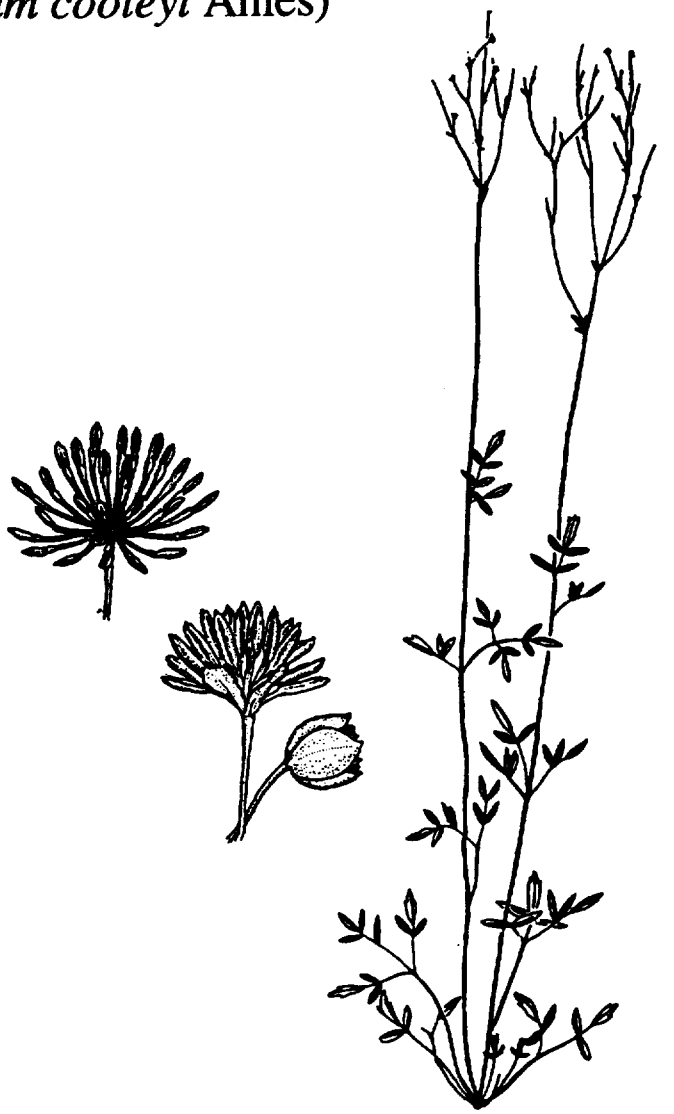
RECOVERY PLAN

Cooley's meadowrue

(*Thalictrum cooleyi* Ahles)



U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

RECOVERY PLAN

for

Cooley's Meadowrue (*Thalictrum cooleyi* Ahles)

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for

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Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Acknowledgment

The cover sketch of Cooley's meadowrue was done by freelance artist Susan Sizemore.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1994. Cooley's Meadowrue Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, GA. 29 pp.

Additional copies may be purchased from:

Fish and Wildlife Reference Service
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EXECUTIVE SUMMARY

Current Status: *Thalictrum cooleyi* Ahles is federally listed as an endangered species. It is currently known from 12 locations (11 in North Carolina and 1 in Florida); one possible population reported from Georgia has been identified as *T. revolutum*).

Habitat Requirements and Limiting Factors: This rare herb is typically found in wet pine savannas, grass-sedge bogs, and savannalike areas with circumneutral soils, in habitat kept open by frequent fire or other disturbance. It is threatened by habitat loss due to drainage, conversion to forestry, agriculture or development road building, and succession through fire suppression.

Recovery Objective: Delisting.

Recovery Criteria: Cooley's meadowrue will be considered for delisting when there are at least 16 self-sustaining populations that are protected to such a degree that the species no longer qualifies for protection under the Endangered Species Act.

Actions Needed:

1. Survey suitable habitat for additional populations.
2. Monitor and protect existing populations.
3. Conduct research on the biology of the species.
4. Establish new populations or rehabilitate marginal populations to the point where they are self-sustaining.
5. Investigate and conduct necessary management activities at all key sites.

Total Estimated Cost of Recovery ($000's): It is impossible to determine costs beyond estimates for the first few years' work.

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Total
1994	20.0	25.0	34.0	2.5	5.0	86.5
1995	10.0	22.5	18.0	22.5	5.0	78.0
1996	10.0	4.5	18.0	10.5	5.0	48.0
TOTAL	40.0	52.0	70.0	35.5	15.0	212.5

Date of Recovery: Impossible to determine at this time.

TABLE OF CONTENTS

	Page
PART I:	
INTRODUCTION	1
Background	1
Description	1
Current and Historic Distribution	3
Habitat	4
Life History and Ecology	6
Threats and Population Limiting Factors	9
Conservation Efforts	10
PART II:	
RECOVERY	11
A. Recovery Objectives	11
B. Narrative Outline	12
C. Literature Cited	19
PART III:	
IMPLEMENTATION SCHEDULE	21
PART IV:	
LIST OF REVIEWERS	24

PART I

INTRODUCTION

Background

Cooley's meadowrue (*Thalictrum cooleyi* Ahles, Ranunculaceae) is a rare perennial herb endemic to the Southeastern coastal plain; 11 populations occur in southeastern North Carolina and one occurs in the Florida panhandle. The herb grows in circumneutral soil in moist to wet savannas and savannalike areas kept open by frequent fire or other disturbance. *Thalictrum cooleyi* is particularly notable for its extremely high chromosome count and ploidy level. Due to its rarity and its vulnerability to habitat destruction and loss, the species was federally listed as endangered on March 9, 1989 (U.S. Fish and Wildlife Service [Service] 1989). Cooley's meadowrue is listed as endangered in North Carolina (Sutter 1990) and in Florida (Florida Natural Areas Inventory 1991). The Center for Plant Conservation ranks the species as a priority A taxon, one which "could become extinct within the next 5 years if no conservation efforts are implemented" (Peggy Olwell, Center for Plant Conservation, personal communication to Brian P. Cole [Service], 1992).

Description

General nontechnical description. Cooley's meadowrue is a tall herb (1 meter [m] or more in flower), with the slender stems erect in sunny locations to lax or sprawling in shade, leaves ternately divided (lower leaves usually subdivided). Leaflets are about 2 centimeters (cm) long, mostly narrow (four or more times as long as wide), with entire (untoothed) margins or rarely with two to three lobes near the tip. All parts of the plant are glabrous (smooth) and have virtually no hairs or glands. Male and female flowers are on separate plants, in loose few-flowered clusters, appearing at the top of the plants in late June to early July.

The flowers lack petals, and the sepals are small and fall early. The male flowers are conspicuous for their numerous pale lavender stamens, while the female flowers have several separate spindle-shaped carpels which develop into narrowly ellipsoid, ribbed, one-seeded fruits (achenes) 6 millimeters (mm) long, each tipped with a persistent linear style.

Technical Description. Kral (1983) gives this description of *Thalictrum cooleyi*:

> Perennial, smooth herb from a slender, erect caudex.
> Stems.-- Erect or leaning on other plants, slender, greenish, to 1 meter tall or slightly more, teretish but with a few low, minutely scabrid ridges.
> Leaves.-- Both basal and cauline, the lowermost cauline leaves and basal leaves petiolate, ternately compound, the

ultimate leaflets lanceolate to lance-linear or ovate (highly variable in shape and length), mostly 1-2(-5) cm long, 0.3-1.0 cm broad, the laterals nearly sessile or on slender petiolules to 5 mm long, the terminal one often longer-stalked, leaflet apices rounded to acute, the margins entire or (in the larger leaflets) often 1-3 lobed or with a strong pair of lateral teeth, the venation of larger leaflets ternate or subpalmate, the bases rounded or acute; larger petioles 0.4-1.0 decimeters (dm) long, ascending, slender but with broadly scarious-auriculate clasping bases; stem leaves progressively smaller, shorter-petioled, more distant upward on stems, in the inflorescence sessile or nearly so.
Inflorescence.-- Flowers few, in an open panicle on slender pedicels to 2 cm long.
Flowers.-- Regular, unisexual (the species is dioecious); sepals mostly obovate, 4-5, distinct, early deciduous, the staminate ones yellowish to white, ca. 2 mm long, broadly rounded or bluntly acute, apiculate, slightly longer than the greenish pistillate ones; petals absent; stamens with slightly clavate, lavender filaments ca. 5-7 mm long, the yellowish anthers ca. 2 mm long, apiculate; carpels several, fusiform, distinct, short-stipitate, many-ribbed, smooth save for the minutely hairy, linear stigmas.
Fruit.-- Achenes narrowly ellipsoidal, ca. 5-6 mm long, 1.5-2.5 mm wide, many-ribbed, the stigmas persisting, straight but bent somewhat inward at base.

Thalictrum cooleyi has a chromosome count of $2n = 210$, higher than any other species in the genus (the closest species are *T. revolutum* [$2n = 140$] and *T. pubescens* [$2n = 156$]) (Park 1992; Marilyn Park, Grand Valley State University, personal communication, 1992).

Steve Leonard (North Carolina Division of Soil and Water Conservation, personal communication, 1992) and Rome (1987) have pointed out that the species is rhizomatous.

In the original species description, Ahles (1959) distinguished *Thalictrum cooleyi* from similar species by its narrow leaflets, fewer leaf divisions, and lavender rather than white anther filaments. Filament color has proved to be indicative rather than definitive; it can vary in *T. cooleyi*, the color is lost on drying, and some other species occasionally have lavender filaments (Leonard, personal communication, 1992; Park, personal communication, 1992; Rayner 1980).

Field identification. Cooley's meadowrue resembles other species of *Thalictrum*, with its 1 to 2 times ternately compound leaves, the leaflets about 2 cm long, green, glabrous, more or less rounded at apex and base, with entire margins and rarely 2 to 3 apical lobes. In *Thalictrum cooleyi* and similar meadowrues, the inflorescence is paniculate (not umbellate), the flowers are imperfect, the leaflet or

lobe margins are not crenate, and flowering occurs in summer, not early spring. *Thalictrum cooleyi* is distinguished from other such members of the genus, *Thalictrum revolutum* in particular, by the combination of leaflet narrowness (4 to 26 times as long as wide), lack of lobing in the majority of the leaflets, and absence of hairs, glands, or papillae on lower leaflet surfaces, petioles, peduncles, and achenes (Park 1992).

Except in the smallest individuals, basal leaves of *Thalictrum cooleyi* are two (or more) times ternately compound. This degree of three-part division separates Cooley's meadowrue vegetatively from most other herbs with compound leaves.

According to Leonard (personal communication, 1992), Cooley's meadowrue plants growing in shade or with their bases shaded tend to have lax stems, membranous leaf texture, and relatively broader, frequently lobed leaflets, while plants in full sun have erect stems and tend toward more coriaceous leaflets which are narrow (linear to narrowly lanceolate) and unlobed. The linear leaflets and slender stems in a grassy habitat make the plant difficult to locate except when in flower.

Current and Historic Distribution

Current. Twelve populations of Cooley's meadowrue are known to exist (all verified since 1987). One of these, discovered by Godfrey in 1964, lost, then rediscovered in 1987, is in Walton County in northwestern Florida. The remaining 11 populations are found in two limited areas, 60 miles apart, in southeastern North Carolina (five sites within 8 miles of each other in Columbus and Brunswick counties and six sites within 4 miles of each other in Onslow and Pender Counties) (Leonard 1987). Most populations have 100 to 300 individuals, with the smallest population numbering 12 and the largest over 1,000.

Historic. Three historic North Carolina populations--Brunswick, Columbus, and Pender Counties--are assumed extirpated, because recent surveys showed habitat destruction at the sites and no plants were found (North Carolina Natural Heritage Program 1992). Cooley's meadowrue has been reported from New Hanover County, North Carolina (Radford *et al.* 1968), but without documentation.

South Carolina and Georgia. Searches by Rayner, Leonard, and others, in apparently suitable habitat in South Carolina, have failed to discover *Thalictrum cooleyi* in that State (Leonard, personal communication, 1992; Bert Pittman, South Carolina Nongame and Heritage Trust Program, personal communication, 1992).

One *Thalictrum* population in Worth County, Georgia, with narrow leaflets, originally identified as *T. subrotundum* (=*T. macrostylum* [Park 1992]), has been considered as possibly *T. cooleyi* (Tom Patrick, Georgia Natural Heritage Inventory, personal

communication, 1992) or a *T. cooleyi* X *T. revolutum* hybrid (Rayner 1980). Park (1992; personal communication, 1992) has concluded that, on the basis of leaf surface (glandular), habitat (atypical for *T. cooleyi*), and habit (erect in shade), the population belongs within *T. revolutum*, although she did not rule out the possibility of some degree of hybridization. A hybrid would indicate at least a historic occurrence of *T. cooleyi* in southwestern Georgia. The Georgia Natural Heritage Inventory is undertaking a 1993 chromosome count to better identify this population.

Habitat

General description. Cooley's meadowrue grows on circumneutral soils in wet pine savannas, grass-sedge bogs and savannalike areas, often at the border of intermittent drainages or swamp forests. Park (1992) describes the habitat as follows:

> ...boggy savannah-like borders of low woodlands, roadside ditches, and power line rights-of-way. Usually associates with some type of disturbance, e.g., clearings, the edges of frequently burned savannas, power line right-of-ways which are maintained either by fire or mowing, and roadside edges. Typically on Grifton soil.

This borderline type of habitat would have been disturbed historically by naturally occurring savanna fires moving through at 1- to 5-year intervals, clearing litter from the soil surface and causing the cyclical advance and retreat of woody growth. A typical population of Cooley's meadowrue has robust reproductive plants among shrubs and in adjacent open savanna and repressed vegetative individuals in nearby dense shade.

Soils and hydrology. Soil requirements are summarized by Rayner (1980): "*Thalictrum cooleyi* is found on fine sandy loams. These soils are at least seasonally (winter) moist or saturated and are only slightly acidic (pH 5.8-6.6)."

Sufficient moisture is critical to plant vigor and reproductive effort (Carolyn Wilczynski, University of North Carolina at Chapel Hill, personal communication, 1992). Like several rare coastal plain species, Cooley's meadowrue occupies a narrow hydrologic niche, where soil is moist to saturated but water does not stand above the soil surface. As a rule of thumb, microsites wet enough for *Sarracenia flava* are slightly too wet for *Thalictrum cooleyi*.

Four of the North Carolina populations of *Thalictrum cooleyi* are found on Grifton soils, poorly drained fine sandy loams overlying a marly substrate. In typical Grifton soil the surface is acidic, but subsoil may have an alkaline reaction (Barnhill 1986, 1990). In a field study at one of the Grifton-mapped sites, Wilczynski (personal communication, 1992) found that soil characteristics varied significantly over a very small distance. Soil where *Thalictrum*

cooleyi was growing was distinctly higher in calcium, phosphorus, and cation exchange capacity than surrounding soil a few feet away where there was no *Thalictrum*.

It was once thought, or hoped, that Grifton soils may be the key to *Thalictrum cooleyi* locations (Leonard, personal communication, 1992). This has not held true, at least on the scale at which county soil surveys distinguish pedons. Soils at the other North Carolina *Thalictrum cooleyi* sites are mapped as Foreston, Woodington, and Foreston-Torhunta transition, and, at the type locality, as Muckalee. All the soils are sandy loam, fine sandy loam, or loamy fine sand on 0 to 2 percent slopes; all but the Foreston series are poorly drained with seasonal water tables within 1.5 feet of the surface (Barnhill 1990; Spruill 1990; U.S. Department of Agriculture, Soil Conservation Service, 1992). The various series are classified (Barnhill 1990) as:

> Foreston: Coarse-loamy, siliceous, thermic Aquic Paleudults.
> Grifton: Fine-loamy, siliceous, thermic Typic Ochraqualfs.
> Muckalee: Coarse-loamy, siliceous, nonacid, thermic Typic Fluvaquents.
> Torhunta: Coarse-loamy, siliceous, acid, thermic Typic Humaquepts.
> Woodington: Coarse-loamy, siliceous, thermic Typic Paleaquults.

Associated and indicator species. Tulip, poplar, and cypress growing together, bordering a savannalike area, has been the best (though not invariable) indicator of Cooley's meadowrue sites, according to Leonard. The drainage bordering the open area may also be dominated by willow oak or nonriverine swamp forest species rather than the pond pine-pocosin vegetation typical of more acidic, longer hydroperiod sites (Leonard, personal communication, 1992; Rayner 1980). Rayner states:

> *Thalictrum cooleyi* is found at the border of low woods that are dominated by *Acer rubrum*, *Nyssa sylvatica* var. *biflora*, *Liriodendron tulipifera*, and *Taxodium ascendens* in the canopy and *Myrica cerifera*, *Cyrilla racemiflora*, *Clethra acuminata* [*C. alnifolia*], *Magnolia virginiana*, *Gaylussacia frondosa*, *Ilex glabra*, *Ilex coriacea* and other bay shrubs in the shrub zone.

Rayner further states, "The presence or absence of pond pine appears to be of great help in searching for additional populations of *T. cooleyi*. If pond pine is present, the habitat is not suitable for *T. cooleyi*." Pond pine does grow in some Cooley's meadowrue sites, but within those sites the meadowrue is found near *Liriodendron* and *Taxodium*, not close to *Pinus serotina*.

Leonard (personal communication, 1992) reports:

> Associated species are *Myrica cerifera*, *Pycnanthemum flexuosum* and *P. muticum*, *Allium* cf. *cernuum*, *Ludwigia microcarpa*, *L. maritima* and/or *L. virgata*, *Eryngium integrifolium*, *Penstemon laevigatus*, and *Parnassia caroliniana*. Margins of Ctenium aromaticum savannas are fairly good sites for Cooley's meadowrue. Other moist savanna indicators are *Aletris aurea*, *Dichromena latifolia*, *Polygala lutea*, and *Asclepias lanceolata* or *A. rubra*. Margins of drainages dominated by *Liriodendron tulipifera*, *Taxodium ascendens*, *Acer rubrum*, *Pinus taeda*, and *Chamaecyparis thyoides* are suitable areas to search, especially if there are recent fire plow scars and power line cuts where the vegetation is maintained at no more than a meter in height.

Rayner (1980) points out that Cooley's meadowrue:

> ...is usually found associated with a mixture of savanna and swamp (marsh) herbaceous species and the fire history of the area where it occurs seems to determine which of these types will predominate.

Rayner lists the most common marsh species associated with Cooley's meadowrue as *Rhynchospora miliacea*, *Dracocephalum purpureum* (=*Physostegia purpurea*), *Scleria pauciflora*, *Carex walteriana*, and *Cladium jamaicense* and the most common savanna associates as *Dichromena* spp., *Ctenium aromaticum*, and *Parnassia caroliniana*.

Life History and Ecology

Phenology. *Thalictrum cooleyi* flowers from mid-June to early July, with males flowering somewhat earlier than females and shade plants later than sun plants. Plants mowed or burned during the growing season have been observed to resprout and flower later in the same season (Park 1992; Leonard, personal communication, 1992; White 1992). Populations are easiest to locate at flowering time by watching for male plants, which have showier flowers and tend to be taller than females. Fruits mature in August and September and remain on the plant at least into October (Rome 1987).

Genetics. Park (1992) found a chromosome count of $2n = 210$ in *Thalictrum cooleyi*, in a genus "long regarded as highly polyploid, with a base number of x = 7." Park notes that the count for *Thalictrum cooleyi* represents one of the highest in angiosperms, as is the ploidy level (30x). Park states:

> This also represents a puzzle since previously it had been proposed that a high degree of polyploidy, particularly in *T. pubescens* [$2n = 156$], enabled the species to colonize a

wide variety of habitats (Kuzmanov, 1986). On the other hand, *T. cooleyi* is a habitat specialist.

Cooley's meadowrue could be derived from *T. revolutum* (*2n* = 140); Park has found some populations of the latter species with leaflets resembling *T. cooleyi* (in North Carolina as well as at the Worth County, Georgia, site mentioned above).

The high chromosome number in *Thalictrum cooleyi* may represent only a high degree of autoploidy, which may or may not entail genetic diversity. Sherman-Broyles *et al.* (1991) state:

> Species with limited geographic distributions that occur in small, isolated populations pose special problems for the conservation of genetic diversity. Both the species and its individual populations are not only susceptible to extinction but they may have also lost much of their genetic diversity due to a limited number of reproductive individuals. Recent reviews of the plant allozyme literature have shown that the geographic range of a species has a large effect on the amount of genetic diversity maintained by the species. Endemic species have fewer polymorphic loci, fewer alleles per polymorphic locus and less than 50% of the genetic diversity of more widespread species.

J. L. Hamrick (University of Georgia, personal communication to Brian P. Cole [Service], 1992) points out that limited-range species vary greatly in level of genetic diversity; the Sherman-Broyles rule is based on average values. In an autopolyploid species, each individual may have several alleles per locus; therefore, the species is less at risk from genetic drift. Whether *Thalictrum cooleyi* is an anto- or allopolyploid has not been determined.

Sexual expression/pollination. Leonard (personal communication, 1992) observed a 3:1 ratio of male to female *Thalictrum cooleyi* plants in the field. White (1992) found male to female rations of 10:9 (1988) and 4:3 (1989) in the Florida population. In 1992 the author found near equality between males and females, with females exceeding males at some sites.

Cooley's meadowrue, although described as dioecious, belongs to the *Leucocoma* section of the genus *Thalictrum* that is characterized by polygamodioecy. Plants in this section are not necessarily strictly male or female. The basis of sexual expression in an individual needs more investigation. There is evidence within the genus both for environmental and for genetic sex determination (Park 1992).

Like other members of the genus, *Thalictrum cooleyi* displays characteristics of wind pollination (smooth pollen, elaborate stigma, reduced perianth, terminal inflorescence in an open habitat) with some suggestion of insect pollination (conspicuous stamens with

somewhat expanded filaments). Both entomophily and anemophily are known in the genus (Park 1992).

Reproduction. Female flowers reportedly develop few fruits. In field studies, Wilczynski (personal communication, 1992) found that seed production was positively correlated with plant height, which in turn was dependent on adequate rainfall. *Thalictrum cooleyi* produces fewer and larger seeds than do other *Thalictrums* (Leonard, personal communication, 1992).

Field observations have failed to find seedlings (Wilczynski, personal communication, 1992; Leonard, personal communication, 1992). Under a variety of treatments, seed germination trials resulted in few seedlings. Those seeds that did germinate were fresh seeds that were cold-stratified for several weeks (roughly 20 percent germination), while seeds stored from previous seasons failed to germinate (Park, personal communication, 1992; Robert Gardner, North Carolina Botanical Garden, personal communication, 1992). On this evidence, Gardner suggests that seed life is short.

Leonard (personal communication, 1992) and Rome (1987) discovered (by careful excavation) that small plants of Cooley's meadowrue found in the field were not seedlings but offshoots of rhizomes of nearby larger plants. Plants kept in pots over several years have shown no evidence of rhizomes, but sprout from the same base each year (Gardner, personal communication, 1992). While meadowrue species described as rhizomatous are rare (Carl Keener, Pennsylvania State University, personal communication, 1981), Park (personal communication, 1992) says that various species of *Thalictrum* can produce rhizomes facultatively; the triggering factors are not known.

Response to disturbance/succession. According to Rome (1987), Cooley's meadowrue requires:

> ...a fairly open habitat in order to flourish. It will persist in shady conditions, but may produce only a single leaf. When the overstory is removed, however, it will grow more leaves and produce flowers.

Thalictrum cooleyi grows in communities historically kept in an early secondary-successional stage by frequent natural fires. Cooley's meadowrue persists where controlled burning or some equivalent form of disturbance (mowing, clearing, ditching, plowing fire lines) controls or creates openings in woody overgrowth.

Wilczynski (personal communication, 1992) tested the effects of various fire frequencies (1-, 2- and 3-year cycles) on *Thalictrum cooleyi* plants. Over a 3-year period she found no significant differences attributable to fire frequency but felt that more needs to be known, particularly whether long-term annual burning may have deleterious effects.

Leonard (personal communication, 1992) suggests that, given the species' rhizomatous nature and its occurrence and persistence in artificially disturbed habitats, some mechanical disturbance may actually be beneficial (increasing population size by distributing rhizomes, besides opening habitat). Some plant species in, for example, aquatic habitats do propagate by the breaking off and dispersal of vegetative parts. However, there is no historic natural disturbance of this kind in typical *Thalictrum cooleyi* habitats.

Predation/disease. Leonard (personal communication, 1992) reports a lack of any evidence of predation or disease in *Thalictrum cooleyi* in his extensive surveys of the species.

Threats and Population Limiting Factors

To begin with, potential habitat for Cooley's meadowrue--wet savanna/bog on circumneutral soil--is rare in the Atlantic coastal plain, and the species probably was never abundant. Loss of this habitat, through succession, clearing for agriculture, forestry, mining and development, draining, and highway construction, is the major threat to the survival of Cooley's meadowrue.

Even for those populations that have been identified and are under some degree of protection, succession and alteration of hydrology are major concerns. The thorough fragmentation of fire compartments in the present-day landscape has eliminated the possibility of maintaining an open habitat by spontaneous means, as naturally occurring fires are too infrequent at any given site even if allowed to burn freely. Therefore, the survival of the species depends on active management of the remaining sites. *Thalictrum cooleyi* persists on roadsides and rights-of-way where mowing, burning, and similar management serve to replace the historic natural processes. However, such management cannot be considered protective until it is guaranteed permanent and is deliberately tailored to the needs of the species.

The fragmentation and isolation of areas of suitable habitat severely limits the ability of the extant populations to spread to new locations. Added to the lack of readily available expansion habitat, the species apparently has a low rate of fruit production, poor germination, lack of a seed bank, and no means of long-distance seed dispersal. Dioecy lowers the probability of successful colonizations because, to be sexually viable, new populations need to be established by enough propagules to represent both sexes. Unisexual populations may be possible, but so far all known populations are bisexual. Low sexual reproductive rate and the specialized environmental niche the plant occupies suggest genetic restrictions in the species, limiting its ability to survive environmental changes.

Conservation Efforts

Of the 12 current *Thalictrum cooleyi* sites, two more or less intact savannas, including the site with the largest population, are owned wholly or partly by The Nature Conservancy. These two sites (Lanier Quarry and Myrtle Head Savanna) are being managed to maintain open savannas by controlled burns, although the patchwork nature of land ownership at Lanier Quarry makes effective burning difficult.

At the Florida site and one site in North Carolina (known as the "*Thalictrum Cooleyi* Power Line Site")--both power line rights-of-way on paper company tracts--owners have entered into nonbinding natural areas registration. The North Carolina site is mowed. The Nature Conservancy has used fire to maintain the Florida site; the owners and power company managers have cooperated in curtailing site preparation activities and herbicide use (Steve Gatewood, Florida Field Office, The Nature Conservancy, personal communication, 1992). Even with these cooperative efforts, the Florida *T. cooleyi* population is at risk of being overrun by *Rubus* and has literally been overrun by vehicles (White 1992).

The remaining eight sites are privately owned and unprotected. The Cooley's meadowrue populations at three of these are wholly or partly contained in road or power line rights-of-way.

As mentioned above, Wilczynski conducted a 3-year study (1988 through 1990) at Lanier Quarry, establishing permanent plots to investigate the species biology and management needs of Cooley's meadowrue (report to The Nature Conservancy, in preparation). These marked plots can be used to continue research in future years.

The North Carolina Botanical Garden currently holds stored seed collections and some live plants of *Thalictrum cooleyi* as part of the Center for Plant Conservation's National Collection of Endangered Plants. Seed viability and longevity need further study before the usefulness of storing these possibly short-lived seeds is established. In the meantime, the germ plasm of this species would be better protected by holding a representative collection of live plants, with precautions taken to prevent interpopulational genetic mixing.

PART II

RECOVERY

A. Recovery Objectives

Cooley's meadowrue (*Thalictrum cooleyi*) will be considered for delisting when there are at least 16 self-sustaining, geographically distinct populations in existence that are protected to such a degree that the species no longer qualifies for protection under the Endangered Species Act (see criteria below). A self-sustaining population is a reproducing population that is large enough to maintain sufficient genetic variation to enable it to survive and respond to natural habitat changes. The number of individuals necessary and the quantity and quality of habitat needed to meet this criterion will be determined as one of the recovery tasks.

This recovery objective is considered an interim goal because of the lack of data on the biology and management requirements of the species. As new information is acquired, the estimate of the number of self-sustaining populations required for the species' survival may be readjusted. The recovery objective for Cooley's meadowrue will be reassessed in light of any new information that becomes available.

The first step toward recovery will be protection and management of all viable extant populations to ensure their continued survival. Much is unknown about the life history and habitat requirements of this species. Therefore, it will be necessary to conduct additional demographic studies and ecological research to gain the understanding needed to develop appropriate protection and management strategies. The ultimate effects of various kinds of habitat disruption must be determined, and destructive alterations must be prevented. Active management required to ensure continued survival and vigor must be defined and implemented. Therefore, Cooley's meadowrue shall be considered for removal from the Federal list when the following criteria are met:

1. It has been documented that at least 16 self-sustaining populations exist and that necessary management actions have been undertaken by the landowners or cooperating agencies to ensure their continued survival.

2. All of the above populations and their habitat are protected from present and foreseeable human-related and natural threats that may interfere with the survival of any of the populations.

B. Narrative Outline

1. Protect existing populations and essential habitat. Only 12 populations of Cooley's meadowrue are currently known to exist, all within the States of North Carolina and Florida. Until more is known about the species' biology, genetic diversity, and specific habitat requirements and about the measures necessary to protect the integrity of occupied sites, all existing populations should be protected. The long-term survival of 16 populations is believed to be essential to the recovery of the species.

1.1 Develop interim research and management plans in conjunction with landowners and managers. Cooley's meadowrue is known to need a moist open habitat. Therefore, immediate emphasis will be on habitat maintenance (prevention of woody succession, hydrologic alteration, and habitat destruction), in cooperation with the landowners and site managers, until more specific management procedures have been developed through research. Pre- and postmanagement demographic studies should provide important insights into particular management needs. Interim plans should provide that field workers (e.g., bushhog operators) are informed as to plant locations and appropriate procedures.

1.2 Search for additional populations and potential habitat. Although searches for the species have been conducted, a thorough, systematic effort to locate additional populations is still needed. Small populations of this rather cryptic plant and small remnants of appropriate habitat are easily missed in less intensive efforts. Searches should be preceded by an examination of geological, wetlands, and soils maps, aerial photographs, and locations of associated species to determine potential habitat and to develop a priority list of sites to search. The species seems to favor poorly drained, sandy-loam soils on flats or slight slopes in open areas bordered by hardwood wetlands. Areas where marl or other calciferous deposits are near the surface should be pinpointed. A master data base should be maintained, containing maps of areas that have been searched with negative results, as well as locations of known populations, so that efforts are not duplicated. Leonard (1992) proposes that the theoretical range may extend as far west as DeSoto National Forest, Mississippi, besides including all the area between western Florida and southeastern North Carolina.

1.3 Rank populations for focus of protection efforts. Because of the small number of existing populations and the pervasive threats to the habitat, it is essential to protect as many populations as possible. However, efforts should be concentrated first on the sites owned by conservation agencies, those owned by cooperative private landowners, and where the most genetically diverse and most vigorous populations occur. Ownership by The Nature Conservancy assures the protection of two good populations as long as appropriate management activities continue.

1.4 Evaluate habitat protection alternatives. The greatest possible protection should be obtained for those existing populations that are considered critical to the recovery of the species. Fee simple acquisition or conservation easements provide the greatest degree of protection by placing management in the hands of agencies whose primary purpose is conservation. It is unknown as yet how much buffer land around each population is necessary to protect the integrity of occupied sites, particularly from hydrologic alteration. Protection through management agreements or short-term leases may provide adequate short-term protection but should only be considered as intermediate steps in the process of ultimately providing for permanent protection. Short-term protection strategies may be necessary if private landowners are not agreeable to, or monies are not available for, acquisition of conservation easements or fee simple title. Conservation agreements with adjacent landowners should be developed to prevent inadvertent adverse alterations of the habitat, particularly hydrologic alterations.

2. Determine and implement management necessary for long-term reproduction, establishment, maintenance, and vigor. Protection of the species' habitat through acquisition, easement, or agreement is only the first step in ensuring its long-term survival. Management that provides early-successional communities is necessary to allow the species to perpetuate its life cycle over the long term. Information on its genetic diversity, population biology, and ecology is necessary before effective management guidelines can be formulated and implemented.

2.1 Determine population size, stage-class distribution and sex ratios for all populations. Population size and stage-class distribution data are essential to predicting what factors may be necessary for populations to become self-sustaining (Menges 1987). Sex distribution data is also critical for this dioecious species, including records of any deviation from strict

dioecy. Such data are needed for the existing populations and for any newly discovered populations. This task should be combined with the work described under Task 1.2.

2.2 Study abiotic and biotic features of the species' habitat. An understanding of the nature of the habitat occupied by the species is essential to the long-term survival and recovery of Cooley's meadowrue. It is currently unknown what the tolerances are for this species in terms of such factors as moisture, pH, soil texture and nutrient levels, insolation, litter depth, competition, and disturbance. Monitoring studies should include populations within a wide range of habitats, both altered and undisturbed. Permanent plots should be selected and established to determine the relationship between abiotic factors (such as light intensity and soil type, moisture content, pH, and nutrients) and biotic factors (such as reproduction, germination, seedling establishment, rhizome production, sexual expression, and competition). Some of this data has been collected in the Lanier Quarry study (Wilczynski, personal communication, 1992).

Water is undoubtedly a crucial factor in the survival of Cooley's meadowrue. Research is needed into the long-distance effects of off-site drainage and other hydrologic alterations near the Cooley's meadowrue populations to determine the necessary size of protective buffers.

Fire is a major historical factor and is currently used in managing Cooley's meadowrue sites. Particularly, the response of the species to fire at different seasons and frequencies needs to be determined, building on information already gathered in the Lanier Quarry study. The timing of fire may have quite different effects on seed germination as compared to vegetative response.

Several elements of species biology need study: pollination mechanisms and pollen viability, as inadequate pollination may be a cause of low fruit set; seed viability, longevity, and germination requirements, as all these present problems on initial evidence; frequency and causality of rhizome formation; and sex constancy in individual stems and in clones. The spatial arrangement of male and female plants in a population is also relevant to the potential for interbreeding. The relative importance of sexual and vegetative reproduction to the long-term survival of the species is unknown and must be determined for effective management and protection to take place.

Genetic diversity within and between populations needs to be determined. The very limited geographic coverage of the species (three small areas), the apparently narrow habitat requirements, and the low rate of sexual reproduction so far encountered all suggest a depauperate genome. Tests should identify those populations with the highest genetic diversity and those with unique alleles.

2.3 Conduct long-term demographic studies. Long-term demographic studies should be conducted in permanent plots located within each study site established for habitat analysis. Plots should be visited annually, preferably by the same person, for at least 5 consecutive years. The locations of individual plants of all stage-classes should be mapped or photographed; data collected should include overall plant size, the number and size of leaves, inflorescence size, plant sex, and fruit set. Larger plots, surrounding each of the smaller, more intensively measured and mapped plots, should be monitored for seedling or shoot establishment. Seedlings should be mapped and measured. Within the larger plots, overall species composition should be recorded (with a cover score given to each species) so that changes in surrounding vegetation can be determined. Any changes in the habitat within each plot (soil disturbance, increases or decreases in light intensity, soil moisture, etc.) should be noted at each visit. Permanent plots already established at Lanier Quarry can be incorporated into a wider study.

2.4 Determine the effects of past and ongoing habitat disturbance. For a disturbance-dependent species, it is especially important to distinguish effective management from harmful disturbance and superfluous efforts. This could be done best by controlled experiments, testing various disturbance regimes over several years, which might be conducted on suitable but unoccupied habitat using plants from cultivated stock, such as the Center for Plant Conservation's collections. Long-term monitoring of permanent plots in established populations will also yield essential information. Both experiments and monitoring should follow parameters specified in Tasks 2.2 and 2.3.

2.5 Define criteria for self-sustaining populations and develop appropriate habitat management guidelines based upon the data obtained from tasks 2.2 through 2.4.

2.6 Implement appropriate management techniques as they are developed from previous tasks.

2.7 Develop techniques and reestablish populations in suitable habitat within the species' historic range. Transplantation and reintroduction should only be undertaken after the genetic composition of the individual populations is known. Restoration of populations should maximize genetic variation through the use of material from several maternal sources and by using a sufficient number of propagules (at least 50 survivors) to prevent genetic drift or inbreeding depression. Populations with the highest genetic diversity should be the primary source. With regard to the disjunct Florida population, particularly, thought should be given to the possibility that mixing genomes adapted to different environments may decrease population fitness. Techniques for propagation and transplantation of this species should be summarized and disseminated to appropriate organizations and individuals. Reintroduction efforts should be conducted in cooperation with knowledgeable personnel at private nurseries, botanical gardens, and the Center for Plant Conservation. Transplant sites must be closely monitored to determine success and to adjust methods of reestablishment.

3. Maintain and expand cultivated sources for the species and provide for long-term maintenance of selected populations in cultivation. Maintaining the genotypes of small, isolated populations in cultivation should be of high priority. Vegetative propagules or seed should be collected as soon as possible from all populations that are still healthy enough to tolerate such harvest. Vegetative propagation is preferred until more knowledge is available about long-term seed storage for this species. Representatives of different populations should be separated to prevent interpopulational genetic contamination until the distribution of genetic diversity is known (Olwell, personal communication to Brian P. Cole [Service] 1992). A ready source of cultivated material should ease the threat of taking from wild populations. The Center for Plant Conservation has expressed interest in helping maintain and expand cultivated sources.

4. Enforce laws protecting the species and/or its habitat. Cooley's meadowrue is federally listed as endangered. It is not now and is not likely to become an element of horticultural trade but does have botanical, educational, and possibly medicinal interest. The Endangered Species Act prohibits taking of the species from Federal lands without a permit and regulates trade. Section 7 of the Act provides additional protection of the habitat from impacts related to federally funded or authorized projects. In addition, for listed plants, the 1988 amendments to the Act prohibit: (1) their malicious damage or destruction on Federal lands

and (2) their removal, cutting, digging, damaging, or destroying in knowing violation of any State law or regulation, including State criminal trespass law.

Cooley's meadowrue is a legally protected plant listed as Endangered in North Carolina, where the North Carolina Plant Protection and Conservation Act (North Carolina General Statute 106, 19B; 202.12-202.22) prohibits taking from the wild without a North Carolina Department of Agriculture permit and taking or deliberate disturbance on another's land without the landowner's written permission. North Carolina Department of Agriculture permits for endangered species are generally granted only for scientific studies or plant rescues.

The species was added in the fall of 1992 to the Florida Department of Agriculture's list of legally protected endangered species under the Preservation of Native Flora of Florida Act, F.S. 581.185. The Florida Act prohibits willful destruction or harvest of an endangered species from the lands of another except by permits from the landowner and the Florida Department of Agriculture.

5. Develop materials to inform the public about the status of the species and the recovery plan objectives. Public support for the conservation of Cooley's meadowrue could play an important part in encouraging landowner assistance and conservation efforts. This is especially true where fire management, beneficial to the species, has been a traditional local tool in maintaining an open landscape for hunting and other purposes. Informational materials should not identify the plant's locations so as not to increase the threat of taking. The Center for Plant Conservation has expressed a willingness to help with public education (Olwell, personal communication to Brian P. Cole [Service], 1992).

   5.1 Prepare and distribute news releases and informational brochures. News releases concerning the status and significance of the species and recovery efforts should be prepared and distributed to major newspapers in the range of the species, as well as to smaller newspapers in the vicinity of the species' habitat.

   5.2 Prepare articles for popular and scientific publications. The need to protect the species in its native habitat and cooperation among local, State, and Federal organizations and individuals should be stressed. Scientific publications should emphasize additional research that is needed and solicit research assistance from colleges and universities that have conducted studies on this or closely related species.

6. Annually assess success of recovery efforts for the species. Review of new information, evaluation of ongoing actions, and redirection, if necessary, is essential for assuring that full recovery is achieved as quickly and efficiently as possible.

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PART III

IMPLEMENTATION SCHEDULE

Priorities in column one of the following implementation schedule are assigned as follows:

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

2. 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.

3. Priority 3 - All other actions necessary to meet the recovery objective.

Key to Acronyms Used in This Implementation Schedule

CPC - Center for Plant Conservation
TE - Endangered Species Division of the U.S. Fish and Wildlife Service
FWS - U.S. Fish and Wildlife Service
R4 - Region 4 (Southeast Region), U.S. Fish and Wildlife Service
SCA - State Conservation Agencies - State plant conservation agencies of participating States. In North Carolina, these are the Plant Conservation Program (North Carolina Department of Agriculture) and the Natural Heritage Program (North Carolina Department of Environment, Health, and Natural Resources); in Georgia, the Freshwater Wetlands and Heritage Inventory (Georgia Department of Natural Resources); and in Florida, the Natural Areas Inventory and the Florida Department of Agriculture and Consumer Services.

COOLEY'S MEADOWRUE IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency FWS	Responsible Agency Other	Cost Estimates ($000's) FY1	Cost Estimates ($000's) FY2	Cost Estimates ($000's) FY3	Comments
1	1.1	Develop interim research and management plans in conjunction with landowners.	2 years	R4/TE	SCA	5.0	5.0	---	
1	1.3	Rank populations for focus of protection efforts.	1 year	R4/TE	SCA	1.0	---	---	
1	1.4	Evaluate habitat protection alternatives.	2 years	R4/TE	SCA	1.0	1.0	---	
1	4	Enforce laws protecting the species and/or its habitat.	Ongoing	R4/TE	SCA	2.0	2.0	2.0	
2	1.2	Search for additional populations and potential habitat.	3 years	R4/TE	SCA	20.0	10.0	10.0	
2	2.1	Determine population size and stage-class distribution for all populations	2 years	R4/TE	SCA	20.0	10.0	10.0	
2	2.2	Study abiotic and biotic features of the species' habitat.	5 years	R4/TE	SCA	15.0	10.0	8.0	
2	2.3	Conduct long-term demographic studies.	5 years	R4/TE	SCA	16.0	6.0	6.0	
2	2.4	Determine the effects of past and ongoing habitat disturbance.	3 years	R4/TE	SCA	12.0	6.0	4.0	
2	2.5	Define criteria for self-sustaining populations and develop appropriate habitat management guidelines based upon the data obtained from Tasks 2.2 through 2.4.	1 year	R4/TE	SCA	---	---	5.0	
2	2.6	Implement appropriate management techniques as they are developed from previous tasks.	Unknown	R4/TE	SCA	15.0	15.0	20.0	

COOLEY'S MEADOWRUE IMPLEMENTATION SCHEDULE (continued)

Priority	Task Number	Task Description	Task Duration	Responsible Agency		Cost Estimates ($000's)			Comments
				FWS	Other	FY1	FY2	FY3	
3	2.7	Develop techniques and reestablish populations in suitable habitat within the species' historic range.	5 years	R4/TE	SCA	---	15.0	25.0	
3	3	Maintain and expand cultivated sources for the species and provide for long-term maintenance of selected populations in cultivation.	3-5 years	R4/TE	SCA, CPC	5.0	5.0	1.0	
3	5.1	Prepare and distribute news releases and informational brochures.	Ongoing	R4/TE	SCA, CPC	2.0	1.0	1.0	
3	5.2	Prepare articles for popular and scientific publications.	Ongoing	R4/TE	SCA, CPC	1.0	0.5	0.5	
3	6	Annually assess success of recovery efforts for the species.	Ongoing	R4/TE	SCA, CPC	0.5	0.5	0.5	

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