Assisted Migration for a

Bring *Torreya taxifolia* North—Now

by Connie Barlow and Paul S. Martin

Torreya taxifolia (often referred to as T. tax or Florida torreya) is an evergreen conifer tree historically found only along a short stretch of the Apalachicola River of northern Florida and the adjacent sliver of southern Georgia. It favors the cool and shady ravines that dissect the high bluffs of the river's east shore. Despite its current extreme endemism, the species was once a prominent mid- and under-story member of its forest community, which includes an odd mix of northern and southern species: towering beech and hickory next to tall evergreen magnolia, and surrounded by stubby needle palm.

In the 1950s, the species suffered a catastrophic decline, the ultimate cause of which is still unexplained. By the mid-1960s, no large adult specimens—which once measured more than a meter in circumference and perhaps 20 meters tall—remained in the wild, felled by what seemed to be a variety of fungal pathogens. Today, the wild population persists as mere stump sprouts, cyclically dying back at the sapling stage, such that seeds are rarely, if ever, produced. T. tax thus joins American chestnut in maintaining only a juvenile and diminishing presence in its current range.

A 1997 Nature Conservancy pamphlet introduces *Torreya taxifolia* as "the world's most endangered conifer." It is no surprise that the Florida chapter of the Nature Conservancy, the State of Florida through Torreya State Park, a number of botanical gardens, and dispersed academic researchers are all actively involved in trying to restore this tree—guided by a U.S. Fish and Wildlife Service recovery plan pursuant to the Endangered Species Act.

Some, like Mark Schwartz and others, maintain hope for recovering T. tax in reproducing, self-maintaining populations in its current range. Since 1997, staff at the Atlanta Botanical Garden have been experimentally taking healthy T. tax grown from seed at the garden and planting these trees at the periphery of the existing range and somewhat further north in Georgia. The efficacy of applying fungicides and supplemental fertilizers to these transplants is now also being tested. The transplants are all progeny of "potted orchards" established from cuttings taken from wild specimens in Florida in November 1989.

Another *Torreya* expert, Rob Nicholson, conservatory manager at the Botanic Garden of Smith College in Northampton, Massachusetts, participated in the 1989 salvage of wild genotypes and their propagation as clonal stock. Nicholson presents a less hopeful view of resurrecting a healthy and self-maintaining population of T. tax in its current range. He writes:

> Mature trees in cultivation outside of Florida may number less than two dozen. At the beginning of the twentieth century, there were wild populations of *Torreya taxifolia* estimated at about 300,000 to 600,000. The estimated number of plants in the original habitat is about 500, which means that 99.3 to 99.6% of the population found at the beginning of the 1900s has died. Where 60-foot trees were formerly found, few individuals over 10 feet are now known. Although research into the cause of this decline is ongoing, *in situ* preservation appears problematic, and management efforts now include the propagation of rooted cuttings from documented wild stands to be grown in *ex situ* populations.

Many botanists and climate specialists agree that at some point in the future, human-induced global warming will push many plants to the edge of viability; at that time, "assisted migration" (a term coined by Brian Keel, 2004) may be the only stay against extinction. We believe T. tax is already at that juncture. In a 1990 article, Rob Nicholson speculated, "Is *Torreya* an early victim of global warming and a precursor of a new wave of inexplicable extinctions?" We ask: Why wait

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until a hundred species are on the brink? Rather, let us undertake assisted migration for *Torreya taxifolia* today, in part, as a trial run for the decades to come. With Florida torreya we can explore the ecological and social dimensions of what seems likely to be a radically new era for plant conservation.

Moving endangered plants: Easy, legal, and cheap

Assisted migration as a conservation tool is both fascinating and frightening for anyone focused on plants. It is fascinating because endangered plants can be planted by whoever so chooses, with no governmental oversight or prohibitions—provided that private seed stock is available and that one or more private landowners volunteer suitable acreage toward this end. This cheap-and-easy route for helping imperiled plants is in stark contrast to the high-profile, high-cost, and governmentally complicated range recovery programs ongoing for highly mobile animals, such as the gray wolf, lynx, and California condor.

Assisted migration frightens for precisely the same reasons it fascinates: anybody can do it, for good or ill, and with care or abandon. Its promotion could undermine decades of public education about the dangers of non-native plants, as well as more recent efforts to promote the concept of wildlands corridors and connectivity. Still, in an age of deforestation, severe habitat fragmentation, and rapid global warming, assisted migration as a plant conservation tool should not be ignored. As Peter Wharton, curator of the Asian Garden of the University of British Columbia Botanical Garden writes, "The *Torreya* question is a door to immense issues relating to how we facilitate global 'floraforming' of vegetational zones in a warming world. It is another layer of responsibility for those of us who have a passion for forests and wish to promote the ecologically sensitive reforestation of so many degraded forest ecosystems worldwide."

We are proposing test plantings of T. tax, using privately available seed stock, onto forested private lands of the southern Appalachians and Cumberland Plateau. Mark Schwartz and others who know the tree through years of professional engagement agree that it is very unlikely to become noxious in recipient ecosystems to the north. T. tax might, in fact, serve an ecological function similar to that of eastern hemlock: providing evergreen shade along streams and streamlets within deciduous forests. Overall, the ecological interactivity (for good or ill) of T. tax in recipient ecosystems will become apparent only when test plantings in natural forest habitats to the north are carried out and monitored.

In North Carolina, there is already evidence that Florida torreya is both benign and thriving. In 1939, Chauncey Beadle collected about a dozen specimens of T. tax from the Apalachicola and planted them along a streamlet as part of a grove of open pine forest within the vast holdings of the Biltmore Gardens in Asheville (elevation 2200 feet). Interestingly, today, hemlock is prominent on the north-facing slope of this slight ravine, and all the *Torreya* specimens (including self-propagated saplings, probably planted by squirrels) occur and are thriving on the south-facing slope. As to *Torreya*'s cold-hardiness, Bill Alexander, forest historian at the Biltmore Gardens, reports that in the winter of 1985 all *Torreya* specimens survived unharmed an episode of unusual cold; temperatures plunged to minus 16° Fahrenheit.

Rewilding and deep time

Thus far, the arguments we have made in favor of assisted migration for *Torreya taxifolia* are grounded entirely in an ethic of biodiversity preservation: T. tax is in deep trouble in its historic native range, so let's give it a chance to establish in cooler realms. Biodiversity preservation is not, however, the only environmental ethic that should guide conservation choices. Increasingly, "rewilding" (Soulé and Noss 1998, Barlow 1999, Foreman 2004) is a powerful motivator. According to this standard, a network of "potted orchards" of T. tax tended in northern botanical gardens, though a good hedge against outright extinction, falls far short of the mark—potted is the botanical equivalent of caged.

Might it be possible for T. tax to take its place once again as a thriving member of some subset of Appalachian forest communities? We say *again* because we believe that northern Florida is more properly viewed not as native range for T. tax but as peak-glacial range. Helping T. tax establish in the southern Appalachians is thus not so much relocation for a plant struggling with global warming as repatriation of a once-native. It is a form of rewilding that uses a deep-time baseline for determining appropriate range.

Torreya is a member of the ancient gymnosperm family Taxaceae, whose ancestors were evolutionarily distinct from other conifers by the Jurassic, some 200 million years ago. Because *Torreya* pollen is indistinguishable from the pollen of yews (*Taxus*), bald cypress (*Taxodium*), and cypress (*Cupressus*), known fossil occurrences of this genus are limited to macrofossils (seeds, leaves, and secondary wood), and these are sparse. There are no known Cenozoic fossils of *Torreya* in eastern North America. The most recent macrofossils identified as the genus *Torreya* in eastern North America are upper Cretaceous, and these were unearthed in North Carolina and Georgia—hence, our suggestion that assisting T. tax to rewild in North Carolina would be assisting the return of a deep-time native.

Because worldwide climate during the Cretaceous was much warmer and far less seasonal than that of today, it is not surprising that *Torreya* macrofossils of Cretaceous age have also turned up along the Yukon River of Alaska. In western North America, there is Cenozoic fossil evidence of genus *Torreya* in the John Day region of Oregon (lower Eocene) and variously in California (Oligocene and late Pleistocene). Today, the genus is highly disjunct. *Torreya californica* survives as a rare tree, locally abundant in a score of isolated populations within the coastal mountains of central and northern California and on the west slope of the Sierras. It favors moist canyons and mid-slope streamsides, growing beneath a canopy of taller conifers and deciduous trees. *Torreya nucifera* is found in mountain habitats of Japan and Korea, and four other species of genus *Torreya* inhabit mountainous regions of China. We would not be surprised if one day a remnant grove of *Torreya* were discovered in the mountains of northeastern Mexico, in patches of mesic forest that still support sweet gum, beech, and yew (Martin 1957). *Torreya taxifolia* is the only one of the six known species that is highly imperiled, and we believe we know why.

Near-time obstacles to natural migration

Torreya taxifolia is a glacial relict, left behind in its pocket reserve of rich soils and cool, moist microclimates afforded by ravines along the east shore of the Apalachicola River. The current richness of North America's deciduous forests is, in large part, thanks to this and other glacial refuges—including the Tunica Hills of Louisiana and the Altamaha River of southeastern Georgia (Delcourt 2002). For some of the repatriated plants, relict populations still remain in one or more of these refugia, while the bulk of the range is disjunct much farther north—beech is a notable example. We infer that T. tax was unable to follow the other plant refugees north when the ice retreated, beginning some 15,000 years ago.

Consider that the last interglacial—110,000 to 140,000 years ago and preceded by many others of equal magnitude—peaked at a global temperature not much different from that of today. If *Torreya* is having trouble surviving in northern Florida now, it should also have had trouble in multiple interglacials. So what makes our own interglacial uniquely inhospitable for natural migration? There are two significant differences between this interglacial and the previous ones that could have posed grave problems for *Torreya*, and together they could have sealed the fate of this botanical refugee.

One difference is that our current interglacial is uniquely understocked in large herbivorous mammals, both in diversity and in numbers. By 10,000 years ago, the mastodons, the mammoths, the giant ground sloths, and other mammals that powerfully affected vegetation had vanished. Notably, we lost all our big browsers. Small trees would have been left untoppled by elephants; saplings and shrubs gone uneaten. Overall, the landscape would have become brushier, and thus more susceptible to fires reaching beyond the fire-adapted pinelands of sandy flats into the moist ravines through which fire-intolerant *Torreya* would have been edging north (Robinson 2003).

A second difference between this interglacial and the previous is that only in the current interglacial has North America been home to a creature that can make fire on demand. Indeed, the migration of humans into North America is evidently the cause of the coinciding loss of megafauna by overkill (Martin and Klein 1984). Near the onset of the present interglacial, the first paleoindians arrived. Both accidentally and intentionally, and for thousands of years, wildfires would have been ignited to favor plant species that provided food (the acorns of oaks), to make land easier and safer to cross, to flush out game, and to lure game animals to patches of abundant new growth. This scenario may partially account not only for the suppression of *Torreya* (and Florida yew) but also for the extinction of a recently described new species of spruce, *Picea critchfieldii*. Late Pleistocene extinctions of plants, to match the devastation suffered by large mammals, are otherwise unknown.

There is yet a third way in which humans might have stressed local populations of T. tax in near time. The dispersal agents upon which T. tax depended for movement of its large, fleshy seed—squirrels, and perhaps also tortoises—would likely have been severely reduced in numbers, even extirpated, as these creatures are attractive foods, safely and easily killed by people (Barlow 2001, Martin and Szuter 1999).

T. tax may thus have been a victim of contact, relegated to a short stretch of moist, riverside ravines by anthropogenic loss of big browsers, anthropogenic and natural fires, and anthropogenic extirpations of seed dispersers. If these are indeed the causes of T. tax's troubles, then why have the other species of genus *Torreya* been spared? The other species did not have to move hundreds of kilometers north in order to keep pace with a warming climate. Rather, they shifted their ranges hundreds of meters upslope. Thus we believe that topographical differences are at cause.

Torreya californica resides in shady ravines and rocky gorges in isolated pockets of the Coast Range and the west slope of the Sierras, between 1000 and 2500 meters elevation. In China, *T. grandis* is found in mountain habitats of seven provinces, often alongside streams, at an elevational range of 200–1400 meters; it is common enough that the wood is used commercially. *T. fargesii* is also found in seven provinces, but at higher altitudes, 1000–3400 meters. The only Chinese species listed as "vulnerable" is *T. jackii*, which occurs in three provinces at an altitudinal range of 400 to 1000 meters. *Torreya nucifera* is found in mountainous terrain of Korea and Japan; more than 2500 ancient specimens of *T. nucifera* (500 to 800 years old), with trunks up to 1.4 meters in diameter and heights up to 14 meters, still survive in the wild in Korea's Pija-Rim National Park. For Florida torreya, in contrast, a journey of 400 kilometers (as the crow flies; far more as the ravine meanders) would have been required before it could take advantage of the quick elevational gain that mountains afford in a warming climate.

One final note in the story: because some other glacial refugees of eastern North America had to make do with mountainless terrain, *Torreya* was not alone in its troubles. Severe endemism of the Florida yew (*Taxus floridiana*, also only along the Apalachicola River), historic extirpation in the Altamaha of America's only big-blossomed relative of Asian camellia (*Franklinia*), and extinction in "near time" (that is, after paleoindian arrival) of the once-widespread Critchfield spruce may all be attributed to the advent of the fire-makers (Martin, in press). Given the sequence of loss in their pocket reserves, it would seem that Critchfield spruce was the least heat- and drought-tolerant of the bunch, followed by *Franklinia*, which now thrives in cultivation in the mid-Atlantic states. Next comes T. tax, followed by Florida yew, which is not yet sickly in its Florida refuge but is doing a poor job of reproducing.

"Left behind in near time" may thus be a syndrome that applies to a number of extinct, imperiled, and soon-to-be-imperiled plants, and perhaps to small, isolated populations of species that are not themselves in danger of extinction. How might this awareness alter our conservation options as climate shifts? By assisting the migration of *Torreya taxifolia* now, we can help to shape a better next chapter for this beleaguered tree and, perhaps, many other plants.

Let's get started

The first opportunity to begin collecting T. tax seed at the Biltmore Gardens of Asheville (supervised by the Biltmore's Bill Alexander and local activist Lee Barnes) will be autumn 2005. Those who would volunteer their time, their students, or their forested properties in this historic effort to rewild T. tax—and thus to test the efficacy and pitfalls of the first intentional assisted migration of an imperiled plant in a warming world—are encouraged to visit www.TorreyaGuardians.org. ☾

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