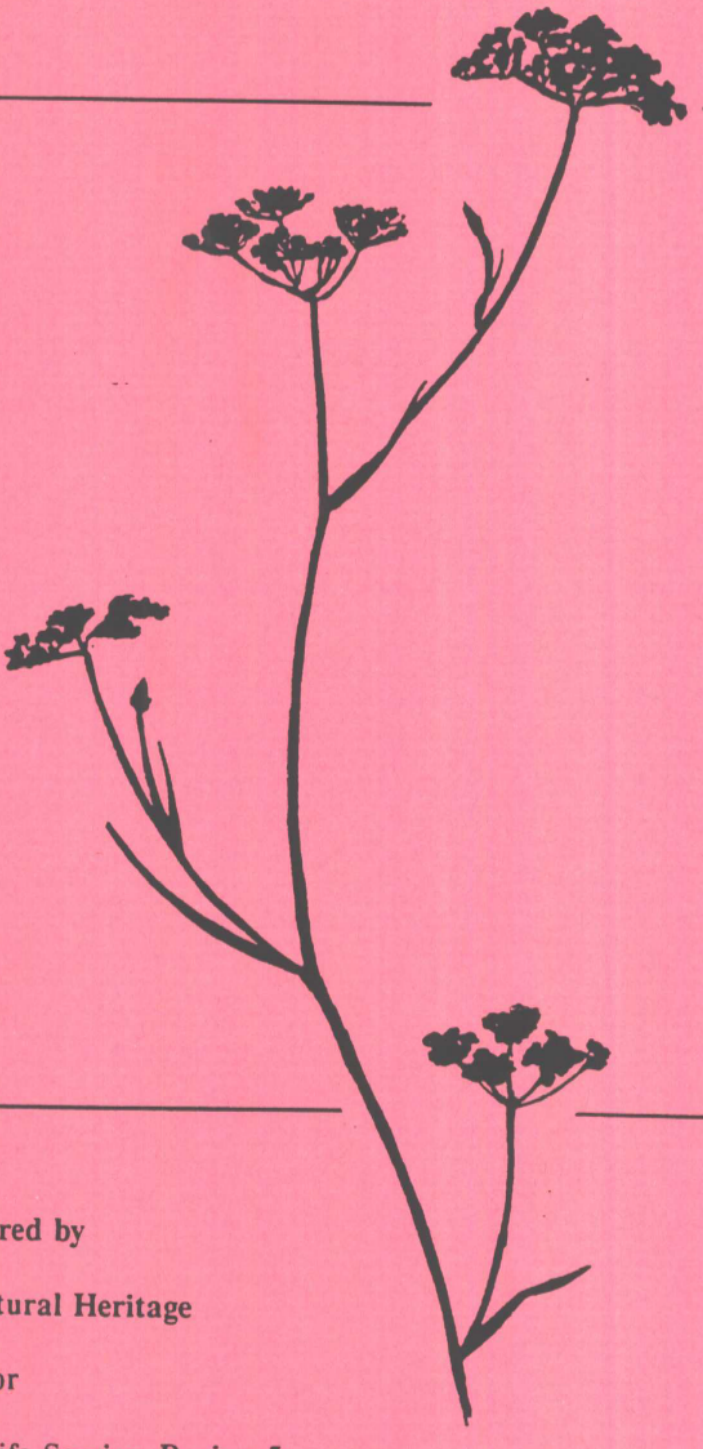
HARPERELLA (*Ptilimnium nodosum*)

RECOVERY PLAN



Prepared by

Maryland Natural Heritage

for

U.S. Fish and Wildlife Service, Region 5

Harperella (*Ptilimnium nodosum* (Rose) Mathias)

Recovery Plan

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The following recovery plan, prepared by the Maryland Natural Heritage Program for the Northeast Region of the U.S. Fish and Wildlife Service, delineates reasonable actions directed toward recovering and/or protecting the endangered harperella (Ptilimnium nodosum). Recovery objectives will be attained and funds made available subject to budgetary and other constraints, as well as the need to address other priorities.

The plan does not necessarily represent the approval or official position of any individuals or agencies other than the U.S. Fish and Wildlife Service. This approved recovery plan is subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Harperella (Ptilimnium nodosum) Recovery Plan. Newton Corner, Massachusetts. 60 pp.

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Fish and Wildlife Reference Service
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EXECUTIVE SUMMARY

Current Status: Harperella (Ptilimnium nodosum) consists of 13 known populations in seven southeastern states, down from 26 historical populations. The plant is threatened by small population sizes and hydrological manipulations of the habitat. This species was listed as endangered in September, 1988.

Habitat Requirements: P. nodosum is a rare plant native to seasonally flooded rocky streams and coastal plain ponds. One site occurs on a granite outcrop. In both its riverine and pond environments (and its outcrop occurrence), the plant occurs only in a narrow range of water depths; it is intolerant of deep water or conditions that are too dry. The riverine form is found in microsites that are sheltered from rapidly moving water.

Recovery Objective: To delist the species.

Recovery Criteria: To **downlist**: (1) 13 stable populations and (2) permanent protection for all 13 populations. To **delist**: (3) 26 self-sustaining populations, (4) distribution throughout the historical range, and (5) permanent protection of all populations.

Recovery Strategy: Nine currently large or stable populations must be protected and maintained at current status or increased. Four marginal populations must be protected and augmented to the point where they can be self-sustaining. Thirteen additional populations must be discovered or established. These levels will be achieved through habitat protection and watershed conservation measures, increased understanding and implementation of management and propagation techniques, and increased public awareness.

Actions Needed:

1. Protect plants and their habitat through landowner cooperation, land protection, and regulatory authorities.

2. Where needed, seek conservation of watersheds to protect populations.

3. Search for additional populations.

4. Study species and habitat characteristics.

5. Develop a cultivated sources of plants and provide for seed storage.

6. Implement appropriate management techniques, particularly for pond populations.

7. Re-establish populations within the species' historical range.

8. Inform the public about the plant's status and recovery needs.

Estimated Costs and Time Frame: The total cost over the next three fiscal years for recovery of P. nodosum, exclusive of the cost of land acquisition and conservation easements, amounts to $185,000. Costs for full recovery have not been estimated at this time. The time frame for achieving full recovery is unknown, pending further studies of the species' requirements.

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PART I: INTRODUCTION

Ptilimnium nodosum (Harperella) is a small member of the carrot family (Apiaceae) that was originally described by Rose (1905) and taxonomically revised by Kral (1981) to include P. fluviatile Rose. It is a rare plant native to (1) seasonally flooded rocky streams in Maryland, West Virginia, North Carolina, Alabama, and Arkansas, and (2) coastal plain ponds in South Carolina (Figure 1). The sole Georgia site occurs on a granite outcrop.

In both its riverine and pond environments, P. nodosum occurs only in a narrow band of water depths: neither too shallow, for the plant cannot tolerate dry conditions, nor too deep for the plant to complete its life cycle. The plant is threatened by small population sizes and hydrological manipulations of the habitat such as upstream water impoundments, declining water quality, and pond drainage.

Despite the taxonomic synonymy between the pond ("Nodosum") and riverine ("Fluviatile") forms, important ecological, genetic, and conservation distinctions remain that affect the protection strategy outlined in this plan. For example, the pond form is both profoundly threatened (by habitat disturbance and very small population sizes) and genetically distinct from the riverine form, necessitating particular recovery emphasis. As for the riverine form, annual flooding cycles cause significant dynamism in the distribution of plants within populations, warranting a broad view of habitat protection.

Ptilimnium nodosum was Federally listed as an endangered species on September 28, 1988 (U.S. Fish and Wildlife Service 1988). It is also listed as endangered in Maryland and

Figure 1. Flowering stem of Ptilimnium nodosum

North Carolina. An unofficial list of rare plants in Alabama records it as threatened (Freeman et al. 1979), and the South Carolina Heritage Trust lists it as a species "of national concern." State listing of P. nodosum in Georgia and Arkansas is pending.

Taxonomic and Morphological Description

The genus Ptilimnium contains four species (P. nodosum, P. costatum, P. capillaceum, and P. nuttallii), of which all but one (P. nuttallii) are found in the southeastern United States. While all Ptilimnium species are found in swampy or wet areas, the other Ptilimnium species differ from P. nodosum in having finely compounded leaves.

Rose (1905) originally described two new species collected from southwestern Georgia and northern Alabama. These plants were named Harperella nodosum Rose and H. fluviatilis Rose. Rose also collected a related plant in the Potomac River basin, near Hancock, Maryland. He named this plant H. vivipara because of its tendency to form asexual buds (Rose 1911).

Mathias (1936) determined that Harperella did not differ fundamentally from members of the genus Ptilimnium, despite differences in leaf morphology. She renamed the species Ptilimnium nodosum (Rose) Mathias, P. fluviatilis (Rose) Mathias, and P. viviparum (Rose) Mathias.

Easterly (1957) decided that the relative size of P. fluviatilis and P. viviparum, which had been used to separate the types, was too variable a character to distinguish the species. Consequently, he joined the two forms under the name P. fluviatile.

Kral (1981) studied the quantitative differences in morphology and phenology between P. nodosum and P. fluviatile (Easterly 1957). He concluded that the species'

characteristics differed in mean but broadly overlapped and were probably the result of environmental factors -- particularly the extent of flooding -- rather than genotypic differences that would warrant a species rank. Additionally, Kral (1981) noted that P. nodosum and P. fluviatile have an identical haploid chromosome number (N = 6) differing from other species in the genus (Easterly 1957). Thus, Kral (1981) synonymized the two species under the earlier name, Ptilimnium nodosum. As listed under the Endangered Species Act, P. nodosum includes P. fluviatile.

Despite the synonymy, there are significant differences in some basic life history features and the genetic composition of populations. For example, while the coastal plain pond form is apparently a true annual (i.e., germinates, flowers, and dies within one season or year), the riverine form is a perennial (or at least a biennial that can flower in both years) (Maddox and Bartgis 1989).

P. nodosum (nodosum vs. fluviatile) populations are genetically variable (Kress et al. 1990), although like most rare species it is genetically depauperate. Preliminary evidence suggests that the pond form is genetically distinct from the riverine form, although the difference does not necessarily warrant a species rank. Genetic studies, funded by the Maryland Natural Heritage Program and the U.S. Fish and Wildlife Service, are continuing.

A summary of morphological characters for the riverine and pond forms of P. nodosum is given in Table 1. The primary morphological distinction between the Nodosum and Fluviatile forms is that the former is somewhat larger and flowers earlier in the summer (Easterly 1957, Radford et al. 1968, Kral 1981).

Many workers have noted that the Fluviatile form tends to proliferate at the nodes (Easterly 1957, Kral 1981, Maddox and Bartgis 1989) while the Nodosum form does not. Easterly (1957) observed that the leaves of "P. fluviatile" were

Table 1. Morphological characteristics of the "Nodosum" and "Fluviatile" forms. Based on Easterly (1957), Radford et al. (1968), Kral (1981), and Maddox and Bartgis (1989).

Character	Nodosum	Fluviatile
Height (cm)	40 - 100	20 - 50
Leaf length (cm)	8 - 30	4 - 12
Bract length (mm)	2 - 5	1 - 4
Number of primary rays	4 - 16	3 - 15
Ray length (cm)	1 - 2.5	0.5 - 1.5
Calyx teeth length (mm)	1 - 2	1 - 2
Color of anthers	rose	rose
Flower	for both forms, each umbel contains both perfect and male florets (i.e., andromonoecy)	
Styles (mm)	0.4 - 0.8	0.4 - 0.8
Fruit Shape	elliptical	elliptical
Fruit lateral ribs	inconspicuous	inconspicuous
Fruit length (mm)	1.5 - 2.0	1.5 - 2.0
Pollen grain length (μ)	20.1 - 23.5	17.1 - 22.1
Pollen grain width (μ)	10.4 - 13.6	9.8 - 12.6
Chromosome number	6	6
Flower Phenology	May - June	July - October
Germination period	probably spring?	fall
Asexual reproduction	no	yes
Habitat	edges of coastal plain ponds, also a wet granite outcrop	shoals, bedrock outcrops, and protected banks of seasonally flooded rocky streams

"evergreen" and conspicuously present throughout the winter, while Nodosum leaves were not. Easterly (1957) called "P. fluviatile" an asexual annual, that is, a plant that produces asexual buds that live one year. Maddox and Bartgis (1989, 1990a) found that such asexual buds can survive over two years and flower each year, suggesting that it is a (perhaps short-lived) perennial.

Current and Historical Distribution

Thirteen populations of P. nodosum are currently known to exist in seven states (Figure 2). Eleven populations have been extirpated, and two are of uncertain status (Table 2).

Nine of the extant populations contain the riverine form for the species, and four populations (in South Carolina and Georgia) contain the coastal plain pond form. The plant has been extensively searched for in much potential habitat; new populations were verified in 1988 (Maryland) and 1990 (Arkansas), and a population was rediscovered in 1990 (Alabama). The discovery in Arkansas is particularly notable because it expands the known range of the species, and shows that it is important to search for the plant in previously unsurveyed areas. Further searches in Arkansas, as well as new searches in southern Missouri and eastern Oklahoma, are warranted.

Although no records for the plant exist from Tennessee or Pennsylvania, activities in these states may affect P. nodosum. Three populations occur along creeks that pass through these states: Sideling Hill and Fifteen Mile Creeks in Maryland originate in Pennsylvania and contain suitable habitat (R. Bartgis and D. Maddox pers. obs.); Town Creek in Alabama originates in Tennessee.

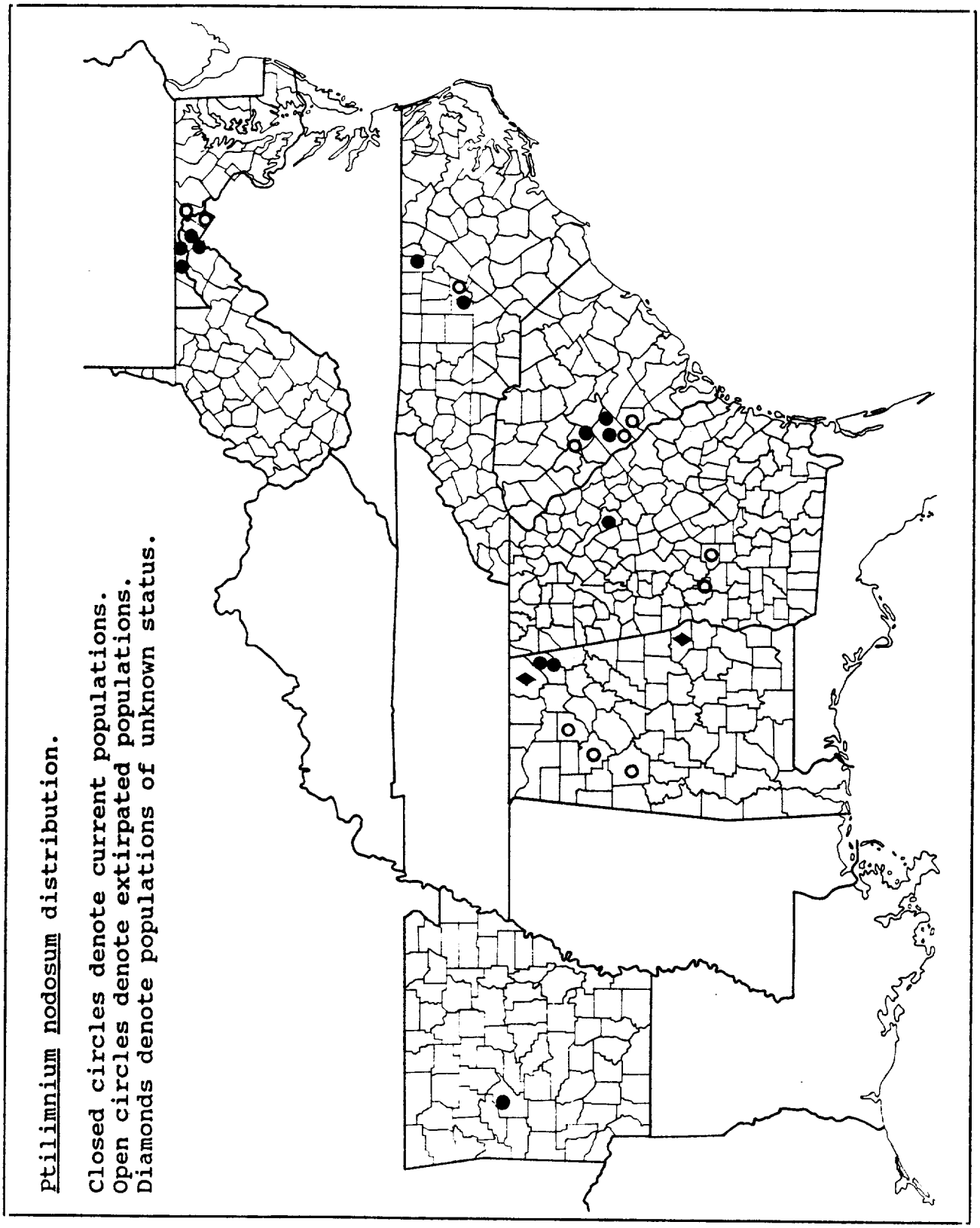

Figure 2. Distribution of current and historical P. nodosum populations.

Table 2. State and county locations of current and historical *P. nodosum* populations.

STATE	COUNTY	EXTIRPATED POPULATIONS	SITES NOT VERIFIED	EXTANT POPULATIONS
AL	Cullman	1	0	0
AL	DeKalb	0	0	2*
AL	Jackson	0	1	0
AL	Lee	0	1	0
AL	Tuscaloosa	1	0	0
AL	Walker	1	0	0
AR	Yell	0	0	1
GA	Dooley	1	0	0
GA	Greene	0	0	1
GA	Schley	1	0	0
MD	Allegany	0	0	2**
MD	Washington	1	0	0
NC	Chatham	1	0	1
NC	Granville	0	0	1
SC	Aiken	1	0	2
SC	Barnwell	1	0	0
SC	Saluda	1	0	1
WV	Jefferson	1	0	0
WV	Morgan	0	0	2
	TOTAL	11	2	13

* One site partially in Cherokee County.

** Sideling Hill population on border between Allegany and Washington Counties.

Population Status

A state-by-state summary of the size and protection status of each population follows.

Alabama

Two extant populations occur in Alabama (see Table 3). One consists of several thousand individuals distributed among fewer than ten subpopulations along 10-15 miles of the Little River, which occurs on the border of Cherokee and DeKalb Counties. A second population of < 100 plants was recently confirmed on Town Creek in DeKalb County (Scott Gunn and Mark Bailey, Alabama Natural Heritage Program, pers. comm. 1990); prior to 1990, this occurrence had been last seen in 1960 (S. Gunn pers. comm. 1989).

Approximately one-third of the Little River site is within DeSoto State Park, and one-third is under private ownership but leased to the Department of Game and Fisheries; the other third is in private ownership. The population on Town Creek is entirely under private ownership.

In 1979, Freeman et al. reported the plant from Jackson and Lee Counties and made deposits in the Auburn University Herbarium. Although these two sites have not been recently confirmed (S. Gunn pers. comm. 1989), they make Jackson and Lee Counties high priority for future searches. The occurrence of populations in other counties such as Tuscaloosa, Cullman, and Walker is unlikely due to heavy strip-mining and extensive impoundment of rivers (S. Gunn pers. comm. 1989).

There is some residential development in the area of the Little River population. In addition, there are several small abandoned dams upstream from the population. Flooding could damage the population if any of these dams was to

Table 3. Current status of extant populations.

ST	County	Site Name	Most Recent Survey	Size	Ref.	Ownership
AL	DeKalb	Little River	1990	thousands	1	public/ private
AL	DeKalb	Town Creek	1990	< 100	1	private
AR	Yell	Irons Fork	1990	hundreds	2	public
GA	Greene	Outcrop	1990	< 100	3	private
MD	Allegany	Sideling Hill	1990	30,000	4	public
MD	Allegany	Fifteen Mile	1990	500	4	public
NC	Chatham	Deep River	1989	200-300	5	private
NC	Granville	Tar River	1989	200-300	5	private
SC	Aiken	Monetta Sink	1990	51-100	6	private
SC	Aiken	Windmill	1990	100's	6	private
SC	Saluda	High Ponds	1990	50-100	6	private
WV	Morgan	Sleepy Creek	1990	1,000,000	7	private
WV	Morgan	Cacapon	1990	10,000	7	private

References:

1 - S. Gunn (AL Heritage)
2 - V. Bates (AR Heritage and TNC)
3 - T. Patrick (GA Heritage)
4 - Maddox and Bartgis (1989)
5 - M. Boyer and R. Sutter (NC Plant Conservation Program)
6 - J. Nelson (SC Heritage)
7 - B. McDonald (WV Heritage)

collapse. Construction of new dams and the consequent permanent inundation of habitat is also a potential threat.

Analysis of Little River water samples revealed high levels of human choleriform bacteria, suggesting a high amount of sewage input (S. Gunn pers. comm. 1990). Also, some sites contained heavy algal populations (R. Bartgis pers. obs.), which may reduce the number of suitable sites for establishment of young plants. Acidic runoff from abandoned but unreclaimed strip mines may pose a pollution threat to both populations, but especially to Town Creek (S. Gunn pers. comm. 1990). There is no state legal protection for P. nodosum (or any plant) in Alabama.

A section of the Little River which includes a major subpopulation is currently under review for possible inclusion in the National Park system.

Arkansas

The single extant population in Arkansas was discovered in 1990 on Irons Fork in Yell County (Vernon Bates, Arkansas Natural Heritage Program and TNC, pers. comm. 1991). The population contains several hundred plants distributed among three subpopulations over 5-7 miles of river.

At the present time, all three subpopulations are in relatively good condition. Two of the subpopulations are within the Ouachita National Forest, and appear unthreatened. The third subpopulation occurs on private land, on a gravel bar that is often used as a source of gravel for roads. Although the plant is due for state listing, this will not afford any state legal protection to these subpopulations.

Discovery of the Arkansas population dramatically increases the known range of P. nodosum, and suggests the possibility that the plant may occur in several heretofore unsurveyed areas, including southern Missouri, eastern

Oklahoma, and the Boston Mountains in northwest Arkansas (V. Bates pers. comm. 1991).

Georgia

The single extant population in Georgia occurs in Greene County on a small (0.25 acre) granite outcrop that is in private ownership. The site is within 0.5 mile of a freeway exit ramp, but there are currently no known plans to expand the freeway or develop this area.

The population has no legal protection; although the plant is proposed for inclusion on the state list of endangered plants, state legal protection is extended only to populations on public lands. Further, because it is very small and isolated, it is especially susceptible to chance events in weather or demography.

Plants in this population number approximately 100 in a good year and as few as two in a poor year, and grow at the edges of a small seasonal pond. Although this outcrop site would seem to be atypical P. nodosum habitat, it is similar to other sites in regard to the seasonality of water levels. The plants grow at an intermediate water depth where they are neither drowned nor desiccated (Tom Patrick, Georgia Natural Heritage Inventory, pers. comm. 1989). The site has been used for experimental transplants of several granite outcrop species; however, P. nodosum is thought to be a natural occurrence (T. Patrick pers. comm. 1989).

Two historical sites in Schley and Dooley Counties still have appropriate habitat but contained no P. nodosum in 1989. Both sites are coastal plain pond habitats.

No other granite outcrop sites have been discovered despite intensive surveys (over 150 granite outcrops in Georgia, Alabama, and South Carolina have been checked for P. nodosum) by Jim Allison and others (T. Patrick pers. comm. 1989). Many coastal plain ponds in Georgia have been

surveyed either for P. nodosum or a related species, Oxypolis canbyi, and no new pond populations are expected to be found in the state. However, rocky streams in the northern half of the state need investigation because the Little River (the P. nodosum site in Alabama) originates in Georgia's Cumberland Plateau.

Maryland

Both extant Maryland populations appear to have a stable population size and distribution within their habitats. The larger of the two Maryland populations occurs in Sideling Hill Creek on the border of Allegany and Washington Counties, and contains at least 30,000 individuals divided among 50-60 subpopulations (Maddox and Bartgis 1989). About three-quarters of these subpopulations are on state-owned sites (State Forest, Wildlife Management Area, or State Highway Administration lands) or sites that are unlikely to be developed (a Boy Scout Reservation).

Taking endangered species on Maryland state lands is prohibited without a permit, and land managers are required to consider the plant when planning land management activities. Subpopulations within the wildlife management area occur in designated Natural Heritage Areas, but specific management prescriptions for these or other state-owned areas have not yet been developed. The State is negotiating for acquisition of the largest privately-owned tract of P. nodosum habitat on Sideling Hill Creek. The National Guard leases this area, but their activities have not affected the plant or its habitat.

The second population (Fifteen Mile Creek) consists of a single subpopulation containing less than 500 individuals. The plants occur on state forest land, but no specific management program for protecting this habitat has been developed.

Major bridge and freeway construction projects recently occurred on both streams, causing erosion and heavy siltation problems. Experimental transplants of P. nodosum exhibited poor survivorship at the freeway construction site on Sideling Hill Creek despite the existence of appropriate habitat (Maddox and Bartgis 1990a), suggesting that environmental perturbations from construction (chemical or sediment runoff) may be detrimental to the plant's survival.

Despite these projects, both creeks remain generally undisturbed, and there is little residential development on the adjacent uplands, although some agriculture occurs in the floodplain on Sideling Hill Creek. Human impacts may eventually increase since tourism and vacation home development are expected in the future.

Several other stream systems in the state, including the Potomac River (with a historical harperella site adjacent to the C&O Canal National Historic Park), contain apparently potential habitat for P. nodosum. The Potomac, however, has been heavily polluted in the past by industrial (especially coal mining) and agricultural waste; experimental transplants on a Potomac River site experienced 100% mortality within nine months (Maddox and Bartgis 1989, 1990a).

Most other streams in the area that appear to be physically suitable and relatively undisturbed have been surveyed for the plant. Although the Fifteen Mile Creek site was not verified until 1988, no new sites in Maryland are expected to be found.

North Carolina

The two North Carolina populations are found on the Tar and Deep Rivers. Each population consists of a single subpopulation containing less than 300 individuals, and both have been relatively stable since 1985. Both populations are in private ownership and are not protected.

A historical site on the Haw River, near its confluence with the Deep River, was destroyed by construction of a dam. This site occurs one kilometer downstream from the confluence with the Rocky River, suggesting that additional sites may exist on the Rocky River.

Three proposed projects upstream from the extant Deep River P. nodosum population are potential threats: expansion of a sewage treatment facility in Siler City, which may affect the water quality of the Rocky River; an industrial park in Siler City; and reactivation of a coal mine (last operative in the 1800's) on the Deep River.

Currently under review is designation of a High Quality Water Administrative Rule (General Statutes 143-214 and 143-215) that provides limited protection to drainage systems containing rare species. Both P. nodosum sites would be strong candidates for a High Quality Water designation.

South Carolina

Four of seven historically known populations were reported as extant in 1989. However, one of the four did not contain P. nodosum in 1990 (John B. Nelson, South Carolina Heritage Trust, pers. comm.). Instead the site contained P. cappillaceum, and there is now some doubt as to whether it ever contained P. nodosum (in Table 2 the site is classified as "extirpated").

All seven populations occur or occurred in seasonal coastal plain ponds (sometimes called "Carolina Bays" or "boggy ponds"), which have been disturbed by drainage ditches. The three extant populations appear to be feeble or declining. All three populations are relatively small and experience wide yearly population fluctuations. The causes of such fluctuations are unknown, although Oxypolis canbyi experiences population fluctuations caused by annual variation in water levels (Boyer 1988).

None of the extant sites is protected. Coastal plain pond sites are affected by ditching and dredging that is done to make land more suitable for agriculture, silviculture, or livestock watering. The plant is very intolerant of dry conditions, and such activities pose severe and immediate threats to the populations.

Because these populations are small and isolated, they are particularly susceptible to chance natural events.

West Virginia

The Sleepy Creek population, the larger of the two extant West Virginia populations, contained as many as one million individuals in 1990, with many subpopulations distributed over 15 river miles (Brian McDonald, West Virginia Natural Heritage Program, pers. comm.). The second population, on the Cacapon River, contained approximately 100,000 individuals in 20 subpopulations in 1990, distributed over 20 river miles.

P. nodosum was reported in 1830 at Harpers Ferry (probably on the Shenandoah River). This area was subsequently heavily disturbed by industrialization, dams, Civil War events, and severe floods; recent attempts to find P. nodosum there were unsuccessful. Although excellent habitat occurs on several other streams in West Virginia, all have been extensively surveyed for P. nodosum (a total of 422 km) and apparently do not contain the species (R. Bartgis pers. obs.).

Much of the area where P. nodosum occurs in West Virginia has been subdivided and sold for vacation home sites. From 1970 to 1985, 47% of the river frontage on the Cacapon was subdivided into lots of ten acres or less. Possible threats to the species posed by shoreline use include (1) tree clearing along the river banks and consequent erosion, (2) herbicide and pesticide runoff, and

(3) trampling and bank destabilization through human use. In 1984 on Sleepy Creek, up to 10,000 plants were destroyed by soil dumping and siltation from one construction project. The highly fragmented land ownership patterns on Sleepy Creek and the Cacapon River seriously complicate habitat protection activities.

In terms of impending threats, a ski resort has been proposed along the Cacapon River. Potential impacts of the resort include increased sediment runoff from steep mountains during slope clearing and heavy use of river water for snow-making.

Further, the West Virginia Department of Commerce, Labor and Environmental Resources is proposing to divert water from the Cacapon River for a golf course and other state park facilities. Both the ski resort and the commerce department proposals would divert water from the Cacapon watershed and release it into the Sleepy Creek watershed.

Only one of the subpopulations in West Virginia occurs on a protected site (a Nature Conservancy easement on one Cacapon River stand); however, The Nature Conservancy has included in its Registry Program some of the landowners on both streams whose land was known to contain P. nodosum in 1985.

Habitat, Life History, and Ecology

Published reports (e.g., Easterly 1957, Kral 1981) and current observations (Rob Sutter, The Nature Conservancy; T. Patrick; J. Nelson; B. McDonald; Maddox and Bartgis 1989) confirm that P. nodosum comprises populations that occupy two somewhat distinct habitats. These differences in habitat constitute the historical P. nodosum and P. fluviatile division. There is also some evidence that the Nodosum and Fluviatile forms are genetically differentiated, although not

necessarily at the level of distinct species (Kress et al. 1990).

Since differences in both habitat and biology are potentially important to issues of conservation and stewardship, the ecology of each form, or ecotype, is discussed separately in the following sections.

Pollination and seed viability do not appear to be limiting for either form, although much more is known about Fluviatile in these respects. Plants of both forms contain both bisexual and male florets and at least some self-pollination is possible (Easterly 1957).

Neither form has any reported herbivores, although slugs killed some experimental transplants in drier sites in Maryland (Maddox unpubl. data).

Fluviatile Ecotype

Life History:

Fluviatile grows on rocky and sandy shoals and, rarely, on muddy banks of seasonally flooded and quickly moving streams in Maryland, West Virginia, North Carolina, Alabama, and Arkansas.

Plants flower in July and August, and fluctuating water levels tend to knock over flowering stems. In the Potomac watershed, seeds germinate in September, often clustered at the site of the fallen flower. Decumbent flowering stems proliferate by developing rooting shoots at each node (Rose 1911; Easterly 1957; Maddox and Bartgis 1989, 1990a). The flowering stems then decompose, leaving physically distinct parent and offspring shoots; the flowering stem thus acts as a stolon. The parent plants, the asexual buds, and the surviving seedlings then overwinter as evergreens under high

water. All plants may grow and produce flowering stems the next season (Maddox and Bartgis 1989, 1990a).

Thus, the Fluviatile type behaves as a perennial in the manner of such stoloniferous perennials as Fragaria virginiana and Viola species, which produce vegetative daughters that live up to three years (Cook 1983).

Perennial behavior in Fluviatile was originally recorded by Rose (1911) and Easterly (1957), and has been recently observed in West Virginia (B. McDonald pers. comm. 1989), North Carolina (R. Sutter pers. comm. 1990), and Alabama (S. Gunn pers. comm. 1989). Easterly (1957) believed that the asexual buds survived only two years (asexual biennality) and described the plant as an asexual annual. It may be more appropriate, however, to call Fluviatile a short-lived perennial (Maddox and Bartgis 1989, 1990a).

An alternative possibility is that Fluviatile is a long-lived annual that does not annuate because it is protected from cold and drought by high winter water (i.e., a facultative perennial). However, Fluviatile is somewhat frost hardy. Ten Maryland plants grown in pots (five submerged and five in water up to the soil surface) survived eight weeks in intermittently sub-zero weather occasionally as low as -10°C (Maddox unpubl. data).

The major adaptive significance of vegetative spread in this plant may be that it permits the plant to maintain a grip on a substrate that is continuously eroded by heavy water flow in winter and spring. Seedlings, which at the onset of winter high water have only cotyledons or one small leaf, may be too small and insecurely rooted to survive winter flood in meaningful numbers. In 1988 in Maryland, Maddox and Bartgis (1990a) observed significant over-winter mortality among seedlings. No seedlings were produced in 1989 because of unusually high summer and fall water levels.

Seeds readily float, so dispersal probably is mediated by water flow; however, safe sites downstream are

infrequently and haphazardly found. Further, seeds have no structures to facilitate aerial dispersal and drop quickly to the ground, with many seeds germinating directly under the parent plant. Thus, seed dispersal to new sites is probably a rare event. The longevity of seeds in the soil or water is unknown.

Vegetative buds (leaves plus roots) can live indefinitely floating in water, and can root themselves when grounded under wet and stable conditions. Vegetative dispersal downstream is thus possible. Slow dispersal upstream may occur as subpopulations expand along the river banks or by the movement of shoals through upstream accumulation of sediments.

Habitat Description and Requirements:

Fluviatile typically grows on rocky shoals, in crevices in exposed bedrock, and, rarely, along sheltered muddy banks. The largest subpopulations are often found in sunny sections of creeks.

Within such areas the plants are found in microsites that are sheltered from the erosive effects of rapidly moving water; for example, plants are usually found on the downstream side of large rocks or amidst thick clones of water willow (Justicia americana (Acanthaceae)). This anecdotal evidence indicates that Fluviatile is restricted to sites that are somewhat protected from the onslaughts of flood waters and, possibly, ice scouring.

Fluviatile is restricted to a very narrow range of mean water depths. For instance, the presence of Fluviatile in Maryland was strongly associated with certain intermediate water depths (Maddox and Bartgis 1990a). The plant was entirely absent from the shallowest or driest areas and deep waters, even though such areas could include J. americana.

There are three basic explanations for this restriction to intermediate water depths. First, P. nodosum may be too small to complete its life cycle in very deep water. Seed germination would be especially problematic in continuously inundated areas. Second, water depth is strongly correlated with water velocity. P. nodosum may be physically eliminated from deeper water simply because the plants cannot hold on to the substrate. Maddox and Bartgis (1989, 1990a) observed significant mortality among experimental transplants placed in slightly deeper water. Third, P. nodosum may be absent from shallow water because of either the negative effects of competition by other species and/or physiological intolerance of dry conditions. Potted P. nodosum in a greenhouse are very sensitive to even moderately dry conditions experienced for short periods (D. Maddox pers. obs.). Sufficiently watered individuals survive well in otherwise similar conditions.

Associated Species:

Typical associates of Fluviatile in riverine habitats include: (1) on rocky shoal sites, Justicia americana, Isoetes riparia, and Orontium aquaticum; (2) on sandy banks at the water's edge, Eupatorium coelestinum, Eupatorium fistulosum, Lobelia cardinalis, Arthraxon hispidus, Lysimachia terrestris, Andropogon gerardi, Tripsacum dactyloides, Panicum spp., Carex torta, and Scirpus expansus.

In Arkansas, associated species include Juncus repens, Dulichium arundinaceum, Xyris spp., Hydrolea ovata, Alnus serrulata, and Gratiola brevifolia.

Demography:

Fluviatile populations exhibit considerable substructure consisting of many small units situated on small patches of

appropriate habitat. Two observations concerning population substructure are potentially important: (1) there is significant turnover in subpopulations, and (2) a large majority of subpopulations are small, containing less than 200 individuals.

There is significant dynamism in the persistence of individual stands. Fifteen percent (15%) of subpopulations at Maryland's Sideling Hill Creek were extirpated or created during 1988-1989 (Maddox and Bartgis 1990a). Over a five-year period, 25% of stands along a 1.5 km section of Sleepy Creek in West Virginia were lost or created (5% per year). There was a 30% rate of stand turnover on the Cacapon River from 1984 to 1988.

This dynamism is correlated with the size of subpopulations: small stands are more likely to be reduced in size or extirpated altogether (Maddox and Bartgis 1990a). This observation has important ramifications, since most subpopulations range-wide are small, containing less than 200 individuals.

The fact that small stands have a relatively high probability of extirpation or decline is critical to management and recovery. High rates of stand dynamism suggest that populations made up of one or a few small stands, such as the two populations in North Carolina, Maryland's Fifteen Mile Creek, and to a lesser extent West Virginia's Cacapon River, are at significant annual risk. Even in large populations, subpopulation turnover rates of 5-15% per year suggest that a series of several "poor" years could transform these large populations into relatively small ones.

The implication for the development of a protection or recovery strategy is that the species cannot be protected by preserving a few of the exemplary subpopulations. For example, several West Virginia sites containing P. nodosum were registered on the basis of 1985 data, but contained no

P. nodosum in 1989. A broader view of protection -- a watershed perspective -- must be adopted that accounts for P. nodosum's sensitivity to environmental stochasticity.

Nodosum Ecotype

Significantly less is known about Nodosum because it is less common and has not been the subject of intensive research. What is known comes from the publications of Mathias (1936), Easterly (1957), and Kral (1981), from observations during site visits by local biologists (T. Patrick, GA Heritage; J. Nelson, SC Heritage Trust; Doug Rayner, Wofford College), and extrapolation from research on Fluviatile. The lack of knowledge about Nodosum and its extreme rarity suggest that further research into its ecological requirements and conservation needs is urgent.

Life History:

Nodosum occupies the edges of coastal plain ponds in South Carolina and a granite flatrock site in Georgia. Five other historical sites in South Carolina and southern Georgia, now extirpated or destroyed, were coastal plain ponds.

Nodosum does not tend to proliferate (Easterly 1957), perhaps because flowering stems are not made decumbent by high water (Kral 1981). The plant behaves as a true annual on these sites, germinating, growing, and flowering in one season. Seedling germination has not been observed, but the fall die-back of adults suggests that germination occurs in spring.

The plant apparently annuates without experiencing a frost; rather, dry conditions seem to stimulate die-back (T. Patrick pers. comm.). The Fluviatile type has also been

shown to be extremely sensitive to dry conditions (Easterly 1957, Maddox and Bartgis 1989). Decreasing photoperiod could also play a role in Nodosum's annual behavior.

Dispersal in Nodosum has not been studied. Like Fluviatile, seed dispersal within a site is probably mediated by water flow. Because Nodosum does not proliferate at the nodes, it does not disperse locally through vegetative spread. The longevity of seeds in the soil or water is unknown.

The natural founding of new pond populations is probably very rare because of the plant's (apparently) poor capacity for long distance dispersal and the fragmented dispersion of appropriate habitat. However, the mechanism and frequency of dispersal to new sites has not been studied. Aerial dispersal is possible given the small seeds (without other mechanisms for aerial dispersal, however). Seeds or vegetative shoots may disperse on the feet or coats/feathers of animals, but this has not been observed.

Habitat Description and Requirements:

The few existing sites for Nodosum in the coastal plain are shallow pineland ponds and low savanna meadows. An exception is the Georgia population, which exists on a granite outcrop. Both habitats are seasonally flooded, typically with standing water from late fall through early summer and saturated conditions for the balance of the year. Soils tend to be a peat muck overlying sand or sandy-silt.

Like Fluviatile, Nodosum probably requires intermediate water levels. This is not precisely known and more research could be beneficial, but the conjecture is supported by the fact that Nodosum grows at the edges of its native ponds. Continuously inundated areas are probably too deep for the plant to complete its life cycle, and Nodosum is probably

excluded from drier areas by physiological intolerance of drought and by inter-specific competition.

Associated Species:

The dominant species at P. nodosum sites is often Panicum hemitimon. Other species may include many sedges in the genera Rhynchospora (e.g., R. perplexa, R. microcarpa), Carex (e.g., C. walteri, C. lupulina), Eleocharis (e.g., E. tricostata, E. melanocarpa), Psilocarya, Dichromena colorata, and Fimbristylis. Dicot associates include Hypericum fasciculatum, H. denticulatum, H. myrtifolium, Rhexia virginica, R. mariana, R. aristosa, Proserpinaca pectinata, several Ludwigia species, and Sclerolepis uniflora (Kral 1983).

Population Genetics of Both Forms

In a study of electrophoretically detectable genetic variation conducted by the Smithsonian Institution and the Maryland Natural Heritage Program (Kress et al. 1990), seven populations from Maryland, West Virginia, and the Carolinas were sampled (all were Fluviatile populations except for one Nodosum population). Thirteen loci were scored for 118 individual plants.

Levels of genetic variation in P. nodosum were exceptionally low. The mean number of alleles per locus was 1.1 with very little variation among populations. The mean observed heterozygosity (HO) for all populations was 0.011 (Kress et al. 1990). Most genetic variation was found between populations, and at least two populations exhibited significant departures from Hardy-Weinberg equilibrium (i.e., showed a deficiency of heterozygotes). These observations suggest a primarily inbreeding type of breeding system.

Further, analysis suggested that, based on a single Nodosum sample, Nodosum and Fluviatile are genetically distinct.

This work is continuing and will ultimately include all thirteen populations.

Threats and Conservation Needs

Threats to Fluviatile Populations:

Primary threats to the persistence of P. nodosum in riverine habitats involve manipulations of water flow and water quality. Because Fluviatile tends to occupy a narrow range of water depths, manipulations of water flow upstream from populations can easily destroy suitable habitat by inundation or persistent desiccation. Dams, reservoirs, or other water impoundments or diversions would almost certainly threaten any P. nodosum downstream.

Natural fluctuation in water flow causes significant yearly variation in subpopulation persistence. Small subpopulations are particularly susceptible to loss during normal high water events. Thus, small populations such as those in North Carolina or Maryland's Fifteen Mile Creek are at significant yearly risk. Hydrological manipulations on rivers with small populations should be strictly avoided or controlled.

Fluviatile is apparently also sensitive to reductions in water quality. Siltation caused by heavy construction, residential development, and agriculture has been cited as detrimental to the plant. The negative effect of sediment on Fluviatile was substantiated in a greenhouse experiment: turbidity equal to that near a bridge construction site reduced Fluviatile growth rate by 40% (Maddox and Bartgis 1990b).

Another greenhouse experiment indicates that stream acidification (especially pH < 5.0) may cause significant plant mortality (Maddox and Bartgis 1990b). Plants growing in water with pH approximately equal to 3.4 had a 70% mortality rate; in water with pH = 4.6 plants grew at a significantly lower rate than controls. This is potentially important in Alabama, where the extant population has historically experienced low pH due to mining. At Maryland and West Virginia sites, the pH is typically 7.0. However, the acid neutralizing capacity is very low, suggesting that minor acid inputs could significantly lower pH. Other water quality variables, such as increased sewage or nitrate concentration, may also be detrimental.

Finally, habitat moves up and down the river as water flow rearranges the distribution of rocky shoals on the landscape. Thus, protection of small areas of habitat are likely to be ineffective.

This wide range of stream influences on Fluviatile survival and distribution suggests that a broad view of habitat conservation should be adopted. Specific areas of habitat and population occurrence along river corridors will require protection. However, these should be designed as corridors that allow populations to track moving habitat. The integrity of the drainage system upstream is critical and should be protected from perturbations resulting from intensive land use practices such as mining, dams, reservoirs, construction, and agriculture.

Fluviatile grows only in microsites that contain few other plants. This constitutes circumstantial evidence that (a) few other plants are adapted to this plant's harsh flooded environment, and/or (b) P. nodosum is a poor competitor (although no explicit assessment of the plant's competitive ability has been made). The exotic grass Arthraxon hispidus is a potential threat in West Virginia and Maryland, where it occasionally occurs at P. nodosum

microsites. However, casual observations in Maryland suggest that Arthraxon's annual habit makes it susceptible to high turbulent water. Unusually high water levels in 1989 apparently eliminated the grass from many P. nodosum areas in Maryland. Nevertheless, the presence of Arthraxon in P. nodosum sites is a threat and should be monitored.

Threats to Nodosum Populations:

Nodosum, like Fluviatile, depends on intermediate water levels and is threatened by either dry conditions or total inundation. Thus, the primary threats to Nodosum populations are hydrological manipulation and physical destruction of their pond habitats.

Coastal plain ponds everywhere are threatened by active drainage for conversion to pine plantations or row crops (Godfrey and Wooten 1979). Lowered water tables are probably detrimental to Nodosum through increased competitive and physiological stress. While hydrological manipulations directly to the pond are clearly detrimental, ditching and other manipulations of the water table from some distance away may affect coastal plain ponds, although the exact area of effect is not known (Pat Phillips, U.S. Geological Survey, pers. comm. 1989). The effective distance of such manipulations clearly is important in determining the zone around a population needed to ensure protection of the hydrological resource.

Occasionally ponds are dredged to create deep ponds for livestock; these deeper water levels probably disrupt the life cycle of Nodosum, a small plant.

No experiments have been conducted to determine the sensitivity of the Nodosum type to declines in water quality.

Despite these threats, P. nodosum sites are spatially discrete and, as such, their protection needs may be easily identified (although the effect of more distant hydrological

disturbances remains a question). Since all Nodosum sites have been disturbed by drainage attempts, active management of the sites may be required.

The ecological and life history uniqueness of the Nodosum type and the small size of the few populations suggest that conservation measures for Nodosum should have high priority.

Current Conservation Measures

State Natural Heritage and Endangered Species Programs and The Nature Conservancy have been active in searching for new P. nodosum populations (all states within the species' range except Arkansas), monitoring extant sites (all states except Arkansas), conducting studies of life history and ecology (Maryland), and negotiating voluntary protection agreements with landowners (Maryland, West Virginia). No work has been conducted in Arkansas because, until recently, the state had not been known to be within the plant's range.

While none of the smallest and most immediately threatened sites are protected, a few of the populations are located, at least in part, on state-owned lands, and two of the three Arkansas subpopulations are located on Federal property.

Conservation and management activities accomplished to date are summarized below.

- Population surveys and inventories have been performed at all current sites by State Heritage Programs or botanists from various universities. Active population monitoring occurs only in Maryland and West Virginia.

- Surveys for new populations have been undertaken in all states containing extant populations, except Arkansas. New

populations were verified in Maryland in 1988 and Arkansas in 1990. Significant potential habitat or recent unconfirmed records remain to be investigated in Alabama, Georgia, North and South Carolina, Arkansas, southern Missouri, and eastern Oklahoma.

- The Nature Conservancy, Western Pennsylvania Conservancy, and Maryland Department of Natural Resources have begun a comprehensive program to protect Sideling Hill Creek, including upstream areas as buffer. To date, a number of tracts have been registered in Maryland and Pennsylvania, a tract has been acquired on the border of Maryland and Pennsylvania, and the potential purchase of the most significant tract supporting P. nodosum is being negotiated by the State of Maryland and The Nature Conservancy.

- The Nature Conservancy has acquired an easement on one Cacapon River subpopulation. Additional subpopulations in West Virginia have been added to the Conservancy's registry program. The U.S. Fish and Wildlife Service contracted with The Nature Conservancy in 1990 to expand landowner contact efforts on the Cacapon River.

- The Maryland Natural Heritage Program has conducted an extensive two-year investigation of the ecology and life history of Fluviatile (Maddox and Bartgis 1989, 1990a, 1990b).

- The Maryland Natural Heritage Program has collaborated with the Smithsonian Institution on a study of electrophoretically detectable genetic variation throughout the range of P. nodosum. This study is expected to be completed in spring of 1991.

- The Maryland Natural Heritage Program has produced and distributed several information brochures on the biology of P. nodosum and its habitat.

- In a 1988 survey conducted by the Center for Plant Conservation to determine the plant taxa in most imminent danger of extinction, P. nodosum was identified by botanists as a "B" priority taxon, i.e., one which could go extinct in the wild within the next ten years. The Center has assisted in the recovery of the plant: 7,500 seeds have been collected as part of the National Collection of Endangered Plants and are housed at the North Carolina Botanical Garden (NCBG), one of the Center's participating institutions in the region. All seeds were collected from the Tar River area in Granville County, North Carolina. Although not currently being propagated at NCBG, these seeds provide a valuable conservation resource.

Recovery Strategy

To reach recovery, nine currently large or stable populations must be protected and either maintained at current status or increased. Four marginal populations must be protected and augmented to the point where they can be self-sustaining. Thirteen additional populations must be discovered or established.

Initial recovery efforts will focus on site protection and gaining a better understanding of species and habitat characteristics. Most of the existing populations are on private lands and are not protected. Acquisition of land containing significant populations will be sought on a willing seller basis, or agreements with landowners for permanent protection will be negotiated. Where permanent protection is not possible, voluntary landowner registry will

be pursued. Habitats with priority for near-term habitat protection include the pond sites and the significant riverine habitats.

Continued monitoring of all populations will be conducted to assess population trends and habitat disturbances, and to identify potential threats and problems. Appropriate management techniques will be implemented as soon as possible to stabilize disturbed habitats of existing populations. Active management may be required at some coastal plain pond sites, and attempts to reverse hydrological manipulations may be required to make some populations self-sustaining.

Over the longer term, a broad-based approach to protection will be undertaken. Sources of potential impacts throughout the watersheds of known populations will be identified, and watershed-wide conservation measures will be sought. To reach full recovery, searches for additional populations will be conducted and/or populations will be re-established within the historic range of *P. nodosum*, using propagation and transplant techniques developed through ongoing investigations into the plant's requirements.

PART II: RECOVERY

Recovery Objectives

The recovery goal for Ptilimnium nodosum (Harperella) is to delist the species. This will be accomplished by meeting the following recovery objectives.

P. nodosum will be considered for **reclassification** to threatened status when:

1. Thirteen populations (the number of currently extant populations) have been relatively stable in population size for five years.

2. All thirteen populations are permanently protected.

P. nodosum will be considered for **delisting** when:

3. There are at least 26 self-sustaining populations in existence. To reach this level, at least thirteen new populations will have to be discovered or established. This is the total number of current and historically known populations.

   Self-sustaining populations of P. nodosum are defined as being large enough to have a high probability of (1) surviving normal population cycles, (2) persisting through natural extremes in weather, and (3) containing sufficient genetic variation to adapt to natural habitat changes.

4. The populations are distributed throughout the historical range from Arkansas to Maryland.

Specifics such as the exact location of populations, the number of individuals required in each population, and their potential response to environmental variation will be studied among the recovery tasks.

3. All 26 populations are permanently protected.

This recovery objective is subject to modification based on information gathered during the completion of the recovery tasks. The recovery process will be assessed annually, after which recovery objectives may be revised upward or downward and recovery tasks redirected.

Recovery Tasks

1.0 Protect existing populations and essential habitat. Thirteen populations of P. nodosum were extant in 1990. Several of these populations are small or declining and only four populations contain 1,000 or more individuals; three of the four are in the northern part of the range. Because of the low number of extant populations and their generally small size, all known populations should be protected.

1.1 Delineate essential habitat for existing populations. The geographic limits of the pond populations and five of the riparian populations (in West Virginia, Alabama, and Maryland) are known, but limits have not been fully determined for the North Carolina populations, several unconfirmed Alabama populations, and the newly

discovered Arkansas population. Essential habitat for all known populations will be delineated using available information about habitat and species characteristics. Delineation of riparian habitats will take into account the dynamic spatial patterns of these populations, and will include unoccupied stream-side sections that may be colonized in the future.

1.2 Identify and monitor threats to all known populations. Activities that may affect P. nodosum habitat are widespread and continually changing. Populations that are most threatened at the current time will be identified, and existing threats will be closely monitored. Over the longer term, existing and potential threats to all known populations -- including development, drainage, filling, water diversion, sedimentation, declining water quality, and appearance of alien (non-native) competitors -- will be monitored and documented. Further, remote sensing or aerial photographs will be used to monitor watershed trends such as changes in land use patterns. For both riparian and pond populations, impacts to the watershed at some distance from occupied habitat may affect the P. nodosum. Sources of impacts will be identified within watersheds of all populations.

1.3 Determine habitat protection priorities. Initial protection efforts will focus on the most significant populations, i.e., those of particular ecological importance and/or those that are particularly threatened.

As a preliminary strategy, priority will be given to all four Nodosum populations due to their ecological and life history distinctiveness, as well as their extreme vulnerability to habitat impacts.

For riparian systems, priority sites should include both North Carolina populations (because of their small size), Little River, Alabama and Irons Fork, Arkansas (to represent the southern and western range limits), and at least one of the large northern populations (Sideling Hill Creek, Maryland; Sleepy Creek, West Virginia; or Cacapon River, West Virginia).

Priorities will be refined, and modified if necessary, as habitat protection activities proceed and/or conditions change.

1.4 Seek cooperation and active support of private landowners in protecting known sites. Landowners of all known sites will be informed of how their activities may affect the species, and voluntary protection by landowners will be sought when appropriate. In riparian systems, voluntary protection will be sought for unoccupied and upstream sections to provide adequate buffers for water quality maintenance and protect sites for potential future colonization.

1.5 Secure permanent protection of occupied habitats. Means of providing permanent protection to each known population in order to meet the conditions of the reclassification objective will be defined. As a preliminary strategy, private and

public conservation organizations will seek fee title or conservation easements on occupied habitat (and suitable buffer) on a willing seller basis. Efforts will focus on areas where voluntary cooperation may not provide complete protection, particularly if landownership has a high turnover rate (as in West Virginia), or where necessary to alleviate impending threats or actively manage the population.

1.6 Develop management plans for populations on public lands. Several significant sections of riparian P. nodosum populations occur on land owned by public agencies. In cooperation with these agencies, management plans will be developed to address potential impacts, maintain suitable habitat and the vigor of the population, and maintain appropriate streamside and upstream buffer zones.

1.7 Evaluate effectiveness of protection programs and redirect efforts as necessary. Because the species' demography and habitat are so dynamic, the effectiveness of protection efforts for any population will be evaluated annually in terms of (1) spatial and temporal changes in the dispersion of individuals, (2) changes in land use and impacts to habitat, and (3) adequacy of existing protection tools.

People involved in acquisition and registry activities in riparian systems should annually assess the current pattern of population distribution in order to redirect efforts to new subpopulation occurrences.

2.0 Develop watershed protection programs. It may prove necessary to go beyond localized habitat protection to secure long-term protection for P. nodosum populations.

2.1 Identify populations in need of watershed-wide protection. It will be necessary to go beyond localized protection if (1) significant threats occur away from occupied habitat (as in parts of Maryland), or (2) landowner cooperation or habitat acquisition provide insufficient protection for any reason. Potential sources of impacts will be identified for all populations. Populations will be given priority for securing watershed-wide protection based on extent of threats, adequacy of localized site protection, and/or public support for watershed conservation.

2.2 Delineate appropriate watershed boundaries (area of effect) for the populations identified in Task 2.1. Using available information, hydrologic modelling, and other methods, the watershed area that must be protected to ensure a stable water regime for each population specified in the preceding task will be determined.

2.3 Seek watershed-wide conservation measures for specified populations. Watershed-wide conservation measures will be implemented as part of the protection program for specified populations of P. nodosum. Strategies to offset identified impacts will be identified, and measures will be sought to maintain suitable riparian and pond habitat, natural hydrologic

regimes, and water quality. Specific measures will vary by watershed, but may include local zoning and planning regulations, landowner contacts, site acquisition or easements on a willing seller basis, or some combination of these.

3.0 Enforce laws protecting the species and/or its habitat. Provisions of the Endangered Species Act of 1973, as amended, and of Maryland regulations prohibiting the taking of the species from private property without the landowner's written permission and from state property without a permit (Code of Maryland Regulations 08.03.08) will be enforced. Over the longer term, the passage of laws and promulgation of regulations that will promote protection of P. nodosum throughout its range will be encouraged.

4.0 Search for additional populations, and extend protection to newly discovered populations. In most states, discovery of new populations is unlikely. However, much potential habitat remains to be searched in Arkansas, southern Missouri, and eastern Oklahoma. These are areas that were not previously believed to be within the range of P. nodosum, so no field work designed to locate the species has been conducted. Other locations deserve continued searches, particularly North Carolina, northwestern Georgia, and the Piedmont rivers of Alabama. Searches will be continued and expanded as warranted by any new information developed in Task 5.0. Protection as described in Tasks 1-3 will be extended if and when additional populations are found.

5.0 Investigate species and habitat characteristics. More information on habitat requirements and life history characteristics of the species is needed in order to accurately evaluate potential impacts and to fully identify appropriate protection and management strategies.

5.1 Monitor size and spatial distribution of populations. Since spatial distribution of subpopulations in riparian systems can change significantly from year to year, distribution patterns in these systems will be redetermined every three years and after major natural (drought or severe flood) or human (land use) perturbations.

5.2 Conduct long-term demographic studies. P. nodosum populations are quite dynamic and appear to be largely controlled by annual or permanent changes in hydrology. Small riparian stands appear to be at high risk of extirpation over short time periods; pond populations may be more stable, at least in the absence of major hydrologic disturbance.

For pond populations, permanent plots will be established and visited annually for at least four consecutive years at the peak of flowering. Data will be collected on the density of P. nodosum and its neighbors, plant size, number of flowering stems, and water depth. Complete counts of the number of individuals will be made in smaller populations, while estimates will suffice for populations with individuals too numerous to count. This information will also be

gathered during and after hydrologically unusual years in order to understand the influence of such events on population trends.

For riparian populations, comprehensive demographic studies at all sites would be prohibitive because of the difficulty in working along rivers, the large numbers of individuals, and the wide distribution of subpopulations. Detailed studies on the structure of three large subpopulations in Maryland's Sideling Hill Creek will continue to provide insight into long-term stand dynamics. Otherwise, bi-annual estimates of the number of individuals and mapping of subpopulation distribution should suffice. Such surveys will also be conducted during and after hydrologically unusual years or other major perturbations. For small riparian populations actual counts or careful estimates of populations size will be made.

These efforts will provide data on global and local trends in population size, advance warning of potential threats to P. nodosum, and help in the evaluation of protection efforts. A standard monitoring methodology will be developed so that data can be compared among years and sites throughout the plant's range. A proposed methodology is outlined in Appendix A.

5.3 Continue to define habitat requirements of the species. Little is known about the habitat requirements of pond populations. While some extrapolations can be made from knowledge of riparian plants, questions unique to the pond

habitat remain: the potential for competitive stress from neighbors, the importance of water quality, the effects of fire or fire suppression, and the mechanistic effects of drought and flooding.

Much has been learned about habitat requirements of riparian populations through studies in Maryland. However, some questions remain, including the plant's susceptibility to habitat acidification, heavy sedimentation, and other water quality variables.

5.4 Delineate potential habitat. The habitat characterization derived from Task 5.3, as well as information derived from protection efforts conducted in Tasks 1-3, will be used to delineate habitat that may potentially support the species. Potential habitat throughout the species' historical range will be delineated. These areas will then provide the basis for future searches and attempts to establish new populations.

5.5 Correlate past and ongoing habitat disturbances with population trends. Studies will be initiated to correlate habitat disturbances over time with population trends. This will heighten understanding of potential impacts and possibly help in identifying management actions that could reduce or reverse negative impacts. Basic water quality data will be gathered for all riparian sites to use as baseline information in monitoring the effects of impacts.

5.6 Determine the extent of P. nodosum seed storage in ponds. While riparian plants utilize asexual and sexual reproduction to varying degrees depending on seasonal hydrologic regimes, pond populations appear to be restricted to sexual reproduction. It will be determined whether Nodosum are obligate sexual reproducers. The frequency and longevity of stored seed will also be determined.

5.7 Refine and implement appropriate management techniques based on information derived from tasks 5.1-5.6. When species and habitat characteristics are more fully understood, current population and habitat management techniques will be refined, and/or additional techniques will be developed. This information will be incorpated, as appropriate, into the management plans developed through Task 1.6.

5.8 Develop transplant techniques. The riparian form, at least, is easily propagated asexually and field transplants in Maryland have been somewhat successful. Mortality of transplants has been high at several sites that appeared superficially suitable, but where water quality impacts were known to have occurred. A refined understanding of what constitutes suitable habitat (as defined in Tasks 5.3 and 5.4) should help in this regard. The long-term success of transplants is unknown. Nothing is known about the ease of propagating the pond form.

6.0 Conduct further genetic studies. Electrophoretic analyses that have been performed to date suggest that

further study of genetic distinctions between the Nodosum and Fluviatile forms may be warranted. Studies will be designed to further characterize genetic distinctions or similarities between the two forms, and to further determine the genetic composition of all extant populations.

7.0 Develop a cultivated source of plants and provide for long-term seed storage. For smaller populations that are ecologically unusual (e.g., the granite outcrop site in Georgia) or at great risk (the North and South Carolina sites), long-term storage of material may maintain genetic material if the population is lost. There is no current need to maintain material from the larger populations, but this should be re-evaluated if population declines occur.

7.1 Determine requirements for cultivation of live plants.

7.2 Determine conditions necessary for long-term seed storage.

7.3 Develop techniques for re-establishment of populations using cultivated material.

8.0 Re-establish populations in suitable habitat within the species' historical range. Up to thirteen reintroduced populations may be required to reach the delisting objective, if no additional existing populations are located. While some reintroduction efforts could take place on historical sites, several such sites have been destroyed. Thus, suitable sites that have not previously contained the species must be identified.

9.0 Develop materials to inform the public about the status of P. nodosum and the recovery plan objectives. Public support of recovery efforts for P. nodosum could play a significant role in encouraging landowner assistance and raising awareness of activities in behalf of the species. This is particularly important considering the large number of landowners along the occupied riparian corridors and within occupied watersheds. Informational materials will continue to be developed and distributed to landowners and the general public.

In addition, more specialized educational materials or workshops on rare plants, off-site conservation techniques, and reintroduction methods will be designed and conveyed to conservationists.

10.0 Annually assess success of recovery efforts for the species. Recovery efforts are likely to result in the rapid accretion of information available on P. nodosum, its habitat, and potential threats. Recovery efforts should be reviewed annually in order to redirect recovery efforts as necessary.

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PART III: IMPLEMENTATION SCHEDULE

The following schedule indicates recovery tasks that will be initiated sometime during the next three fiscal years. It outlines responsibilities and costs, and provides a general indication of how long it will take to achieve a given task. The tasks are arranged in priority order.

Priorities shown in Column 1 have been assigned based on the following criteria:

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

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

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

Responsible agencies, designated in columns 5 and 6, are abbreviated as follows:

USFWS = U.S. Fish and Wildlife Service

R4, R5 = Regions 4 and 5 of the U.S. Fish and Wildlife Service

SCA = State Conservation Agencies of participating states, including:

Alabama Natural Heritage Program (AL Department of Conservation and Natural Resources)

Arkansas Natural Heritage Program

Georgia Natural Heritage Inventory (GA Department of Natural Resources)

Maryland Natural Heritage Program (MD Department of Natural Resources

North Carolina Plant Conservation Program (NC Department of Agriculture)

South Carolina Heritage Trust Program (SC Wildlife and Marine Resources Department)

West Virginia Natural Heritage Program (WV Department of Commerce, Labor and Environment Resources).

TNC = The Nature Conservancy

CPC = The Center for Plant Conservation

IMPLEMENTATION SCHEDULE
Harperella (Ptilimnium nodosum)

March, 1991

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates, $000			Comments
				USFWS	Other	FY1	FY2	FY3	
1	Delineate essential habitat for existing populations.	1.1	2 years	R4, R5	SCA	3	3		Completed WV, MD, GA. Needed for AL, SC, NC, and AR.
1	Identify and monitor threats to known populations.	1.2	Ongoing	R4, R5	SCA	3	3	3	
1	Determine habitat protection priorities.	1.3	2 years	R4, R5	SCA	1.5	1.5		
1	Seek cooperation of landowners.	1.4	Ongoing	R4, R5	SCA, TNC	10	8	6	Being implemented MD, WV.
1	Identify populations in need of watershed-wide protection.	2.1	2 years	R4, R5	SCA		3	3	
1	Delineate watershed boundaries for specified populations.	2.2	2 years	R4, R5	SCA		4.5	4.5	
1	Enforce laws protecting species and habitat.	3.0	Ongoing	R4, R5	SCA	2	2	2	
1	Search for additional populations.	4.0	2 years	R4, R5	SCA		6	6	
1	Monitor size and distribution of populations.	5.1	Ongoing	R4, R5	SCA	3	3	3	
1	Conduct long-term demographic studies.	5.2	5 years	R4, R5	SCA	5	5	5	Ongoing for Fluviatile type. Needed for Nodosum type.
2	Secure permanent protection of occupied habitats.	1.5	10 years	R4, R5	SCA, TNC				Costs undetermined.
2	Develop management plans for populations on public lands.	1.6	5 years	R4, R5	SCA	3	3	3	

Harperella Implementation Schedule -- March, 1991

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates, $000			Comments
				USFWS	Other	FY1	FY2	FY3	
2	Seek watershed-wide conservation measures.	2.3	5 years	R4, R5	SCA	2.5	2.5	2.5	
2	Annually assess recovery efforts.	10.0	Ongoing	R4, R5	SCA	1	1	1	
3	Evaluate effectiveness of protection programs.	1.7	Ongoing	R4, R5	SCA	.5	.5	.5	
3	Continue to define habitat requirements.	5.3	4 years	R4, R5	SCA	5	5	5	Ongoing for Fluviatile type. Needed for Nodosum type.
3	Delineate potential habitat.	5.4	2 years	R4, R5	SCA			3	
3	Correlate habitat disturbance with population trends.	5.5	Ongoing	R4, R5	SCA	2	2	2	Greatest urgency is at pond sites.
3	Determine length of seed storage in ponds.	5.6	4 years	R4	SCA	4	2	2	
3	Refine and implement appropriate management techniques.	5.7	Ongoing	R4, R5	SCA		3	5	Greatest urgency is at pond sites.
3	Develop transplant techniques.	5.8	2 years	R4	SCA, CPC				Not currently a need in R5. Germplasm resource at NC Botanical Gardens.
3	Conduct further genetic studies.	6.0	2 years	R4, R5	SCA	5	5		
3	Develop a cultivated source of plants.	7.0	2 years	R4, R5	SCA, CPC		3	3	
3	Re-establish populations within historical range.	8.0	Ongoing	R4, R5	SCA, CPC				Contingent on other studies.
3	Develop information materials.	9.0	2 years	R4, R5	SCA, CPC	4.5		4.5	

Appendix A

Proposal for Monitoring Methodology

The two most important issues in any monitoring program are:

(a) Make population size counts or estimates that are comparable primarily among years within sites and, secondarily, among sites. Within-site reliability is of highest importance because it facilitates meaningful assessments of population trends. Reliability (whether the counts are consistently obtained and relatively correct) is more important than precision (whether the count is actually correct).

A counting scale recommended here is:

(i) for populations with < 100 individuals perform an actual count;
(ii) for populations containing 100-1,000 individuals round an estimate to the nearest hundred;
(iii) for populations containing 1,000-10,000 individuals round an estimate to the nearest 1,000;
(iv) and so on for larger orders of magnitude.

(b) Make a rough map of individual distribution within the site. These maps need not be quantitative, but should be sufficient to relocate subpopulations and verify changes in dispersion (e.g., subpopulations associated with a topographic feature or flagged marker).

P. nodosum can be difficult to count because of its morphology (small, densely packed rosettes). There can be many rosettes packed into small areas, which can be connected or physiologically distinct (Maddox and Bartgis 1990a). Also, there can be genetic variation at small scales (Kress et al. 1990). These facts make counts based on rosettes unreliable and subject to large observer bias.

Consequently, we recommend that all counts of P. nodosum be made based on the number of flowering stems. This can be an underestimate of the number of rosettes in riverine populations (Maddox and Bartgis 1989), but it is likely to be the most consistently reliable estimate among sites and observers.

Coastal Plain Pond Populations (Nodosum)

Coastal plain pond sites are relatively easy to census because their boundaries are clear and they tend to support small populations of P. nodosum. Thus, at each census an attempt should be made to:

(a) conduct a complete count of the number of individuals, or an estimate based on the scale above;

(b) create a map of individual dispersion, grounded with either flagged stakes or topographic features.

Riverine Populations (Fluviatile)

Riverine populations can be large with considerable population substructure, both of which are important in a monitoring program. At each census an attempt should be made to:

(a) conduct a complete count of the number of individuals, or an estimate based on the scale above;

(b) create a map of individual dispersion, grounded by referring each subpopulation to a location on a

topographic map; this will facilitate (i) the relocation of subpopulations in future censuses, (ii) verification of subpopulation loss or gain, and (iii) analyses of patterns in subpopulation loss that could be used in management decisions.

Appendix B

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