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Three Granite Outcrop Plants:

Black-spored quillwort (*Isoetes melanospora*)

Amor
9-26-08

Mat-forming quillwort (*Isoetes tegetiformans*)

Little amphianthus (*Amphianthus pusillus*)

Five-Year Review:

Summary and Evaluation

**U.S. Fish and Wildlife Service
Southeast Region
Georgia Ecological Services Field Office
Athens, Georgia**

5-year Review

Black-spored quillwort (*Isoetes melanospora*), Mat-forming quillwort (*Isoetes tegetiformans*),
Little amphiathanus (*Amphianthus pusillus*)

I. GENERAL INFORMATION

A. Methodology used to complete the review:

This review was completed by the U.S. Fish and Wildlife Service's (Service) lead recovery biologist for each of these species, who is located in the Georgia Field Office, Athens, Georgia. No part of this review was contracted to outside parties. All literature and documents used in this review are on file at the Georgia Field Office and are cited in the Literature Cited section. We used peer-reviewed publications; and data and information available on the internet; in unpublished surveys; and in personal communications with land managers, biologists, and researchers involved in plant conservation work. Public notice of this review was given in the Federal Register on July 26, 2005, and a 60-day comment period was opened. The draft of this document was distributed for peer review (see Appendix A) and comments received were addressed. The following is a list of people that provided significant information to this review:

Elaine Nash, Botanist.

Tom Patrick, Botanist, Georgia Department of Natural Resources Heritage Program.

Jim Allison, Botanist.

Malcolm Hodges, The Nature Conservancy.

Marry Terry, Park Ranger, Arabia Mountain.

Eric VanDeGenachte, The Nature Conservancy.

Jennifer Ceska, Botanist, Georgia Botanical Garden

B. Reviewers

Lead Region: Southeast Region, Kelly Bibb, (404) 679-7132

Lead Field Office: Georgia, Ecological Services, Wildlife Biologist, James Rickard,
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C. Background

- 1. FR Notice citation announcing initiation of this review:**
July 26, 2005; 70 FR 43171

- 2. Species Status:**

Declining - the status of all 3 plant species as reported in the 2007 Recovery Data Call.

Little amphianthus: 2007 surveys visited 33 of 65 original element occurrence records (EOs). Cumulatively, between the three states, a total of 44 *A. pusillus* sites are thought to be intact. Fourteen populations were destroyed prior to the recovery plan, one population has been documented as destroyed since the recovery plan, two populations have been lost due to dumping, and two are believed destroyed. Habitat conditions are very poor for at least 7 populations and these could be lost in the near future.

Black spored quillwort: Surveys in 2007 visited 12 (including all known extant populations) of the original 15 EO's, there are 3 additional EO's where the plant appears to have hybridized. Currently, there are 6 extant EO's at 5 sites (Arabia Mountain is a large state owned site with two EO's). Four EO's are in conservation status, 1 EO is owned by a city municipality and 1 EO is owned by a private land owner. 1 EO could not be found and appears to have been lost due to dumping activities by the land owner.

Mat forming quillwort: By far, the greatest threat to these species is the destruction of habitat due to quarrying activities. Quarrying continues to destroy granite outcrops, and populations of all three plants have been lost. Surveys in 2007 of the original 13 EO's found 10 extant occurrences. However, one site was covered by fill dirt and two with on-going quarry work and a state owned population was at critically low levels. Therefore, the population could be reduced to 6 EO's in the near future.

3. **Recovery achieved:** 1 for all 3 plants (0-25% species recovery objectives achieved; 2007 Recovery Data Call)

4. **Listing history**

Original Listing

FR notice: 53 FR 3560

Date listed: February 5, 1988

Entity listed: All 3 plants are listed as species.

Classification: threatened (little amphianthus); endangered (both quillworts)

5. **Review History:**

The Service conducted a five-year review for all 3 plants in 1991 (56 FR 56882). In this review, the status of many species was simultaneously evaluated with no in-depth assessment of the five factors or threats as they pertain to the individual species. The notice stated that Service was seeking any new or additional information reflecting the necessity of a change in the status of the species under review. The notice indicated that if significant data were available warranting a change in a species'

classification, the Service would propose a rule to modify the species' status. No change in listing classification was found to be warranted for these 3 plants.

1993 Recovery Plan (see below)

Recovery Data Call – 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, 1998

6. **Species' Recovery Priority Number at start of review (48 FR 43098):** 5 for *I. melanospora* (black spored quillwort), 8 for *I. tegetiformans* (mat forming quillwort), and a 13 for *A. pusillus* (little amphianthus).
The 5 means degree of threat is high and recovery potential is low. The 8 means moderate degree of threat and high recovery potential. The 13 means low degree of threat and high recovery potential.

7. **Recovery Plan or Outline:**

Name of plan: Recovery Plan for Three Granite Outcrop Plant Species.
Date issued: July 7, 1993

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

The Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review are plants and the DPS policy is not applicable, the application of the DPS policy to the species listings is not addressed further in this review.

B. Recovery Criteria

1. **Do the species have a final, approved recovery plan containing objective, measurable criteria? Yes**

2. **Adequacy of recovery criteria.**

- a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?**

No, the recovery criteria are more than 12 years old. There is new genetic information, and the baseline status for all three species continues to decline.

- b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?**

Yes, the relevant factors are covered. However, there is a new threat to the habitat. Development pressure appears to be increasing, particularly in the Metro Atlanta area. An additional threat might be fire ants (*Solenopsis wagneri*)(see Threats pg. 13).

- 3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. For threats-related recovery criteria, please note which of the 5 listing factors are addressed by that criterion. If any of the 5-listing factors are not relevant to this species, please note that here.**

The recovery plan states that: reclassification of *I. melanospora* or *I. 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.

Currently, a total of six *A. pusillus* sites are protected, two *I. tegetiformans* sites protected, and three *I. melanospora* sites protected. Threats from quarrying, farm animals, dumping, vehicular traffic and recreational impacts have been largely abated on these sites. However, ongoing active management is required. Prior to the recovery plan, five major outcrops had some form of conservation management (US Fish and Wildlife Service 1993) and each has made improvement to the status of the plants found on site (Jim Allison, botanist, retired GDNR, pers. comm., May 2006). Since the recovery plan was published, one new outcrop has been placed in conservation status; however, at least 2 (likely more) populations of *A. pusillus* and 2 populations of *I. melanospora* have been extirpated.

1. Stone Mountain- Owned by the State of Georgia, with protective easement and extant populations of *A. pusillus* and *I. melanospora*. At the time of listing, this population was entirely within a State-owned park operated by the public authority, the Stone Mountain Memorial Association. The inclined railway threat (US Fish and Wildlife Service 1993) has abated and fencing has been added to prevent recreational trampling (Jim Allison, botanist, May 2006).

2. Eatonton Rock – Owned and managed by the State of Georgia, Department of Natural Resources (GDNR) with extant populations of *A. pusillus* and *I. tegetiformans*. Acquired from Georgia Power, this property is managed as a Wildlife Management Area (WMA), protecting it from major threats. However, some recreational threats persist. Located east of Eatonton Georgia, this site includes, approximately 40 acres of exposed rock. Eatonton Rock has many pools that are occupied by *A. pusillus* and two pools of *I. tegetiformans*. On the edge of a major recreational lake, the outcrop receives heavy recreational use that has an adverse impact (Tom Patrick, GDNR, pers. comm. March 2006). Trash and vehicle damage are evident at the site and at least one pool had been used as a fire pit.

3. Forty Acre Rock – Owned by the State of South Carolina with extant populations of *A. pusillus* and a hybrid population of *I. melanospora*. No new information available at this time. The recovery plan states:

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. A strategy must be developed to diminish these threats.

4. Heggies Rock – Owned by The Nature Conservancy (TNC) with extant populations of *A. pusillus* and *I. tegetiformans* (Malcolm Hodges, TNC, pers. comm. March 2006). A portion is owned by Columbia County with a protective easement. Located west of August, GA, TNC owns 101 acres, most of which is outcrop habitat. TNC also holds a conservation easement on an additional 140 acres owned by Colombia County, approximately 30 acres of which is outcrop habitat. Within the TNC ownership, one natural population of *I. tegetiformans* occurs in a shallow pool of approximately 250 square feet. *A. pusillus* is abundant on the site with approximately 50 pools occupied in a given year.

Two populations of *I. tegetiformans* were transplanted onto the property owned by Colombia County. The plants were rescued from Mount Gemini, which has been extensively quarried over the last decade. The two transplanted pools are not deep enough naturally and were modified by placing a lip of concrete around the lower curve of the pool. Fire ants (see Threats pg. 13) on the site may be an emerging threat (Malcolm Hodges, pers. comm. March 2006).

5. Camp Meeting Rock – Owned by TNC, with a large extant population of *A. pusillus* and two pools of *I. tegetiformans* (Malcolm Hodges, pers. comm. March 2006). Located north of LaGrange GA, this rock formation has approximately 330 acres of outcrop habitat. Nearly 80 acres have been acquired by TNC and an additional 30 acres are protected by easement. Some of the property is still held in private ownership with persistent threat of development.

6. Arabia Mountain – Owned by DeKalb County, Georgia, with extant populations of *A. pusillus* and *I. melanospora*. This complex of habitats comprises over 2,400 acres of granite outcrop, wetlands, pine and oak forests, streams, and a lake in DeKalb County. The nucleus of this heritage area is Davidson-Arabia Mountain Nature Preserve. This County Park contains the largest and most important population of *I. melanospora* as well as one of the largest *Amphianthus* populations (US Fish and Wildlife Service 1993). These species intermingle in multiple vernal pools at the summit of the mountain. In addition, *Amphianthus* occurs in a number of pools along the sides of the mountain, and *I. melanospora* occurs in a quarry pool near the base of the mountain.

This site has grown from 500 acres to more than 2,400 acres since the inception of the Recovery plan. Part of the acreage was purchased to protect *Sedum pusillum* (Mary Terry, Arabia Park Ranger, pers. comm. April 2006). Staff have been added to include; a Supervisor/Ranger, Nature Center Ranger and Secretary. The staff is in the process of documenting pools occupied by *I. melanospora* and *A. pusillus*, mapping the pools and trying to record the number of plants at each pool. The recovery plan called for the removal of pines at the quarried pools which has been accomplished.

The additional acres purchased have resulted in more traffic and recreational activities at the Preserve (Mary Terry, pers. comm. April 2006). The PATH Foundation installed a bike/hike concrete trail that bisects the Preserve on the western side of Klondike Road. Future plans call for additional trails on the east side (Bradley and Arabia Peaks). The trails will follow the base of the Arabia Peak to the north and east side. Enforcement to protect sensitive areas needs improvement.

Publicly-owned sites with limited conservation potential:

1. Bald Rock, Rockdale County, Georgia.

This outcrop contains six to ten pools supporting *A. pusillus* (Jim Allison, May 2006). Historic use of the outcrop as a pasture resulted in some eutrophication of pools and the introduction of exotic species, such as *Poa annua*. The outcrop was acquired by Rockdale County as a portion of a much larger tract 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. 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 as pasture has resulted in improved conditions for *A. pusillus*.

2. Clinton Nature Preserve, owned by Douglas County, Georgia has two small pools occupied by *A. pusillus*, however, they are located in a bike trail with no conservation agreement.

C. Updated Information and Current Species Status

1. Biology and Habitat

Black-spored quillwort - A perennial fern ally, this plant's distinguishing characteristics include a sporangium wall that is unpigmented and completely covered by a transparent membrane (velum), dark, tuberculate megaspores and short (2 to 7 centimeters long), spiraled leaves (Boom 1979, 1982). Linear, bunched leaves arise from a bulbous base. Immature plants may have distichous leaves (Boom 1979, Rury 1978). Spores are produced within a cavity (sporangium) in the base of the leaf. Each sporangium may produce either dozens of larger female spores (megaspores) which are black or hundreds of smaller male spores (microspores). Spores are sporadically produced from May through June. Black-spored quillwort may hybridize with *Isoetes piedmontana* in habitats which are ecologically intermediate between the two species. A more common granite outcrop quillwort, *Isoetes piedmontana*, has incomplete velum coverage, white megaspores, and longer leaves (up to 16.7 cm long)(Heafner and Bray 2005). Black-spored quillwort is restricted to shallow, flat bottomed depressions on granitic outcrops in the piedmont region of Georgia. Depressions are entirely rock rimmed and generally occur near the summit, with most water accumulating from direct rain fall and little flowing water to provide nutrient input.

Mat-forming quillwort – A perennial fern ally, this plant is similar to the black-spored quillwort in size and reproductive features (Rury 1978, Heafner and Bray 2005). Mat-forming quillwort plants are prolific, forming interconnected clumps by means of numerous caudine, adventitious buds, and differ from all other North American species in having non-dichotomizing roots at maturity (Rury 1978, Boom 1979, 1982). Two forms of unbranched roots include a stout, coiled root that emerges from the leaf base and a slender, uncoiled root emerging from the base of the elongated stem. Narrow, linear leaves arise in two rows (rather than a spiral) 3-7 cm long and 1mm wide. Spores are produced in a cavity of the flared leaf base (sporangium). The sporangium has unpigmented walls and is completely covered by a transparent membrane (velum). Each sporangium may produce either dozens of larger female spores (megaspores) or hundreds of smaller male spores (microspores). Sporadic spore production occurs from May to October. Mat-Forming quillwort is restricted to shallow, flat bottomed depressions on granitic outcrops in the piedmont region of Georgia. Depressions are entirely rock rimmed and generally occur near the summit, with most water accumulating from direct rain fall and little flowing water to provide nutrient input.

Little amphiaphyllum - A member of the family Scrophulariaceae, this plant is the only member of the genus *Amphiaphyllum*. This small, fibrous-rooted winter annual normally begins germination in late autumn and peaks in late winter or early spring. Light is required for germination (Lunsford 1939), therefore, buried seeds may serve as a seed bank (US Fish and Wildlife Service 1993). Habitat has been typified as high light intensity, shallow soils low in nitrogen and organic matter, soil depth may range from 0.3-6.6 cm and organic matter from 1.1 % to 29% (Hilton and Boyd 1996). The species

has both submerged lanceolate leaves less than 1 cm in length arranged in a basal rosette and ovate floating leaves 4 to 8 mm long and 3 to 5 mm wide. The floating leaves are opposite and attached to the stem near the submerged leaves by long, delicate stems.

Amphianthus begins flowering in February or March and continues until the habitat is desiccated by a spring drought that kills the plants (usually occurs March-May) (US Fish and Wildlife Service 1993). The plant's white flowers are 4 to 5 mm in length and are borne in the axils of both the floating and submerged leaves. Floating flowers are open, and submerged flowers are closed except when exposed to air (Lunsford 1939, Rayner 1986). The species self-pollinates, resulting in reduced genetic variation within populations (US Fish and Wildlife Service 1993). *Amphianthus* produces capsules 2 or 3 mm broad and 1 mm long; when mature, the capsules dehisce (or open at certain points) along the sutures, releasing seeds that remain dormant until suitable moisture and light conditions for germination are met. The entire life cycle for *Amphianthus* often lasts only 3 to 4 weeks (Garris 1980, Kral 1983, Rayner 1986).

Ideal moisture and light conditions are required for successful seed germination and growth. Also, the dormancy period for the seeds is unknown (Garris 1980, Lunsford 1938, Rayner 1986). *Amphianthus* has a substantial seed bank that may be 18 times greater than the germinating plants in a given year (US Fish and Wildlife Service 1991). Randall (1986) speculates that this plant produces seeds predominately by self-pollination, a genetic factor which may limit its ability to adapt to habitat alteration.

a. Abundance, population trends (e.g. increasing, decreasing, stable), demographic features, or demographic trends:

Little Amphianthus (see Attachment 1) - Historically known from 57 sites in 17 Georgia counties, four sites in two Alabama counties, and three sites in three South Carolina counties. Two of the Georgia counties (Newton and Oglethorpe) have lost their populations. Seven of the Georgia counties (Henry, Douglas, Walton, Butts, Harris, Meriwether, and Gwinnett) support limited populations of 1 to 5 pools. One or two extensive populations (15 to 25 pools) are located in Dekalb, Heard, Greene, Hancock, and Columbia Counties, Georgia. The number of individuals in the pools range from a dozen to several thousand. Limited populations exist in Randolph (2 sites) and Chambers Counties (1 site) in Alabama. Two sites contain fewer than 50 plants in a single vernal pool, while the third population consists of several hundred plants in two to three pools (Miller 1985). In South Carolina, half of the 12 existing pools had extensive populations of more than 200 plants, and six had limited populations of less than 25 plants during the 1983 and 1984 growing seasons (Rayner 1986). Seven pools exist in Lancaster County, one in Saluda, and four in York County (Rayner 1981, 1986).

Cumulatively, between the three states, of the 64 known populations, a total of 43 *A. pusillus* sites are known to be intact. Another 5 populations in Georgia have not been evaluated since the recovery plan. Fourteen populations were destroyed prior to the recovery plan, two populations have been documented as destroyed since the recovery plan. One new population of *A. pusillus* has been discovered since the recovery plan (U.S. Fish and Wildlife Service 1999). Artificially established sites are not treated in these numbers because they are not considered to be self sustaining.

Black-spored quillwort (See Attachment 2)- This plant, historically known from 15 sites in central Georgia, with an additional 3 hybrids populations (2 in Georgia and 1 in South Carolina) was first discovered by Canby in 1869 on Stone Mountain (DeKalb County). Currently, the plant exists at only eight sites (including two hybrids populations) in Georgia (Butts, DeKalb, Heard, Rockdale, and Gwinnett Counties). Its status at the one South Carolina site is unknown since it has not been observed there since its collection in 1969, were it is also thought to be a hybrid population (Boom 1979), Matthews & Murdy reported only intermediates.

At one Georgia site, this plant is located in remnant quarry pools. The largest population contains plants in an estimated 7 pools. Other black-spored quillwort populations are confined to one to five pools each. This plant co-occurs with amphianthus at four of its five extant sites.

Mat-forming quillwort (See Attachment 3) - This plant was first described by Rury (1978) from material he collected from a single vernal pool at Heggies Rock in Columbia County, Georgia. Mat-forming quillwort is historically known from 13 populations in Georgia; however, three have been destroyed. Populations are confined to porphyritic (igneous rock with crystals embedded in it) granite outcrops in Columbia, Hancock, Putnam, and Greene Counties (Dr. Phillip Rury, Consulting Ecologist, pers. comm., February 1986). Seventy percent of these extant sites contain only one or two pools with mat-forming quillwort. At the rest of these sites, the plant has been observed in four to eight pools. Individual pools may contain few genetic individuals since mat-forming quillwort is a colony-forming species (Bridges 1986a).

b. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Isoetes tegetiformans has little allozyme diversity, typical for a colonial species (Van De Genachte 1996). Due to limited genetic diversity, *I. tegetiformans* may have limited ability to adapt to environmental change. On the other hand, protection of all populations may not be required in order to capture the entire genetic diversity of the species. Van De Genachte (1996) showed that hybridization may also occur between *I. tegetiformans* and *I. piedmontana*.

Van De Ganachte (1996) showed that *I. melanospora* had much more genetic diversity than would have been expected for a species with a restricted range and isolated populations. Safe-guarding efforts may be required to preserve the genetic integrity of *I. melanospora*. Hybridization between *I. melanospora* and *I. piedmontana* has seemingly occurred in the past (Matthew and Murdy 1969, Rury 1978, Van De Genachte 1996), but has not been rigorously proven. The genetic integrity of black-spored quillwort may be threatened by occasional hybridization with *I. piedmontana* and subsequent introgression. In disturbed or altered habitats, hybrids may displace *I. melanospora*, which requires a highly specialized microhabitat. The more adaptable hybrids may displace *I. melanospora* which requires a more specialized type of microhabitat.

Isoetes tegetiformans has been collected from Heggies Rock, Camp Meeting Rock and Eatonton Outcrop and are in indoor cultivation at the Atlanta Botanical Garden and the Georgia Botanical Garden (Jennifer Ceska, Botanist, Georgia Botanical Garden pers. comm. June 2006). *Isoetes melanospora* has been difficult to maintain in long term cultivation. *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 pusillus* 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 *A. pusillus* is more difficult to maintain than either of the listed *Isoetes* species.

Genetic analysis of *A. pusillus*, suggested that there was very little variation and strong indication of self-fertilization. A few protected sites may capture much of the global genetic diversity of *A. pusillus*. Therefore, priorities of which sites to seek preservation for should be based on factors other than just the presence of amphianthus.

c. **Taxonomic classification or changes in nomenclature:** None to report.

d. **Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species within its historic range, etc.):**

The range of these species has not changed. See Figure 1. Conserved properties (including TNC) receive some level of monitoring; however, outcrops that are in private holdings receive sporadic monitoring at best and most of the information is outdated (see attachment 1, 2 and 3 latest status column). Due to poor monitoring efforts, the current status (extent of decline) of all three outcrop plants cannot be accurately assessed. In 2006, the Service began an effort to evaluate

each of the known populations; however, this effort will not be complete until 2008.

e. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

These endemics are vulnerable because of the limited amount of potential habitat and specialized microhabitat requirements. These species are found on granitic outcrops in the Piedmont physiographic region of the southeastern United States generally in eroded depressions or, rarely, quarry pools formed on flat- to doming granite outcrops. Generally similar in appearance, outcrops may differ geologically as igneous, quartzitic, gneissic, or porphyritic granite (McVaugh 1943, Wharton 1978, Wyatt and Allison 1999). These taxa generally occur in shallow flat-bottomed pools on the crest or flattened slopes of unquarried outcrops (Lester 1938, Garris 1980, Rury 1985, Rayner 1985). Pools might be several meters in diameter and are circular or irregularly-shaped due to the coalescence of adjacent pools (Lunsford 1938, McVaugh 1943); typically these pools average 0.5 to 1 square meter. The depressions generally have an intact rim that restricts drainage with an accumulation of a few centimeters of mineral soil that is low in nutrients, particularly nitrogen (Lammers 1958). Following heavy rains, pools retain water for several weeks before completely drying out with summer droughts. Both *Isoetes* are able to go dormant when pools dry out, then resume growth whenever water is replenished, regardless of season (US Fish and Wildlife Service 1993, Wyatt and Allison 2000).

2. Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

As documented in the recovery plan, quarrying continues to be the primary threat destroying granite outcrops, and populations of all three species have been lost (U.S. Fish and Wildlife Service 1993). Environmental conditions on the remaining outcrops are still being modified by cattle eutrophication, littering, trash dumping, fire building, vandalism, and off-road vehicles.

A new threat has evolved with the expansion of Atlanta; development has become a new threat to this habitat. The Lithonia Rock outcrop was buried under an estimated 1-2 meters of fill and houses were placed on top (Eric Van De Genachte, pers. comm. May 2006). As Atlanta continues to expand and land becomes a scarce and valuable commodity, property that was previously economically unsuitable for development becomes more suitable. Development resulting in substantial habitat destruction for this plant can be expected to continue to grow as a threat.

Invasive fire ants have been hypothesized to be an additional threat (Malcolm Hodges, pers. comm. March 2006). Fire ants have become well established on some outcrops and

their impact is unclear. Fire ants may impact insects that play a role as pollinators or in seed dispersal.

a. Present or threatened destruction, modification or curtailment of its habitat or range:

Quarrying.

By far, the greatest threat to these species is the destruction of habitat due to quarrying activities. Quarrying continues to destroy granite outcrops, and populations of all three plants have been lost. Of the 16 documented local extinctions of the listed species, 11 can be attributed to this cause. *Amphianthus* may have been extirpated at up to four additional sites that are now being quarried. The numerous exposures of granites and gneisses in the Piedmont, particularly in Georgia, have been quarried extensively, and an unknown number of undocumented populations of the listed species (most likely *amphianthus*), were doubtless unknowingly destroyed. Thirty-eight percent of the total populations of black-spored quillwort, 25 percent of *amphianthus*, and 23 percent of mat-forming quillwort have been destroyed by this threat.

Populations of the listed species (and other granite outcrop organisms) may be impacted by accumulation of rock dust when quarry operations are undertaken nearby (US Fish and Wildlife Service 1993). As late as 1979, *I. melanospora* could be found in two pools at Bradley Mountain in DeKalb County, Georgia. 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 *I. melanospora* may have been altered by the accumulation of quarry dust. Although the recovery plan addressed the need to study effects of quarry dust on vernal pool vegetation, no studies have been conducted.

Farm animals.

At other sites, the habitat supporting these species has been degraded through conversion to pasture (US Fish and Wildlife Service 1993). Excessive animal wastes have resulted in eutrophication of pools, promoting excessive algal growth, that 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 *Callitricha heterophylla*, *Eleocharis obtusa*, *Ranunculus pusillus*, and various *Juncus* spp., as well as exotic weeds, such as *Poa annua*.

Bald Rock, is now in Rockdale County ownership in Georgia and has fencing around the extant pools (Jim Allison, pers. comm. May 2006). Forty Acre Rock

in Hancock County, Georgia, is slowly recovering from grazing impacts. Clinton Nature Preserve, Douglas County, Georgia, has 2 *amphianthus* pools threatened by animal waste (horseback riding). This does not appear to have been brought to the attention of the site's management and no improvements have been made (see attachment 1, 2 and 3).

Dumping.

Because granite outcrops are regarded by many 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.

Philadelphia Road outcrop in Georgia has a mixed picture, with the owner fencing the outcrop and removing trash, but filling other portions of the rock (See attachment 1, 2 and 3).

b. Overutilization for commercial, recreational, scientific, or educational purposes:

Not a known factor for these taxa (see factor e for further detail on recreational use).

c. Disease or predation:

Not a known factor for these taxa.

d. Inadequacy of existing regulatory mechanisms:

State protective measures.

Under the provisions of Georgia's Wildflower Preservation Act, *Amphianthus pusillus*, *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.

The Georgia Wildflower Preservation Act 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.

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.

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 1995).

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.

e. Other natural or manmade factors affecting its continued existence:

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 (Lamer 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. *Isoetes melanospora* is susceptible to damage or even killed when subjected to abnormally low

temperatures (below ca. -12C [10F]). 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.

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.

Arabia Mountain has experienced increased visitors with traffic becoming a potential problem (Marry Terry, pers. comm. April 2006). At Stone Mountain, the remaining pools supporting *I. melanospora* and *Amphianthus* have benefited from fencing (Jim Allison, pers. comm. May 2006). Eatonton Outcrop is located on the edge of a recreational lake and is currently managed as a WMA; evidence of painting and fire building can be found (Tom Patrick, pers. comm. March 2006). (See attachment 1, 2 and 3). At Heggies Rock, fencing has reduced access to the site (Malcolm Hodges, pers. comm. March 2006). Other activities such as excavating artificial pools appeared to work but outcrops where artificial pools were created has been destroyed by development (Eric Van De Genachte, pers. comm. May 2006).

Vehicular traffic.

Vehicular traffic is a serious problem at many sites. This can be due to recreational traffic, such as off-road vehicles, motorbikes, or even automobiles. 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.

Mt. Carrie Church South outcrop continues to suffer vehicular traffic (Jim Allison, pers. comm. May 2006). The populations at Heggies Rock have benefited from fencing, however traffic at Camp Meeting Rock is a persistent issue (See attachment 1, 2 and 3).

Hybridization

At three outcrops where *I. melanospora* presumably once occurred with *I. piedmontana*, *I. melanospora* has seemingly been outcompeted by hybrids between these two species (Matthews and Murdy 1969). 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.

In addition to historic hybridization impacts, hybridization events may also have occurred at attempted transplant sites, both Siloam outcrop and Thompson Mills Forest (Jim Allison, pers. comm. May 2006). New evidence shows *I. tegetiformans* may also suffer from hybridization (see Genetics pg. 12).

At least three attempts have been made at conducting transplants using both *Isoetes* species, with mixed results achieved. All known efforts to conducted transplanting efforts were conducted without consultation with GDNR or the Service. No protocol or monitoring was established and no supportable conclusions can be drawn from the efforts (Jim Allison, pers. comm. May 2006). Any future efforts need to develop a protocol and monitoring prior to moving plants. Any protocol must consider how to limit the potential hybridization of black-spored quillwort with other *Isoetes*.

- D. **Synthesis** – These species are found exclusively in a distinctive granite outcrop habitat whose distribution is well known, at least in Georgia (mapped by the State Geological Survey due to their economic importance as a source of stone), and nearly all known populations were discovered prior to publication of the recovery plan. A few populations have been placed in conservation; however, the majority of the populations occur on privately-owned property and face imminent threats from quarrying, development, farm animals, dumping, vehicular traffic, and recreational impacts. Very little new research has been conducted on these species. Only one new population of *A. pusillus* has been found and no new populations of *Isoetes*. Several populations of all 3 taxa have been destroyed since the recovery plan, these species are declining.

Black-spored quillwort has 4 EO's (3 locations) in conservation, 1 EO is owned by the city of Snellville and therefore has the potential for conservation, 3 EO's in private ownership could be lost to any of the listed threats and the remaining 3 EO's are considered hybrid populations. One of the hybrid populations is owned by a mining company and may already be lost. At least, 7 (38%) EO's have been destroyed.

Mat-forming quillwort has 2 EO's in conservation (1 of these is in poor condition), 8 EO's in private ownership and 3 (23%) EO's that have been destroyed. Of the 8

populations in private ownership, 3 are owned by mining companies and the remaining populations are threatened by the threats listed above. The eventual destruction of the populations currently owned by mining companies would result in a 46% reduction in known populations of this plant.

Of 64 known populations, little amphianthus has 6 EO's in conservation, 42 EO's in private ownership and 16 (25 %) extirpated. At least, 5 EO's are owned by mining companies and at least 4 EO's have been reduce to a single, severely degraded pool, so that they could be lost at any time. The loss of an additional 9 populations would constitute a 39% reduction in the total population.

As a whole, all three taxa are experiencing continuing threats. Few populations have been placed into public ownership or conservation. The majority of populations occur on privately-owned property and face imminent threats. Since the recovery plan, one new population of *A. pusillus* has been found and several populations of *I. melanospora* and *A. pusillus* have been destroyed, the available habitat for all three species is declining. Therefore based on the threats described above and the status of each of the three plants, little amphianthus continues to meet the definition of threatened and black-spored and mat-forming quillworts continue to meet the definition of endangered under the Act.

III. RESULTS

A. Recommended Classification:

No change in status for these plants is recommended.

B. New Recovery Priority Number:

Mat-forming quillwort (*Isoetes tegetiformans*), Change from 8 to 5.

The current conditions for both *Isoetes* are similar. Due to the few remaining populations and continued quarrying, the *Isoetes* have a degree of threat that is "high." There are not enough remaining populations to meet recovery criteria (see attachment 2 and 3). To achieve the reclassification criteria of 10 populations for both species, conservation agreements will have to be implemented or habitat purchased outright along with transplanting into unoccupied and possibly artificial habitat. Due to the difficulty in achieving reclassification criteria the recovery potential is "low" for both species. The "high" degree of threat with a "low" recovery potential should result in a RPN of 5 for *I. melanospora* and similarly *I. tegetiformans* should have its RPN changed from 8 to 5.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS :

Any future efforts to move any of the 3 plants need to develop a protocol and monitoring schedule prior to moving plants. Any protocol must consider how to limit the potential hybridization of black-spored quillwort with other *Isoetes*. *Amphianthus* cannot reasonably be expected to be kept in cultivation, therefore, an effort to maintain seed stock from the various pools should be established. The implications of seed storage should be studied to evaluate germination success and techniques. The recovery plan suggested that the effects of quarry dust should also be investigated.

Conservation priorities need to be developed that protect and/or enhance each of these listed plants as well as other community associates of the granite outcrop. At outcrops with conservation potential, the land owners need to be contacted to seek conservation easements or fee simple acquisition. The Service and State Heritage programs should contact private landowners to request their cooperation in plant conservation. Status surveys need to be completed for these species in all three States.

The Implementation schedule in the recovery plan needs to be updated.

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**U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of**
Black-spored quillwort (*Isoetes melanospora*)
Mat-forming quillwort (*Isoetes tegetiformans*)
Little amphiантus (*Amphiантus pusillus*)

Current Classification Black-spored quillwort - Endangered.
 Mat-forming quillwort - Endangered.
 Little amphiантus - Threatened.

Recommendation resulting from the 5-Year Review

- Downlist to Threatened
 Uplist to Endangered
 Delist
 No change is needed

Review Conducted By James Rickard

FIELD OFFICE APPROVAL:

Sandra Tucker, Field Supervisor, Fish and Wildlife Service

Approve Sandra Tucker Date 9/8/08

COOPERATING FIELD OFFICE APPROVAL:

for Bill Pearson, Field Supervisor, Fish and Wildlife Service

Approve Bill Pearson Date 9/4/08

COOPERATING FIELD OFFICE APPROVAL:

Tim Hall, Field Supervisor, Fish and Wildlife Service

Approve Tim Hall Date 9/8/08

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

for Lead Regional Director, Fish and Wildlife Service

Approve Maren E Walsh Date 9/30/08

APPENDIX A: Summary of peer review for the 5-year review of
Black-spored quillwort, (Isoetes melanospora) Engelmann
Mat-forming quillwort, (Isoetes tegetiformans) Rury
Little amphiантus, (Amphiантus pusillus) Torrey

A. Peer Review Method: Professionals familiar with these species and outcrop habitats were provided a copy of this document and asked to comments on the contents.

B. Peer Review Charge: The following instructions were provided to individuals that conducted a peer review of this document.

Guidance for Peer Reviewers of 5-Year Review of Granite Outcrop Plants
U.S. Fish and Wildlife Service, Georgia Ecological Services
May, 2006

As a peer reviewer, you are asked to adhere to the following guidance to ensure that your review complies with Service policy, and conforms with the statutes and regulations which are applicable to the Federal recovery policy for threatened or endangered species.

Peer reviewers should:

1. Review all materials provided by us
2. Identify, review, and provide other relevant data apparently not used by us.
3. Provide written comments on:
 - Validity of data, especially those data cited in the proposal.
 - Adequacy of the data (e.g., are the data sufficient to support the designation).
 - If data are inadequate, identify additional data or studies that are needed to adequately justify the proposal.
 - Adequacy of the proposed designation for the conservation of the species.
4. Use the definitions found in the Endangered Species Act and implementing regulations:
 - Endangered species - any species which is in danger of extinction throughout all or a significant portion of its range.
 - Threatened species - any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
 - Species - includes any subspecies of fish or wildlife or plants.
 - Conservation - the use of all methods and procedures that are necessary to bring any endangered or threatened species to the point at which listing under the Act is no longer necessary.

5. Keep in mind the requirement that we must use the best available scientific data in making proposals. This does not mean we must have statistically significant data on population trends or data from all known populations.

All peer reviews and comments will be public documents, and portions may be incorporated verbatim into our final decision document with appropriate credit given to the author of the review.

Questions regarding this guidance, the peer review process, or other aspects of the Fish and Wildlife Service's 5 year review process should be referred to Kelly Bibb, Regional Recovery Coordinator, at 404/679-7132 (fax: 404/679-7081; email: kelly_bibb@fws.gov). Questions regarding reports, publications, or other data dealing with a specific taxon, or areas proposed as critical habitat should be referred to Jimmy Rickard, Athens, Georgia, Ecological Services Field Office, at (706) 613-9493x223.

C. Summary of Peer Review Comments/Report –

(How we addressed each comment in this document is shown in parenthesis below the comment received.)

Eloise Carter
Professor of Biology
Oxford College

Overall, the document is comprehensive and well-researched. There are a few typos that I think you will pick up. I have tried to comment on areas where I had questions or comments. I hope these will be helpful to you as you complete your work.

The following comments are organized by page number and either heading or paragraph:

Since Amphianthus cannot reasonably be expected to be kept in cultivation, shouldn't there be an effort to maintain seed stock from the various pools? I know that there is little genetic variation, at least from the allozyme data, but there still could be some differences in the survivability of different populations. Do we know how long the seeds are viable on the outcrops or in storage? I know the seeds are difficult to germinate, but have others had success with that? If so, then a seed bank could be established and then the bank tested periodically for viability.

(Addressed in section IV, research needs.)

Does Jim Allison think that all populations of Amphianthus are known in GA, SC and NC? (Jim Allison provided the information that, in Georgia, all outcrops had been mapped for economic development and had been searched, although it is possible that outcrops were not searched at the appropriate time.)

Either here or somewhere in the document the problem of hybridization, and therefore the loss of the unique genome for the protected species of Isoetes should be discussed. Simply moving the species around, and using habitat with other species of Isoetes as an indicator of appropriate habitat could wind up with hybrids, and questionable genome for the species. (Hybridization has been briefly addressed under the site discussions of these plants and under the five factor analysis.)

The life cycle of Amphianthus at Mt. Arabia usually begins with germination in November or December and the plants usually survive until April. I think 3-5 months would be a better estimate. In the 4th paragraph, the “weeks” should be “months.” It’s a repeat of the sentence in the previous paragraph.

(This section has been edited.)

What might those other factors be in the genetic analysis of amphianthus? Ecological differences in season, rock, survivability? Depending on how genetic analysis is done, we are only looking at a sampling of the genes. I agree that Amphianthus is self fertilized, and genetically limited, but I just am not sure how ecologically different these populations are. (In section IV, conservation priorities that consider the entire rock outcrop habitat need to be established and evaluated using factors specific to all three of these plants.)

At the end of this section, you describe what happens to Isoetes in drought, but not Amphianthus. In very dry winters, do the seeds have a second round of germination? After the ice freezes and heaves the tiny plants out of the soil, is there another round of germination? I feel certain that once spring arrives in late Feb. and March that probably germination is limited or nonexistent. However, I don’t know this. This seems like something we should know. (We do not have information to address this comment, but will continue working with experts like Professor Carter in addressing these important life history questions.)

I think recreational activities or pressures should be included.
(Recreation has been addressed in the five factor analysis.)

In the section on fire ants, the question of pollinators arises. Part of the problem is that we do not know what insects are pollinators for Amphianthus. I had a student do observations on this, with no success. I have seen honey bees pollinate the open flowers when the pools have dried up, but not while floating. Perhaps that is the biggest threat of fire ants, is our lack of knowledge about what insects are important to Amphianthus. Obviously, Isoetes is not pollinated, but the fire ants could still be destructive as they change the soil characteristics and structure for these plants.

(We do not have information to address this comment.)

Is the reason freeze damage has not been recorded, because it has not been monitored, or that we have looked for it, and it did not happen. I do think freeze damage contributes to swings in population size for Amphianthus from year to year. I think for small populations it might be a factor, although larger ones would have a sufficient seed bank to recover.
(For Isoetes, freeze damage has been recorded and is cited.)

Should there be some note about quarry practices, given the quarry dust issue? This seems to be more than just asking for assistance from land owners.

(No new information has been accumulated. This is a potential research need that has been added to section IV.)

James Allison
State Botinast (retired) Georgia DNR Heritage Program

As indicated in the Recovery Plan, true *Isoetes melanospora* has not been reliably confirmed from Forty Acre Rock or anywhere else in South Carolina; this is one of three "intermediate" populations discussed in Matthews & Murdy 1969.

(This section has been edited to reflect this suggestion.)

Small is not the right word for ca. 1/3 of this huge outcrop at Heggies Rock. Suggest dropping "small," since actual numbers follow immediately.

(This section has been edited to reflect this suggestion.)

Are you sure these two counties should appear in the Arabia Mountain section (though the proposed *Heritage Area* extends to these counties, this is not at all the same thing)? (This section has been edited to reflect this suggestion.)

After 10 years, this Bald Rock section should read instead, "... should have resulted in" The current condition has not been assessed in recent years. Publicly-owned, so it oughtta be! (Updated information received during 2007 surveys).

Clinton Nature Preserve Yes, a threat, but no determination of extirpation has been made. Maybe, ".... Georgia has a small population. Unrestricted horseback riding across the outcrop may pose a threat from eutrophication due to animal wastes. No evidence as of 2002 of any significant impacts. (Updated information received during 2007 surveys).

Heggies Rock " Plants from the Mount Gemini population (two pools) of *I. tegetiformans* were transplanted by the landowner or his agents to a portion of Heggies Rock that he also owned at the time. This portion of Heggies Rock was subsequently purchased by Columbia County and placed under a conservation easement."

(This section has been edited to reflect this suggestion.)

Siloam Outcrop "... population of *I. melanospora* may have hybridized with the *I. tegetiformans* or may have gone extinct. Only *I. tegetiformans* has been confirmed in recent years." [No *piedmontana* at site to hybridize with.] (Updated information received during 2007 surveys).

Siloam Outcrop The *I. melanospora* has likely hybridized with It is greatly declined or is extinct here."

(This section has been edited to reflect this suggestion.)

Siloam Outcrop “.. threatened by development, especially given its proximity of an exit of I-20, and the property is for sale.”

(This section has been edited to reflect this suggestion.)

Black-spored quillwort, Pg 16. "often" (only 3 alleged cases known). "Morphologically intermediate populations have been reported (Matthews & Murdy 1969) from disturbed habitats, especially quarry pools."

(This section has been edited to reflect this suggestion.)

Mat-forming quillwort, Pg 8. Better, "Mat-forming quillwort plants are proliferous, forming interconnected clumps by means of numerous caudine, adventitious buds, and differ from all other North American species in having non-dichotomizing roots at maturity (Rury 1978, Boom 1979, 1982)

(This section has been edited to reflect this suggestion.)

Little Amphianthus, Pg 9. It is likely that amphianthus is predominately self-pollinating; this is NOT at all the same thing as *asexual* seed production

(This section has been edited to reflect this suggestion.)

Little Amphianthus, Pg 9. Limited populations exist in Randolph (2 sites) and Chambers Counties (1 site) in Alabama.

(This section has been edited to reflect this suggestion.)

Cumulatively, Pg 9. Although "known" is indeed more forceful prose than "believed," I think the original language is more accurate.

Cumulatively, Pg 9. not considered to be self-sustaining."

(This section has been edited to reflect this suggestion.)

Black-spored quillwort, Pg 10. Matthews & Murdy reported only "intermediates;" I studied (ca. 1980) a large sample of plants dislodged by vehicular traffic and found plants to be uniformly of intermediate morphology.

(This section has been edited to reflect this suggestion.)

Black-spored quillwort, Pg 10. This number is inflated. The true number does not exceed 7.

(This section has been edited to reflect this suggestion.)

Black-spored quillwort, Pg 11. "Hybridization ...has seemingly occurred in the past (Matthew and Murdy 1969; Rury 1978, Van De Genachte 1996), but has not been rigorously proven. The genetic integrity of black-spored quillwort may be threatened by occasional hybridization with *I. piedmontana* and subsequent introgression. In disturbed or altered habitats, hybrids may displace *I. melanospora*, which requires a highly specialized microhabitat." [The intermediate "populations" could prove to represent a distinct taxon, perhaps derived originally from a hybridization event. There is NO evidence that hybridization is occurring now or in the very recent past.]

(This section has been edited to reflect this suggestion.)

Genetic analysis, Pg 11. *Demonstrated* is way too strong a word to apply to this paper, which which reached conclusions only weakly unsupported by the results (looking at so very few loci is *not* anything like a statistically valid sample of the whole genome). Use *suggested* instead of *demonstrated*.

(This section has been edited to reflect this suggestion.)

A new threat, Pg 12. Not “could” but “can be expected”

(This section has been edited to reflect this suggestion.)

An additional , Pg12. Fire ants are undoubtedly impacting granite outcrops; but the three listed species are probably the least affected, because of the repeated inundation of their microhabitats.
(This is a potential impact that is still not understood.)

Populations, Pg 13. “... recovery plan recommended that studies specifically address the effects of quarry dust on vernal pool vegetation, no studies have been conducted.”

(This section has been edited to reflect this suggestion.)

Bald Rock, Pg 13. has 1 or 2 amphianthus pools threatened by animal wastes (horseback riding).
This does not appear to have been brought to the attention of the site’s management.
(Updated information received during 2007 surveys).

Not a known factor for these taxa, Pg 13. Collection of *Isoetes tegetiformans* from the Eatonton outcrop seems to apply here!

(Different opinion form Tom Patrick who gave permission to take these plants into a “safe guarding” program to preserve this site.)

Synthesis, Pg 17. “... outcrop habitat whose distribution is well known, at least in Georgia (mapped by the State Geological Survey due to their economic importance as a source of stone), and nearly all known populations were discovered prior to publication”

New Recovery Number, Pg 18. “Counteracts to some degree ongoing threats such as quarrying, so that the threat...”

(This section has been edited to reflect this suggestion.)

D. Response to Peer Review – Each comment provided by peer review has been taken into account. Below each comment of the peer reviewers is a sentence in parenthesis that describes how the comment was addressed or integrated into the document.