 (Cruse-Sanders 2010, pers. comm.). The seedlings have the correct vertical architecture and are good candidates for reestablishment in the wild populations (Cruse-Sanders 2010, pers. comm.).

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.

Recovery Action 4: Investigate the ecological requirements, population dynamics, and life history of Florida torreya

This is an ongoing action.

Study the ecological physiology of torreya

Koehn and Doudrick (1999) investigated diurnal patterns of chlorophyll fluorescence and CO_2 fixation. The study indicated that plants recovered from daily periods of high light and temperatures, suggesting that they may tolerate higher light conditions in their native habitat. Tree rings studies somewhat indicated that growth in *T. taxifolia* is light limited (Schwartz and Herman 1999).

Herman and Schwartz (1997) conducted shade and open canopy treatments on TNC Apalachicola Bluffs, TSP, and the Corps property. Mortality was high, and no patterns associated with light were detected when data was pooled across sites.

Evaluate the native habitat

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*. According to Cruse-Sanders (2010, pers. comm.), the population range has not contracted and in some cases habitat management has improved and restored habitat especially at TSP and in the Nature Conservancy's Apalachicola Bluffs and Ravines reserve, but the demographic health of the population has declined. Future efforts should evaluate the success of habitat management experiments in improving the health of *in situ* trees (Cruse-Sanders 2010, pers. comm.).

Study population dynamics and life history

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 (see section C1 for details). All of the plants were stem sprouts and none of the plants had reached reproductive maturity. No seeds or seedlings were found. Funding should be made available to continue the status surveys and update the information regularly. No demographic studies have been done.

Recovery Action 5: Establish experimental collections of torreya outside its native habitat

This is an ongoing action.

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 (Cruse-Sanders 2010, pers. comm.). 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. Major threats to the trees at this location are lawn management (weed wackers) and fire ants. The trees at Vogel State park are smaller than those at Smithgall Woods and have not yet reached reproductive maturity (Cruse-Sanders 2010, pers. comm.). Trees that are planted outside of the range of *T. taxifolia* need documentation of lineage.

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).

Recovery Action 6: Place seed in long-term storage

See action 3 section *disseminate and propagate from seeds.*

Recovery Action 7: Reestablish Torreya in its native habitat

This is an ongoing action.

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 (ABT 2007). 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.

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

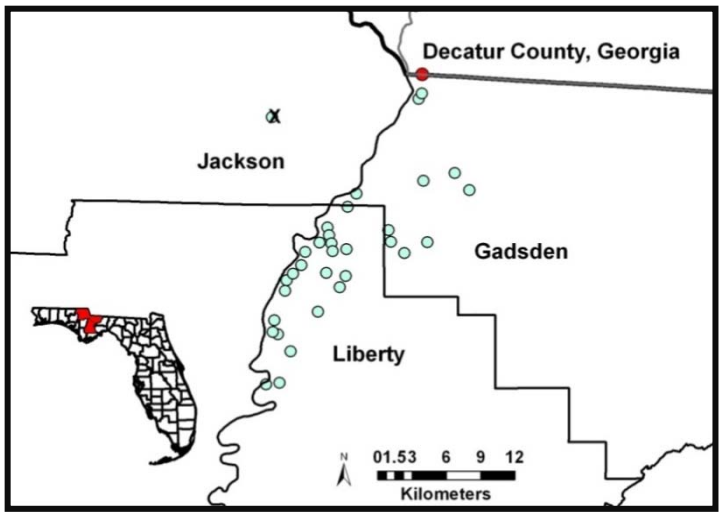

Fig. 1. Map of Florida (inset) showing the counties and locations of *T. taxifolia.* The dots show the historical EOs of *T. taxifolia* in Florida and Georgia.

This species, which belongs to the yew family (Taxaceae), is an endemic tree of ravine slopes on the eastern bank of the Apalachicola River in northern Florida and in Georgia (Fig. 1). Based on GIS coverage, the range of *T. taxifolia* is about 55,239 ha (Schwartz et al. 2000a). The authors suggested that the ravines probably occupy 36.8% of the total area, resulting in an estimate of 20,370 ha of ravine habitat potentially available for *T. taxifolia*.

Prior to 1950's, *T. taxifolia* was estimated to be the seventh most abundant tree species within Apalachicola Bluff regions; over 600,000 individuals were estimated (Schwartz 1993). Surveys conducted in areas with known high tree densities suggested that *T. taxifolia* has **lost at least 98.5% of its total population size**; it was estimated less than 1500 trees in the wild (Schwartz et al. 1995, 2000a). At present, the Florida torreya population is estimated to be less than a 1,000 individuals (likely there are 500-600 trees; T. Spector 2010, pers. comm.) distributed in 33 Element of Occurrences[2] (EOs or occurrences; FNAI 2009; Fig. 1). The west side of the Apalachicola River in Jackson County was surveyed about 20 years ago. No live trees were found, although logs were located (G. Nelson 2010, pers. comm.; Fig. 1).

T. Spector and collaborators (2010, pers. comm.) measured stem length and diameter of 223 *Torreya* trees surveyed in its native habitat between 2007-2009. The trees show an average height of 115 cm and a basal diameter of about 1 cm. About 80% of the trees were with stem cankers, affecting all diameter classes. Twelve plants were measured on June 2009 by Dr. Lydia Rivera (2009). All trees

[2] Element Occurrence (EO): an area of land and/or water in which a species or natural community is, or was, present. For species, it corresponds with the local population (portion of a population or a group of nearby populations). It is also referred to as occurrence, location, or site.

sampled showed different degrees of decline: root necrosis and stem cankers were observed in 45.8 % of trees examined.

Three surveys conducted in Decatur County, Georgia between 1980 and 2010 indicated the presence of 27 trees (Allison 1988; Griffin 2010, per. comm.; Table 1). Overall, the surveys indicated a 22 % decline in the number of trees. Twelve plants were measured on June 2009 by Dr. Lydia Rivera (2009) and PCFO botanist. Heights of main stems varied from 80 - 400 cm with a mean of 176.4 cm. Stem circumference varied from 4 - 14 cm with a mean of 10.9 cm. Five of the 12 plants had stem cankers; one of the five plants had both stem canker and root rot (necrosis); and one plant shows signs of declining (branches were dying).

Table 1. Number of trees reported on three censuses conducted on *T. taxifolia* in Decatur County, GA population. '-' represents no data.

Year censused	# of trees	Mean Height (cm)	Notes
1980-1981	27	100 (25-200)	Stem canker on one tree
1988	26	139 (28-272)	Sprouts observed with stem canker, stem lesions, necrotic spots on leaves
2010	21	-	one plant has deer damage (rub) and one is in decline

In general, the current populations, which are declining in numbers, are characterized by small individuals that are failing to achieve reproductive maturity. Based on current surveys, trees appeared to be smaller at Florida sites compared to trees in Georgia's site. Given the lack of seed production in the wild and potentially a decline due to a disease, all population viability models predict extinction (Schwartz et al. 2000b).

b. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.)

Allelic variation was examined for 189 *T. taxifolia* in 17 populations distributed throughout the range. Results revealed that low levels of genetic variation characterize the species (Schwartz 1993). Of the 20 loci sampled, seven exhibited allelic variation (contained two alleles), and three of these were variable in only one population. The author concluded that the genetic pattern observed is consistent with a species subjected to several population bottlenecks, and these bottlenecks probably occurred prior to the 1950's decline.

Additional studies: The ABG and collaborators will be determining the extent of genetic diversity within the extant populations and the cultivated clonal material at ABG using microsatellite markers. In addition, they will be screening for the presence of the Y chromosome that determine maleness, since it has been reported for other *Torreya* species (Cruse-Sanders, 2010 pers. comm.). When reintroducing dioecious species one should plant equal numbers of male and female plants; therefore by being able to identify the gender at the seedling stage, reintroduction efforts would be more efficient.

c. Taxonomic classification or changes in nomenclature:

Kingdom:	Plantae
Division:	Conifers
Order:	Taxales
Family:	Taxaceae
Genus:	*Torreya*
Species:	*taxifolia* Arn.
Common name:	Florida torreya, Florida nutmeg, stinking cedar

Comparisons of *rbc*l chloroplast DNA sequences involving *T. californica, T. grandis, T. jackii, T. nucifera,* and *T. taxifolia* indicated that Florida torreya is very distinct from other species, and is most closely related to *T. californica* and *T. grandis* (Price 1999). In addition, the DNA sequences suggested that the closest generic relative is the Asian *Amentotaxus.*

Interspecific relationships of *Torreya* were examined using nuclear ribosomal DNA ITS region (Li et al. 2001). The study shows that the New World species, *T. californica* and *T. taxifolia,* form a monophyletic clade separated from the Old World *Torreya* species. This suggests that the present distribution is a result of a single vicariance event separating the New World from the Old World.

Other taxonomic studies have not been conducted.

d. Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.)**, or historic range** (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Fossil records of *Torreya* are limited to seeds, leaves, and secondary wood of the Upper Cretaceous (Boeshore and Gray 1936, Chaney 1950). The records indicated that the distribution of the genus in past geological times was much wider than the present distribution. A fossil named *T. Antigua,* which has some characteristics in common with *T. taxifolia* and *T. californica,* was described from the Mid-Cretaceous of North Carolina and was also collected near MacBride's Ford, Georgia (Boeshore and Gray 1936).

Currently, Florida torreya grows naturally in three counties in Florida: Gadsden, Liberty, and Jackson. It is also found in southern Decatur County, GA, just north of Chattahoochee, FL. Based on fossil records, we can speculate that the geographical range of *T. taxifolia* included North Carolina and perhaps, it was forced south by glaciers, and when they retreated, it became isolated in small areas of the southeastern United States.

Historically, the distribution of *T. taxifolia* included the ravine slopes along the eastern side of the Apalachicola River from Bristol (Liberty County), FL to just across the Florida-Georgia state line, north of Chattahoochee, FL (Schwartz et al. 2000a). According to G. Nelson (2010, pers. comm.), no live trees were found in a survey conducted for the Jackson County's EO, therefore the current historical range has declined to just three counties (Fig. 1).

e. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The Florida torreya is a dioecious coniferous tree found in the slope forest (FNAI 2010) that cover hammocks, steep, deeply shaded limestone slopes and wooded ravines along the east side of the Apalachicola River in Florida (Fig. 1), and adjacent Lake Seminole in Georgia. Soils in these areas are within the orders Alfisols and Mollisols. Although the cause of the decline has not been determined, scientists speculate that construction of Lake Seminole and logging contributed to the destruction of Florida torreya's habitat (e.g., alteration of water seepage patterns; http://www.uga.edu/gpca/project1.html).

2. Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

a. Present or threatened destruction, modification or curtailment of its habitat or range:

Habitat loss was not a factor in the decline of this species. Two factors have been speculated as potential threats: changes in soil chemistry associated with disruption of hydrology when upload topsoils were plowed in the 1950's, and perhaps fire suppression (Schwartz et al. 1995). In addition, a Woodruff dam construction at Lake Seminole in Chattahoochee, Georgia coincided with the decline and may have been responsible for warming ravine microclimates (Schwartz et al. 1995). But based on dendronological evidence, Atchley (2004) concluded that the construction of the dam was not a major factor contributing to the decline of *T. taxifolia* because growth of *Torreya* plants was not suppressed during or immediately following the construction of the dam. She mentioned that "large-scale changes in the landscape coincided with unfavorable climate conditions during the mid-1950s decreasing photosynthesis rates and weakening *T. taxifolia."*

T. Spector (2010 pers. comm.) indicated that the slope forest is highly altered as a result of logging practices. Several uplands nearby some of the ravines have been managed as pine plantations (loblolly, slash and sand pine; Spector 2008). She also suggested that the non-native earthworms in leaf litter are affecting the forest health. As to fire, W. Baker (2010, pers. comm.) stated that many of the lower

slopes do have longleaf pine and wiregrass down in the ravines, and may burn but could have a long fire interval. But the areas where *T. taxifolia* occurs are unlikely to have had fire in the past given the type of topography and the presence of a river on one side (Harper 1914).

Since the habitat continues to be altered due to logging and the plants in outplanted areas grow but eventually die, then habitat alteration is a present threat.

b. Overutilization for commercial, recreational, scientific, or educational purposes:

Many of the largest Florida torreya trees were harvested and used for fenceposts, shingles, and as fuels for riverboats (Schwartz et al. 2000a). Also, the species has been cut for Christmas trees, but in 1980 and 1981 there were only a few Florida torreya tall enough to be used for this purpose. Therefore, at present there is no evidence to suggest that harvest is a threat.

c. Disease or predation:

Disease: The Recovery Plan identified a fungal disease as one of the primary threats responsible for the species' decline. Attempts to isolate the main disease agent had failed. Currently, researchers are still puzzled as to the cause, and research is ongoing to determine or arrest the fungal infestation (J. Smith potentially found a causal agent of current decline, see *Recovery action 2* for details). Therefore this factor is a threat.

Deer damage: According to T. Spector (2010, pers. comm.), deer browsing affects small trees accounting for 46.5 % of the damage. Deer rub was present on more than 50% of the 223 *Torreya* trees surveyed in 2008-2010 (Spector, Cruse-Sanders, Smith, and Determann 2010, pers. comm.). Some of these rubs were extremely severe to the cambium as to break stems or kill trees. Deer rub the main stem and could introduce disease into the vascular cambium (Smith, 2010 pers. comm.). It is a major problem at the TSP; only one plant was reported with deer rub damage at the Georgia population. Therefore, stem damage caused by deer rubbing represents a threat to the *T. taxifolia* populations.

d. Inadequacy of existing regulatory mechanisms:

The Endangered Species Act (Act) of 1973, as amended prohibits the removal of federally listed threatened and endangered plants or the malicious damage of such plants on areas under federal jurisdiction, or the destruction of endangered plants on non-federal areas in knowing violation of state law or regulations or in the course of any violation of a state criminal trespass law. However, the Act does not provide protection for plants on private lands or unless it is in violation of state law. Several populations of *T. taxifolia* occur on private land.

The State requires permission of private landowners for collecting of state-listed

plants from their property. *Torreya taxifolia* is protected under Florida State Law, chapter 85-426, which includes preventions of taking, transport, and the sale of the plants listed under the State Law. The rule Chap. 5B-40, Florida Administrative Code, contains the "Regulated Plant Index" (5B-40.0055) and lists endangered, threatened, and commercially exploited plant species for Florida; defines the categories; lists instances where permits may be issued; and describes penalties for violations (http://www.virtualherbarium.org/EPAC).

The existing regulatory mechanisms are inadequate for plants.

e. Other natural or manmade factors affecting its continued existence: None are known.

D. Synthesis

This five-year status review prepared for *T. taxifolia* provides the most current assessment of the species' status and the present threats.

Torreya taxifolia is a conifer tree presently located in two Florida panhandle counties and one county in Georgia (Fig. 1). It is extremely vulnerable because of its limited range, its low population number, and rarity of habitat. The main threat for this species decline is still not well understood, even though considerable research and management activities have been and are presently conducted on this species. The loss of *T. taxifolia* is thought to have primarily been a result of fungal pathogens during the 1950s and 1960s, and/ or a combination of environmental stress and native pathogens, but studies have yet to provide an explanation for this species' decline. Overcollection was a threat of high importance in the past, but at present is not of concern. The magnitude of stem damage caused by deer rubbing represents a current threat; the vascular cambium is rubbed off causing an aperture for fungal infection.

Current survey information indicates a decline in the number of populations and the present historical distribution. Only 33 EO's distributed throughout this species range in Florida were documented (FNAI 2009). Based on current survey information, only 32 EOs are currently present, in total they have less than 1000 plants. A comprehensive population survey is needed in order to update the actual counts of plants. The Georgia population had declined overtime (Table 1).

Despite the conservation actions to protect and determine the cause of this species' decline, the degree of threat to its persistence remains high; therefore the threat of extinction that faces *T. taxifolia* is imminent.

III. RESULTS

A. Recommended Classification:

__X__ No change is needed

B. New Recovery Priority Number: 5C

As the species is in conflict with development and growth, the conflict category 'c' has been added to the Recovery Priority number**.**

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

- **Immediate actions**
  - ✓ **Management**
  - o Build and maintain enclosures at TSP to protect the plants from deer herbivory and rubbing, and to better assess the impact of browsing on *T. taxifolia.* One concern is tree fall hitting the enclosure; it takes the enclosure and the *Torreya* plant. This is an ongoing action implemented by the TSP and now they are testing a narrow enclosure design.
  - o Foster a coalition of private landowners for help managing the plants on private land.
    - B. Boothe (2010, pers. comm.) suggested the establishment of the Torreya Conservation Commission at Crooked Creek, FL. They could pre-survey, flag the plants, and provide access to survey team.
    - R. Determann, J. Smith, and A. Trulock are working on developing a protocol to help landowners to manage the trees.
    - J. Smith (2010 pers. comm.) mentioned that his position at the Univ. of Florida includes a 40% extension appointment for outreach, so he could organize a workshop for private landowners to educate them on best management practices such as surveying.
  - o Foster a working partnership with Plum Creek Timber to oversee *T. taxifolia*. They have an agreement to manage G1, G2 plants but they are failing to comply; they are clearing and using herbicides (W. Baker, 2010 pers. comm.).
  - o Acquire the Plum Creek parcel that is north of I-10 along Flat Creek. It has a very high density of *Torreya* trees and good quality slope forest.
  - o Foster a working partnership between the Univ. of Florida and the Florida Forestry Association to address the importance of best management practices
  - o Safeguarding of ex-situ collection should continue. Expansion of ex-situ collection is important to ensure continued genetic preservation of a wide range of *Torreya* individuals including long term storage of embryos.
  - o Complete a comprehensive census/survey for all the current ravines containing *Torreya.* The TSP, ABG and Dr. Jason Smith have been collaborating on a survey of current ravines containing *Torreya*, and have developed a standardized protocol that is followed during surveys. Copy of the protocol should be provided to the Corps.
  - o Annual census (recommended at least once a year): Follow a standardized method for accurate population trends to ensure consistency in collected data.
    - Georgia population
      - ➢ Since plants are tagged, for each plant record height, circumference, # of branches, stems and leaf disease (e.g., stem canker, leaf yellowing) and reproduction (male vs. female cones).

- Florida population: mark a subset of the population (i.e., Ms. Anderson's monitoring of 400+ trees), and follow for each plant the above recommendations.

✓ **Research**

- Conduct surveys for new populations (and potentially for reintroduction) where similar habitat exists. This action can include the use of aerial photographs and/or species distribution modelling methods (e.g., Niche modelling) to initially determine potential sites, with subsequent validation or inspection of the sites for plants. This action needs to consider the below effort carried out by previous botanists.
  - Allison (1988) searched areas near the Flint River within a few miles of the known populations as well as of floristic composition similar to known population located north near the Chattahoochee River with. The searches didn't find additional populations.
  - Robert F. Thorne conducted botanical explorations in southwestern Georgia between 1946 and 1949 without finding new sites (Allison 1988).
  - Roland Harper walked along the Flint River from Chattahoochee to Bainbridge, without finding additional *T. taxifolia* sites (Allison 1988).
- Continue and expand studies related to the identification of pathogens. Research should include determining treatments and recommendations applicable for managing *Torreya* in its historic range.
- Complete studies on somatic embryogenesis (the production of disease-free trees) and genetics.
- Management practices: Further investigations of three commonly used management practices (preventing and curative) in forest ecosystems recommended by Dr. Lydia Rivera-Vargas (2009) should be considered:
  - Curative measure: Application of phosphites
    Also referred to as phosphonates, are excellent candidates for diseases treatment because of their extremely low toxicity to invertebrates, aquatic organisms, or animals, including humans (Garbelotto et al. 2007). Phosphite applied as injections on trees and as foliar sprays on herbaceous shrubs have been extensively used in Australian wild lands invaded by the soil-borne pathogen, *Phytophthora cinnamomi* (low volume phosphite applications are recommended: 24 and 96 kg/ha; Barrett et al. 2003). However, it can be phytotoxic, therefore different concentrations should be tested.
  - Preventing measures (plants have to be healthy and treated at the moment they are transplanted into the forest):
    - Fungal biocontrol agents (i.e. *Trichoderma* spp.):
      Trichoderma spp., have been used as biological control agents of plant pathogens since 1930s, and are commonly applied to control economically important crop diseases (Agrios 2005). *Trichoderma* spp. is a soil-borne fungi and a natural component of the mycoflora in Georgia forest soils associated with *T. taxifolia* (Rivera-Vargas 2009).

Some species of *Trichoderma* have been shown to parasitize other fungi {coiling around hyphae of the host fungi (Agrios 2005; Schubert et al. 2008); it also produces enzymes that degrade pathogen cell walls, compete aggressively for nutrients, produce antibiotics, and induce systemic acquired resistance (Rouhana 2010)]. These species are competitive antagonists against important forest trees pathogens such as *Heterobasidion annosum, Armillaria* spp. and *Fusarium oxysporum* (Mousseaux et al. 1998).

- Use of mycorrhizae: Forest tree roots develop symbiotic mycorrhizal association with fungi belonging to the Zygomycetes, Ascomycetes and Basidiomycetes, that often result in enhanced growth because of increased acquisition of phosphorus (P), and of other low mobile mineral nutrients (Turk et al. 2006). Mycorrhizae colonize roots inter (ectomycorrhizae) and intracellularly (endomycorrhizae) competing with pathogens for ecological niche thus providing protection against soil-borne diseases (Agrios, 2005; Marx et al. 2010). Studies on the natural mycorrhizal communities associated with *T. taxifolia* ecosystems need to be address in order to be used as a management tool; the study will be initiated on September 2010.

- Conduct grafting experiments
  This action should be considered no longer appropriate and removed from the plan because *T. californica* is exhibiting some issues with cankers caused by pathogens. See page 7 for details.
- The recovery plan should be updated to define with present data the objective measurable criteria and better address the five factors.

- **Preventing extinction emergency plan**

A plan should be developed to address guidelines for reintroduction, translocation (and/or managed relocation), and augmentation, a three-step process of planning, implementing and monitoring. Since this species is unlikely to disperse and colonize on its own because current populations are characterized by small individuals that are failing to achieve reproductive maturity, therefore it is a candidate for assistance. Below are preliminary points to be considered:

- Initiate a reintroduction/translocation scheme with disease-free *T. taxifolia* in environments in which the pathogens are not recognized and/or the habitat has been managed and cleared from the threat that brought the species to endangerment.
- Foster a working partnership between the Torreya Guardians, the Service, and other interested parties to help direct their managed relocation efforts.
- Basic general considerations (modified from Bruegmann et al. 1999):
  - Objectives: establish short- and long-term objectives.
  - Maps: The proposed outplanting sites should be accurately mapped. The GIS database can be used as a permanent record of the source of a population and to track the propagules.

- Management activities should include monitoring of growth, threats, and habitat.
- The plan should address all the risks (e.g., present threats, whether pathogen mitigation on an ecological scale is pragmatic, introduction of diseases, alteration of natural communities, etc). and actions to determine the impacts of each management option.
    - Reintroduction[3] within the historical site: habitat characteristics of the source population must be matched as close as possible with the outplanting site (using aerial photographs and/or species distribution modeling methods), and there should be no remnant population to prevent disease spread.
        - Allison (1988) provided recommendations of potential sites. These sites should be revisited and evaluated.
    - Augmentation of an existing wild population: the source stock for augmentation should be chosen from the same or a geographically adjacent population (within a 1,000 meter radius (http://www.botany.hawaii.edu/faculty/duffy/DPW/2003_MIP/Sec_1/16.pdf). If the goal is to increase the genetic variability in a population to reduce the risk of extirpation, then a careful analysis of the source stock should be conducted prior to its implementation.
    - Translocation (introduction of a species to a site outside the known historical range), could offer a best management option if the site provides the only place safe from the threats that brought the species to endangerment, and should only be considered if it can be shown that there is a net gain for the species conservation, i.e., recovery unit. This management option should be carefully evaluated, and planning should be done with the very best biological science. If a population has been already translocated, it could potentially be evaluated as an experimental population.

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Acknowledgements

Thanks to the participants of the Recovery Working group (see below names); they provided their time, knowledge, and updates of current conservation activities. This meeting was held on May 11, 2010.

Participant	**Information**
Ms. Pamela Anderson	Private landowner NW Florida
Mr. W. Wilson Baker	Biological Consultant, Florida
Ms. Connie Barlow, and Dr. Russell Regnery	Torreya Guardians: North Carolina
Mr. Bill Boothe	Private landowner NW Florida
Dr. Edward Croom	Adjunct Associate Professor of Pharmacognosy , School of Pharmacy, Univ. of Mississippi
Mr. Ron Determann	Conservation Director, Atlanta Botanical Garden
Ms. Angela Griffin	Army Corps- Georgia
Dr. Gil Nelson	Gainesville, FL
Dr. Jerry Pullman	Professor, Georgia Institute of Technology
Dr. Lydia Rivera	Professor of plant pathology, Uni. of Puerto Rico
Dr. Jenny Cruse-Sanders	Director of Research and Conservation, Atlanta Botanical Garden
Dr. Jason Smith	Assistant Professor of Forest Pathology, Univ. of Florida
Ms. Tova Spector	Environmental Specialist II, Florida Park Service
Mr. Aaron Trulock	Graduate student, Univ. of Florida

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of
Torreya taxifolia (Florida torreya)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

__ x__ No change is needed

Recovery Priority Number: 5C

The review was completed by botanist Dr. Vivian Negrón-Ortiz, Panama City Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 27 July 2010

REGIONAL OFFICE APPROVAL:

Acting
Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 7-30-10

APPENDIX A
Summary of peer review for the 5-year review of *Torreya taxifolia* (Florida torreya)

A. Peer Review Method:

The document was peer-reviewed internally by Ms. Lorna Patrick and Dr. Donald Imm in the Panama City Field Office. Once the comments were added to the document, it was sent to four outside reviewers (see below). The outside peer reviewers were chosen based on their qualifications and knowledge of the species.

B. Peer Review Charge: The below guidance was provided to the reviewers.

1. Review all materials provided by the Service.
2. Identify, review, and provide other relevant data that appears not to have been used by the Service.
3. Do not provide recommendations on the Endangered Species Act classification (e.g., endangered, threatened) of the species.
4. Provide written comments on:
   - Validity of any models, data, or analyses used or relied on in the review.
   - Adequacy of the data (e.g., are the data sufficient to support the biological conclusions reached). If data are inadequate, identify additional data or studies that are needed to adequately justify biological conclusions.
   - Oversights, omissions, and inconsistencies.
   - Reasonableness of judgments made from the scientific evidence.
   - Scientific uncertainties by ensuring that they are clearly identified and characterized and those potential implications of uncertainties for the technical conclusions drawn are clear.
   - Strengths and limitation of the overall product.
5. All peer reviews and comments will be public documents, and portions may be incorporated verbatim into our final document with appropriate credit given to the author of the review.

C. Summary of Peer Review Comments/Report

Dr. Cruse-Sanders provided vast information related to *Recovery actions 3* (seed-bearing trees at the ABG, seed protection from squirrel at the ABG and Smithgall Woods, and the ABG seedling production and propagation programs), *4* (current surveys conducted by ABG and collaborators on habitat conditions and population status of *Torreya,* and their observations related to population dynamics and life history of the species), and *5* (clarified the purpose of the Smithgall Woods' outplanting and updated the status of these plants) .

Dr. Rivera clarified the types of management practices into preventing and curative.

Due to current commitments, **Dr. Smith** was not able to provide comments. He concurred with T. Spector's comments.

Ms. Spector indicated: to expand the ABG efforts on *Torreya* propagation and safeguarding, Dr. Smith' study, the stem length and heights of 223 Torreya trees surveyed in its native habitat between 2007-2009; to explain the role of the construction of the dam in the decline of *Torreya*, why the habitat continues to be altered. She doesn't agree with the following statement "Initiate a reintroduction/ translocation scheme with disease free *T. taxifolia* in environments in which the pathogens are not recognized." She mentioned that the "reasons for not moving *Torreya taxifolia* outside of its range was addressed by Schwartz (2005). Moving Torreya outside of its range would alter the natural community where it is introduced. In addition the species may be susceptible to decline from factors in the introduced location. Instead trees should be safeguarded in botanical collections until the causal agent(s) for its decline can be mitigated in its historical range."

D. Response to Peer Review

Drs. **Cruse-Sanders and Rivera's** peer reviewer comments were evaluated and incorporated where appropriate. Dr. **Cruse-Sanders'** comments addressed Ms. Spector's concerns related to *Torreya* propagation and safeguarding.

Ms. Spector's concerns:

Disagreement exists among conservationists related to introducing species beyond their historical ranges (translocation), and Schwartz (2005) clearly addressed his opposition to assisted migration for Florida torreya and other similar cases. The author also stated that, "if assisted migration is going to be used sparingly, and only in conditions where the need is dire, then the conservation community should begin now to specify and advertise a consensus view on when this may be appropriate." As I stated in this document, before an emergency plan is implemented, guidelines should be developed. Further development of the points raised in the plan is warranted, including all the risks (e.g., present threats, whether pathogen mitigation on an ecological scale is pragmatic, introduction of diseases, alteration of natural communities, etc). Translocation as well as any other management option should be: supported after careful review of impacts, integrated with research, and properly designed and monitored. For more information see Soorae, P. S. (ed.) (2008) Global re-introduction perspectives: re-introduction case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE. viii + 284 pp. (http://www.iucnsscrsg.org)

Her other main concerns were addressed in the document.