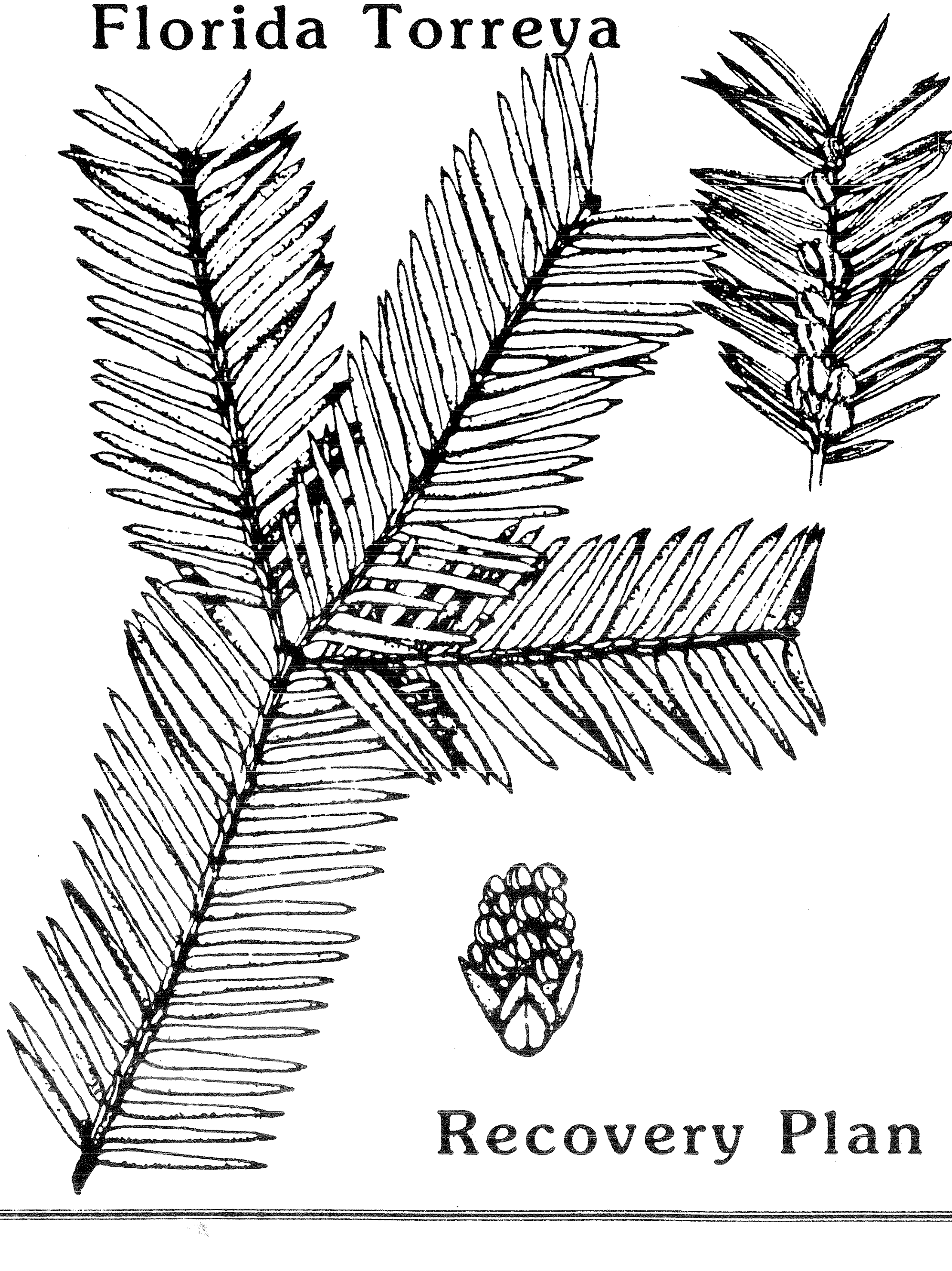
Florida Torreya



Recovery Plan

FLORIDA TORREYA (*TORREYA TAXIFOLIA*) RECOVERY PLAN

Prepared by

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Date: September 9, 1986

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ACKNOWLEDGMENTS: This document is based substantially on a manuscript by Dr. O. Greg Brock of the Florida Department of Natural Resources, Tallahassee, titled "Management Plan for *Torreya taxifolia* in Florida State Parks." This manuscript in turn is largely based on the results of the Torreya Tree Management Symposium conducted by the Florida Department of Natural Resources in November, 1983. The Service is grateful to Dr. Brock and to the Florida Department of Natural Resources for generously sharing the material, and is also grateful to the symposium participants for their contributions. A number of persons provided comments on the technical and agency drafts. Their help is greatly appreciated. The drawing on the cover is adapted from an illustration by Lisa C. Megahee on p. 62 of *Rare and Endangered Biota in Florida*, Vol. 5, D.B. Ward, ed., University Presses of Florida, Gainesville.

LITERATURE CITATIONS SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 1986. Florida torreya (*Torreya taxifolia*) recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 42 pp.

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PART I. INTRODUCTION

The Florida torreya (*Torreya taxifolia*) is a small gymnosperm tree native to four counties along the Apalachicola River and Lake Seminole in northwest Florida and adjoining Georgia. Some of the torreya's habitat is protected on lands managed by The Nature Conservancy, the Florida Park Service, and the U.S. Army Corps of Engineers. The species is endangered because the wild populations have succumbed to stem cankers and stem and needle blight that has killed the main trunks of all the mature trees leaving only stump sprouts that rarely live long enough to bear seed. The trees may be vulnerable to decline because of stress caused by habitat alteration and/or drought. Cultivated trees are also affected by fungal infections including stem and leaf blight of varying severity. The Florida torreya was listed as endangered pursuant to the Endangered Species Act of 1973 on February 22, 1984 (49 Federal Register 2783). It is also listed as endangered under the Preservation of Native Flora of Florida Act (Section 581.185-187, Florida Statutes).

Description

The Florida torreya is a small, conical tree of the yew family (Taxaceae), with whorled branches. The evergreen needle-like leaves are 1-1.5 inches long and 0.13 inches wide, stiff, sharply pointed at the tip, and are arranged on both sides of the twigs in a single plane. The leaves and twigs have a distinctive pungent, resinous odor (Kurz and Godfrey 1962). Pollen cones and ovules are borne on separate trees. The ovule develops into a single seed with a fleshy aril covering. Torreya seeds are large, 1-1.5 inches long.

In the past, the Florida torreya has been used for fence posts, shingles, firewood, and Christmas trees (Chapman 1885, Burke 1975, Gholson 1983).

Distribution

Torreya is a genus of four or five species from Florida and Georgia, California, China, and Japan. The present geographic distribution of the genus is similar to the distributions of several other plant genera. The distributions, together with fossil evidence, suggest that these genera had wide distributions during the Tertiary Period that were subsequently reduced by climatic changes during the Quaternary (James 1961, Delcourt and Delcourt 1975).

The Florida torreya ranges primarily along the east side of the Apalachicola River from near Bristol, Liberty County, Florida northward through Gadsden County and across the state line into southernmost Decatur County, Georgia (Figure 1). Trees have been found as much as eight miles east of the river. In Florida, portions of the habitat have been preserved in The Nature Conservancy's Apalachicola Bluffs and Ravines Preserve, in Torreya State Park, and in Chattahoochee city parks. In Georgia, the tree is present on land owned by the U.S. Army Corps of Engineers at Lake Seminole, Decatur County (Kurz 1938b, Savage 1983a, Butler 1981). *Torreya taxifolia* is most abundant in the Rock Creek drainage of Torreya State Park (Southeastern Wildlife Services, Inc. 1982). One small population of torreya is on the west side of the river at Dog Pond in Jackson County, Florida (Kurz 1938a, Milstead 1978). The Nature Conservancy is working to preserve this site, which is a beech-magnolia forest.

Population Status

The decline of *Torreya taxifolia* in its native habitat may ultimately be due to environmental factors that stressed the trees, including alteration of its forest habitat, alteration of vegetation above the ravines it inhabits, alteration of water seepage into the ravines, or droughts. The proximate causes of the decline are an assortment of fungal infections, resulting in stem cankers, stem and leaf blight, and possibly other problems (see p. 6). The decline has affected all wild Florida torreya trees (Godfrey and Kurz 1962) and possibly all cultivated trees. Trees with stem and leaf blight infections defoliate, losing their photosynthetic capacities (Alfieri *et al*. 1967). Mature trees and those approaching maturity are affected most (Bowden 1981), perhaps because of the additional stresses associated with sexual reproduction. At Maclay Gardens in Florida, all mature cultivated trees, even well-watered ones, have developed stem and leaf blight when 16-17 years old, which is the approximate age of sexual maturity (Bowden 1981). Some younger specimens have died, apparently at random (Weidner 1986).

In the wild, individual trees affected by decline often die, but many persist by resprouting from roots (Godfrey and Kurz 1962, Turnage 1983). The new shoots may be healthy and vigorous for a number of years, but they succumb at or before reaching sexual maturity. The number of times a torreya tree can resprout is unknown. Field observations of many torreya snags, with no live sprouts nearby, suggest that populations cannot persist indefinitely by resprouting (Baker 1983, Brock 1983).

Mature torreya trees exist in cultivation at the Biltmore House and Gardens near Asheville, North Carolina, but even there, seedlings and young trees show blight symptoms similar to those seen in trees in Florida. There has been no testing or identification of pathogens from the trees at Biltmore. The 14 large trees, approximately 40 years old, show occasional lesions but appear to be healthy. They may have escaped more serious symptoms because they suffer little water stress in the cool, moist climate (Barnes 1983a, Turnage 1985). Cultivated male trees may be more resistant to decline than female trees (Turnage 1985).

Reproductive Status

The wild populations of *Torreya taxifolia* may still contain a few seed-bearing trees. Seed can be obtained from cultivated trees at several locations. Florida torreya trees require 15-20 years to reach sexual maturity (Bowden 1981). Mature staminate (male) trees can be distinguished in March or April when the reproductive structures, rows of delicate creamy-white pollen cones beneath the axils of some terminal twigs, are present. Pollen is usually released before the ovules are receptive, based on observations of cultivated trees at the University of Florida (Barnes 1985). Ovulate (female) trees, when producing, bear very small ovules on shoots of the current year's growth. The ovule is fertilized 4-5 months after pollination. The ovule develops into a single seed covered with a fleshy aril (Coulter and Land 1905, Buchholz 1940, Willson and Burley 1983). In September or October of the second year, the fleshy aril surrounding the seed matures, turning from light green to purplish-brown, and often splitting horizontally (Barnes 1985). At Maclay State Gardens, gray squirrels gather the seeds as soon as the arils turn purplish: September 20 in 1984, September 29 in 1985 (Weidner 1986).

Mature, ripened torreya seeds harbor immature embryos that require substantial development before germinating (Roy 1974). Alternating periods of stratification under warm (ca. 50-70° F) followed by cool/cold (ca. 40° F) and a second warm period appear essential for proper embryo development, although the duration and degree of cold stratification needed is still unclear (Barnes 1983b, Roy 1974). Germination is slow, ensuing in one to three years but most frequently in two years (Meyer 1981). The long seed dormancy period, combined with the long seed development period, means that roughly four to five years elapse between pollination and seedling emergence.

Growth following germination is slow. Eight to 12-year-old torreya trees are generally 6-8 feet tall. They become sexually mature when 10 feet or taller (Bowden 1981). Under optimal conditions, growth continues after maturation, attaining heights of 60 feet (Reinsmith 1934). The largest existing tree is one that was moved to Norlina, North Carolina in 1840. It is 45 feet tall with a basal diameter of 34 inches (Turnage 1983).

Habitat Description

The principal native habitat of the Florida torreya is the network of bluffs, ravines and steepheads [steep slopes at the heads of ravines where the seepage of groundwater at the base continually undercuts the slope, causing erosion (Clewell 1985)] on the east side of the Apalachicola River (Chapman 1885, Savage 1983b, Southeastern Wildlife Services, Inc. 1982). The largest concentration of trees is in the vicinity of Torreya State Park (Reinsmith 1934, Baker 1983). Elevations in this area range from about 50 feet along the river to 250 feet at the tops of the ravines. A study of a portion of the torreya populations in the State Park showed that 61% of the trees were located on the middle portions of the slopes between 100-180 feet in elevation, 29% above 180 feet, and 10% below 100 feet (Brock 1983). This pattern of distribution that favors middle elevations and mid to lower slopes of individual ravines is confirmed by maps prepared by Southeastern Wildlife Services, Inc. (1982). The greatest number of trunks are located below certain sandstone and clay strata, which suggests that uninterrupted seepage is important (Barnes 1986).

The Florida torreya is an understory tree of mature beech-magnolia-pine forests (hammocks) (Harper 1914). The canopy trees are mostly deciduous, but evergreen hardwoods and conifers are also fairly common. These areas have diffuse sunlight in summer, and a relatively open canopy in winter (Kurz 1938b, Brock 1983). The mesic habitat and the morphology of the tree's roots, which are thick and stubby with limited secondary branching and root hairs (Barnes 1985) suggest that *Torreya taxifolia* requires a humid microclimate (Delcourt and Delcourt 1975).

Other species of *Torreya* appear to have similar habitat requirements (Burke 1975). *Torreya californica* is found on "... moist, shaded slopes and along water courses" (Abrams 1940). *Torreya nucifera* is an understory element of beech forests in Japan (Ishizuka 1974). *Torreya grandis* occurs in mixed forests of southeastern China (Lee 1973). Fossils of the genus occur in assemblages of other species indicative of mesophytic forests (Knowlton 1919, Leopold and Macginitie 1972, Raven and Axelrod 1978).

Limiting Factors

The basic limiting factor of Florida torreya is its restricted geographic range and habitat, rendering the species vulnerable to human disturbance of its habitat and to natural factors, such as climate change, which are likely to be felt by all of the populations. Habitat alterations, augmented by periodic severe droughts (Barnes 1983b) may have predisposed the trees to the stem and needle blight and/or other infections that are the proximate causes of decline of the wild populations. The decline has been so great that few if any seed-bearing trees exist in the wild, making recovery of the populations through natural sexual reproduction impossible.

Stem and needle blight (Godfrey and Kurz 1962) affects Florida torreya. Expression of disease symptoms is associated with stress and probably with changes in carbohydrate sinks and sources associated with sexual maturity (Barnes 1985). Symptoms include small, circular chlorotic spots (lesions) on the needles which turn light brown until the entire needle becomes necrotic. Needles of the present season often do not develop lesions until they mature, so the twigs become bare except for young needles toward the tip. Then the stem becomes infected. Severely diseased trees suffer much needle and stem necrosis and defoliation (Alfieri *et al*. 1967). A number of fungi have been isolated from infected needles and twigs (Alfieri *et al*. 1967, Rowan and Chellman 1980). Cankers occasionally form at the base of the stem (Southeastern Wildlife Services, Inc. 1982). Galls or cankers, possibly caused by *Phyllosticta* spp. are apparently common on the stems of wild trees (Barnard 1986). A current list of fungi associated with diseases of *Torreya taxifolia* is as follows (Alfieri *et al*. 1984):

Alternaria sp., needle spot.
Botryosphaeria sp., needle spot.
Diplodia natalensis P. Evans, Twig dieback.
Fusarium sp., root rot.
Macrophoma sp., needle blight.
Phyllosticta sp., needle spot.
Physalospora sp., twig and needle blight.
Phytophthora sp., root rot.
Pythium sp., root rot.
Rhizoctonia solani Kuehn, root rot.
Sclerotium rolfsii Sacc., southern blight.

Sphaeropsis sp., needle blight.

Recently, Fusarium lateritium was isolated from spots on needles of 30-year-old Florida torreya trees. The light grayish green spots, which became tan, were up to 8.4 millimeters long, with brown, irregularly shaped necrotic centers 2.4 millimeters long and 2 millimeters wide. When F. lateritium was spray-inoculated onto two-year-old cuttings, symptoms developed within 3 days. The fungus was reisolated from all spots (El-Gholl 1985). There is a possibility that an introduced, non-native pathogen such as Phytophthora cinnamomi is involved (Barnard 1985). The occurrence of multiple fungi, some of them known to be soil inhabitants and opportunistic pathogens of several plant species, suggests that the fungal infections are merely symptoms of another underlying cause of decline (Kurz 1938, Mundkur 1949, Hartman and Kester 1968, Alfieri 1983, Barnard 1985). Barnes (1983b, 1984) noted that the major episodes of torreya dieback have occurred following periods of drought. Major diebacks of mature torreya trees occurred in the late 1930's and the late 1950's (Godfrey and Kurz 1962, Alfieri et al. 1967). In both cases, 4-7 years of below average rainfall preceded diebacks. Drought stress renders plants more vulnerable to fungus infections. But torreya has presumably survived droughts in its native habitat for millenia; this suggests that other factors may have contributed to the decline.

Torreya appears to occupy sites where a steady supply of moisture is available from seepage, and where it is shady in the summer. Soil moisture at these sites may have been affected by alteration of the pine forests on uplands above the ravines (Clewell 1977, Kurz 1938b), which altered the drainage and retention of surface and ground water, in turn probably altering seepage into the ravines. Logging has altered the forests in the ravines (Reinsmith 1934). Concern has also been expressed over changes in the microclimates of the ravines that may have been caused by construction of the Jim Woodruff Dam, completed in 1956. This impoundment altered the Apalachicola River flooding cycle and raised downstream water temperatures, which possibly raised air temperatures near the river (Toops 1981) resulting in a change of microclimate. No inquiry has been made into the possible effects of air or water pollution. It is possible that relatively minor human alterations of the habitat may seriously affect torreya; it is possible that the present-day physical environment of the Apalachicola bluffs and ravines is only marginally suitable to Florida torreya. The species may be restricted to the area because it failed to migrate northward at the end of the Pleistocene.

At Torreya State Park, when a decline in Florida torreya was observed about 1955, the Florida Division of Forestry suggested methods to improve the health of the trees. Plots surrounding affected trees were thinned of competing trees to increase air circulation and sunlight, and various fertilizers were applied, with negligible results (Coldwell 1962).

The cultivated trees at the Maclay State Gardens in Florida are severely affected, but trees at a number of sites, including Columbus, Ga., Norlina, N.C., Fort Gaines, Ga., Highlands, N.C., and Asheville N.C. (Turnage 1985) and Callaway Gardens (Barrick 1985) appear to be in good health. At Maclay Gardens, various methods to control fungal blight have been tried. Maneb, Benomyl, Daconil (Chlorothanlonil) and Zyban have been applied since 1962 in various combinations and at various intervals, with no noticeable benefits. New systemic fungicides that are being studied by commercial nurseries for use on rhododendrons might benefit torreya (Turnage 1985). Fertilizer, dolomite, and copper sulfate have also been applied intermittently at Maclay Gardens since 1955 (Bowden 1981). None of these treatments appeared successful, but because no quantitative data were collected, definite conclusions are not possible (Smith 1986). Trees planted in sunny sites at Maclay rarely bear seed, but two of these trees, transplanted to the shade, have.

Threats to Future Existence

The principal threat to Florida torreya will remain the decline of the wild populations. The lack of genetic diversity among cultivated trees is a secondary threat. The trees at Maclay Gardens are all direct descendants of the original male and female trees planted there in the 1930's. A few seed-bearing trees not descended from the Maclay trees exist at the Biltmore House and Gardens near Asheville, N.C., near homes in Highlands and Norlina, N.C.; and in Columbus and Albany, Ga. (Turnage 1983). A few seeds can be obtained from trees on the University of Florida campus (Barnes 1986). Burl Turnage and others have distributed seedlings and seed to various botanical gardens and private individuals. An up-to-date inventory of cultivated specimens is not available.

PART II. RECOVERY

A. Recovery Objective

Because the existing wild populations of <u>Torreya taxifolia</u> are composed of individuals that can neither survive indefinitely nor reproduce, and because no methods are at present available to improve the health of wild *Torreya* trees, the first objective of this recovery plan is to produce a genetically diverse collection of sexually mature, reasonably healthy trees in cultivation to preserve a representative gene pool to serve as stock for possible reintroduction into the native habitat. Reintroduction can be considered when there is reason to believe that the trees would survive to maturity. The second objective is to ensure the integrity of its native habitat. Florida torreya could be considered for reclassification to threatened status when 5 healthy populations, with sexually mature offspring, are established in secure portions of its native range. Recovery and delisting could be considered if 15 self-sustaining populations are established in separate ravine systems. An appropriate minimum population size and minimum land area for each population must be determined.

The principal methods to attain the objectives are to: 1) Ensure the preservation and appropriate management of enough of torreya's native habitat to allow for reintroduction; 2) produce cultivated plants of torreya and conduct empirical investigations of methods to control the decline in cultivated plants; 3) investigate the decline to determine its cause and, if possible, to find a cure; and 4) introduce cultivated plants into secure habitat within its former range.

B. Step-down Outline

1. Protect the existing habitat.
   11. Management of existing biological preserves.
       111. Protect torreya habitat from activities within preserve boundaries.
       112. Protect torreya habitat from the impacts of activities outside preserve boundaries.
   12. Determine protection strategies for torreya habitat outside of preserves.
       121. Implement habitat protection measures.
2. Control torreya decline.
   21. Identify pathogen(s) responsible for the decline.
   22. Conduct empirical experiments into disease management.
       221. Conduct integrated scientific tests of the effectiveness of various culture regimens.
       222. Investigate mycorrhizal relations of torreya.
   23. Develop a protocol for experiments on seedlings and cuttings.
   24. Maintain good sanitation on cultivated trees.

25. Water, cut back, and/or transplant cultivated trees growing on dry sites.

3. Produce seedlings and cuttings.
    31. Produce seeds.
        311. Obtain seed from cultivated trees.
            3111. Locate seed bearing trees.
            3112. Protect seed from frugivores.
                31121. Cover trees.
                31122. Experiment with rodent taste repellents.
            3113. Harvest cultivated seed.
        312. Obtain seed from wild trees.
            3121. Search habitat for seed-bearing wild trees.
            3122. Harvest seed from wild trees.
    32. Disseminate and propagate seed.
        321. Arrange seed exchange.
        322. Establish seedling production programs.
            3221. Obtain and grow seeds at Maclay State Gardens, Florida.
                32211. Assess results yearly.
            3222. Initiate other programs.
                32221. Enlist institutions.
                32222. Arrange cooperation among individuals.
    33. Propagate from cuttings.
        331. Establish program to obtain cuttings.
        332. Establish cuttings.
    34. Conduct grafting experiments.
4. Investigate the ecological requirements, population dynamics, and life history of Florida torreya.
    41. Study the ecological physiology of torreya.
    42. Evaluate the native habitat.
    43. Describe the physical environment, neighboring vegetation, and condition of cultivated torreya trees.
    44. Study the population dynamics and life history of torreya.
5. Establish experimental collections of torreya outside its native habitat.
    51. Inventory plantings at botanical gardens and arboreta.
    52. Supplement existing plantings.
    53. Establish new plantings.
6. Place seed in long-term storage.
7. Reestablish torreya in its native habitat.
    71. Transplant cultivated torreya trees into the wild.

72. Ensure proper management of reestablished torreya populations.

C. Outline Narrative

1. Protect the existing habitat.
A small portion of the tree's original habitat is managed as park or nature preserve. Much habitat outside the preserves has been disturbed or will be in the future. Existing preserves must be managed appropriately and, if possible, be enlarged.

11. Management of existing biological preserves.
The Nature Conservancy's Apalachicola Ravines and Bluffs Preserve and the Torreya State Park, both in Florida, are the primary protected areas of torreya habitat. The Army Corps of Engineers' Lake Seminole, Georgia, a park in the City of Chattahoochee, Florida, and Dog Pond, Florida are smaller areas with fewer trees. The land managers should be encouraged to develop torreya conservation plans.

111. Protect torreya habitat from activities within preserve boundaries.
Visitor management and deer populations appear to be concerns. Deer rub torreya stems, often breaking them (Southeastern Wildlife Services, 1982). Deer impacts on torreya do not appear to be significant at the present time, but should be monitored; seed-bearing wild trees could be protected during rut with commercially available deer repellants or fencing. Visitors should be educated to protect torreya trees.

112. Protect torreya habitat from the impacts of activities outside preserve boundaries.
Changes in land use on the uplands above the ravines can affect the hydrology of the ravines. Preserve managers should monitor land use changes and investigate historical change.

12. Determine protection strategies for torreya habitat outside of preserves.
Private lands should be searched for torreya trees and cooperation sought from owners to protect trees and allow access for conservation purposes. As information becomes available from the search for trees, and from step 41., determine what land is needed to support reintroduced populations, and develop a plan for habitat protection

including cooperative agreements, easements or land acquisition, and habitat management measures.

121. Implement habitat protection measures.
As measures are identified, implement them.

2. Control the torreya decline.
This is a multi-faceted program. Full implementation requires extensive work at a suitable horticultural facility or facilities, and/or at a plant pathology research institution such as a state university. The Maclay State Gardens in Florida is a potential site, but the stem and needle blight is so severe there that several participants at the 1983 Torreya Tree Management Symposium thought that blight research, as well as other aspects of recovery, should be conducted elsewhere (Brock 1985).

21. Identify pathogen(s) responsible for the decline.
Identification of the pathogen(s) responsible for *Torreya* decline and working out the etiology would facilitate the development of control procedures, increase the feasibility of cultivating the trees in Florida and possibly make it feasible to reintroduce the trees into their native habitat. Some progress has been made toward this objective at the Florida Department of Agriculture and Consumer Services (El-Ghol 1985). Obtaining plant material for the study of stem cankers or root disease is destructive of the plant. For canker research, it is possible that wild torreya plants could be cut down or dug up, and the material so obtained used for both plant pathology research and for cutting propagation (see 33).

22. Conduct empirical experiments into disease management in mature cultivated specimens.
Existing information on stem and needle blight is sufficient to suggest control procedures, but procedures implemented to date have been complex, sometimes contradictory, and unsuccessful. Barnes (1984) was advised that Zyban eliminates *Phyllosticta*, and Mertect 340 F (Thiabendazole) may also be an effective fungicide. However, the coarse, thick roots of *Torreya* suggest that vescicular-arbuscular mycorrhizae may be very important to *Torreya*. Wide spectrum fungicides probably harm beneficial mycorrhizal fungi which could accentuate stress on the trees and further predispose them to fungal infection. Nevertheless, it may be feasible to restore diseased cultivated trees to a reasonably healthy condition.

221. Conduct integrated scientific tests of the effectiveness of various culture regimens.
A quantitative program for testing selected fungicide, irrigation, and fertilizer regimens has been proposed by Dr. O. Greg Brock for the 272 trees at the Maclay State Gardens near Tallahassee, Florida. This proposed program should be reviewed by plant pathologists.

222. Investigate mycorrhizal relations of torreya.
Information on mycorrhizal fungi associated with *Torreya* may be helpful in maintaining mature trees and in propagation and establishment of young plants.

23. Develop a protocol for experiments on seedlings and cuttings.
Mature trees are affected by decline more than juveniles, so experimentation with juvenile plants has a lower priority. Treatments could be similar to those proposed for mature trees.

24. Maintain good sanitation on cultivated trees.
Because blight-killed branches are likely to be an excellent source of pathogenic fungi (Ingold 1971), cultivated trees (except those on which fungicide tests are conducted) should be carefully pruned of dead branches once or twice a year. Dead trees and snags should be removed. Wounded branches and twigs can be treated with a commercial grafting compound or fungicidal paste/wax.

25. Water, cut back, and/or transplant cultivated torreya trees growing on dry sites.
At the Maclay State Gardens, the least sickly trees growing in an old field habitat should be transplanted into a more shaded, mesic woodland habitat. Other trees in dry areas should be cut back close to ground level and allowed to resprout. Deciduous hardwoods should be planted around them, and a watering system set up.

3. Produce seedlings and cuttings.
Cuttings from wild trees offer the most practicable way to increase the genetic diversity of the cultivated stock of Florida torreya. If seeds can be obtained from wild trees, they can serve the same purpose. If the decline of torreya is caused by an introduced pathogen, seeds are less likely to spread the pathogen than cuttings.

31. Produce seeds.

311. Obtain seed from cultivated trees.

This will increase the number of cultivated trees, but not the cultivated gene pool.

3111. Locate seed-bearing trees.

Few seed-bearing torreya trees exist: several at Maclay State Gardens in Florida, two at the Biltmore House and Gardens near Asheville, N.C., one each at Norlina, N.C.; Highlands, N.C.; Albany, Ga.; and Columbus, Ga. (Turnage 1985), and one or more at the University of Florida (Barnes 1986). Several hundred seeds can be harvested from trees at the Biltmore House and Gardens every year. Trees at the Maclay State Gardens, Fl., produce 50-175 seeds annually. Most of those at Maclay are descendents of a single female tree. The information on seed-bearing trees assembled by Turnage (1985) should be confirmed and updated.

3112. Protect seed from frugivores.

Torreya seeds are sought by gray squirrels. Protection measures should be developed. Tests at the Maclay Gardens indicate that seed should be allowed to ripen on the tree (Weidner 1986).

31121. Cover trees.

Shade cloth has been tried on smaller trees at the Maclay Gardens in 1980-1982 (Bowden 1984), but the results were not quantified, so the degree of success is unknown. An attempt to protect individual seeds by covering each with nylon netting failed (Weidner 1984). Small mesh metal (i.e., screen wire) bags may work (Barnes 1985). Another approach is to construct a tree enclosure consisting of a framework covered with hardware cloth (Weidner 1986).

31122. Experiment with rodent taste repellents.

Dr. O. Greg Brock has developed a protocol for testing repellents at Maclay Gardens. Possible repellents include nicotine sulfate, fox urine, pepper sauce, and ammonia.

3113. Harvest cultivated seed.
When fruits begin to turn pinkish-purple on the distal end, ripeness can be checked by probing this area with a knife. If the metacarpal has hardened, the seed can be harvested (Turnage 1983). The knife test risks damage to the embryo. Alternately, one can assume that if the fleshy tissue (aril) changes color or is easily removed, then the seed is ripe, although it may need moist (not wet) conditions for afterripening. Storage in slightly moistened well drained coarse sharp sand for several months at roughly 70° F may be appropriate (Barnes 1985).

312. Obtain seed from wild trees.
Because the existing cultivated trees are descended from relatively few individuals, it is very desirable to attempt to obtain seeds from the wild.

3121. Search habitat for seed-bearing wild trees.
There may be some wild trees of seed-bearing size. Sex is easily determined at the time of leaf emergence or later. The location and sex of such trees should be mapped so they may be checked for seed in August and September.

3122. Harvest seed from wild trees.
Harvest time varies from year to year, ranging from early September to late October (Barnes 1985). Experience at Maclay Gardens indicates that late September is the prime time (Weidner 1986).

32. Disseminate and propagate seeds.

321. Arrange seed exchange.
The Center for Plant Conservation, Jamaica Plain, Massachusetts, can facilitate collection, transfer, and storage of live material according to established protocols (Falk 1985). This includes exchange of seed and cuttings (see 33.), and germplasm storage (see 6.). Seeds from most institutions should be treated with fungicides before being shipped to disease-free areas to

prevent transmission of pathogenic fungi (Ingold 1971).

322. <u>Establish seedling production programs.</u>

3221. <u>Obtain and grow seeds at the Maclay State Gardens, Florida.</u>
Seedlings would augment the existing collection of trees and provide material for plant pathology experiments (see 23.). To produce 25 seedlings/year will require obtaining at least twice as many seeds. Methods for germinating and growing seeds are described in Appendix A. Advice should be sought from persons who have successfully germinated seed.

32211. <u>Assess results yearly.</u>
As successful germination and seedling care procedures are identified, adopt them.

3222. <u>Initiate other programs.</u>
Mature trees in Georgia and North Carolina produce enough seed to support propagation programs. Institutions, businesses, or individuals in these or other states may be able to produce seedlings.

32221. <u>Enlist institutions.</u>
Botanical gardens in the Southeast, on the Pacific coast or elsewhere may be able to grow Florida torreya successfully (See 5. below).

32222. <u>Arrange cooperation among individuals.</u>
A number of individuals own mature Florida torreya trees. These individuals and their trees may be able to contribute to seed and seedling production.

33. <u>Propagate from cuttings.</u>
Cuttings from wild trees maintain genotypes that have succeeded in the wild. Gensel (1984) has emphasized that cultivating wild genotypes insures against selecting genotypes that thrive in cultivation but not in the wild. The small number and limited genetic diversity of cultivated mature female Florida torreya trees also makes it necessary to take cuttings from wild plants. Cutting propagation procedures for this species are reasonably

well understood (Barnes 1983b, Bowden 1981, Turnage 1983, Weidner 1986). See Appendix B.

331. Establish program to obtain cuttings.
Florida Department of Natural Resources personnel are probably in the best position to collect cuttings. Each cutting should be assigned an accession number, and the collection locality noted. Written permission to collect must be obtained from landowners. Collection of cutting material should be coordinated with collection of material for plant pathology studies (21.).

332. Establish cuttings.
Establish cuttings at suitable horticultural facilities. The possibility that cuttings may spread disease to existing cultivated plants suggests that cuttings should be disseminated cautiously, to a limited number of sites that are not near existing mature trees.

34. Conduct grafting experiments.
Root rot may increase the rapidity of onset and severity of the torreya disease(s) (Barnes 1985). The blight infections of Florida torreya may begin with a weakening of the root system (Alfieri 1983). Procedures to produce a stronger root system may help alleviate problems with fungal blight. One way to produce stronger root systems may be to graft scions of Florida torreya onto compatible root stocks. Many conifers do not graft easily, except onto seedlings or 1-3 year old trees (Barnes 1985). *Torreya nucifera* and *T. californica* are the most promising rootstocks for *T. taxifolia* although they may be at least as susceptible as *T. taxifolia* to the blight when planted in the Southeast (Turnage 1983). Monticello Nursery, Monticello, Florida, grew and sold *T. nucifera*, *T. californica*, and *T. frazeri*, and specimens may still exist there (Turnage 1985). If one of these species shows resistance to the blight infections, then grafting experiments could help determine whether the disease originates in the root system.

4. Investigate the habitat requirements of Florida torreya.
The health of Florida torreya trees appears to depend on climate, microclimate, and the availability of soil moisture. Understanding the relations of these factors to the species is necessary for determining the feasibility of reestablishing populations of trees within their native habitat.

41. Study the ecological physiology of torreya.
Torreya trees in their native habitat may be vulnerable to disease because they are under physiological stress. These studies may determine whether this is the case, and, if so, describe the environmental parameters within which torreya can thrive.

42. Evaluate the native habitat.
Reports on the native habitat of torreya provide information on the canopy composition (Harper 1914, Kurz 1938b, Kurz and Godfrey 1962, Brock 1983). Only limited information is available on soil characteristics, general location on ravine slopes, and other factors (Southeastern Wildlife Services, Inc. 1982, Alfieri 1983, Bowden 1981, Barnes 1983b, Brock 1983, Kurz 1938b). Studies of soil moisture, nutrients, mycorrhizae, humidity, and temperature could be useful. It is desirable to map the habitat of Torreya. Barnes (1985) suggests that minimum soil moisture levels may be critical, and that it may be possible to find evidence of changes in the hydrologic regimes of the ravines. A forest hydrologist should participate in the planning and execution of such evaluations. Any such studies should be conducted while shoots, stumps, and downed trunks are still present.

43. Describe the physical environment, neighboring vegetation, and condition of healthy cultivated torreya trees.
The trees at the Biltmore House and Gardens near Asheville, N.C. appear to be thriving. It will be useful to describe the climate and soils at Biltmore, with particular regard to soil moisture through the year. Owners of other trees around the country, especially botanical gardens, should be queried about the health of their specimens.

44. Study the population dynamics and life history of torreya.
It may be possible to design appropriate studies, which ought to be integrated with pathology studies (see 2.).

5. Establish experimental collections of torreya outside its native habitat.
Torreya trees may stay healthy with little or no special care in other climates outside historic range. The healthy trees at Biltmore and other Appalachian mountain locations suggest that experimental torreya planting(s) could be established in the southern Appalachians, under the auspices of the Center

for Plant Conservation and suitable botanical garden(s). Because of the remote possibility that blight is caused by an introduced pathogen, it is probably not prudent to transport Torreya cuttings or plants into localities within the native range of Torreya nucifera or where healthy cultivated seed-bearing Torreya taxifolia exist. The purpose of establishing or enlarging such experimental populations would be to produce healthy plant material which could be used to reestablish populations within historic range.

51. Inventory plantings at botanical gardens and arboreta.
Florida torreya is in the collections of a number of these institutions, possibly including some on the Pacific coast. Information on where the plants are, and how they are thriving, could be valuable in planning future plantings (see 43.).

52. Supplement existing plantings.
Expansion of existing plantings could eventually lead to greater genetic diversity in the seeds produced at these sites. The risk of spreading disease suggests that young plants propagated from cuttings should not be planted near existing mature trees (332.). If there is success in controlling fungal blight, a planting of Florida torreya at a lakeside woodland at the Maclay Gardens, Tallahassee, Florida, outside historic range, can be expanded.

53. Establish new plantings.
Sufficient information is available to suggest that Florida torreya in cultivation thrives under specific climatic, soil or soil moisture regimes (see 42., 43., and 5.). Living collections of torreya would be established and maintained under the auspices of botanical gardens.

6. Place seed in long-term storage.
The Center for Plant Conservation has a cooperative agreement with the U.S. Department of Agriculture, National Germplasm System, to store seed of endangered species.

7. Reestablish torreya in its native habitat.
Reestablishment of Florida torreya on the Apalachicola bluffs and ravines may eventually be possible if changes in the local hydrologic regime have not been too severe. Success will depend heavily on research into the habitat requirements of Florida torreya, which may determine whether reintroduction of torreya into all or part of its native habitat is feasible. Preliminary experimental plantings must precede any large

scale reintroduction efforts, and suitable cultivated plant material must be available for transplanting.

71. Transplant cultivated torreya into the wild.
Seedlings may become available in quantity. In utilizing plants established from cuttings, care should be taken not to deplete the gene pool in cultivation. Cuttings derived from robust wild trees should be used, as their survival probabilities are greatest. It may prove feasible to plant cuttings near where they were taken. Site selection for plantings will depend on information obtained through research (tasks 21., 41.). The first transplant sites should be easily accessible to minimize the time needed to monitor or treat transplants.

72. Ensure proper management of reestablished torreya populations.
The status of the transplanted trees including growth, health, and reproduction must be monitored to assess the success of transplants and to predict where future planting would be successful. Protection from disease must be provided. All measures undertaken to conserve torreya habitat must be continued and periodically evaluated.

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PART III. IMPLEMENTATION SCHEDULE

Priorities in Column 4 of the following Implementation Schedule are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the forseeable future.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

GENERAL CATEGORIES FOR IMPLEMENTATION SCHEDULES

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

IMPLEMENTATION SCHEDULE

Florida Torreya (Recovery Priority #5)

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	FWS Division	Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/ Notes
M-3	Manage existing biological preserves	11	1	1 yr.	4	SE	City, COE, FDNR, TNC	5K			
M-3	Protect habitat from activities within preserves	111	1	Ongoing/ Continuous	4	SE	City, COE, FDNR, TNC	20K	20K	20K	
M-3	Protect habitat from activities outside preserves	112	1	Continuous	4	SE	City, COE, FDNR, TNC				
I-3	Determine protection strategies for habitat outside preserves	12	1	1-3 yrs.	4	SE	FDNR, TNC, GDNR	5K			
M-3 A-1,6	Implement protection measures	121	1	Continuous	4	SE	FDNR, Indiv., TNC, GDNR				
R-11	Identify pathogen(s) responsible for the decline	21	1	2-10 yrs.	4	SE	FDPI, Univ.	5K	5K	5K	
R-6	Experiments in disease management in mature cultivated specimens	22	2	Continuous	4	SE	FDNR	5K	5K	5K	

IMPLEMENTATION SCHEDULE

Florida torreya

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	Responsible Agency: FWS Division	Responsible Agency: Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/ Notes
R-6	Conduct tests of culture regimens	221	2	3-5 yrs.	4	SE	FDNR	2.5K	2.5K	2.5K	
R-3	Investigate mycorrhizal relations	222	2	2 yrs.	4	SE	Univ., USDA	2.5K	2.5K		Univ. of GA has mycorrhizal research facility
R-11	Develop protocol for blight control experiments on seedlings and cuttings	23	3	1 yr.	4	SE	FDNR	2.5K			
M-6	Maintain good sanitation on cultivated trees	24	2	Continuous	4	SE	FDNR, Indiv.				
M-6	Water, cut back, and/or transplant trees on dry sites	25	3	Ongoing	4	SE	FDNR				
M-1	Locate seed-bearing cultivated trees	3111	3	1-2 yrs.	4	SE	CPC, FDNR, Indiv., GDNR				
M-5	Protect seed from frugivores	3112	3	2-10 yrs.	4	SE	FDNR, GDNR				

IMPLEMENTATION SCHEDULE

Florida torreya

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	FWS Division	Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/ Notes
M-5	Cover trees	31121	3	1-10 yrs.	4	SE	FDNR				
R-9	Experiment with rodent repellants	31122	3	1-2 yrs.	4	SE	FDNR	2.5K			
M-2	Harvest cultivated seed	3113	3	2-10 yrs.	4	SE	CPC, FDNR				
I-1	Search for seed-bearing wild trees	3121	2	2-4 yrs.	4	SE	FDNR, TNC, GDNR	5K	5K	5K	
M-1	Harvest seed from wild trees	3122	2	1-10 yrs.	4	SE	FDNR TNC, GDNR				
M-1	Arrange seed exchange	321	2	2-5 yrs.	4	SE	CPC, GDNR				
M-1	Establish seedling production programs	322	2	2-5 yrs.	4	SE	CPC				
M-1	Obtain and grow seeds at Maclay	3221	2	Contin.	4	SE	CPC, FDNR	2.5K	2.5K	2.5K	
M-1	Assess results	32211	2	Annually	4	SE	FDNR				

IMPLEMENTATION SCHEDULE

Florida torreya

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Division	Responsible Agency Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	Comments/ Notes
M-1	Initiate other programs	3222	2	1-5 yrs.	4	SE	CPC	2.5K	2.5K	2.5K	
M-1	Enlist institutions	32221	2	1-5 yrs.	4	SE	CPC				
M-1	Arrange cooperation among individuals	32222	3	1-5 yrs.	4	SE	Indiv., GDNR				
M-1	Establish program to obtain cuttings	331	1	1 yr.	4	SE	CPC, FDNR, TNC, GDNR	1.5K			
M-1	Establish cuttings	332	1	3-10 yrs.	4	SE	CPC, FDNR, GDNR	2.5K	2.5K	2.5K	
I-7	Conduct grafting experiments	34	3	5 yrs.	4	SE	FDNR				
I-1	Investigate ecological requirement	4	2	1 yr.	4	SE	CPC, FDNR, TNC				
R-3,11	Study the ecological physiology of torreya	41	3	2 yrs.	4	SE	Univ.				
I-1	Evaluate the native habitat	42	3	2 yrs.	4	SE	FDNR, TNC, Univ., GDNR	2.5K	2.5K	2.5K	

IMPLEMENTATION SCHEDULE

Florida torreya

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	Responsible Agency: FWS Division	Responsible Agency: Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/ Notes
I-1	Describe climate and neighboring vegetation of healthy cultivated trees	43	3	1 yr.	4	SE	CPC, GDNR				
R-6	Study population dynamics	44	3	Unknown	4	SE	GDNR, Univ.				
M-1	Establish experim. collections outside native habitat	5	1	Ongoing/ Continuous	4	SE	CPC, FDNR, GDNR	3K	3K	3K	
I-1	Inventory plantings at botanical gardens	51	2	1 yr.	4	SE	CPC, GDNR				
M-2	Supplement existing plantings	52	2	1-10 yrs.	4	SE	CPC				
M-2	Establish new plantings	53	2	1-10 yrs.	4	SE	CPC				
M-1	Place seed in long term storage	6	2	Ongoing	4	SE	CPC, USDA				
M-2	Reestablish torreya in its native habitat	7	2	10 yrs.	4	SE	FDNR, TNC, GDNR				

IMPLEMENTATION SCHEDULE

Florida torreya

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Division	Responsible Agency Other	Estimated Fiscal Year Costs FY 1	Estimated Fiscal Year Costs FY 2	Estimated Fiscal Year Costs FY 3	Comments/ Notes

LIST OF ABBREVIATIONS

City = City of Chattahoochee, FL.
COE = U.S. Army Corps of Engineers.
CPC = The Center for Plant Conservation, including member botanical gardens.
FDNR = Florida Department of Natural Resources, Division of Recreation and Parks.
FDPI = Florida Division of Plant Industry, Department of Agriculture and Consumer Services.
GDNR = Georgia Department of Natural Resources
Indiv. = Individuals/Landowners.
SE = Endangered Species Program, U.S. Fish and Wildlife Service.
TNC = The Nature Conservancy.
Univ. = Universities.
USDA = U.S. Department of Agriculture.

APPENDIX A

Methods for Germinating and Growing Florida Torreya Seeds

Torreya taxifolia has been successfully propagated from seed by a number of individuals and organizations, apparently including Callaway Gardens (Barrick 1985), Tom Dodd Nurseries, Inc., of Semmes, Ala. (Weidner 1985), Mr. Harry Seaman of Poplar Mount Farms, Henderson (Norlina), N.C., and Mr. Burl Turnage of Columbus, Ga. (Turnage 1985). Several procedures have been proposed for germinating *Torreya* seeds (Barnes 1983b, 1984, Turnage 1983, Meyer 1981). Most state that warm (possibly about 70 F) moist conditions after ripening of the seeds, followed by at least one cold stratification (moist-chilling at roughly 40 F) is essential (Barnes 1983b, 1985). But Turnage (1983) reported greater success in germinating *Torreya* seed outdoors, exposed to the elements on the ground. Seeds which he cold-stratified invariably rotted, so he concluded that a six-month period of "dry stratification" was preferable. Others have reported occasional rotting among cold stratified seeds, and have suggested that this could be reduced by treating seeds with fungicides or by acid scarification (Bowden 1981; Barnes 1983b). At Maclay Gardens, "very dry" seeds planted in outdoor seed beds all failed to germinate (Bowden 1981). Apparently Florida torreya seeds have narrow moisture tolerance limits. If seeds are too dry or wet, they become inviable or they rot. Embryo culture suggests that more careful study of changes in gibberelic acid, cytokinins, and inhibitor(s) is justified. Changes in these substances and abscisic acid may be involved in dormancy. Under natural conditions, torreya seeds are generally exposed to 2-3 months of warm fall weather followed by 2-3 months of cool to cold wet winter weather, and then a warm spring. Some seeds germinate during their first spring, but most germinate after a second or third year, so a long warm stratification may be more important than cold. The warm stratification requirement may be as much as 6 months, as is the case for *T. californica*. The long warm stratification period preceeding cold treatment may be required to overcome a second dormancy block (Barnes 1985).

Germination can be speeded up by various pre-treatments. Gently cracking the distal end of the hard metacarpal (seed coat) with pliers should increase water absorption and embryo development (Bowden 1981). This technique has been demonstrated with seeds of the cycad *Zamia*, which has a similar hard seed coat (Smith 1978). Acid scarification may be a better technique, because it is less likely to allow entry of seed rotting microbes (Barnes 1985). Acid scarification and treatment with growth stimulants reduced the germination period for Zamia seeds and increased the proportion of germinating seeds at most levels tested (Dehgan and Johnson 1983; Dehgan and Schutzman 1983). Preliminary experiments on torreya (Barnes 1984) have provided little information because of the small number of seeds tested. The following germination procedures can be tried:

1) Remove fleshy aril from all seeds.

2) Randomly divide seeds into nine groups:
   - a) 3 month warm moist stratification followed by 3 month cool, moist stratification, then sow.
   - b) 6 month warm stratification, then sow.
   - c) Sow directly into an outdoor seedbed.
   - d-f) Same as a-c, but acid scarified with dilute acid.
   - g-i) Same as a-c, but distal end of metacarpal gently cracked with pliers. In this case, treat the seeds with fungicide and pasteurize the germination medium.

3) The stratification medium will be a 1:1 mixture of Canadian peat and coarse sand, treated with a fungicide combination of Zyban and Benomyl.
4) Groups of seeds should be containerized in distinctively marked plastic pots or bags and explicit records maintained.
5) Warm stratification containers should be placed in the greenhouse under dense shade and maintained at 55-65°F for 4 to 8 months.
6) Cold stratification should be placed in a refrigerator set at 35-40°F (or a typical winter temperature for the Apalachicola Bluffs) in one cup of medium, with enough water added so the medium is just moist enough to form a "ball" when squeezed, but no wetter.
7) Pots should be placed under dense shade cloth with intermittent mist or covered with a moist cloth in the greenhouse; care must be taken to keep the seeds from getting too wet.
8) Seeds in containers should be inspected monthly for signs of rot and tested in water for viability (viable seeds are firm and sink in water; rotten seeds are soft and squeezable).
9) The outdoor seed bed will be located in moderate shade. The seedbed needs a secure wire mesh top. It will be inspected monthly for germination.
10) For each group of seeds, the percentage of germination and the average period of germination should be determined, and statistical comparisons made among the groups. Germinating seeds should be transferred into 0.5 to 1.0 gallon pots with sterile medium (see above) and maintained under dense shade and uniformly moist conditions in the greenhouse. If sufficient seedlings are available, they should be tested for fungus control (see 22. in

the main text). Seedlings should remain in the greenhouse for 3-5 years, or until 18-24 inches tall, with a good root system in a 1 gallon or larger container when they may be planted in forest land or another suitable site. The locations of transplanted trees will be mapped.

APPENDIX B

Methods for Cutting Propagation

Cuttings can be collected from late December to February, should be 10-15 cm. long, and relatively free of fungal blight infections. When possible, cuttings should be taken from basal sprouts or apical shoots with a spiral leaf arrangement so that upright growth can be expected (Barnes 1983b, Turnage 1983). Rooted horizontal (plagiotropic) branches may, however, be useful as pollen or seed sources (Barnes 1985b).

From each cutting, remove the leaves from the lower 5-7 cm., then lightly scrape bark away with a razor along two sides of the lower 2 cm of the cutting to expose the light green cambium. Too much scarring causes excessive callus to develop. Next, the basal cut and scarred area should be "quick-dipped" for 10 seconds in 4000-8000 mg/l IBA (indole butinoic acid) in 20% ethyl alchohol and fungicide solution, and then placed 5 cm deep in flats or individually labeled containers with a rooting medium of 1:1 vermiculite and perlite by volume. Potted cuttings should be placed under 50-80% shade cloth and intermittent mist (5 sec every 2 min) during daylight hours. Excessive leaching of cuttings under intermittent misting should be avoided. Bottom heat (28 C) can be provided. Cuttings may be repotted after 2-5 or more roots develop. At this point, rooted cuttings have only grown at most one flush of growth. Cuttings, like seedlings, can be placed under the same experimental protocols as seedlings.

APPENDIX C

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