# Assisted Migration for an Endangered Tree

## 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.

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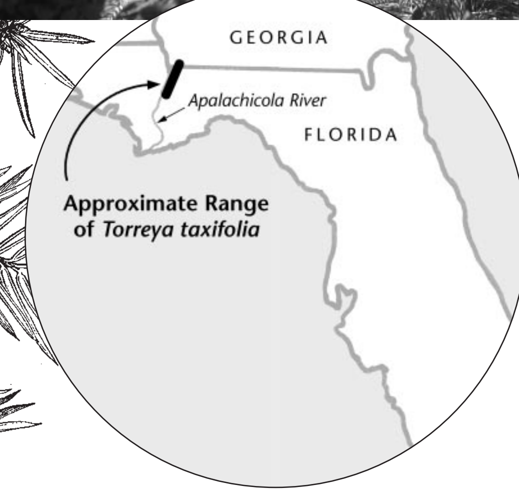
CONNIE BARLOW

*T. taxifolia*, engraving ca. 1900




## Conservationists Should Not Move *Torreya taxifolia*

**by Mark Schwartz**

IN 1988, I BEGAN a long-term study of the Florida torreya (*Torreya taxifolia*). I have followed natural populations across their distribution for more than 15 years and have, from the start, been focused on conservation efforts for this critically endangered coniferous tree. Rob Nicholson and I collected the material from approximately 150 trees that now constitute our *ex situ* plant material. My research has been focused on determining whether there is genetic differentiation across the distribution, understanding the magnitude of the population decline, understanding disease factors, and predicting the likelihood that the species will recover.

During this period, there have been occasional efforts to transplant the species northward on behalf of conservation. One justification for northward introduction may be that the population has suffered from disease within its current distribution and thus a northward movement may allow it to escape its pathogens. This justification is somewhat weak as current individuals do not appear to be overly susceptible to any particular disease, although the population is not recovering from a previous decline. Further, since the disease agent responsible for the original decline is a matter of conjecture, it is not clear what Florida torreya would be escaping from, nor where it should go. In short, I am skeptical of the disease escape arguments as we are, at present, unclear of the cul-

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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 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**

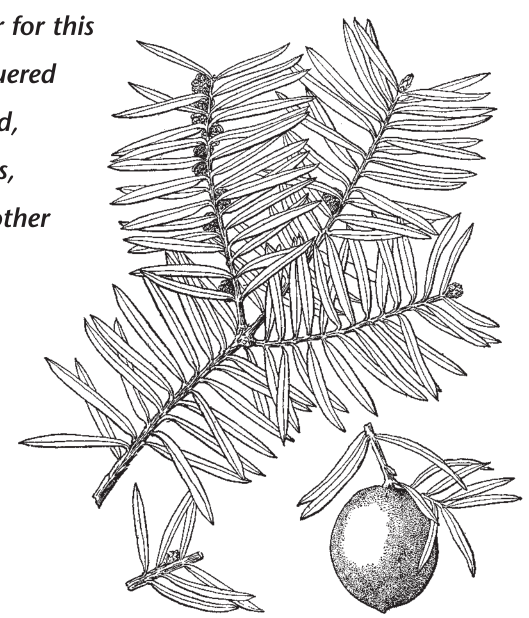
Assisted migration as a conservation tool is both fascinating and frightening for anyone focused on plants. It is fascinating because endangered plants can be planted by whoever so chooses, with no governmental oversight or prohibitions—provided that private seed stock is available and that one or more 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.

***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.***



*T. taxifolia*, engraving ca. 1900



**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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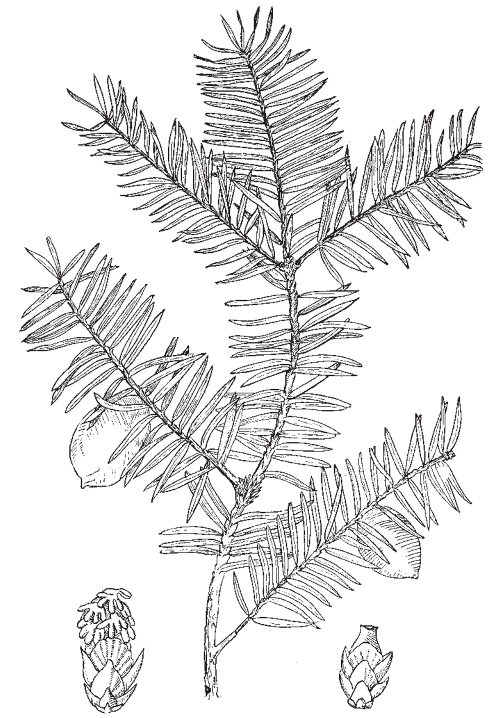

*T. taxifolia,* engraving ca. 1900

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prit and thus the tree is not assured of any relief to the north.

Another rationale for northward introduction is that the species likely existed further north at some time in the past, although not during the current 10,000-year interglacial, and that it is more suited to a cooler climate. Range expansion efforts have begun with the assumption that the reason that the species declined to near extinction is at least partially because the species is trapped in a current distribution that is too far south, too warm, and that the species is now unable to disperse further north, where it is more climatically suited. Thus, the reasoning goes, if we assist migration northward, the species is likely to thrive, thereby assuring the persistence of one of this continent's most distinctive conifers. Based on my reading, research, and personal experience I find some merit in this argument; *Torreya taxifolia* is a glacial relict, quite likely on the edge of its climatic tolerance, and might do well in a cooler climate.

Recent research on global warming provides predictions of rates of tree species range shifts—driven by future climate change—and estimates the ability of tree species to migrate to new distributions (Iverson et al. 2003). One of the findings is that many species with narrow distributions, such as the Florida torreya, are projected to have future distributions that are wholly disjunct from their current distributions. In other words, global warming can put species in jeopardy as a consequence of disassociating the current distribution of a species from what we currently understand to be its envelope of appropriate climate (Schwartz 1992). If these climate-limited species fail to migrate, they can go extinct (Hannah et al. 2002, Midgley et al. 2003). In North America, Florida torreya, a trapped glacial relict, seems a plausible case for such a fate. In addition, this line of thinking goes, we are likely to witness more potential cases in the future as the climate warms, habitats are fragmented, and existing corridors are insufficient to allow species to move northward at a sufficiently rapid rate (Thomas et al. 2004).

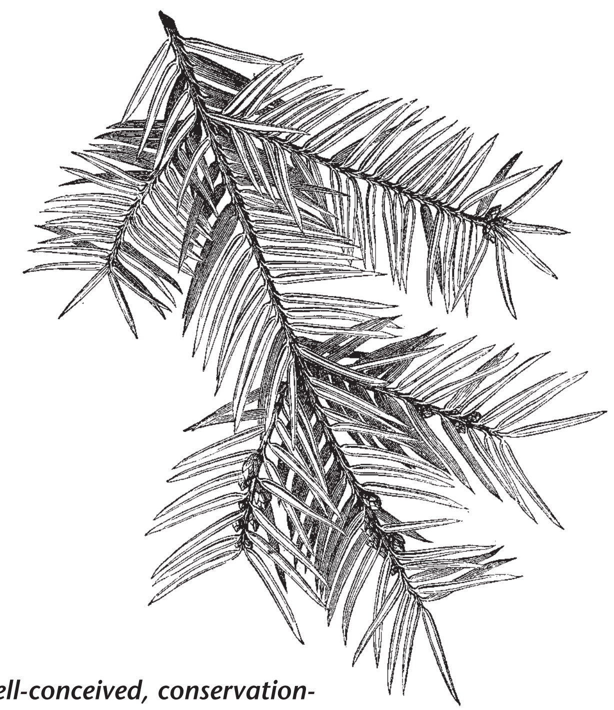
So why, then, am I opposed to assisted migration for Florida torreya and other similar cases? One reason, unfortunately, is that the arguments about range and climate rely on very important assumptions that are not well justified. We usually do not have empirical data from which to judge whether narrowly distributed species are, as assumed, limited by climate and not other environmental factors, such as soils and disturbance regimes. As a consequence, I believe that we should exercise caution.

There is another, more important reason why assisted migration must be a management option of last resort. My logic is simple and based not on the biology of the target species, in this case Florida torreya, but on conservation concerns of the recipient ecosystem. Humanity has a long record of tinkering with natural ecosystems. Largely these have been successful from the perspective of the human endeavor—think agriculture. This tinkering, however, creates a series of ancillary non-target biological winners and losers. It has been argued that the majority of species introduced have had little effect on ecosystem structure, and most introductions do not cause undue ecological damage (Mack et al. 2000). Nevertheless, those few cases where introduced populations rapidly expand and threaten to endanger other species or damage ecosystems and ecosystem functions cost the U.S. billions of dollars each year (U.S. Congress 1993, Pimentel et al. 2000). As a consequence, I believe that conservationists should be very reticent about introducing species to novel environments as a conservation measure. Societal recognition of an appropriate reticence toward species introductions has been slow, but is emerging (Mack et al. 2000). If we are to now advocate species introductions on behalf of conservation, conservationists must have clear guidance as to when this action is warranted and when it is not. It is not an action to be taken lightly.

Assisted migration implies that we do not recognize the target species as native to the newly introduced locale. Local conservationists must then reconcile themselves as recipients of this novel species in their midst. In most cases we use historical records to establish a baseline forest community toward which we manage our current forests. Certainly, we do not want to return to a static view of forests and manage our natural lands as museum pieces, but then again we would like to retain an historical basis for the range of variability in composition of plant communities that are representative of the habitats we are trying to conserve (Landres et al. 1999). Without a baseline we have no target. Without a target, every kind of management, including those that result in lost native species, is arguably a success. I fear such success. Intentional introduction of species outside their current distributions in an effort to conserve them detracts from and trivializes this baseline and threatens to discount standards for conservation. From a visceral level, it seems likely that a range of people would say: Florida torreya has no place in southern Appalachian cove forests. As a consequence, assisted migration should, and will, result in rancor among conservationists. This rancor does not serve conservation.

Novel species becoming out of control is an issue of concern with assisted migration. An example of conservation tinkering gone awry comes from Newfoundland. Pine martens were not doing well, and it was thought that by augmenting their diet by introducing red squirrels, the population might do better. Red squirrels were introduced in 1963 (Benkman 1993). The squirrels and crossbills competed for black spruce cones as a primary food source. A by-product of the squirrel introduction was the dramatic decline and now presumed extinction of the Newfoundland sub-species of the red crossbill (Parchman and Benkman 2002). Well-conceived, conservation-minded introductions have unintended negative ecological consequences. Thus, we must be cautious in our enthusiasm to assist species that are in trouble.

The likelihood of *Torreya taxifolia* expanding out of control is low. Florida torreya is a slow growing, shade-tolerant, dioecious tree that requires relatively large canopy gaps for successful recruitment. The species does not spread clonally and the relatively few seeds that trees produce are a favorite food of squirrels. The tree carries all of the attributes of a species that will not spread and become a noxious weed. Nevertheless, assisted migration sets a risky precedent. Will control assurances and monitoring of problems be followed for future species that are deemed to be in need of assisted migration? I fear not. Thus, it is critical that we take a hard look at what criteria are to be used to justify assisted migration and develop guidelines for appropriate assisted migration in order to preserve biological diversity.



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I share with others the dedication to favoring the preservation of biodiversity over the preservation of historical examples of what we perceive as natural communities. But conservationists must also be reluctant to advocate ecological tinkering. I would advocate assisted migration for plants only when there is a clearly imminent extinction risk. Some believe the Florida torreya is such a case. There are probably fewer than 1000 individuals extant in the current distribution and the numbers are dwindling (Schwartz et al. 2000a). At last count, there is a single known individual that is producing seeds in the wild (personal observation). Aside from this one individual and the approximately eight seeds it has produced, there has been no observed seedling recruitment for at least 20, and probably 40, years. The situation, indeed, seems critical. Nevertheless, our population modeling suggests that the species retains a very high probability of remaining extant for the next 50 years (Schwartz et al. 2000b). Further, there are no current disease symptoms that suggest that an augmentation of the population within its native distribution would not succeed. The germplasm currently housed in botanical gardens of the southeast could be used to augment natural populations. Local population augmentation of Florida torreya has not been adequately explored. All local options for conservation must be exhausted prior to assisted migration. Florida torreya fails this simple criterion.

The reality of the situation, however, bears mentioning: anyone who wants to plant Florida torreya can do so—wherever they want. The ownership and movement of plants are very loosely regulated. The species is commercially available in South Carolina. Anyone is free to venture to a dealer, buy the plant, and introduce it to their property. This is perfectly legal. Thus, 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.

In fact, Florida torreya has already been moved northward in a test planting in northern Georgia. Florida torreya is a native plant of Georgia, but of the approximately 30 trees within the native Georgia distribution, all are within 200 meters of the Florida state line. Planting the tree in northern Georgia as a species native to the state is somewhat of a stretch; this is a northward expansion of more than 10 times the distribution breadth of the species in its native range. Some current assisted migration efforts would like to move the species northward further still, across state lines. This is the sort of effort that should begin with a dialogue with conservation organizations and leaders from the recipient location. In some cases, the result will be no assisted migration and extinction of species in the wild. For *Torreya taxifolia*, with an *ex situ* population in several botanic gardens, and some years before we lose the native population, now is the time to fully explore local solutions—that is, local population enhancement—before taking rash action. ☾

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