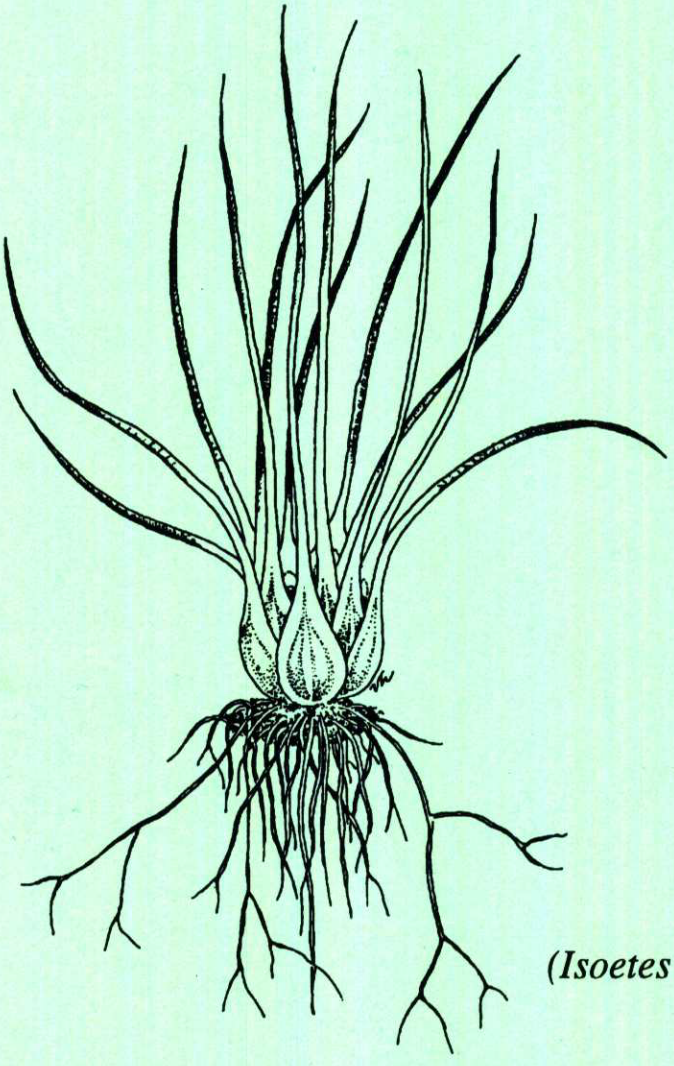
Recovery Plan

Three Granite Outcrop Plants



(Isoetes melanospora)

U.S. Fish and Wildlife Service

RECOVERY PLAN

FOR

THREE GRANITE OUTCROP PLANT SPECIES

Prepared by

James R. Allison
Georgia Department of Natural Resources
Freshwater Wetlands and Heritage Inventory Program
Social Circle, Georgia

for

U.S. Fish and Wildlife Service
Jackson, Mississippi

Southeast Region
Atlanta, Georgia

Approved: _____
James W. Pulliam, Jr.
Regional Director, U.S. Fish & Wildlife Service

Date: July 7, 1993

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. 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.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1993. Recovery Plan for Three Granite Outcrop Plant Species. Jackson, Mississippi. 41 pp.

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EXECUTIVE SUMMARY

Current Status: Isoetes melanospora (black-spored quillwort) and Isoetes tegetiformans (mat-forming quillwort) are listed as endangered species. They are thought to be extant at only eight and seven locations, respectively, all in Georgia. Amphianthus pusillus (amphianthus) is federally listed as a threatened species. It is currently known from 57 locations (4 in Alabama, 3 in South Carolina, and 50 in Georgia).

Habitat Requirements and Limiting Factors: All three species are rooted aquatics restricted to temporary pools formed in depressions on outcrops of granitic rock. Due to their extreme specialization, these species were probably already rare at the time of European contact. The greatest threat to these species is the continuing destruction of habitat from quarrying activities. Other sites have been degraded due to their inclusion in pasture (eutrophication of pools), dumping, and heavy recreational use (i.e., off-road vehicles, vandalism).

Recovery Objectives: Reclassification of both Isoetes spp. to threatened, and delisting of Amphianthus pusillus.

Recovery Criteria: Reclassification of either Isoetes species to threatened will be considered if 10 viable and geographically distinct populations (separate outcrops), each with at least two occupied pools, are protected from any foreseeable threats. Delisting of Amphianthus will be considered if 20 of the known populations (including at least two populations each in Alabama and South Carolina) are protected. Population viability should be confirmed through periodic monitoring for at least a 10-year period.

Actions Needed:

1. Protect populations and habitat.
2. Preserve genetic stock from acutely threatened populations.
3. Monitor populations to determine trends and developing threats.
4. Search for additional populations.
5. Reestablish populations and augment extant populations at protected locations, if deemed necessary.
6. Use management techniques to maintain and/or enhance populations.
7. Educate the public about the value and fragility of these species and their habitat.

Estimated Cost of Recovery: It is not possible to determine costs beyond the first few years. The cost of implementation of tasks over the next 3 years, for which cost estimates have been made, totals $50,000. This does not include the cost of land acquisition.

Date of Recovery: Impossible to determine at this time.

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I. INTRODUCTION

A. Background

On February 5, 1988, the U.S. Fish and Wildlife Service (1988) published in the Federal Register a final rulemaking determining that three granite outcrop plant species were either endangered (Isoetes melanospora Engelm., black-spored quillwort, and I. tegetiformans Rury, mat-forming quillwort) or threatened species (Amphianthus pusillus Torr., amphianthus) under the Endangered Species Act of 1973, as amended. All three species are restricted to the Piedmont Physiographic Province of the Southeast, where they are found only in rock-rimmed temporary pools on ancient weathered exposures of granitic bedrock. Isoetes tegetiformans is known only from Georgia. Isoetes melanospora is extant in Georgia and is historically known from South Carolina. Amphianthus pusillus occurs in both of these States, as well as in Alabama.

Both Isoetes species have been considered extremely rare ever since discovered, with I. melanospora and I. tegetiformans having been collected at only 16 and 10 locations, respectively. All three species have been suffering significant habitat loss during the last 60 years, with the majority of extinctions due to the quarrying of natural exposures of the granite bedrock.

B. Taxonomy and Description

Isoetes melanospora (black-spored quillwort) is a member of the Isoetaceae, one of the families of fern allies. This species was discovered by William Canby in 1869 and later described by Engelmann (1877). It is a typical Isoetes, in that it is a rooted perennial with hollow, finely septate, linear leaves (sporophylls) which are spirally arranged (on mature plants). Leaves are typically less than 7 centimeters (cm) (2.75 inches) long, but may extend up to 15 cm (6 inches) in length. The subterranean bases of the leaves are enlarged and overlapping (imbricate). The leaf bases emanate from the upper portion of a short, squat, corm-like stem, which in this species is bilobed and typically somewhat shreddy. The corm is often somewhat flattened in I. melanospora, and some plants retain a juvenile, distichous leaf arrangement longer than most Isoetes species (Johnson 1938, Rury 1978). When the inner face of the enlarged base of a fertile leaf is examined, a small (1 to 2 millimeters [mm]) (0.4 to 0.8 inches) round to oval sporangium can be seen. The inner face of each sporangium is overlain by a thin, translucent membrane (velum), which in this species completely covers the front of the unpigmented sporangium. Sporangia contain either female spores (megaspores), ca. 0.28 to 0.44 mm in diameter (.01 to .02 inch), i.e., approximately the size of the period at the end of this sentence) or dust-sized male spores (microspores). The mature megaspores of I. melanospora are unique among Southeastern quillworts in that they are gray when dry, black when wet. The megaspore surface varies from tuberculate to nearly smooth (Matthews and Murdy 1969).

The three occurrences of morphological intergradation (I. melanospora X I. piedmontana) documented by Matthews and Murdy (1969) caused them and other authors (e.g., Rury 1978) to question the distinctiveness of the putative parental species. However, Boom (1980) subsequently demonstrated that hybridization is possible in Isoetes, even between species long regarded as only distantly related.

The species of Isoetes considered most closely related to I. melanospora is I. lithophila Pfeiffer (Pfeiffer 1922, Reed 1965, Boom 1982), also restricted to temporary pools on granitic outcrops, but found only in Texas. In the latest plant Notice of Review (U.S. Fish and Wildlife Service 1990), I. lithophila was assigned a category 2 status (i.e., in need of study to determine the appropriateness of listing under the Endangered Species Act). In addition to habitat type, these two taxa share a number of character-states, including dark-pigmented megaspores, a complete velum, and an unpigmented sporangium. Apart from geographic location, these two species have been separated on the basis of leaf length and megaspore size. Both of the latter characters have since been shown to be of uncertain systematic value (e.g., Kott and Britton 1985, Hickey et al. 1989). Further investigation into the relationship of these two taxa would be useful.

Isoetes tegetiformans (mat-forming quillwort or Merlin's-grass) was described by Rury (1978) from material he collected in 1976 in Columbia County, Georgia. It is considered North America's most distinctive quillwort, unique in its distichous leaf-arrangement (never spiraled); its matted growth form due to adventitious budding; and its unbranched, dimorphic roots (Rury 1978). The leaves are typically less than 7 cm long (2.75 inches), but in deeper water they may reach 15 cm (6 inches). Its megaspores are tuberculate and brown (dark brown when wet). A velum completely covers the unpigmented sporangial wall. The stem is commonly surficial rather than being distinctly subterranean. Despite its unique features, Isoetes tegetiformans shows affinity with I. melanospora, as suggested by a significant number of shared characteristics, including darkly pigmented megaspores, unpigmented sporangium, complete velum coverage, lack of peripheral vascular strands in the leaves, habitat requirements, geographic latitude, and phenology.

Additional descriptive information on Isoetes melanospora and/or I. tegetiformans can be found in Boom 1982, Engelmann 1882, Johnson 1938, Lellinger 1985, Pfeiffer 1922, and Rury 1978.

The most common quillwort species of granitic outcrops, Isoetes piedmontana (Pfeiffer) Reed (I. melanopoda Gay & Dur., in the broad sense) possesses white megaspores, an incomplete velum and a pigmented sporangial wall. It is frequently larger than I. melanospora, whose leaves are seldom more than 10 cm (4 inches) long.

Isoetes melanospora and I. tegetiformans have a distinctly different phenology from the common outcrop species I. piedmontana, a distinguishing feature neglected in published studies, although Wherry (1964) appears to have been aware of it. The cycle of growth and dormancy for Isoetes piedmontana is similar to that exhibited by I. butleri (Baskin and Baskin 1979) in that the dormancy induced by late spring or early summer drought is not broken until cool weather returns in autumn. In Isoetes melanospora and I. tegetiformans, dormancy is broken by the presence of ample moisture at any time of the year. Therefore, unlike I. piedmontana, the two listed Isoetes spp. may be found in midsummer, following heavy rains.

Isoetes engelmannii A. Br. is another quillwort occasionally found on granitic outcrops but it has white, reticulate megaspores, a narrow velum, and its leaves are usually longer than 10 cm (4 inches).

Amphianthus pusillus, a member of the flowering plant family Scrophulariaceae, was the first of these three species to be discovered (in 1836) and described (Torrey 1837). The genus contains only this species (monotypic genus), and will henceforth be referred to simply as Amphianthus. It is considered to be a highly specialized form, without close living relatives; similar forms, such as are found in rock pools in Africa (Chamaegigas) and Australia (Glossostigma) are thought to appear similar due to convergent evolution (Pennell 1935).

Amphianthus (amphianthus, little amphianthus, pool sprite, or snorkelwort) is a small, aquatic annual with very short (to ca. 6 mm) (0.25 inch), leafy, rooted, submerged stems which produce flowers and one or more threadlike scapes. The tip of each scape bears two small, ovate to lanceolate, oppositely arranged bracts. The scapes elongate as necessary (to ca. 15 cm (6 inches)) to permit the bracts to float upon the surface of the water. A single small (to 4 mm (0.16 inch) long) white to pale purplish flower is borne between the two bracts. Other flowers borne on the usually submerged short stem are similar to the emersed flowers. The fruit is a small, shallowly bilobed capsule. Seeds are ca. 1 to 1.5 mm (.04-.06 inch) long, dark brown to black, and are oblong (often slightly curved).

Additional descriptive information on Amphianthus can be found in Pennell 1935, Lunsford 1939, and Rayner 1986.

C. Distribution and Ownership

Isoetes melanospora is thought to be extant at only eight locations, all in Georgia (Butts, DeKalb, Gwinnett, Heard, and Rockdale Counties). It is extinct at five historical sites in Georgia (DeKalb and Newton Counties). Due to hybridization with the more common Isoetes piedmontana, it is considered extinct or essentially so at the sole reported site in South Carolina (Lancaster County) and at two additional sites in Georgia (Butts and DeKalb Counties). Only one site supports

more than three inhabited pools. The typical site has one or two pools totaling only a few square meters (m^2).

Two of the eight extant locations for Isoetes melanospora are publicly owned. Both of the publicly owned sites are in DeKalb County. The type locality, Stone Mountain, lies within State-owned Georgia's Stone Mountain Park. The largest remaining population of this species occurs at Davidson-Arabia Mountain Park (Arabia Mountain Park) in DeKalb County (Department of Recreation, Parks, and Cultural Affairs).

Isoetes tegetiformans is restricted to Georgia (Columbia, Greene, Hancock, and Putnam Counties). These four Counties lie to the east of the five Counties known to have extant I. melanospora. Three of the seven extant sites for I. tegetiformans are in Columbia County; prior to quarrying activities, it occurred at three additional outcrops in that County. The largest population (multiple pools, but only totaling about 6 m^2) occurs in Hancock County.

All sites for I. tegetiformans are in private ownership. The type locality, Heggies Rock, is owned by The Nature Conservancy and occupies a single, larger-than-average, vernal pool. The population is healthy and shows recovery from past vehicular traffic (Allison 1989b). The two largest populations (in Greene and Hancock Counties) are owned by the Georgia-Pacific Corporation.

Amphianthus has a broader distribution than the two Isoetes spp., encompassing the ranges of both. It is found from Chambers and Randolph Counties, Alabama, eastward and northward to Lancaster and York Counties, South Carolina. Some 50 of the 57 extant locations occur in Georgia, with 4 small populations in Alabama and 3 in South Carolina. It has been extirpated at least eight sites, all in Georgia (DeKalb, Newton, Rockdale, and Walton Counties).

Amphianthus occurs at all but two sites presently supporting Isoetes melanospora, and at all I. tegetiformans sites. Thus, a total of 13 sites support both Amphianthus and one of the listed Isoetes species.

All but 6 of the 57 known extant locations for Amphianthus are privately owned. The largest and most extensive population on private land is at Heggies Rock, owned by The Nature Conservancy. A small population occurs near the summit of Stone Mountain, within State-owned Georgia's Stone Mountain Park. A moderate-sized population exists on State-owned land in South Carolina, at the Flat Creek Heritage Preserve (Forty Acre Rock, Lancaster County). The largest publicly owned population is in Georgia at Arabia Mountain Park (DeKalb County Department of Recreation, Parks, and Cultural Affairs). A much smaller, less viable, population occurs at the Clinton Nature Preserve, owned by Douglas County, Georgia. A moderate-sized population in multiple pools occurs on land recently acquired by Rockdale County, Georgia, and a small population is located on property owned by Heard County, Georgia.

D. Habitat and Limiting Factors

Isoetes melanospora, I. tegetiformans, and Amphianthus are restricted to eroded depressions or (rarely) quarry pools formed on flat-to-doming granitic (either granite or granite-gneiss) outcrops. These species have maintained themselves for millennia by specializing in a nutrient-poor, seasonally fluctuating micro-environment which in recent centuries, at least,

(1) occurred at perhaps 70 to 100 outcrops, ranging in size from 1 to more than 200 acres, but,

(2) each outcrop only supporting 1 m^2 to 25 m^2 of habitat occupied by these species, typically less than 5 m^2 of same, and,

(3) with the rangewide aggregate area occupied by all three species together of less than 1 acre.

The rock varies from fine-grained granite (e.g., Stone Mountain), to coarse-grained (porphyritic) granite (e.g., Heggies Rock) to granite-gneiss (e.g., Arabia Mountain). These exposures are dotted with round or irregularly shaped islands of vegetation surrounded by nearly bare rock, the latter supporting at most a scant cover of mosses and lichens. Where depressions have been eroded in the granite, rain water collects. The three listed species occur almost exclusively in those depressions which have an intact rim restricting drainage, and with an accumulation of a few centimeters of mineral soil. This soil is low in essential nutrients, particularly nitrogen (Lammers 1958). Pools sustaining the listed species, especially the Isoetes species, are most often found on the higher ground of an outcrop, such that surface flow of water, with its scouring action and siltational effects, is minimized. The higher points on an outcrop are also less likely to be shaded by trees. Water normally stands in the occupied pools from late autumn to mid-spring, but only following showers from summer to mid autumn. For extended periods during the warmer months, the soil is desiccated in these depressions. Consequently, the microhabitat supports only the limited number of species adapted to (1) a substrate of acidic, nutrient-poor mineral soil, and (2) an environment fluctuating between hydric and xeric several times between May and October.

The water depth capacity of extant pools typically varies from about 3 to 10 cm (1.25 to 4 inches). Where water depth is less, such depressions are frequently invaded by annual species, especially Diamorpha smallii, which, like Amphianthus, evade the summer droughts by flowering and setting seed in spring, or by drought-tolerant perennials such as Juncus georgianus or by mosses, such as Polytrichum commune (or P. juniperinum according to Doug Rayner, pers. comm. 1991). With increased water depth, soil depth, or organic matter, moisture is retained for longer periods, enabling less specialized aquatic plants

such as Callitriche heterophylla, Ranunculus pusillus, Eleocharis obtusa, and Lindernia monticola to predominate.

The three listed species occur most frequently as near-monocultures over at least that portion of the microenvironment where the soil and/or water is too shallow or too deep to support the above-mentioned competitors. In cultivation, where competitors can be excluded, the listed species grow well in deeper soil or if provided with supplemental watering. This suggests that their exclusion from areas of deeper soil or water in the wild is due at least in part to poor competitive ability, as shown for the outcrop species Diamorpha smallii and Arenaria uniflora (Sharitz and McCormick 1973).

Because of the specialized microhabitat, the list of frequently associated species is a short one. Typical Amphianthus pools may contain areas where either Diamorpha, Juncus georgianus, Isoetes piedmontana or, rarely, Isoetes melanospora or I. tegetiformans predominates. Typical pools supporting I. melanospora may contain areas dominated by Diamorpha, Amphianthus, Juncus georgianus, or Andropogon virginicus. Pools of Isoetes tegetiformans usually support only a sparse growth of Amphianthus and/or Isoetes piedmontana, rarely other species, such as Selaginella tortipila, Diamorpha, Andropogon virginicus, or Bulbostylis capillaris.

Where Isoetes melanospora is found in quarry pools, it is usually associated with Pilularia americana and/or Eleocharis microcarpa. Isoetes tegetiformans has not been found in any of the few old quarry pools within its range. Most quarry pools appear to be too deep to support Amphianthus, whose scapes are limited in how long they can grow in seeking the water's surface. Only one small quarry pool, in Pike County, Georgia, is known to support Amphianthus.

E. Reproductive Biology

Isoetes melanospora exhibits typical isoetaceous reproduction. In time, the older, outer leaves die and decompose, releasing either megaspores or microspores. The male or female gametophyte develops within the micro- or megaspore wall. When conditions are favorable for fertilization, a flap opens in the megaspore wall, exposing one or more funnel-like necks, through which the motile male gametes (spermatozoids) may enter and fertilize the single egg located at the base of each neck. Following fertilization, a single zygote develops into a sporophyte, enclosed within the megaspore wall. A single juvenile leaf and root are soon produced and after continued growth the old megaspore wall is shed. Sporelings are usually found in late winter or early spring. How rapidly plants reach sexual maturity under the extreme conditions of their habitat is unknown. In cultivation, they can reach maturity in at most a few years. Once mature, a plant of Isoetes melanospora produces mega- and microspores, but typically only one or the other at any one time. These cycles are not synchronized; both types of spores can be

found in the population when sporulation is terminated by the onset of drought-induced dormancy. Once the soil is desiccated, the leaves quickly die and soon no trace of the plant can be found above ground. Eventually, a summer thunderstorm will bring rainfall sufficient to saturate the soil of the depression, stimulating revegetation of Isoetes melanospora (or I. tegetiformans). The plants begin to form new roots and leaves within about 24 hours, and continue to grow until dormancy is reimposed by subsequent drought.

Isoetes tegetiformans exhibits sexual reproduction as in I. melanospora (the author has seen and preserved sporelings of both species with dark megaspore walls still retained). Isoetes tegetiformans is nearly unique among Isoetes species in that it also exhibits clonal reproduction. Because its leaves are produced in a single row on each side of the central axis, the base of the plant (i.e., the stem) is flattened and elongated, rather than globose and corm-like. As the older portion of the stem is displaced outwardly by the (central) newer growth, it is sloughed off and decays in typical Isoetes. In this species, however, areas of dead-looking plant base produce adventitious regrowth, such that a single plant may have several (to many?) distinct areas of leaf/root initiation. The plants are typically crowded and appear as a turf on the floor of a depression.

Amphianthus, being a winter annual, persists during the hot, drought-prone summer only as seeds resting on or within the soil. Germination begins (normally) in late autumn and peaks in late winter or early spring. Light is required for germination (Lunsford 1939), hence buried seeds remain dormant and constitute a hedge (seed bank) against sudden extinction due to unusually early drought. Flowering begins in February or March and continues until the microhabitat is desiccated by a spring drought (sometime from March to May), killing the plants.

Although the flowers borne above water do open, no pollinator has ever been reported to visit a flower, and the stigma is located in such close contact with the anthers that self-pollination is predominant (Lunsford 1939). Those flowers borne at the base of the plant do not open while submerged, and self-pollinate. When the water evaporates and these flowers are exposed to air, however, they open and function as do the flowers borne on floating stems (i.e., they are "hydrocleistogamous"; Lunsford 1939).

The inbreeding inherent in self-pollination systems results in reduced genetic variation within populations. Indeed, an electrophoretic study of Amphianthus (Rott 1988) detected little genetic variation (12 loci <enzyme systems> examined), either within or between three large and/or well separated populations. In a habitat that is exceedingly slow to undergo any physical alteration and that supports few competitors, variability (and hence adaptive flexibility) is of reduced importance. Self pollination can be an advantage, as it permits the rapid elimination of less than optimal genotypes. The same could be said for

the asexual reproduction seen in I. tegetiformans; it (and I. melanospora) exhibit little or no variation at the loci examined electrophoretically (Hickey et al. 1989; N. Luebke, Milwaukee Public Museum, pers. comm. 1991). However, the number of loci examined is only a minute fraction of the total genetic information of any of these species, and not a sufficient sample, from a statistical standpoint, to approximate with confidence the amount of genetic variation present. These studies do suggest that, as expected, variability in these species may be reduced in comparison to species that have wider ranges or in which outcrossing is prevalent.

When mature, Amphianthus capsules dehisce along the sutures, releasing the seeds. The seeds are dormant when shed, and this dormancy is maintained by high summer temperatures (Lunsford 1939). With the onset of cooler weather (and hence, reduced evaporation rate), this dormancy is broken and germination occurs. Rarely, plants can be found in late summer, but always in low numbers.

F. Threats

As these species are adapted to an extremely stable habitat, any disturbance is normally deleterious to their health.

1. Quarrying. By far, the greatest threat to these species is the destruction of habitat due to quarrying activities. Of the 16 documented local extinctions of the listed species (see Appendix A, map 5), eleven can be attributed to this cause. Amphianthus may have been extirpated at up to four additional sites which are now being quarried. The numerous exposures of granites and gneisses in the Piedmont, particularly in Georgia, have been quarried extensively since the Civil War (Watson 1902, 1910), and an unknown number of undocumented populations of the listed species (most likely Amphianthus), were doubtless unknowingly destroyed.

   There are many more abandoned quarries than active ones. Most of the abandoned quarries are small, and may have areas of intact outcrop habitat, sometimes supporting the listed species. These quarries mostly date from the time when granite production consisted of stone for building or ornamental purposes ("dimension stone"). In recent decades, tonnage of crushed stone has greatly outstripped production of dimension stone. A quarry producing crushed stone can easily destroy acres of outcrop in one or a few years, as in the case of the extirpated populations of I. tegetiformans.

   Populations of the listed species (and other granite outcrop organisms) may be impacted by accumulation of rock dust when quarry operations are undertaken nearby. As late as 1979, Isoetes melanospora could be found in two pools at Bradley Mountain (name used in Herrmann 1954) in DeKalb County. Areas near these pools (within several hundred feet) were quarried after 1980 and prior to

1990. Although the depressions themselves are extant, the endangered quillwort has not been seen in them in recent years. The microhabitat of Isoetes melanospora there may have been altered by the accumulation of quarry dust. Studies are needed which specifically address the effects of quarry dust on vernal pool vegetation because current focus in the permitting process is on immediate human health effects rather than long-term effects on the natural environment.

2. Farm animals. At other sites, the habitat supporting these species has been degraded through conversion to pasture. Excessive animal wastes have resulted in eutrophication of pools, promoting excessive algal growth, which competes with these species for dissolved carbon dioxide and light. Addition of matter to the habitat increases soil depth, with concomitant reduction in potential water depth. Increased soil depth and organic matter may benefit these species in the short term, but soon result in the invasion of more aggressive native species, such as Callitriche heterophylla, Eleocharis obtusa, Ranunculus pusillus, and various Juncus spp., as well as exotic weeds, such as Poa annua.

   At a Butts County (Georgia) outcrop supporting Amphianthus in past years, evidence was seen in 1992 of the activities of feral hogs. The hog "wallow" seen was not in an Amphianthus pool. The threat to the three listed granite outcrop species from feral swine is uncertain.

3. Dumping. Because granitic outcrops are regarded by the uninformed as worthless, they are frequently subjected to dumping of waste materials. This leads, in some cases, to destruction of the microhabitat through covering over or filling in of pools, or through eutrophication.

4. Vehicular traffic. Vehicular traffic is a serious problem at many of the extant sites. This can be due to recreational traffic, such as off-road vehicles, motorbikes, or even automobiles in some cases. Even more destructive are the heavy vehicles used in logging operations. At one outcrop in DeKalb County, Georgia, a solitary pool supporting a dense growth of I. melanospora and sparse Amphianthus was destroyed when the adjacent Hayden Quarry Road was paved, because heavy equipment operators used the outcrop as a convenient place to turn around. A unique example of vehicle-related extirpation occurred in Walton County, Georgia, at an outcrop formerly used as a storage site for explosives. These were stored in tractor-trailers on the outcrop. As part of the site preparation, many depressions, including all Amphianthus pools, were filled with concrete to provide a smoother surface.

5. Recreational impacts. Many sites exhibit signs of recreational overuse or abuse. Although those sites that are publicly owned are

protected from quarrying, they are subjected to excess foot traffic, littering, or vandalism, such as spray painting. An example of vandalism occurred in the largest I. melanospora/Amphianthus pool at Arabia Mountain Park: stones in the pool were rearranged from a random pattern to form a rock "archipelago", with the death of those plants which ended up beneath the stones. A similar rearrangement of stones in the only pool supporting listed species in Gwinnett County, Georgia, has caused or contributed to a serious decline of Isoetes melanospora and Amphianthus there. At Stone Mountain, the remaining pools supporting I. melanospora and Amphianthus occur in an area which is subject to intense foot traffic, and cigarette butts and other litter usually can be found in these pools. Litter is also a problem in pools at Arabia Mountain. Another recreational abuse is fire-building within the microhabitat. This has impacted the sole Amphianthus pool in Henry County, Georgia, and may be a factor in the decline of I. tegetiformans in Putnam County, Georgia. Evidence of firebuilding has been seen at other sites, e.g., Saluda County, South Carolina (Rayner 1986), but by chance occurred outside the pool containing Amphianthus. At another South Carolina outcrop, some Amphianthus pools may have been inadvertently poisoned: the water was discolored in 1990 and the depression contained the remains of fireworks (Rayner 1990).

6. Hybridization (Isoetes melanospora only). At three outcrops where I. melanospora occurred with I. piedmontana, I. melanospora has seemingly been outcompeted by hybrids between these two species (Matthews and Murdy 1969). In the early to mid-1980's, the author made collections from all three of these sites, particularly from quarry pools at Rollaway, DeKalb County, Georgia, where the hybrid was first discovered (Dorris 1964). A sizeable collection of plants uprooted by vehicular traffic was made from the South Carolina location. Smaller collections were made from the Butts County hybrid site. None of these collections yielded plants which could be referred unequivocally to Isoetes melanospora, consisting instead of hybrids, putative backcrosses, and I. piedmontana. In particular, these "populations" exhibited extreme variability in the extent of velum development. Analysis of these hybrids is complicated because the distinguishing characteristics of I. melanospora and I. piedmontana are found in the subterranean portion of the plants; each individual plant can be identified only by removing it from the substrate.

   The hybrids have brown megaspores (darker when wet), a wide but incomplete velum, and a pigmented sporangial wall. They are thus intermediate between the presumed parental species (Dorris 1964). As one of the Georgia intermediate populations is found in old quarry pools and the other is adjacent to a highway and agricultural land, these cases of seeming hybridization appear to be disturbance-related (Matthews and Murdy 1969). However, the South Carolina hybrid population may be a natural development. Although the

Isoetes on the main exposure there has been disturbed by vehicular traffic, a pool on an essentially undisturbed exposure, screened from the main outcrop by forest, also appears to support hybrids rather than I. melanospora. The apparent hybridization there may be related to the fact that this site is greatly disjunct from those sites supporting typical I. melanospora. This South Carolina hybrid population (and the existence of I. lithophila in Texas?) suggests that I. melanospora may have had a significantly broader range at one time.

Isoetes tegetiformans grows intermixed with I. piedmontana at three outcrops, and though hybrids have been searched for, none has been found to date.

7. Other factors. In some cases, other environmental factors are suspected to have led to the decline of certain populations of these species. As these species require high light intensities (Lammers 1958), excessive tree growth is suspected to be a problem at a few sites, due to shading. A few pools appear to be moving toward a later stage of succession due to excessive soil accumulation. In most cases, however, this development can be attributed to the activities of man, such as at Isoetes melanospora site no. 8 in Rockdale County, Georgia (close to dirt road and subjected to heavy dumping).

Isoetes melanospora is susceptible to damage or even killed when subjected to abnormally low temperatures (below ca. -12°C [10°F]). When the largest population was visited on January 2, 1984, many, if not most, of the quillworts had shed their outermost leaves. Many of these plants were evidently killed by record cold temperatures of December 1983. During a less severe freeze in December 1937, sufficient to freeze these same pools solid, freeze damage was also observed (Johnson 1938) but did not result in high mortality. Amphianthus is also sometimes killed by freezes but, being an annual, can recover population size more rapidly. Freeze damage may also be a factor in the decline of Isoetes tegetiformans at site no. 8 in Putman County, and perhaps no. 4 in Columbia County, Georgia (see Appendix B).

The effects of widespread environmental changes, such as acid rain and possible global warming, are unclear. For example, both the buffering capacity of outcrop soil and the tolerance of these species to lowered pH are unknown.

8. Inadequacy of existing regulation. The Georgia Wildflower Preservation Act (discussed next page) has not had a significant effect upon retarding habitat loss, the primary threat to the listed species.

Recreational overuse of publicly owned sites is not always addressed by current ordinances. Existing ordinances against littering, spray-painting, fire-building, off-road vehicles, etc., have proved difficult to enforce, and not fully effective.

G. Conservation Measures

1. State protective measures. Under the provisions of Georgia's Wildflower Preservation Act, Amphianthus, Isoetes melanospora, and Isoetes tegetiformans are legally protected species. This law protects State listed plant species by regulating their removal from State-owned lands (McCollum and Ettman 1991). It further requires that any removal of State-protected plants from private land be with the written permission of the landowner, and it also regulates any traffic in these plants by requiring both transport tags and permits to sell or collect in Georgia. Whenever federally listed plant species are involved, provisions of this law (or any other State law or regulation, including State criminal trespass laws), are enforceable by Federal agents under Section 9 of the Endangered Species Act of 1973, as amended.

   Of the three States where Amphianthus occurs, only Georgia has a native plant conservation law. However, the three federally listed outcrop endemics are recognized as species of concern by conservation agencies in all three States where they occur. Databases are being compiled and updated for such species, with information on each occurrence, such as site name, location, population size and ownership. These databases are used to evaluate relative rarity and degree of threat, to assign protection priorities, and to provide information relative to specific sites for purposes such as environmental impact statements.

   An additional Georgia State law affording some protection to these and other listed species is the Georgia Environmental Policy Act (GEPA). Modeled after the National Environmental Policy Act (NEPA), this 1991 law established requirements and procedures for assessing the environmental effects of all proposed State government actions that "may significantly adversely affect the quality of the environment." Guidelines for implementation of GEPA, as promulgated by the Georgia Department of Natural Resources, Environmental Protection Division, describe certain types of activities as "clearly significant", among these being any "action that affects threatened or endangered species or their habitats" (Georgia DNR 1991).

2. Habitat preservation. Due to public ownership or private nature preserve status, six sites supporting Amphianthus, two of these with Isoetes melanospora and one of them with I. tegetiformans, have been protected from quarrying; however, recreational impacts and vehicular traffic continue to pose problems at some sites.

Protection of additional sites through acquisition or negotiation of management agreements is being pursued by The Nature Conservancy field offices, usually in conjunction with State Heritage Programs, in each of the three States where Amphianthus occurs.

3. Studies. Due to their well defined boundaries, granite outcrop communities are among the better studied of all ecosystems. Comprehensive investigations include Oosting and Anderson 1939; McVaugh 1943; Burbanck and Platt 1964; and Shure and Ragsdale 1977; and a number of other ecological studies are summarized in Baker 1945; and McCormick et al. 1974. Graduate studies (all at Emory University, Atlanta) concerning one or more of the listed species include Dorris 1964; Johnson 1938; Lammers 1958; and Lunsford 1939.

   The three listed species have been well searched for, particularly since the discovery of Isoetes tegetiformans in the mid-1970's. Status surveys have been conducted for Amphianthus in each State in which it occurs (Miller 1985, Garris 1980, Rayner 1986). Since 1978, the author has visited several hundred granitic outcrops in the Piedmont of the Southeast (Appendix, Map 1), discovering approximately 6 of 16 extant or historic sites for I. melanospora, 9 of the 10 I. tegetiformans sites (Rury 1985), and approximately 38 of 65 sites for Amphianthus.

   The Nature Conservancy has conducted monitoring of I. tegetiformans and Amphianthus at its Heggies Rock Preserve during the years 1985, 1987, 1988, and 1989 (Bridges 1986, Allison 1987, 1989a, 1989b). Monitoring of Amphianthus has also been conducted at Forty Acre Rock in South Carolina (Rayner 1990, Pittman and Sablo 1991).

4. Cultivation. The two listed Isoetes species and others (including I. lithophila) are in cultivation for research purposes by the Milwaukee Public Museum (N. Luebke pers. comm. 1991). The two Isoetes species are also in indoor cultivation at the Atlanta Botanical Garden. Isoetes tegetiformans is being cultivated by the North Carolina Botanical Garden, as part of the Center for Plant Conservation's National Collection of Endangered Plants.

   Amphianthus is not known to be in cultivation by any horticultural or conservation institution. Because of its annual duration and apparently narrow requirements for germination of its seed, greenhouse cultivation of Amphianthus is more difficult to maintain than either of the listed Isoetes species.

II. RECOVERY

A. Recovery Objective

Reclassification of Isoetes melanospora or Isoetes tegetiformans to threatened will be considered if 10 viable and geographically distinct populations (separate outcrops), averaging at least two pools each, are protected. Delisting will be considered for Amphianthus if 20 such populations (including at least two populations each in Alabama and South Carolina) are permanently protected for that species to such a degree that the species no longer qualifies for protection under the Endangered Species Act. Viability of populations will be assessed through periodic monitoring for a period of not less than 10 years. A viable population has the reproductive capability to sustain itself.

Recovery criteria are preliminary and may be revised on the basis of new information (including information gained from identified recovery tasks).

B. Narrative Outline

1. Protect populations

1.1 Protect existing publicly owned populations.

1.1.1 Georgia's Stone Mountain Park, DeKalb County, Georgia. This State-owned park is operated by a public authority, the Stone Mountain Memorial Association. The Association has recently adopted a Master Plan which envisions a number of significant changes to the park. The Stone Mountain Memorial Association acknowledges that it, like any other agency of Georgia State Government, is subject to the provisions of the Georgia Environmental Policy Act in implementing the proposed alterations to the mountain. Two of the planned actions, if not implemented with adequate safeguards, have the potential to adversely affect Isoetes melanospora and Amphianthus populations occurring in several pools below the summit of the mountain. These changes are (1) the removal of the buildings now found on the summit and (2) the construction of an inclined railway up the mountain.

It is critical that the demolition of the buildings be conducted with stringent safeguards in place to avoid impacts to the listed species, such as vehicular traffic and the washing or blowing of any debris, chemicals or other matter into their microhabitat.

The inclined railway would run from the base of the mountain up to an Interpretive Center to be built in the general vicinity of some of the pools supporting the listed species. It is essential that construction activities employ all necessary safeguards so as to avoid any impact upon the listed species.

Completion of an inclined railway and the holding of some events of the 1996 Summer Olympics within the park could be expected to lead to an increase in the number of visitors to the upper mountain. The Isoetes melanospora and Amphianthus growing near the summit of the mountain are within an area that is already subjected to intensive foot traffic and considerable littering, jeopardizing the continued existence of these populations. The Stone Mountain Memorial Association is aware of this danger; the Master Plan for Georgia's Stone Mountain Park (Robert & Co. 1992) states that "visitor access to the top of the mountain will be restricted to those areas of the upper plateau which do not contain rare or endangered species habitat." Nearby, steeper areas of the mountain are already off limits to visitors, a policy enforced by fencing, signs, and patrolling by park security personnel. The only practical and effective solution to the problem of foot traffic and littering in the microhabitat of Isoetes melanospora and Amphianthus pusillus would appear to be the relocation of the fencing so as to place the listed species and nearby potential habitat within the excluded area. Care must be taken to ensure the use of appropriate fencing material upslope from vernal pools. Certain types of galvanized fencing could leach heavy metals such as zinc in amounts potentially toxic to the listed species, and associated rare life forms, such as "fairy shrimp" and "clam shrimp."

1.1.2 Arabia Mountain Park, DeKalb County, Georgia. This County park contains by far the largest and most critical population of I. melanospora together with one of the largest populations of Amphianthus. The two species grow intermingled in multiple vernal pools at the summit of the mountain. In addition, Amphianthus is present in a number of other pools scattered on the flanks of the mountain, and Isoetes melanospora occurs in quarry pools at the northwestern base of the mountain.

The park is currently undeveloped, and until recently there has been only occasional enforcement of regulations against off-road vehicles, fire-building,

littering, and vandalism. Fortunately, a group of local citizens have formed a group called Friends of Arabia Mountain, Inc. to organize support for protection of the park. The public interest and concern demonstrated by this group's activities (such as a well attended Park Cleanup Day) has resulted in the commitment of additional resources by the DeKalb County Parks and Recreation Department to the park. This includes (but is not limited to) the permanent assignment of a resident, full-time, Park Ranger.

Aside from protecting the populations of Amphianthus and Isoetes melanospora from the threats mentioned above, an additional management activity should be mentioned: it might be desirable to cut down some pines around the periphery of the quarry pool occurrences of Isoetes melanospora, particularly if monitoring indicates a decline attributable to excessive shading.

1.1.3 Clinton Nature Preserve, Douglas County, Georgia. This County-owned property includes a granitic outcrop supporting a very small population of Amphianthus. When the site was visited in 1990, only a single small plant was seen. This decline is probably attributable to eutrophication caused by horse manure. Steps (such as fencing) need to be taken to exclude horses from the outcrop area.

1.1.4 Rusty Rock, Heard County, Georgia. This property, owned by Heard County, is currently home to Capitol Rock, Inc., a crushed stone quarry. The site was visited April 23, 1992 with A.C. Boyd, owner of Capitol Rock, Inc. A portion of the outcrop has been destroyed, along with several pools supporting Amphianthus. However, one small pool was found with extant Amphianthus. At the present low rate of production it may be 10 or more years until the blasting front reaches the vicinity of the extant pool (A.C. Boyd, pers. comm., 1992). It would be desirable to work out a way to preserve the small population of Amphianthus which persists here, or failing that, arrange for removal of seed-bearing soil from the pool for use in captive breeding.

1.1.5 Bald Rock, Rockdale County, Georgia. This outcrop contains about five pools supporting Amphianthus. Use of the portion of the outcrop with the latter as a pasture has resulted in some eutrophication of pools and the introduction of some exotic species, such as Poa annua. The outcrop was recently acquired by Rockdale County as a portion of a much larger tract to be

developed as the Georgia International Horse Park, venue for equestrian events at the 1996 Summer Olympic Games. The Conyers-Rockdale Amateur Athletics Authority was informed of the presence of a listed species on the property and invited the author to survey the population and to provide them with basic information. According to County authorities, no development is planned that should result in impact to the rock outcrop. An end to the use of the area with Amphianthus pusillus as pasture should result in improved conditions for that species.

1.1.6 Forty Acre Rock, Lancaster County, South Carolina. This is a State-owned natural area, managed by the South Carolina Wildlife and Marine Resources Department. Despite the part-time presence of a caretaker, the placement of barriers to exclude automobiles, and the arrests of a few violators, vehicular traffic (particularly motorbikes) and other abuses are continuing (Stu Greeter and Doug Rayner, pers. comms. 1990). A strategy must be developed to diminish these threats.

1.2 Secure plants on private property. Populations on private property may be protected by negotiation of management agreements between owners and public agencies or private conservation groups, or through land acquisition. Land acquisition would provide the best possible means of protection and may be particularly feasible for a number of the smaller sites. Indirect protection may be provided for these species in certain instances through State permitting processes and by way of the formal consultation provisions of Section 7 of the Endangered Species Act of 1973, as amended.

1.2.1 Landowner contacts. This is the first step towards securing plants on private property. Landowner information should be obtained for all Isoetes populations. Landowners should be contacted, the importance of populations on their lands should be explained to them, and possible management options should be discussed.

Due to the large number of sites for Amphianthus, landowner information for this species should first be determined for the best populations.

1.2.2 Enforce laws protecting species and their habitat. The single greatest threat to these species on private lands is from quarrying, especially for crushed stone (aggregate). Granite is an exceedingly durable rock in inexhaustible supply and hence the crushed stone is a

standard roadbuilding material. Fortunately, many, if not the majority of currently operating crushed stone quarries, are not located on natural exposures. These quarries operate by removing the mantle of soil ("overburden") from an area, exposing the underlying bedrock.

Some of those few quarries at outcrops that support one or more listed species supply stone for use in highway construction, which is funded in part by Federal Highway Trust monies. Use of such stone in these circumstances requires compliance with Section 7 of the Endangered Species Act of 1973, as amended (Act). Formal consultation is required between any responsible agency (e.g., the Federal Highway Administration) and the Fish and Wildlife Service to insure that the agency's actions are not likely to jeopardize the continued existence of any federally listed species.

Other means of protection for plants on private property need to be investigated. Under Section 9 of the Act, it is unlawful to take or damage endangered plants in knowing violation of any State law or regulation, including State criminal trespass law. Some populations continue to be impacted by off-road vehicular traffic and vandalism. Any such damage to these listed species should be carefully examined to determined if such occurred during the course of a State law or regulation violation, which would provide the nexus for penalties under the Act.

In Georgia, Surface Mining Permits are issued to prospective operators by the Department of Natural Resources, Environmental Protection Division (EPD), only after surface mine land use plans are reviewed. The Georgia Surface Mining Act of 1968 has as one of its stated purposes to "advance the protection and restoration of land, water, and other resources affected by mining" (GA Laws 1968, p. 9, et seq.). The law, however, contains no language explicitly mentioning protected species. At the least, procedures need to be developed to insure that information compiled by the Game and Fish Division of the Georgia Department of Natural Resources is available for consideration by EPD during its evaluation of permit applications.

The preceding paragraph focuses on Georgia because that State has both the preponderance of populations of the listed species and is the leading producer of granite aggregate in the United States. The same principles

apply, however, to the mining regulatory process in Alabama and South Carolina.

2. Preserve genetic stock and conduct germination experiments on Amphianthus.

   2.1 Preserve genetic stock from acutely threatened populations. Due to the scarcity of extant populations, particularly of Isoetes melanospora and I. tegetiformans, conservation of the genetic diversity that remains in these species is a high priority. Therefore, some living material of these species should be moved from those populations facing imminent local extinction (i.e., where protection is not feasible or cannot be initiated in time to prevent extirpation).

   Fortunately, the listed species can be cultivated; however, cultivation is more difficult with Amphianthus. The author has for years cultivated salvaged material of all three species. Simulated granite outcrops have been constructed at the North Carolina Botanical Garden (see photo, p. 165, in McCormick et al. 1974; see also Platt and McCormick 1964) and might be modified to provide a more aquatic habitat, or new artificial habitat could be constructed.

   2.2 Conduct research on germination requirements of Amphianthus. As discussed above, there appears to be difficulty with germinating seed of Amphianthus. Maintenance of stock in cultivation is dependent upon successful germination of seed. Research is needed to determine this species' germination requirements.

3. Monitor populations to determine trends and developing threats. All sites supporting one of the listed Isoetes species should be censused yearly for a period of not less than 10 years. All but two of these sites support Amphianthus, which should be surveyed at the same time, ideally in early to mid-March. All Amphianthus populations in Alabama and South Carolina should be assessed yearly, as well as at least the best Georgia sites lacking either Isoetes species. Approximate numbers, vigor, areal extent, etc., should be noted, as well as any unfavorable developments (increasing competition, dumping, etc.). Bridges (1986) developed forms to standardize the collection of data on Amphianthus and Isoetes tegetiformans during his monitoring project at Heggies Rock. Photography may be of use in comparing density, area of coverage, etc., over time (Allison 1989a, 1989b).

4. Search for additional populations. As indicated above, these species have been searched for extensively. However, a few outcrops remain to be explored at the optimal time of year (January through March), particularly in Randolph County, Alabama; Heard, Meriwether, and Hancock Counties, Georgia; and perhaps Kershaw and Lancaster

Counties, South Carolina. For the sake of efficiency, these travels should involve other recovery objectives, where appropriate (e.g., landowner determination/contact and population monitoring).

5. Reestablish populations and augment populations at protected locations, if deemed necessary. This requires that the microhabitat of the listed species be present or that similar microhabitat occurs which can be modified or maintained by addition or removal of soil. The necessity/desirability of such invasive techniques will be dependent on the success or failure of other recovery actions.

6. Use management techniques to maintain and/or enhance populations. As the listed species are adapted to an environment in which successional change is very slow, maintenance of populations chiefly requires protection from disturbance. Results of the monitoring program should indicate whether certain natural or experimental microhabitats would benefit from such actions as manipulation of soil depth or the cutting of nearby trees.

7. Educate the public about the value and fragility of these species and their habitat. Granite outcrops support the most distinctive natural community in the Piedmont Physiographic Province, based on the number of endemic species. Since most of the landscape of the Piedmont is developed, in cultivation, or in a successional state, relatively undisturbed outcrops can provide an all-too-rare primeval experience. They also have the potential to serve as outdoor classrooms for studying geology, as well as important ecological and/or evolutionary concepts such as primary succession, competition, endemism, and ecotypic differentiation. A strong effort to inform the public about the significance of these places and their biota is critical to combating the common misconception that these are "waste places."

   At present, interpretive programs concerning granite outcrops are confined to the commendable program at Panola Mountain State Conservation Park in Georgia (but which unfortunately lacks extant populations of the listed species). Georgia's Stone Mountain Park, in addition to Isoetes melanospora and Amphianthus, supports many other rare or otherwise interesting organisms and natural communities (Federal candidate plant species Aster avitus and Sedum pusillum, to name but two). Because Stone Mountain is also the granite outcrop which receives by far the greatest visitation by the public, a natural history interpretive program could reach a large segment of the public here. The Master Plan for the park indicates that the planned inclined railway will have its upper terminus in an Interpretive Center, which "will tell the 'story of the Mountain' and its environs via professionally researched and prepared interpretive displays," and it states that "outdoor interpretive displays will also be provided at strategic overlook points around the Mountain top" (Robert & Co. 1992).

DeKalb County authorities, responsible for Mt. Arabia Park, are being encouraged by Friends of Arabia Mountain, Inc. to help educate the public on the importance of conserving these species and their habitat.

In addition to interpretive programs that include public presentations and guided tours, illustrative brochures and teaching packets should be developed relating to such topics as Piedmont geology and granite outcrop ecology.

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III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for the first 3 years of the recovery program. It is a guide for meeting the objective discussed in Part II of this plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs.

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 impact short of extinction.

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

Key to acronyms used in Implementation Schedule

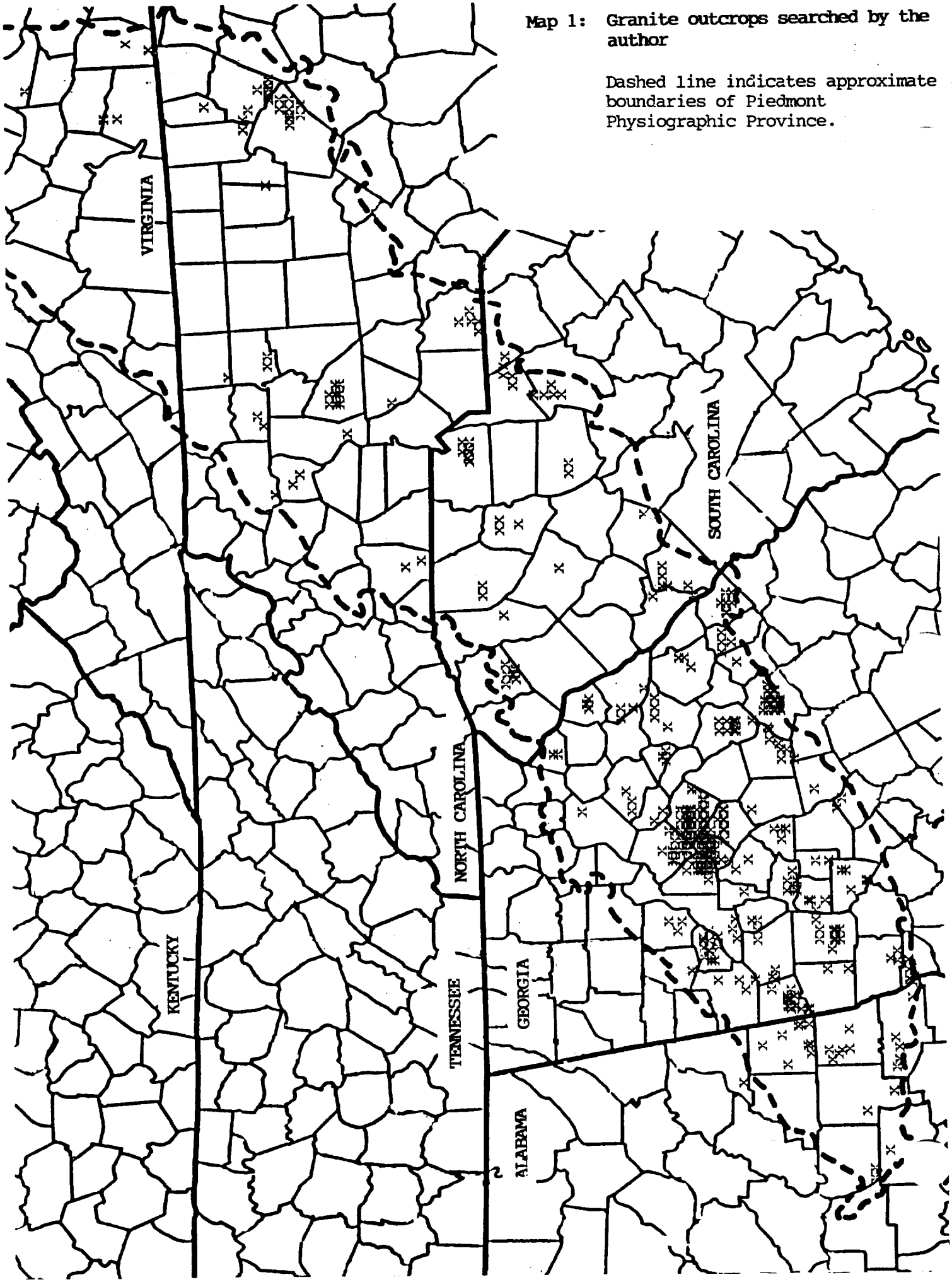
ALNHP	Alabama Natural Heritage Program
CPC	Center for Plant Conservation
Co.	County agencies responsible for administration of Mt. Arabia Park or Clinton Nature Preserve
TE	Endangered Species Division, U.S. Fish and Wildlife Service
GADNR	Georgia Department of Natural Resources
SCWMR	South Carolina Wildlife and Marine Resources Department
SMP	Stone Mountain State Park
TNC	The Nature Conservancy
USFWS	U.S. Fish and Wildlife Service

IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($K)			COMMENTS/NOTES
				USFWS						
				Region	Division	Other	FY 1	FY 2	FY 3	
1	1.1	Improve protection of publicly owned populations	2 years	4	TE	GADNR, SCWMR, SMP,Co.				Costs undetermined.
1	1.2.1	Seek landowner cooperation	Ongoing	4	TE	GADNR, TNC, SCWMR, ALNHP	2.0	2.0		Intensive effort for 2 years to make contact with landowners.
1	1.2.2	Enforce laws protecting species	Ongoing	4	TE	GADNR				
1	2.1	Preserve genetic stock	Ongoing	4	TE	GADNR, CPC	2.5	2.5	2.5	
	2.2	Research germination requirements of Amphianthus					3.5	3.5	3.5	
2	3	Monitor populations	Ongoing	4	TE	GADNR, SCWMR, ALNHP	5.0	2.5	2.5	
2	4	Search for additional populations	2 years	4	TE	GADNR, SCWMR, ALNHP	4.0	4.0		
2	5	Reestablish and/or augment populations		4	TE	GADNR, CPC, ALNHP, SCWMR				Contingent on other studies.
2	6	Investigate and implement appropriate management	Ongoing	4	TE	GADNR, SCWMR, ALNHP, SMP, Co.				Cost to be determined.
3	7	Educate public about species	Ongoing	4	TE	GADNR, TNC, CPC, SMP, Co.	5.0	2.5	2.5	

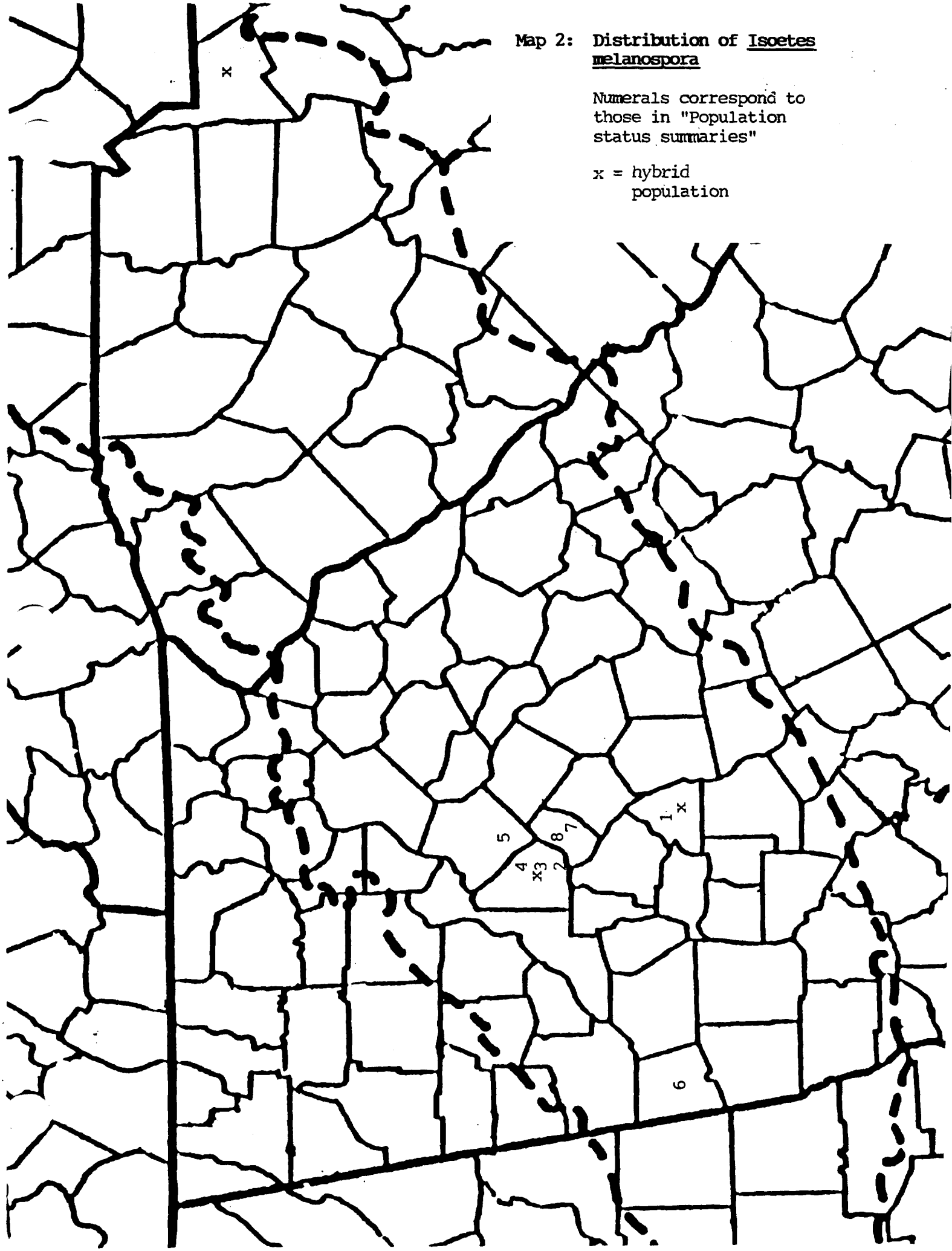
IV. APPENDIX

All known historical or extant populations are summarized in tabular form. Extant sites have been assigned site numbers. Other site names are preceded by a minus sign (-) for extinct populations or, in the case of *Isoetes melanospora*, an "x" for hybrid populations. The names of publicly owned locations are rendered in **bold type**. The next column provides the date on which the population was last observed by the author. The symbol "#" follows the date if the site was last visited out-of-season for these plants, provided that the habitat appeared unaltered. To assist in assigning priority for recovery efforts among sites, each population has been assigned a ranking, taking into consideration population size and acuteness of threat. Finally, known threats are summarized. To save space, "vehicular traffic" is abbreviated as "VT". In the case of extirpated populations, the apparent cause of extinction is enclosed in parentheses.



Map 1: Granite outcrops searched by the author

Dashed line indicates approximate boundaries of Piedmont Physiographic Province.

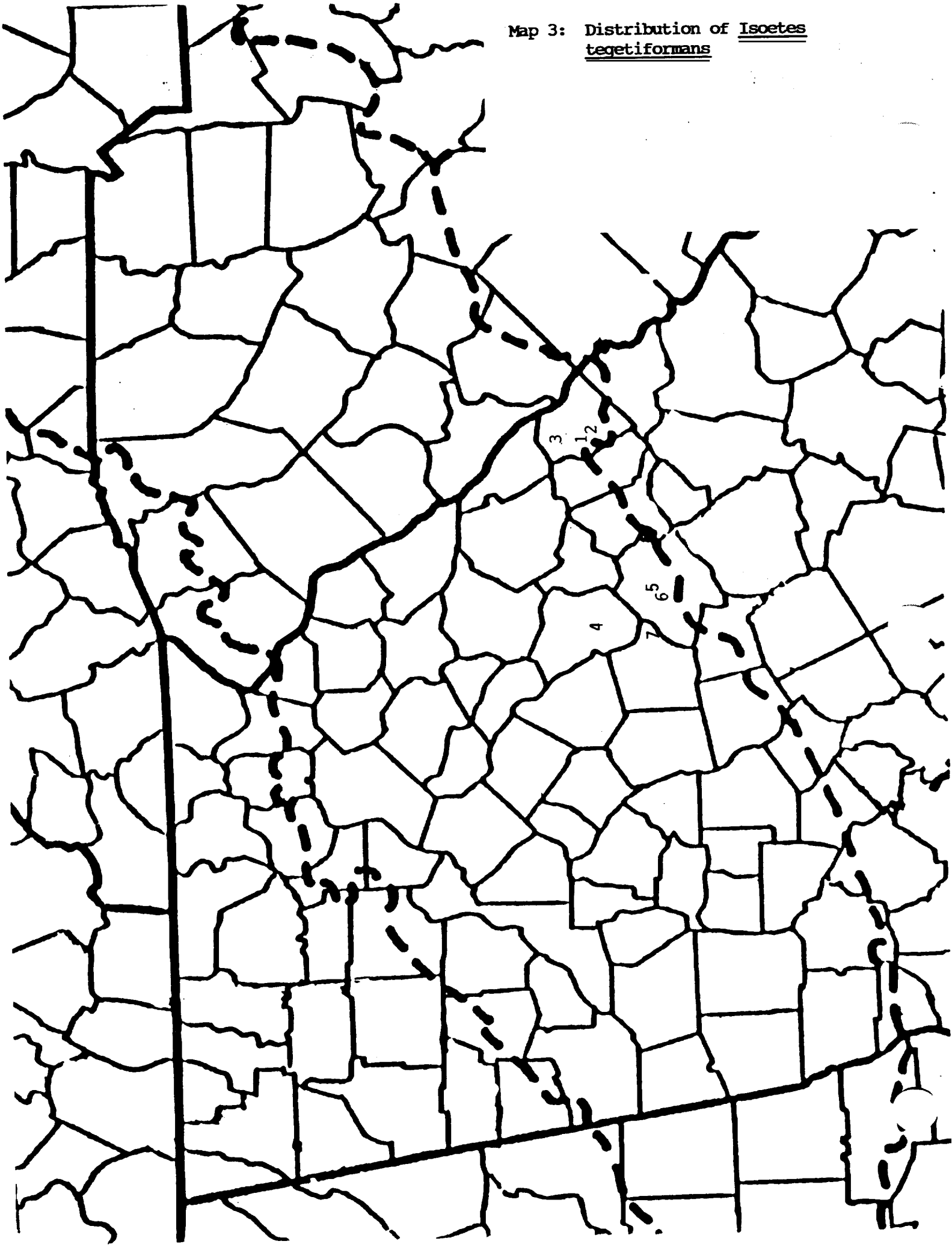


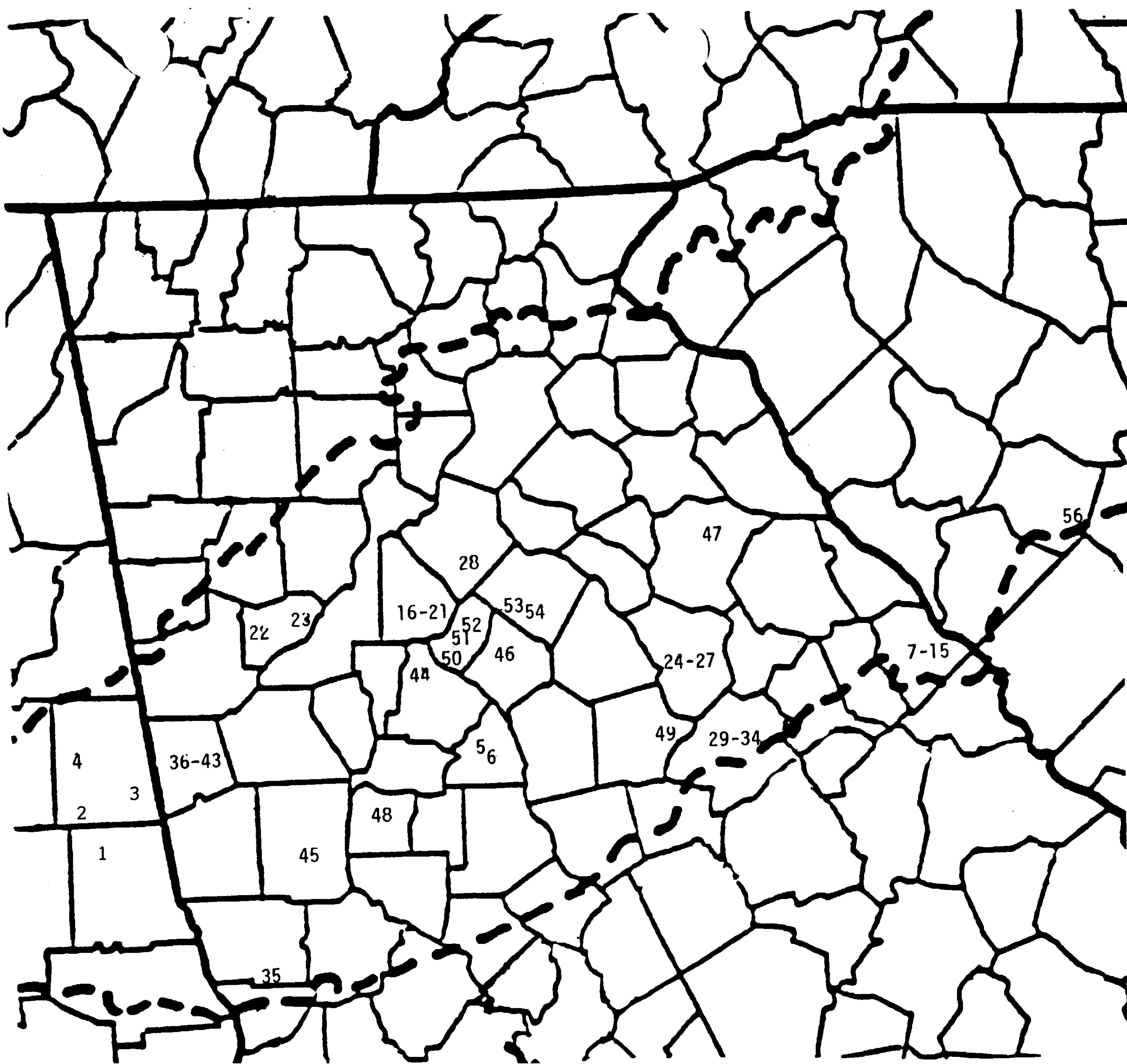
Map 2: Distribution of Isoetes melanospora

Numerals correspond to those in "Population status summaries"

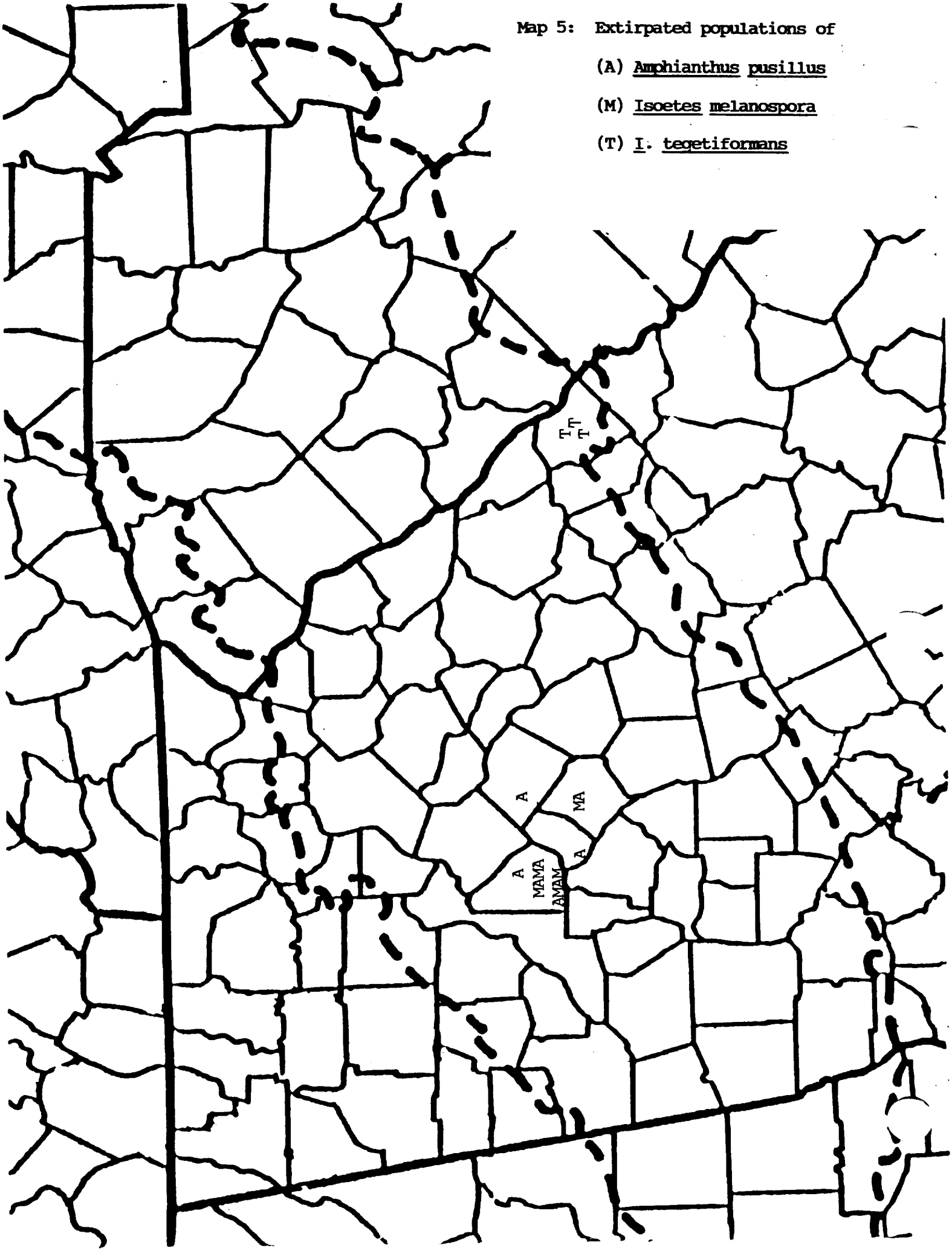
x = hybrid population

Map 3: Distribution of Isoetes tegetiformans





Map 4: Distribution of *Amphianthus pusillus*



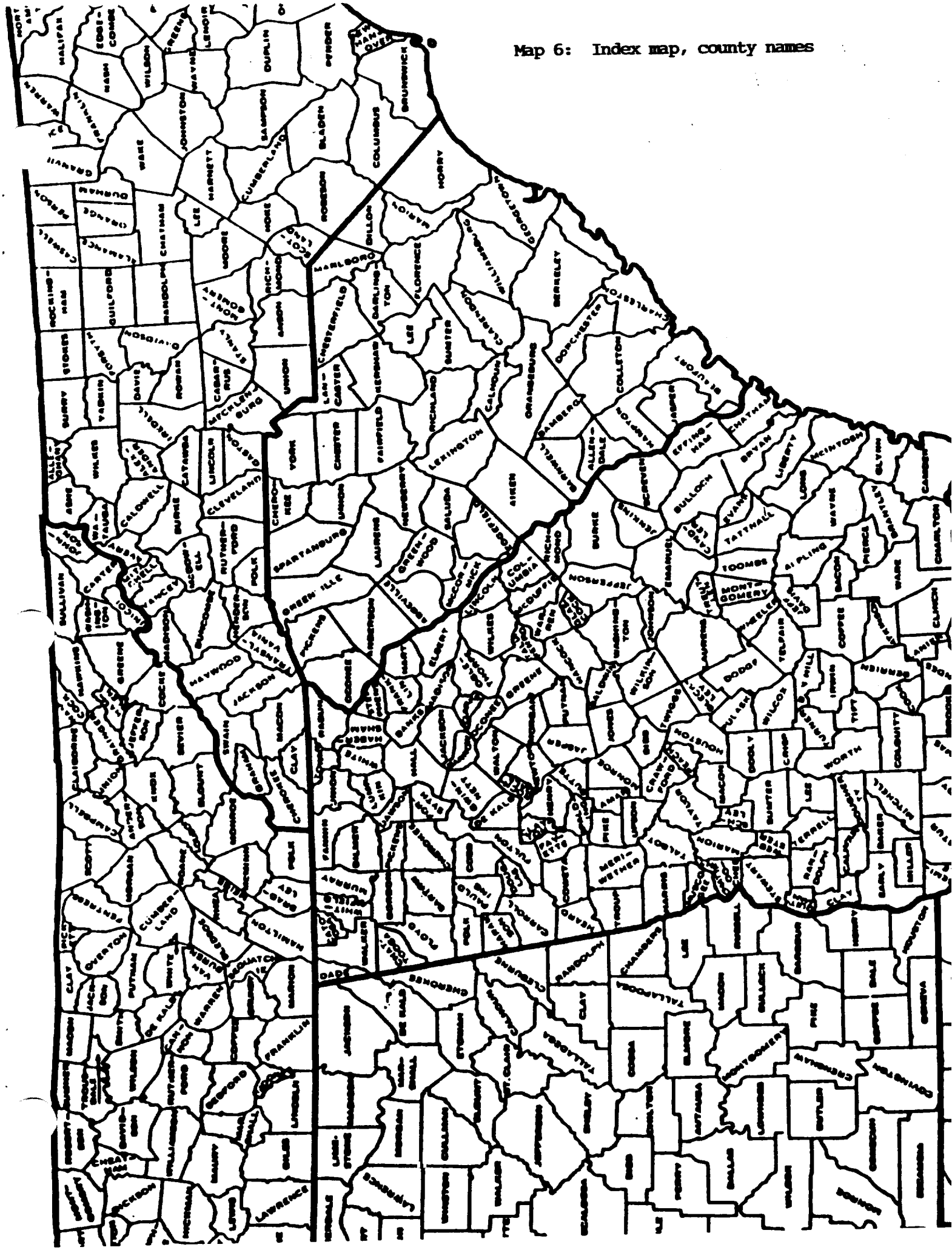
Map 5: Extirpated populations of

(A) Amphianthus pusillus

(M) Isoetes melanospora

(T) I. tegetiformans

Map 6: Index map, county names



POPULATION STATUS SUMMARIES

STATE/COUNTY	SITE NAME	LAST SEEN	SOUGHT SINCE?	RANKING[1]	THREATS
Isoetes melanospora					
GA Butts	1 Mountain Rock	1992-01-03		G	potential quarrying
	x Highway 36	1992-01-03		P	hybrid pop.; road-improvement-VT
Dekalb	2 **Arabia Mountain**	1992-06-10		E	recreational overuse; VT
	- Bradley Mountain	1979-12-26	1992-06-10	EXT	(fire-building; quarrying)
	- Hayden Quarry Road	1982-00-00	1992-06-10	EXT	(road-paving VT)
	3 Lithonia Rock	1992-06-10		F	dumping; potential quarrying
	- Pine Mountain	1897-05-15	90-02-13	EXT	(quarrying)
	- Rock Chapel Mountain	1939-03-15		EXT	(site destroyed by quarrying)
	x Rollaway	1989-07-01		P	hybrid pop.; quarrying
	4 **Stone Mountain**	1993-02-15		G-P	recreational overuse
Gwinnett	5 Baker's Rock	1993-04-21		P	vandalism; shading? [9 pls. seen]
Heard	6 Camp Meeting Rock	1993-04-24		G	VT; quarrying
Newton	- Ellis Farm	1984-04-20	1987	EXT	(quarried; [some salvaged])
Rockdale	7 Gleaton Road	1992-05-02		P	eutrophication; shading?
	8 Philadelphia Road	1992-05-02		P	VT; dumping; competition
SC Lancaster	x **Forty Acre Rock**	1993-04-18		P	hybridization
Isoetes tegetiformans					
GA Columbia	1 Anderson Farm	1989-01-12		G	potential quarrying
	2 Crater Rock	1988-04-07		G-P	potential quarrying
	3 Heggies Rock	1993-01-21		E	
	- Little Kiokee Creek	1982-12-25	1986-03-16	EXT	(quarried;[some salvaged])
	- Lost Rock	1989-01-29		EXT	(quarried; [some salvaged])
	- Mt. Gemini	1991-07-31	1993-01-21	EXT	(deliberately extirpated)
Greene	4 Greensboro	1992-04-07		E-P	quarrying in progress
Hancock	5 Forty Acre Rock	1987-02-06		F	eutrophication; competition
	6 Pinkston Creek	1992-04-07		E	logging and other VT; quarrying
Putnam	7 Eatonton	1991-01-29		P	freeze-damage?; VT?

STATE/COUNTY	SITE NAME[2]	LAST SEEN	SOUGHT SINCE?	RANKING	THREATS
Amphianthus pusillus (continued)					
AL Chambers	1 Penton	1992-04-15		F	VT; potential quarrying
Randolph	2 Bald Rock	1992-04-15		F	dumping; quarrying; VT
	3 Blakes Ferry	1992-04-15		F	vehicular traffic; fire-building
	4 Wehadkee Creek	1990-04-11		F	resumption of quarrying
GA Butts	5 *Mountain Rock	1992-01-03		E	vehicular traffic; quarrying
	6 *Highway 36	1988-04-08		F	road-improvement; VT
Columbia	7 *Anderson Farm	1989-01-12		F	VT; potential quarrying
	8 *Crater Rock	1988-04-07		G	VT; potential quarrying
	9 Crescent Rock	1991-07-31#		E	VT; potential quarrying
	10 *Heggies Rock	1993-01-21		E	
	11 Hwy 232-L'il Kiokee	1987-04-08		F	VT; potential quarrying
	12 Little Heggies Rock	1989-01-29		G	VT; potential quarrying
	13 *Little Kiokee Creek	1982-12-25		P? EXT?	quarrying in progress
	14 *Lost Rock	1989-01-29		P? EXT?	quarrying in progress
	15 *Mt. Gemini	1993-01-21		F-EXT	quarrying application submitted
Dekalb	16 *Arabia Mountain	1992-06-10#	1992-06-10	E	recreational overuse; VT
	17 *Bradley Mountain	1990-03-14	1990-03-14	F	quarrying; competition
	- *Hayden Quarry Rd.	1982-00-00	1992-06-10	EXT	(road-paving VT)
	18 Little Rock Chapel Mtn.	1987-09-07#		P	extinct?; quarrying in progress
	19 North Rock Chapel Mtn.	1986-04-19		P	quarrying
	- *Pine Mountain	1897-05-15?		EXT	(quarrying)
	- *Rock Chapel Mountain	1939-03-15		EXT	(site destroyed by quarrying)
	20 Rock Chapel Park	1992-06-10		F	competition; road-improvement-VT
	- *Rollaway	1979-03-17	1983-12-17	EXT	(quarrying; vehicular traffic)
	21 ***Stone Mountain**	1993-02-15		F	recreational overuse
	- **Stone Mountain-"Flatrock"**	1950's (?)	1984-03-22	EXT	(construction?; quarrying?)
Douglas	22 **Clinton Nature Preserve**	1990-04-06		P	eutrophication? (horse manure)
	23 Pope Road	1990-04-06		F	vehicular traffic; dumping
Greene	24 *Greensboro	1992-04-07		E-P	quarrying in progress
	25 Greensboro South	1992-04-07		G-P	proposed crushed stone quarry
	26 Old Sparta Road	1992-04-07		G-P	logging VT; road improvements
	27 Siloam	1993-01-21		G	logging VT; eventual development
Gwinnett	28 *Baker's Rock	1993-04-21		P	vandalism; shading?
Hancock	29 Culverton South	1989-02-21		G	VT; potential quarrying
	30 *Forty Acre Rock	1987-02-06		G-P	grazing; eutrophication

STATE/COUNTY	SITE NAME	LAST SEEN	SOUGHT SINCE?	RANKING	THREATS
Hancock	31 Galilee Rock	1987-02-06		F-P	Competition, eutrophication; VT
	32 Granite Hill	1989-01-28		F	VT; potential quarrying
	33 *Pinkston Creek	1992-04-07		E	logging and other VT; quarrying
	34 Rocky Flats	1990-03-20		G	competition; eutrophication
Harris	35 Gray Rock	1988-10-23#		E	potential quarrying
Heard	36 Big Rock	1990-01-00		F	eutrophication; quarrying
	37 Boggy Rock	1990-04-26		G	eutrophication; quarrying
	38 *Camp Meeting Rock	1993-04-24		E	quarrying; VT; dumping
	39 Flat Rock North	1987-10-10#		G	potential quarrying
	40 Mile Post Six	1988-09-17#		G? F?	potential quarrying
	41 **Rusty Rock**	1992-04-23		F-EXT	quarrying in progress
	42 Sunflower Rock	1988-09-10#		G	potential quarrying
	43 Mt. Carrie Church South	1992-04-15		F	VT; dumping of logging refuse
Henry	44 Wolf Rock	1990-04-14		P	fire-building; VT
Meriwether	45 Wright Branch North	1992-03-31		F	logging VT; quarrying
Newton	-*Ellis Farm	1984-05-20	1987	EXT	(quarrying)
	46 Geezer Rock	1986-03-15		P-EXT?	eutrophication; competition
Oglethorpe	47 Echols Mill	1986-10-12#		F-EXT?	quarrying in process
Pike	48 Concord	1991-06-01#		G	quarrying; eutrophication; VT
Putnam	49 *Eatonton	1991-01-29		G-F	fire-building; VT
Rockdale	50 **Bald Rock**	1992-05-02		G-P	eutrophication; competition
	- **Panola Mountain**	1939-02-12	1992-04-14	EXT	(succession?)
	51 *Philadelphia Road	1992-05-02		P	VT; dumping
	52 The Rocks	1992-05-02		F	potential quarrying; VT
Walton	53 Anglin Farm	1980-02-26		F	eutrophication; competition?
	54 Rock of the Ages	1991-07-12#		F	quarrying; logging VT
	- Walnut Grove	1979-04-28	1991-02-24	EXT	(pools filled w/concrete)
SC Lancaster	55 **Forty Acre Rock**	1993-04-18		G	VT (motorbikes/bicycles)
Saluda	56 (Batesburg) Flat Rock	1993-04-10		F	VT; quarrying
York	57 Hilltop Lane	1993-04-18		F-G	VT; dumping

[1] EXT = extinct; E = excellent; G = good; F = fair; P = poor. Hyphenated symbols: first symbol is rating with landowner cooperation, second symbol is rating without cooperation; these populations face immediate threats.

[2] * = Amphianthus site which also supports/supported Isoetes melanospora or I. tegetiformans.

List of Reviewers

Mark Bosch
U.S. Forest Service
1720 Peachtree Street
Atlanta, Georgia 30367

Dr. P.E. Bostick
Dept. of Biology
Kennesaw College
Marietta, Georgia 30061

Dr. Robert Boyd
Dept. of Botany and Microbiology
Auburn University
Auburn, Alabama 36849-5407

Stratton Bull
The Nature Conservancy
806D 29th Street, S.
Birmingham, Alabama 35205

Dr. Madeline P. Burbanck
1164 Clifton Rd., NE.
Atlanta, Georgia 30307

Mr. Steve Calves (PD-EI)
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402

Dr. Eloise B. Carter
Oxford College
100 Hamill St.
Oxford, Georgia 30267

Kathy Chapman
U.S. Fish and Wildlife Service
Federal Bldg., Room 334
Brunswick, Georgia 31520

W. Peter Conroy
The Alabama Conservancy
2717 7th Ave. South
Suite 201
Birmingham, Alabama 35233

Dr. Bob Cook
Arnold Arboretum
125 Arborway
Jamaica Plain, Massachusetts 02130

Dr. A. Murray Evans
Dept. of Botany
Univ. of Tennessee
Knoxville, Tennessee 37796-1100

Brad Foster, PD-E
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402

Laurie Fowler
554 Boulevard
Athens, Georgia 30601

Dr. John D. Freeman
Dept. of Botany and Microbiology
Auburn Univ.
Auburn University, Alabama 36849-5407

David Funderburk
Coordinator
Fernbank Science Center
156 Heaton Park Drive, NE.
Atlanta, Georgia 30307

Dr. Judith E. Gordon
Dept. of Biology
Augusta College
Augusta, Georgia 30910

Scott Gunn
Alabama Dept. of Conservation & Natural Resources
Alabama Natural Heritage Program
Folsom Administration Bldg.
64 N. Union St., Rm. 752
Montgomery, Alabama 36130

Dr. Robert R. Haynes
Dept. of Biology
Univ. of Alabama
Tuscaloosa, Alabama 35487-1927

Dr. R. James Hickey
Botany Dept.
Miami Univ.
Oxford, Ohio 45056

Dr. Robert Kral
Department of Biology
Herbarium
Vanderbilt University
Nashville, Tennessee 37235

Dr. David B. Lellinger
U.S. National Herbarium NHB166
Smithsonian Institution
Washington, D.C. 20560

Greg Lucas
South Carolina Wildlife & Marine Resources
P.O. Box 167
Columbia, South Carolina 29202

David Martin
U.S. Fish and Wildlife Service
3100 University Blvd., S
Suite 120
Jacksonville, Florida 32216

Dr. Sidney McDaniel
Mississippi State University
P.O. Box EN
Mississippi State, Mississippi 39762

Steve McKeel
Martin Marietta Aggregates
P.O. Box 212369
Augusta, Georgia 30917-2369

Nora Murdock
U.S. Fish and Wildlife Service
330 Ridgefield Court
Asheville, North Carolina 28806

Michael J. Murphy
2-A Gaines Ct.
Athens, Georgia 30605

Dr. Lytton Musselman
Department of Biological Sciences
Old Dominion University
Norfolk, Virginia 23529-0266

Elaine Nash
3390 Hwy 20, SE
Conyers, Georgia 30208

Cary Norquist
Fish and Wildlife Service
6578 Dogwood View Parkway
Jackson, Mississippi 39213

Peggy Olwell
The Center for Plant Conservation
P.O. Box 299
St. Louis, Missouri 63166

Tom Patrick
Georgia Dept. of Natural Resources
Freshwater Wetlands & Heritage Inventory
2117 US Hwy 278 SE.
Social Circle, Georgia 30279

Dr. Bert Pittman
South Carolina Wildlife & Marine Resources Dept.
South Carolina Heritage Trust
P.O. Box 167
Columbia, South Carolina 29202

Dr. Douglas A. Rayner
Dept. of Biology
Wofford College
Spartanburg, South Carolina 29303-3840

Dr. Phillip M. Rury
Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140-2390

Dale Sablo
The Nature Conservancy
P.O. Box 5475
Columbia, South Carolina 29250

Louise Smith
3221 Pine Ridge Road
Birmingham, Alabama 35213

Jerry Spicer
Director of Administrative Services and Attractions
Georgia's Stone Mountain Park
P.O. Box 778
Stone Mountain, Georgia 30086

Jonathan Streich
The Nature Conservancy
1401 Peachtree Street, NE.
Suite 136
Atlanta, Georgia 30309

Robert Sutter
The Nature Conservancy
P.O. Box 2267
Chapel Hill, NC 27515

Dr. W. Carl Taylor
Milwaukee Public Museum
800 W. Wells Street
Milwaukee, Wisconsin 53233

Gloria Turner
Douglas County Board of Commissioners
6754 Broad Street
Douglasville, Georgia 30134

Sherry Wheat
DeKalb County Recreation Parks and Cultural Affairs
1300 Commerce Drive, Rm 200
Decatur, Georgia 30030

Dr. David Whetstone
Jacksonville State University
Department of Biology
Jacksonville, Alabama 36265

Dr. Robert E. Wyatt
Dept. of Botany
Univ. of Georgia
Athens, Georgia 30602

Environmental Protection Agency
Hazard Evaluation Division- EEB (TS769C)
401 M Street, SW.
Washington, D.C. 20460

Division of Endangered Species
(Mail Stop 452 ARLSQ)
U.S. Fish and Wildlife Service
Washington, D.C. 20240

Office of Public Affairs
(PA, 3447 MIB)
U.S. Fish and Wildlife Service
Washington, D.C. 20240

Office of Research Support
(RD-8/ORS, Mail Stop 725 ARLSQ
U.S. Fish and Wildlife Service
Washington, D.C. 20240

U.S. Fish and Wildlife Service
9 East Broad Street
Cookeville, Tennessee 38503

U.S. Fish and Wildlife Service
801 Gloucester Street
Brunswick, Georgia 31520

U.S. Fish and Wildlife Service
217 Fort Johnson Road
Charleston, South Carolina 29412