ECOLOGICAL AND GENETIC STATUS OF THE PURPLE PITCHER PLANT, *SARRACENIA PURPUREA* L., IN MARYLAND AND VIRGINIA

by

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ABSTRACT

ECOLOGICAL AND GENETIC STATUS OF THE PURPLE PITCHER PLANT, *SARRACENIA PURPUREA* L., IN MARYLAND AND VIRGINIA

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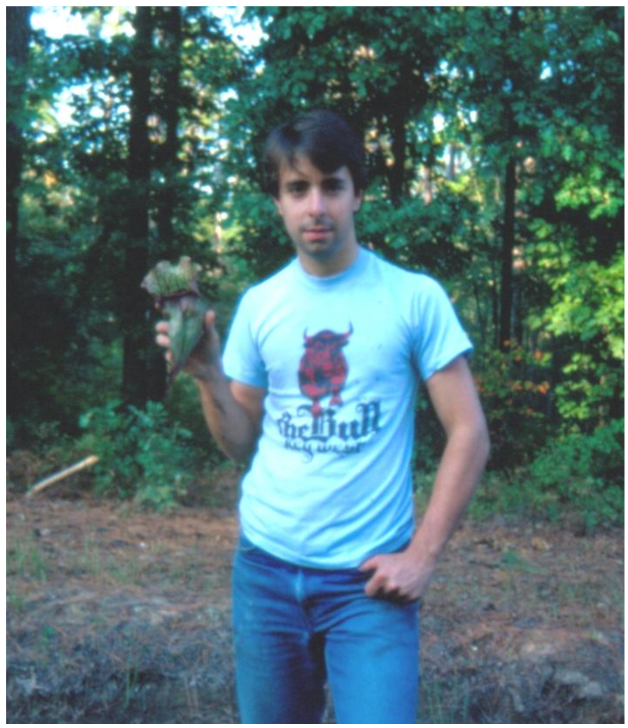
Sarracenia purpurea is a rare wetland plant in Virginia and a threatened species in Maryland, with two potential subspecies in the region. I utilized restriction fragments from the intron of the chalcone synthase gene to compare *S. purpurea* populations and determine whether the subspecies concept was supported. I performed a census of existing populations, compiled all known historical data on the species, and investigated the reasons for the species demise and predicted dates of extinction. Bloom phenology was examined to see if climate change may have influenced bloom period. Soil, vegetation, and climatic information was obtained to determine if taxonomic differences correlated with environmental variables. I found no genetic difference in the intron of the chalcone synthase gene in mid-Atlantic *S. purpurea* populations while I did find differences with other *Sarracenia* species and *S. purpurea* varieties. These results suggest that a single taxon of *S. purpurea* occurs in Maryland and Virginia. Only 31% (4 of 13)of the sites are extant on the western shore of Maryland and District of Columbia while 33% (14 of 42) of the sites remain in Virginia with respective populations of 46 and 513 clumps. Causes of regional extirpation include beaver flooding, succession, and development. Predicted pitcher plant population extinction dates, based on trend line from130 years of data, are 2015 (Maryland) and 2055 (Virginia). Disturbance, especially natural fire, played an essential role in maintaining purple pitcher plant historically in Maryland and Virginia. *Sarracenia purpurea* blooms May 8 – June 12 in Maryland and Virginia with a peak May 18-20. Peak bloom period of *S. purpurea* may have shifted as much as a week from historical dates, perhaps due to climate change. Purple pitcher plant soils in Maryland and Virginia met expected conditions of low pH (3.5–4.9) and were low in almost all macro- and micro-nutrients. Perturbed or polluted sites exhibited elevated levels of exchangeable cations magnesium, calcium, and sodium. Climatic data disclosed that southern Virginia purple pitcher plant

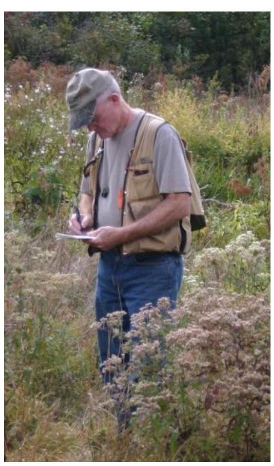
sites are both warmer and wetter than those in Maryland. Maryland pitcher plant bogs had greater species richness than Virginia bogs but the latter had more state rare plants.



The author at Wakefield bog, Sussex County, VA in 1985

This dissertation is dedicated to Margie Sheridan.

"Indeed, it has been quite a pleasure to have experienced and studied these [cedar swamps and bogs] ecologically significant sites. Local and State governments should immediately institute a truly effective effort, perhaps acquisition, including appropriate buffer areas, to preserve their natural integrity. Indeed, I am convinced that society should demand it." Bill Sipple, Days Afield.



ACKNOWLEDGMENTS

Thanks to Drs. Peter and Genevieve Sheridan for all their help and to my loving wife Margie Sheridan. My committee has also provided the support and encouragement to see this project through and I thank them for their assistance. I would also especially like to thank the USDA, Dr. Robert Griesbach, and USDA staff for help, supplies, and equipment to complete the molecular work in the lab in Beltsville, Maryland. I would like to thank the landowners who gave me permission to access their property for field surveys and to those individuals who helped procure samples of *Sarracenia* flowers from distant locations including Louise Kern (US Forest Service Florida), Adam Knatkovich (West Virginia and Pennsylvania), Dave Evans (New Jersey), Matt Opel (Connecticut), Jamie Dozier (South Carolina). Additional thanks are due to the following: Jim Solomon of the Missouri Botanical Garden; Rob Naczi of the New York Botanical Garden; Beth Chambers of William and Mary Herbarium; John Hayden of the University of Richmond; Emily Wood and Carolyn Beans of Harvard University Herbaria; Bill McAvoy of the Delaware Natural Heritage Program; Darren Loomis, Johnny Townsend, and Chris Ludwig of the Virginia Natural Heritage Program; Kathryn McCarthy, Chris Frye, and Jason Harrison of the Maryland Natural Heritage Program; Ron Beck and Charity James of USDA; Dr. Paul Chu of A&L Labs Inc.; Larry Brown of NOAA; Robert Wright; Jim Robinson; Joan Walker. Bill Scholl and his parents, James and Betty Scholl, provided invaluable assistance in my early botanical work looking for *Sarracenia* in Virginia. Keith and Mary Underwood provided logistical support for Maryland efforts. I would also like to thank anyone whom I may have forgotten to mention who helped with this research. Thank you all very much!

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INTRODUCTION

Sarracenia purpurea, the purple pitcher plant, is a rare plant in Maryland and Virginia that is threatened with regional extinction. This research addressed a number of issues germane to the taxon such as a historical review of populations in the study area, a census of existing populations, an analysis of whether there is a genetic difference at the subspecies level within these populations, and an evaluation of soil and vegetative site characteristics. No previous publication has provided a comprehensive review of historical information on *S. purpurea* in Maryland and Virginia. Historical reviews provide invaluable information to interpreting the role and interaction of organisms in a chronosequence. When a historical review is then compared to a census, the trajectory of a taxon may be predicted and longevity inferred. There has also been a long history of taxonomic debate regarding what *S. purpurea* entity resides in Maryland and Virginia. This research addressed that taxonomic issue. Comparison of soil and vegetative site characteristics is important for several reasons. There are few studies of pitcher plant soil macro and micro nutrients and none in the study area. This study included the first comparison of pitcher plant soil characteristics in Maryland and Virginia and allowed me to test underlying assumptions about the nature of pitcher plant soils. Soil analysis also provides important clues to what elements characterize perturbed pitcher plant habitats. Vegetative analysis of purple pitcher plant sites in Maryland and Virginia provided valuable information on what rare species are present or absent, and when combined with soil data, may provide information on shifts in vegetation through succession or pollution. In short, this study filled a gap in our knowledge about mid-Atlantic pitcher plant habitats.

The model journal for this dissertation is HortScience.

Ecology

The Sarraceniaceae (American pitcher plants) is a family of insectivorous pitcher plants restricted to wet, sunny, generally acid, nutrient poor habitats of the southeastern United States, Canada, northern California, southern Oregon, Venezuela, British Guiana (Lloyd, 1942) and Brazil (Maguire, 1978). The family contains a total of three genera: *Darlingtonia*, *Heliamphora* and *Sarracenia*. *Darlingtonia* is found in coastal swamps, moist mountain meadows and serpentine creeks of northern California and southern Oregon. *Heliamphora* occurs in savannas and peat bogs of the sandstone table-mountains in Venezuela, Brazil, and British Guiana. *Sarracenia* is restricted to acid, moist savannas and seepage bogs of the southeastern United States and acid bogs and alkaline meadows of Canada and the northern U.S. The evolution of the three genera is poorly understood due to the lack of any fossils. Albert et al. (1992) suggested an evolutionary relationship of a common ancestor among the three genera based on similarities in the plastid *rubisco L* gene.

Sarracenia pitcher plants are herbaceous, rhizomatous plants that have leaves modified into tubular or funnel shaped structures. These modified leaves catch and digest insects by means of a pitcher or pitfall trap. Presumably, insects are attracted by color, scent and nectar to the pitcher opening, although experiments testing this hypothesis are needed. Insects lose their footing on the loose, waxy walls of the pitcher and fall into a pool of water within the leaf. Escape is prevented by smooth waxy walls, downward pointing hairs and a narcotic agent in the pitcher liquor (Hepburn et al., 1927; Mody et al., 1976). Bacterial and plant enzymes then digest the insect and the by-products are used by the plant for various metabolic activities (Hepburn et al., 1927; Plummer and Jackson, 1963; Plummer and Kethley, 1964). The trapping and digestion of insects by carnivorous plants is thought to have evolved in order to compensate for the lack of nutrients such as nitrates and phosphates in wetland pitcher plant habitats (Romeo et al., 1977).

Wetlands are environments where water is the primary factor controlling plant and animal life (Niering, 1985). They are transitional habitats between upland and aquatic systems and provide a variety of ecosystem services such as nutrient transformation, refugia, aquifer recharge, etc. (Richardson, 1994). Five major wetland systems are recognized:

marine, estuarine, lacustrine, riverine, and palustrine. The palustrine system includes wetlands such as bogs (Niering, 1985) where peat may accumulate. Peatlands develop in those wetland habitats where the water table is at or near the surface, decomposition is exceeded by the growth of plants, and organic matter accumulates (Crum, 1992). Pitcher plants can be found in the lacustrine, palustrine and riverine (rarely) systems.

Bogs are acidic (pH < 4.2), mineral poor, peatlands that are fed exclusively by rainwater (Johnson, 1985; Crum, 1992). Although the term "bog" has been used extensively to denote pitcher plant peatlands in the southeastern and mid-Atlantic United States (Folkerts, 1982; Maryland Natural Heritage Program, 1990), it is something of a misnomer since the strict qualifications for a bog, such as acidic conditions (pH < 4.2) and receiving nutrients exclusively from the atmosphere (ombrotrophic), are not always met (Crum, 1992). The term bog has frequently been applied to Atlantic coastal plain wetlands containing species such as round-leaved sundew (*Drosera rotundifolia* L.), white-fringed orchid (*Platanthera blephariglottis* (Willd.) Lindl.), white beakrush (*Rhynchospora alba* (L.) Vahl.), and purple pitcher plant (*Sarracenia purpurea* L.) (McAtee, 1918; Sipple, 1977; Whigham, 1981; Hull and Whigham, 1987; Whigham, 1987; Maryland Natural Heritage Program, 1990). The classification of these peatlands remains to be determined. One of the outstanding characteristics of southeastern and mid-Atlantic peatlands shared with true northern bogs is the presence of the carnivorous plants, specifically pitcher plants. The common denominator of carnivorous plants has almost certainly led to the extensive use of the term "bog" in vernacular descriptions of these habitats.

There have been several studies investigating pitcher plant soils, habitats, and leaf nutrient concentrations in the southeast (Plummer, 1963; Christensen, 1976; Weiss, 1980). Phosphorus appears to be a key limiting factor in southeastern pitcher plant habitats. Whigham and Richardson (1988) investigated several Anne Arundel County, Maryland "bogs" and found they may be both phosphorus and potassium limited.

Taxonomy and Genetics

Wild-type or normal *Sarracenia* plants (all species) contain some purple or red pigment in the apical meristem, leaves, flowers or a combination of the three. Normally, species leaf color can be red, yellow, purple, red-striped or splotched. Striped or splotched individuals possess a yellow background with varying intensities of pigmentation. Yellow-leaved individuals maintain pigment in the growing point so that leaf primordia are brilliant reddish-purple. Leaf and flower color variation have been extensively discussed in the literature (Masters, 1881; McFarlane, 1908; Bell, 1949; Case, 1956; McDaniel, 1966; Schnell, 1978b, 1979a, 1993).

Flower color, leaf color, leaf shape and leaf number are both genetically and environmentally controlled (Bell, 1949; Mandossian, 1966; Schnell, 1978b). As an example I have observed that red-flowered species growing in shaded habitats will produce red flowers but not as intense as those growing in full sun. Yellow-flowered species maintain yellow in the shade but the color may not be as vibrant. Low light levels may result in reduction of pitchers to flattened leaves. Those plants producing flattened pitchers in stressed situations may easily be observed in winter or early spring. Soil pH can affect the number and size of leaves but appears to have no effect on color. Environmental effects are most pronounced in pigment production in the leaves. Genetic predisposition to produce red leaves is most expressed in full sun. Root disturbance or shading can result in reduction in quantity and distribution of red pigment.

Offspring of crosses between *Sarracenia* species or varieties normally exhibit blending of the parental characteristics (Russell, 1919) called incomplete or partial dominance. As an example, crosses between red-and cream-flowered species typically produce hybrids with pink flowers. Species can be easily crossed and the resulting hybrids can be back-crossed with the parents. Natural hybrids are known between almost all species in the genus (Bell, 1952; Bell and Case, 1956). Hecht (1949) reported a haploid chromosome number of n=12 for all species in the genus, while Bell (1949) identified one more chromosome and arrived at n=13, which is now the accepted figure.

Hybrids can occasionally occur between taxonomically recognized species (Jones and Luchsinger, 1986). In *Sarracenia*, barriers between species interbreeding are not dictated by differences in chromosome numbers. Rather, species integrity is maintained by a combination of different flowering times, flower color and habitat preferences (Bell, 1949).

Two recurring unusual variant forms are found in the genus *Sarracenia*: anthocyanin-free mutants and yellow-flowered individuals within a species that normally produce red flowers. Both variants have been found in a number of species at a variety of locations over the past fifty years (Robinson, 1981; Sheridan and Scholl, 1993a, 1993b; Shomin, 1993). Anthocyanin-free mutants and yellow-flowered variants occur singly or as a few individuals intermixed with normal wild-type plants (Case, 1956; Sheridan and Scholl, 1993a, 1993b). The anthocyanin-free mutation is caused by a recessive allele affecting a late stage of anthocyanin biosynthesis (Sheridan and Mills, 1998a, 1998b). The anthocyanin-free mutation has been found in almost all *Sarracenia* species but the mutation is conspicuously absent in mid-Atlantic *S. purpurea* populations.

Biogeography

Sarracenia purpurea is the most widespread species in the genus. The taxon occupies a wide range in Canada from east of the Rocky Mountains, south of the Arctic Circle, and to the Atlantic coast. In the United States, *S. purpurea* populations are found in formerly glaciated regions of the northeast and mid-west. The range narrows through the Mid-Atlantic States and is chiefly confined to the coastal plain (with the exception of rare populations in the North Carolina piedmont and the mountains of North Carolina, South Carolina and Georgia). A gap in the range occurs in the coastal plain of Georgia and the taxon reappears along the Gulf Coast from southwest Georgia to Mississippi. The Gulf Coast *Sarracenia purpurea* populations have now been elevated to a separate species known as *S. rosea* Naczi, Case & R.B. Case (Naczi et al., 1999).

Purple pitcher plant peatlands in Maryland and Virginia contain a number of rare plant species such as New Jersey rush (*Juncus caesariensis* Coville), yellow pitcher plant (*Sarracenia flava* L.), golden colic root (*Aletris aurea* Walt.), leatherleaf (*Chamaedaphne* *calyculata* (L.) Moench, round-leaved sundew (*Drosera rotundifolia* L.), white-fringed orchid (*Platanthera blephariglottis*), and white beakrush (*Rhynchospora alba*) (Sipple and Klockner, 1984; Sheridan, 1991; Strong and Sheridan, 1991; Sheridan *et al.*, 1999a; Sipple, 1999). These wetlands are located at the head of zero order intermittent stream systems, along meandering streams, fresh tidal marsh/nontidal forested interface, pond margins, and toe slopes.

Goals

The identification of populations with unique genetic characters or special taxonomic designations is essential to properly designing restoration strategies and to assist in addressing the pertinent taxonomic questions. The relatedness of *S. purpurea* populations may be measured by genetic studies at the molecular level and inferences made on the status of the taxa. Restoration of *S. purpurea* populations in Maryland and Virginia requires not only a knowledge of the taxa dealt with but also the degree of variation found within populations. Identification, preservation, and restoration of populations with unique or significant genetic variation are essential to maintaining diversity for the future. Natural variation within and between *S. purpurea* populations not only provides a locally adapted suite of genetic characters for the region but gives restoration ecologists the genetic tools for future restoration. Without an assessment and then preservation of existing *S. purpurea* genotypes in Maryland and Virginia, future conservation work may be seriously handicapped.

To address these questions I investigated the relatedness of *S. purpurea* populations across the range of the taxon but with a special emphasis on the Maryland and Virginia subspecies overlap area. I measured the relatedness of populations by analyzing variation within the chalcone synthase gene to determine whether there is enough genetic differentiation between Maryland and Virginia populations to support separating them as distinct taxa. I also measured and analyzed a number of population and environmental variables including population size, plant associates, soil pH, slope, aspect, soil macro and micro nutrients, and climatological data. The results of this study will help conservation biologists make the important decisions needed to protect and restore the remaining purple pitcher plant wetlands in Maryland and Virginia.

STUDY AREAS

A total of 27 study sites in Maryland and Virginia were identified for census from herbarium specimens, literature citations, or the authors own field work over 20 years. Sites were numbered, geographically located, and compiled within the context of extant and historic sites (Fig. 1). Since many historic sites have been extirpated, the site numbering system in this chapter inherently reflects lost sites by vacancies in the numbering system.

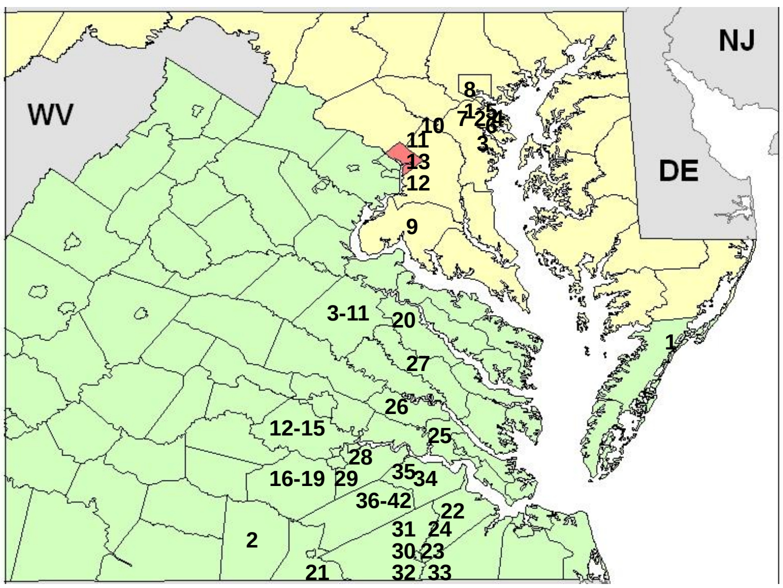

Figure 1. Historic and extant sites for *S. purpurea*. Red box is the District of Columbia.

Site Characterization – Maryland

Anne Arundel County. Arden peat land (3) is located near Annapolis, Maryland on a tributary of the Severn River. The site is characterized by a series of elliptical gaps of up to two hectares dominated by *Chaemadaphne calyculata*, *Sarracenia purpurea*, and *Vaccinium macrocarpon* Aiton. These gaps rapidly grade from an open sedge meadow to an *Acer rubrum* L. swamp. A comparison of aerial photographs from 1945-1996 indicates that these are persistent gaps which have not succeeded to a red maple/black gum (*A.*

rubrum/*Nyssa sylvatica* Marshall) canopy. Numerous dead saplings of *A. rubrum*, which do not exceed 3 meters in height, are found within the gaps. This mortality of *A. rubrum* may suggest some chemically limiting factor or hydrological stress on woody succession within the peat land gap. A series of clear water, peat bottomed spring fed pools occur within the gaps and are ringed by hummocks of *Sphagnum* species. Thousands of seedling *S. purpurea* are (were) found on exposed peat/sphagnum flats while mature pitcher plants are abundantly embedded within the sphagnum hummock matrix.

Maryland Avenue (4) peat land is located on a small tributary of the Magothy River near Annapolis, Maryland. The site lacks the large elliptical gaps observed at Arden and are dominated by a thick shrub layer of *Acer rubrum*, *Chaemadaphne calyculata*, and sweet bay magnolia, *Magnolia virginiana* L. *Sarracenia purpurea* is much more localized than at Arden bog with pitcher plants growing on hummocks under a sub canopy of sapling *A. rubrum*. Scattered throughout the site are mature pitch pines, *Pinus rigida* Miller. Dead snags of pitch pine suggest that the site experienced periods of inundation and woody species dieback, followed by revegetation. The abundance of water loosestrife, *Decodon verticillatus* (L.) Ell., supports an inundation scenario.

Charles County, MD – Piney Branch (9). Piney Branch peat land is a tributary of the Zekiah Swamp located between Waldorf and LaPlata on the coastal plain in Charles County. The site was discovered in 1989 (Sheridan, 1991) and has been listed by the Maryland Natural Heritage Program (1996) as an ecologically significant area. Piney Branch represents the last surviving pitcher plant example of a unique ecosystem described by McAtee (1918) as the gravel bog. Although this wetland is overlain by a veneer of peat, its occurrence on a large deposit of gravel is unique in Maryland.

Piney Branch contains the only population in Maryland of the proposed Federally Threatened New Jersey rush, *Juncus caesariensis*. This plant formerly occurred near Glen Burnie, Maryland at a historical purple pitcher plant site (Smith, 1939) and was thought to be extinct until its rediscovery at Piney Branch in 1989. This species is listed as State Endangered by the Maryland Natural Heritage Program. Piney Branch is the only known native site in southern Maryland for the State Threatened purple pitcher plant. Piney Branch

Bog contains many rare or uncommon plants of State Threatened, State Rare or Watch List status.

Site Characterization – Virginia

Caroline County is home to some of the best pitcher plant peatlands left in Virginia. Seven natural sites are known: Peatross (4), Reedy Creek (5), Meadow Creek (7), Helonias Bog (8), Colemans Mill (9), the impact zone on Fort A.P. Hill (10), and Anderson Camp (11). Site quality varies from open powerline grass-sedge meadow to *Magnolia virginiana* acid seep forest. Frequent associates are *Juncus caesariensis*, *Eriophorum virginicum* L., and *Drosera rotundifolia*.

Chesterfield County has only three *S. purpurea* sites remaining on the fall line and all are in close proximity. The three sites, Zion Church (12), Swift Creek (14), and Timsbury Creek (15) are small woodland colonies. Divisions from these plants were moved onto adjacent, appropriate habitat and at least one site was recently flourishing. Chesterfield *S. purpurea* sites are noteworthy since they harbor small populations of *Kalmia angustifolia* L. Small. These Chesterfield *Kalmia* populations are disjunct from populations to the north in Caroline County and the southern Virginia colonies in Isle of Wight, Suffolk, and Southampton counties.

Dinwiddie County colonies of *S. purpurea* are now almost extinct. Three extant sites were known: Addison (17), Depot Road (18), and Cattail Creek (19). Depot Road was represented by a single individual; Addison plants were removed and safeguarded at Meadowview Biological Research Station before the site was destroyed; and Cattail Creek consisted of a couple of plants under *Magnolia*/*Acer* canopy.

Essex County (20). Only one *S. purpurea* site is known in Essex County, Howerton bog. The Howerton site is an impounded *Magnolia virginiana* seep that has developed floating, quaking mats of sphagnum with *Eriophorum virginicum* and *Drosera rotundifolia*. Recent activities by beaver have degraded the once exemplary site and may pose an extinction threat.

Greensville County (21). The one remaining *S. purpurea* site in Greensville County is a historic M.L. Fernald site. Many of the rare species recorded by Fernald have been extirpated due to pond construction, pasturing, and fire exclusion. Several hundred *S. purpurea* plants were recorded there in the late 1980's within a sphagnous *Magnolia virginiana* acid seep forest.

Isle of Wight County (22). A few plants of *S. purpurea* are reported within the Blackwater Ecologic Preserve (Musselman pers. comm.). The plants are healthy and are in an area where restoration ecologists are cutting back the trees and shrubs to allow more light prior to a prescribed burn (Bray pers. comm.).

Prince George County (29). One site is known within Prince George County. Approximately a dozen plants are found on a tributary of Cherry Orchard Branch in an acid seep forest.

Southampton County (31). One *S. purpurea* site is known in Southampton County along a tributary of Seacock Swamp. The colony occurs on the base of *Nyssa sylvatica* stumps and on moist edges of a small pond within a mixed hardwood/longleaf pine forest. The site is noteworthy for containing one of the last stands of native Virginia longleaf pine at the northern limit of its range.

Sussex County. Five sites remain for *S. purpurea* in Sussex County: a degraded M.L. Fernald site known as Coddyshore (36); a seep and pine woods along a railroad (38); a powerline easement and acid seep forest (39); the Cherry Orchard Bog on the Sussex/Prince George County line (41); a pond edge at a 4-H center (42). The powerline easement site contains one of the few stations left in Virginia for *Ctenium aromaticum* (Walter) Wood. Cherry Orchard Bog is a fairly high diversity site containing rare species such as *Drosera capillaris* Poir., *Zigadenus glaberrimus* Michx., *Lachnocaulon anceps* (Walt.) Morong, and *Platanthera blephariglottis*. The wetland has been the subject of ongoing restoration activities including prescribed burns.

A CENSUS OF PURPLE PITCHER PLANT, *SARRACENIA PURPUREA* L., IN MARYLAND AND VIRGINIA

Introduction

The purple pitcher plant is a threatened species in Maryland (Maryland Natural Heritage Program, 2007) and is rare in Virginia (Townsend, 2009). Serious population declines and local extirpations have occurred as a result of development, pollution, fire suppression, and land use changes. *Sarracenia purpurea* may serve as an indicator species of high environmental quality in peat bogs and seepage wetlands since this species is one of the first to disappear after environmental perturbations such as altered hydrology, change in soil chemistry, or pollution (Sheridan et al., 2000; Schnell, 2002). The purple pitcher plant is not only fascinating because of its carnivorous habit but also because it occurs within a wetland ecosystem that supports a wide variety of other rare species. Hence the study of this species within its supporting ecosystem is essential to understanding how the system works and functions.

Pitcher plant habitats are typically considered to be nutrient limited, early successional communities (Juniper et al., 1989). In the southeastern United States this early successional state is usually caused by frequent, growing season, lightning-caused fires or beaver activity. This natural disturbance suppresses woody species but enhances the herb layer in which pitcher plants occur (Bridges and Orzell, 1989; Fenwick and Boone, 1984; Frost and Musselman, 1987; Frost, 1993, 1995; Folkerts, 1982). Rare, persistent natural gaps also occur in the southeast (Sheridan et al., 1997, 2000a) that support the pitcher plant community in the absence of fire. Pitcher plant peatlands in the northeast typically formed in scoured glacial areas and are maintained in an early successional state by beaver, fire, nutrient limitations, cold temperatures or an interactive effect of all the factors (Johnson, 1985; Crum, 1992; Sheridan, pers. obs.).

Sarracenia purpurea has historically been a local and rare species in Maryland and Virginia (Sipple, 1999). The purple pitcher plant is now a state threatened species in Maryland (Maryland Natural Heritage Program, 2007) with only three natural populations remaining on the Western Shore (Sheridan et al., 2000). In Virginia, *S. purpurea* is listed as an S2 species which means very rare or imperiled within the state (Townsend, 2009). Only 23 populations of *S. purpurea* remained in Virginia at the start of this study, based on ongoing monitoring by scientists at Meadowview Biological Research Station. Many of the Virginia *S. purpurea* populations are imperiled since populations are small (< 12 plants), the sites are in late succession, and components of the obligate pitcher plant invertebrate community are missing (Sheridan & Duffield, unpublished data). Previous inventory and demographic studies by Sheridan et al. (1999a & b) on associated keystone species of *S. purpurea* such as Atlantic white-cedar (*Chamaecyparis thyoides* (L.) B.S.P.) and longleaf pine (*Pinus palustris* Miller) provided invaluable information for conservation and restoration biologists. Therefore, a census of *S. purpurea* populations was performed on the western shore of Maryland and Virginia to determine the number of plants remaining, threats to those populations and extirpations, and to provide baseline information for conservation decisions. In addition, historical occurrences of *S. purpurea* in the study area were compiled from the literature and herbarium collections.

Materials and Methods

Study sites were visited in various seasons between 2003 and 2008 and plants were counted walking through the site. Additional population data were compiled from my personal field notes visiting these sites over a twenty year period. In cases where the wetland covered several hectares, pre-counted vinyl flags were used to mark plants and the population size was determined by counting remaining flags. *Sarracenia purpurea* plants can range in size from individual crowns to large multi-crown plants up to a meter in diameter. However, Virginia and Maryland *S. purpurea* populations, at best, are producing clumps ½ meter in diameter and typically are single stem plants. Plants were therefore identified and counted as clumps (whether single stem or large clumps) and qualitative assessments made of population vigor.

Qualitative assessments of *S. purpurea* habitats were ranked on a scale of 1-6 as follows: 1) population extirpated, subcategories of 1A beaver flooding, 1B site developed, 1C succession, 1D population removed for *ex situ* conservation; 2) sharp population declines from previous census or observation, obvious site impacts such as water pollution and sedimentation, no flowering or reproduction, single crown plants; 3) sharp population decline from previous census or observation but little or no obvious site impacts, minimal or no flowering, no reproduction, single to double crown plants; 4) woody succession underway, impaired leaf development, flowering observed but no reproduction, single to double crown plants; 5) active reproduction observed, robust plants with multiple crowns up to 0.5 meters in diameter, site impaired and impacted by beaver or drought; and 6) active reproduction, robust plants with multiple crowns, plants up to 0.5 meters in diameter, no immediate site threats.

The likelihood of individual population and regional extirpation of *S. purpurea* was calculated in two ways. Regional extirpation for western shore Maryland and Virginia *S. pupurea* populations was determined by assuming that all populations existed starting in 1880. Decrease in number of populations was then compiled on decadal scales based on known extirpations or inferred extirpation date based on historical sources. Regional extirpation was determined based on trend line and confidence of prediction estimated by R^2 value. The assumption that all populations existed in 1880 is likely since *S. purpurea* is a long-lived plant and migrates locally via water dispersion of the hydrophobic seed (Sheridan, 1996). Individual population extirpation predictions were based on at least two data points of population census over the past twenty years. Local population extirpation was calculated with a best fit trend line and confidence of prediction estimated by R^2 value.

Sarracenia purpurea flowering phenology was compiled from data collected at Meadowview Biological Research Station from 1995-1997 and 2009. Current and historic purple pitcher plant flower data were compared to assess the impact of global warming and to investigate whether flowering time differences might be related to sub specific differences between putative *S. purpurea* taxa. Native Virginia purple pitcher plant clumps from central and southern Virginia used in the 1995-1997 phenology study included Dahlia (n = 4), Addison (n = 4), Coddyshore (n = 1), Zion Church (n = 1), Seacock Swamp (n = 1), Joyner's Bridge (n = 1), and Meadow creek (n = 1). Clumps were grown for several years in raised beds prior to data collection. Plants received annual winter burns (Dec. – Feb.). In 2009, a native Maryland population from Arden bog (n = 66) in *ex-situ* conservation at Meadowview Biological Research Station was also used in the phenology study to both test peak flower dates calculated in the 1995-1997 study and to collect additional flower data. The 2009 flower phenology study differed from the 1995-1997 study in that plants were grown in one gallon plastic pots instead of burned raised beds. In all cases, a flower was recorded as open when petals had unfurled and flowering was recorded as complete when petals had fallen or completely withered. *Sarracenia purpurea* flower data were recorded either daily (2009) or every 4-5 days over the flowering period.

Historic occurrences of *S. purpurea* on the western shore of Maryland and Virginia were determined by visiting, or perusing electronic herbaria at the state and national level. Literature sources were also reviewed for historical *S. purpurea* populations. Herbarium, literature, and the authors field notes and experience were then compiled to produce a historical review (Appendix A). A United States distribution map of *S. purpurea* was also prepared utilizing McDaniel (1966), and my herbarium, literature, and field research. Distribution data was then cross referenced with USDA-NRCS plant distribution profile. Herbarium, literature data, and credible reports were compiled to provide a comprehensive survey of historical and extant *S. purpurea* populations in the study area. *Sarracenia purpurea* colonies extant within the past 20 years were assigned an alpha-numeric site code so that population data could be cross referenced to herbarium citations.

Results

A total of thirteen sites for *S. purpurea* were documented on the western shore of Maryland and District of Columbia while 42 colonies were identified in Virginia (Fig. 1 and Appendix B). Four *S. purpurea* sites are extant on the western shore of Maryland while 13 sites remain in Virginia (Fig. 2, Tables 1 & 2). The status of one population could not be determined in Virginia due to lack of access (the impact zone on Fort A.P. Hill in Caroline County). A total of 46 *S. purpurea* clumps remain on the western shore of Maryland while 513 clumps were counted in Virginia (Tables 1 & 2). Only 31% (4 of 13) of the *S. purpurea* sites are extant on the western shore of Maryland and District of Columbia while 33% (14 of 42) remain in Virginia (A.P. Hill impact presumed extant). During the course of this study (1998-2008) 39% (9 of 23) extant sites for *S. purpurea* in Virginia were extirpated. The nine Virginia extirpations were due to beaver flooding (3), succession (4), development (1), or ex-situ conservation (1).

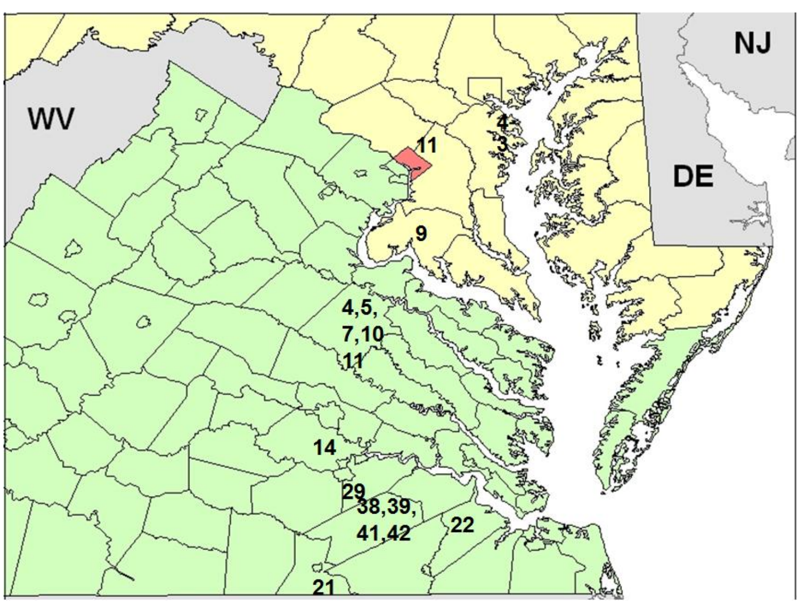

Figure 2. Current distribution of *S. purpurea*. Red block in center is District of Columbia.

Table 1. Census of *S. purpurea* populations on the western shore of Maryland.

Site Name	Population size (clumps)	Score
MDANNE001 - Arden	9	2
MDANNE002 – Md Ave.	4	2
MDCHAR006 – Piney Branch	31	2
MDPRGE001 – Beltsville - USDA	2	4
Total:	46	N/A

Table 2. Census of *S. purpurea* populations in Virginia.

Site Name	Population size (clumps)	Score
VACARO007 - Meadow creek	2	3
VACARO013 – Reedy Creek	410	6
VACARO017 – Helonias Bog (Rt. 601)	0	1C
VACARO023 – Peatross (Rt. 656)	16	4
VACARO024 – Anderson Camp	6	4
VACARO025 – Colemans Mill	0	1A
VACARO027 -A.P. Hill Impact	?	?
VACHES001 – Swift Creek	1	3
VACHES004 – Zion Church	0	1A
VACHES002 & 006 Timsbury Creeks 1&2	0	1C
VADINW002 - Addison	0	1D
VADINW003 – Depot Road	0	1C
VADINW005 – Cattail Creek	0	1B

Table 2. Continued

Site Name	Population size (clumps)	Score
VAESSEX001 – Howerton	0	1A
VAGREE019 – Skippers (Delbridge)	18	3
VAISLE002 - Blackwater Preserve (Zuni)	12	5
VAPRIN003 – Cherry Orchard II (Rt. 35)	8	3
VASOUT001 – Seacock (Bains)	16	4
VASUSS002 – Wakefield power line	11	3
VASUSS03 – Wakefield Bog	3	2
VASUSS005- Cherry Orchard	4	4
VASUSS011 - Coddyshore	0	1C
VASUSS012 – Wakefield 4H	6	4
Total	513	N/A

The phenomenon of purple pitcher plant extirpation regionally, and general population decline, was reflected in lack of plant vigor, flowering, and reproduction in most remaining sites. In particular, steep population declines were documented in several sites which appear to be in the process of extirpation or were extirpated during the study period. Specifically, VACHES001 – the Swift Creek population went from 10 plants in 1990 to 1 plant in 2008, VADINW003 - Depot Road went from 5 plants in 1991 to 0 in 2007, VAGREE019 – Skippers (Delbridge/Dahlia) bog declined from 130 purple pitcher plants in 1985 to 18 in 2007, VACARO007 - Meadow Creek went from 10 plants in 1990 to 2 in 2008, VASUSS002 - Wakefield Power Line went from 84 in 1991 to 11 in 2008, VACARO024 – Anderson Camp went from 12 plants in 1994 to 6 in 2008, VASUSS011 – Coddyshore went from 30 clumps in 1985 to 0 in 2007, VAISLE002 - Blackwater Preserve (Zuni) went from 24 plants in 2005 to 12 in 2009, MDANNE002 (Maryland

Avenue) went from 9 plants in 2004 to 4 plants in 2007, and MDCHAR006 went from 84 plants in 1991 to 31 plants in 2009 . The documented decline of purple pitcher plants within extant sites reflects observed population declines in most remaining sites. Only one site, VACARO013 – Reedy Creek, scored as a robust reproducing population due to two interventions (seed dispersal) by a local naturalist.

The predicted year of regional extirpation of all *S. purpurea* populations in Virginia and the western shore of Maryland is 2055 (R^2 = .86) and 2015 (R^2 = .82), respectively (Fig. 3). Local population extirpation prediction for two Maryland sites indicate extirpation by 2020, the predicted regional extirpation year (Fig. 4). Six of the 13 remaining Virginia *S.*

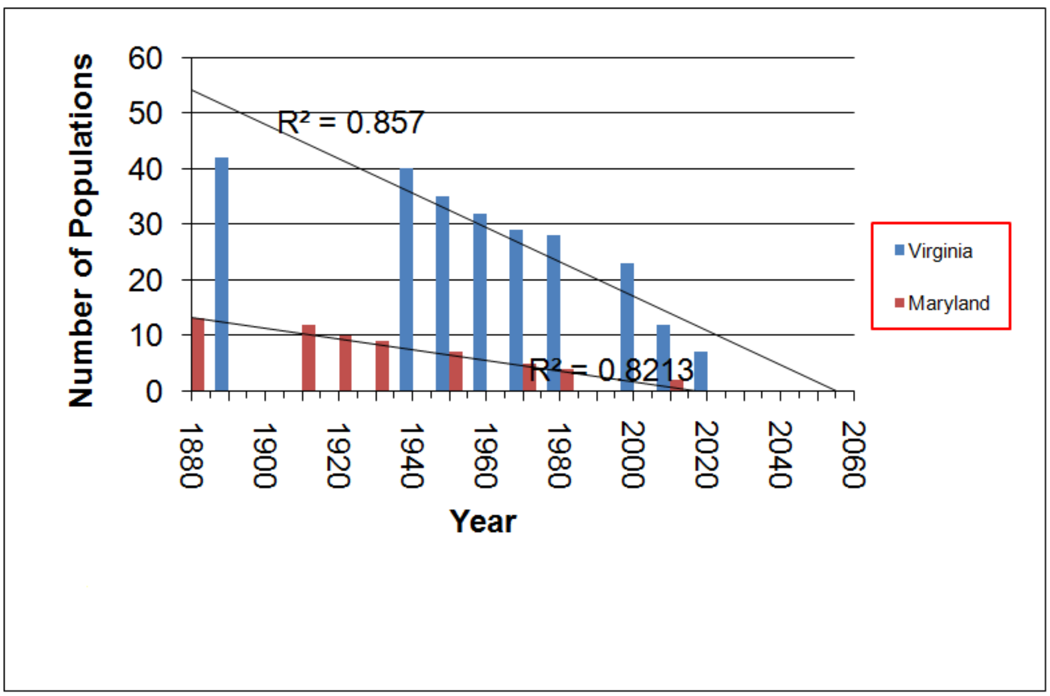

Figure 3. *Sarracenia purpurea* L. regional extirpation prediction.

purpurea populations will be extinct by 2020 (Fig. 4) with the remaining seven sites extirpated by 2055 (Fig. 3).

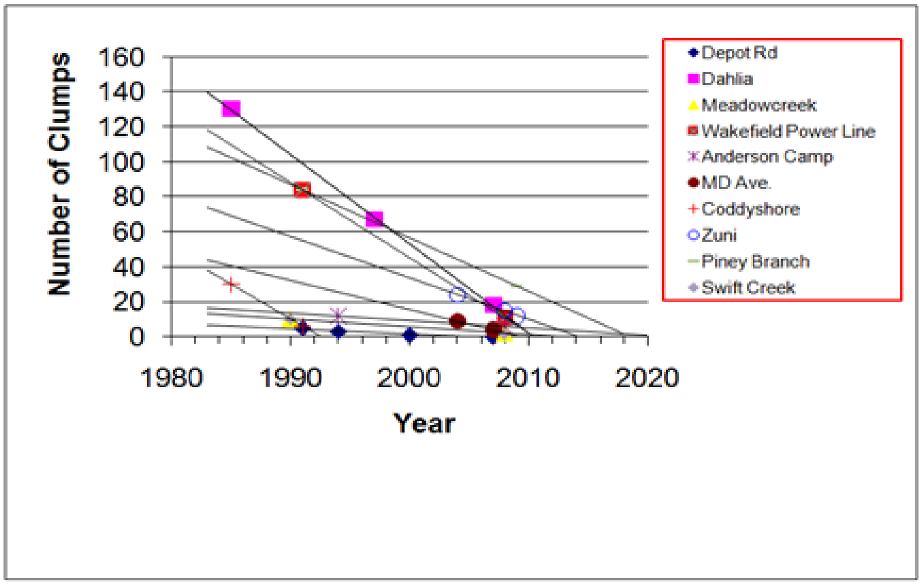

Figure 4. *Sarracenia purpurea* L. local population extirpation prediction.

Peak flower for *S. purpurea* (Fig. 5) at Meadowview Biological Research Station in Caroline County, Virginia ranged from May 17-20 with blooming starting around May 8 and ending as late as June 12 . To my knowledge this is the first, controlled, observation of the complete bloom cycle of *S. purpurea* recorded over several years. Date of first bloom of *S. purpurea* in the Washington, D.C. area ranged from 5/2 to 5/17 with an average of 5/11 from 1991-2008 (Shetler and Wiser, 1987; Sylvia Orli pers. comm.). Shetler and Wiser (1987) defined blooming as pollen release from anthers, a more conservative method than mine since petals unfurl before pollen release. Historical blooming of *S. purpurea* in the District of Columbia and the western shore of Maryland was recorded by Killup at Site 2 on May 27, 1953, by Ward at Site 10 on May 27, 1883 and May 28, 1884, and by Bartsch at Site 11 on June 1, 1903 (Appendix B). While Marshall wrote on his label that his specimen from Site 11 was flowering on July 11, 1895 I have disqualified this as a blooming specimen since all petals were dehisced. Plitt (Sipple, 1999) recorded at Site 1 (Glen Burnie Bog) on May 30, 1900 that “hundreds of Pitcher Plants were still found in bloom, notwithstanding

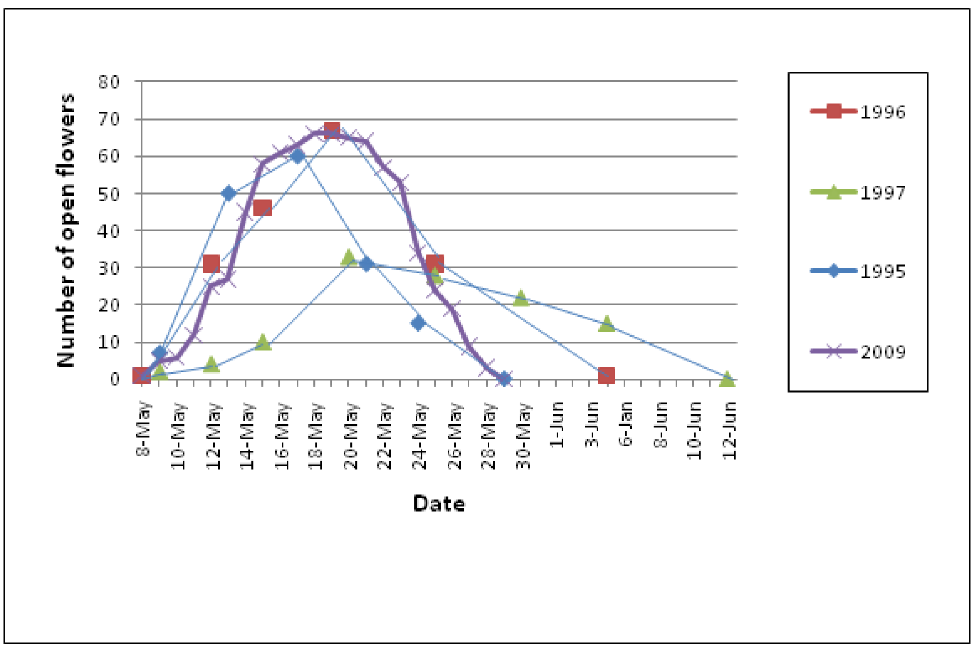

Figure 5. *Sarracenia purpurea* bloom phenology.

the depletion that is constantly going on. This locality is known to a great many (hundreds of) people, botanists, and others, who each year visit the place to get one or more specimens. Still the plant seems to hold its own and even is increasing…" and on May 17, 1902 "Sarracenia was to-day in all its glory. Hundreds of flowers were seen [at Glen Burnie Bog]."

Sarracenia purpurea historically occurred in the mountains of North and South Carolina, the piedmont of North Carolina and throughout the coastal plain of the mid-Atlantic of the United States. There is a gap in the range of *S. purpurea* between rare isolated Atlantic coastal plain populations in Georgia and coastal populations in South Carolina. From New Jersey north *S. purpurea* fans out through formerly glaciated regions into Canada. *Sarracenia rosea* is found along the gulf coast of Mississippi, Alabama, and Florida with historic populations in southwest Georgia (Fig. 6).

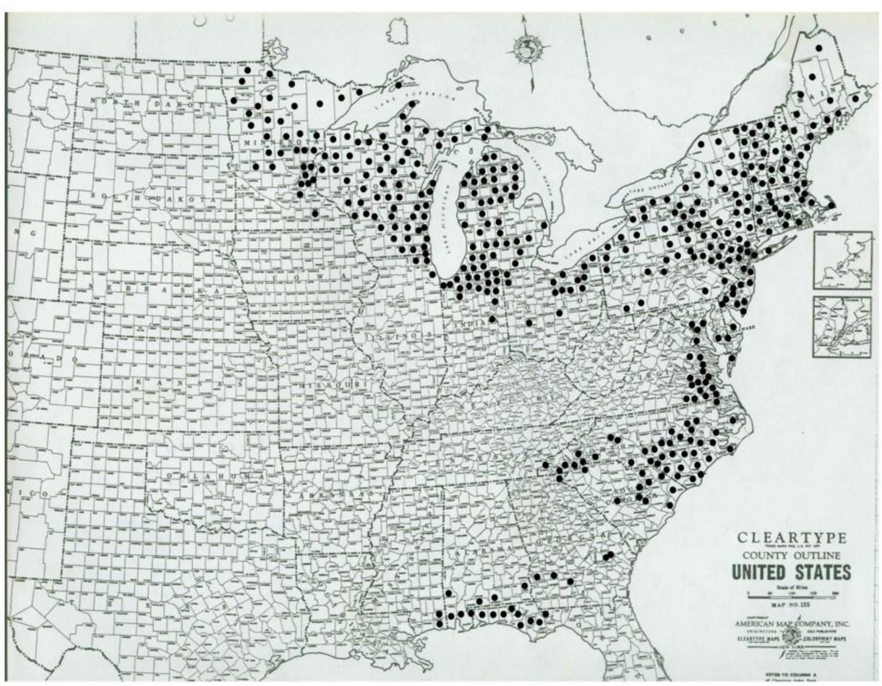

Figure 6. United States distribution of *S. purpurea* and *S. rosea*. Copyright American Map Corporation. Reprinted with permission.

Discussion

Census of rare plant populations is an effective way to obtain baseline data and to make inferences about population behavior and future viability (Sheridan et al., 1999a & b). The purple pitcher plant, *Sarracenia purpurea*, has undergone over a century of documented population decline and extirpation in Virginia and the western shore of Maryland. How long will this trend continue before local (state) extinction occurs, are the factor(s) responsible for extirpation comprehensible and reversible, and are there other ways of preserving this species within the region? Do taxonomic differences within *S. purpurea* populations in Virginia and the western shore of Maryland affect the ability of local populations to resist extirpation pressure?

Extinction Watch

Every one of the historic purple pitcher plant sites on the western shore of Maryland and District of Columbia sites was extirpated before I could see them and no one collected material to put in *ex-situ* conservation, or start back-up populations, for future study and repatriation. If current trends continue all native purple pitcher plant populations will be gone on the western shore of Maryland by 2020 and by 2055 in Virginia. These are robust predictions and include both stochastic events and known causes of extirpation (flooding, succession, etc.) over a one hundred and thirty year period. The Virginia extirpation date is extremely conservative and does not consider the recent acceleration in loss of pitcher plant populations. When the current rate of extirpation is considered all native purple pitcher plant sites in Virginia may be lost as soon as 2030. One could argue that purple pitcher plants on managed preserves should be immune from such insults but even here I have shown either whole large populations can be almost completely eliminated (Maryland Site 3 - Arden Bog on Gumbottom Branch) or populations are in decline and headed towards extirpation (Blackwater Preserve). Moreover, if natural events don’t eliminate the few remaining purple pitcher plant populations than stochastic events almost certainly will. Stochastic events could include poaching, accidental pollution or herbicide application, creation and fertilization of feed plots and subsequent runoff and pollution of bogs, or any number of possible scenarios. Part of the problem is that we are now down to only a few populations of purple pitcher plants, typically with a low population size, in small, fragmented habitats. This is a classic situation where a population is vulnerable to extirpation.

I don't think that extirpation of the taxon is a foregone conclusion if we intervene. There are a number of things that can and should be done to prevent *S. purpurea* extinction from happening. First, *ex-situ* conservation of existing *S. purpurea* populations is absolutely essential to prevent further loss of the genetic base. Second, protective easements or purchase of remaining natural purple pitcher plant sites should be pursued by federal, state, or non-profit organizations. Third, existing natural purple pitcher plant sites need appropriate management and enhancement efforts to restore them to the open, sunny, wet conditions necessary for the survival and reproduction of the pitcher plants and their important plant and animal associate species. Fourth, additional native purple pitcher plant populations should be established (within an acceptable conservation framework) to expand the base number of pitcher plant sites within the respective states. There are major political hurdles to overcome within Maryland and Virginia to accomplish the fourth point but I think I have shown that without such effort native purple pitcher plant populations are almost certainly headed to extinction. I have given several examples where backup populations of purple pitcher plant have been established (from Virginia Sites 4, 13 & 20) that are successful, reproducing, and preserving germplasm from extirpation. I have also shown that with as little as two interventions at Site 5 in Virginia (Reedy Creek) a pitcher plant population can be significantly enhanced to the point where population numbers match historic levels. To avoid the overall factors driving purple pitcher plant extinction in our region, and reverse the extirpation slope, I think we need a total of twenty to thirty flourishing new populations in Virginia, each population containing at least three hundred mature plants, and as many as ten new populations on the western shore of Maryland. Historically, healthy purple pitcher plant populations in Maryland and Virginia (as well as elsewhere within the region) contained hundreds of pitcher plants (Swift and Wells, 1960;

Sipple, 1999) within a site and these are the numbers we should be striving for to have healthy, functioning systems.

Mechanisms for purple pitcher plant persistence in the wild

How could purple pitcher plant survive to the present era when succession can eliminate populations in as little as ten years? My extirpation calculations for purple pitcher plant suggest ecosystem processes are missing that would have historically sustained the species. I mention (Appendix A) the cluster of purple pitcher plant populations around Wakefield, VA and how anthropogenic fire from railroad right-of-way operations would have provided the disturbance regime (woody suppression) to sustain *S. purpurea*. In contrast, as a control where this mechanism was not present within the past fifty years, there is the adjacent Piney Grove Preserve and Big Woods tract which encompass almost eight thousand acres. Piney Grove and Big Woods were originally owned by Gray Lumber Company which only used prescribed fire for site-prep operations (Fred Turck VDOF and Tom Woodacre former forester Gray Lumber pers. comm.). How could four purple pitcher plant populations occur in close proximity along the railroad right-of-way near Wakefield, VA while none are found on 8000 adjacent acres despite similar soils and hydrology? While Piney Grove and Big Woods are now receiving prescribed understory burns the last major fire in that area was the Sussex fire of April 5, 1943 which burned 12,200 acres (Bobby Clontz TNC pers. comm.). If succession can eliminate pitcher plant populations in as little as ten years, and fire has been absent for over fifty years from Piney Grove and Big Woods, than we have a causal mechanism for the extirpation of *S. purpurea* on those properties. Conversely, the frequent fire on railroad right-of-ways and fire escapes onto adjacent properties provided the necessary mimic of natural ecosystem processes to inhibit woody invasion and sustain purple pitcher plant populations. A test of this hypothesis is to remove the disturbance factor (fire) from railroad rights-of-way. In practice this test has occurred with loss of rail lines and their burning at the Chesterfield seeps and the 1996 repeal of code 10.1-1146 Virginia Forest Fire Laws which mandated that railroad companies must maintain their rights-of-way free of brush and flammable material fifty feet from the center of the rail. Not surprisingly, the purple pitcher plant population on the south side of the railroad tracks at Site 38 (Wakefield Bog) declined and is potentially extirpated. In brief, fire from railroad rights-of-way may have played a significant role in sustaining at least 25% (Sites 12-15, 17, 21,37-40) of purple pitcher plant populations in Virginia.

The postulate that purple pitcher plant populations were sustained by fire along railroad rights-of-way, and that populations of pitcher plants should therefore be found along said rights-of-way, must be put in context. Given the rapid decline of purple pitcher plant populations without fire disturbance, it may be difficult to now locate new colonies along railroad right-of-way after thirteen years of woody invasion following repeal of statute 10.1-1146. In addition, the Wakefield and Chesterfield clusters were located in Piney Woods habitat bisected by railroads. Nevertheless, if railroad rights-of-way cross suitable relatively intact purple pitcher plant ecosystem habitat (such as the Piney Woods), and those railroads rights-of-way were consistently maintained long-term with prescribed fire (chemical herbicide application would be a disqualifier), then there is a high probability of discovering a purple pitcher plant population.

More to the point, however, is the essential role that fire (whether anthropogenic from railroad rights of way, native Americans, controlled browse fires of the 1800's, prescribed forestry fires or natural lightning caused fires) must have played in the persistence of *S. purpurea* in the study region. In fact, one could argue that the distribution of *S. purpurea* in Virginia and the western shore of Maryland is a signature of fire history. Significantly, the historic distribution of *S. purpurea* in Virginia falls within three natural fire regime cycles (Fig. 7) between 1 – 12 years (Frost, 1995). Anthropogenic sources of fire were smoking (33%), brush burning (25%), incendiary origin (9%), railroads (6%), campfires (5%), lumbering operations (2%), miscellaneous causes (5%), and unknown origin (15%) (Pederson, 1941a and b).

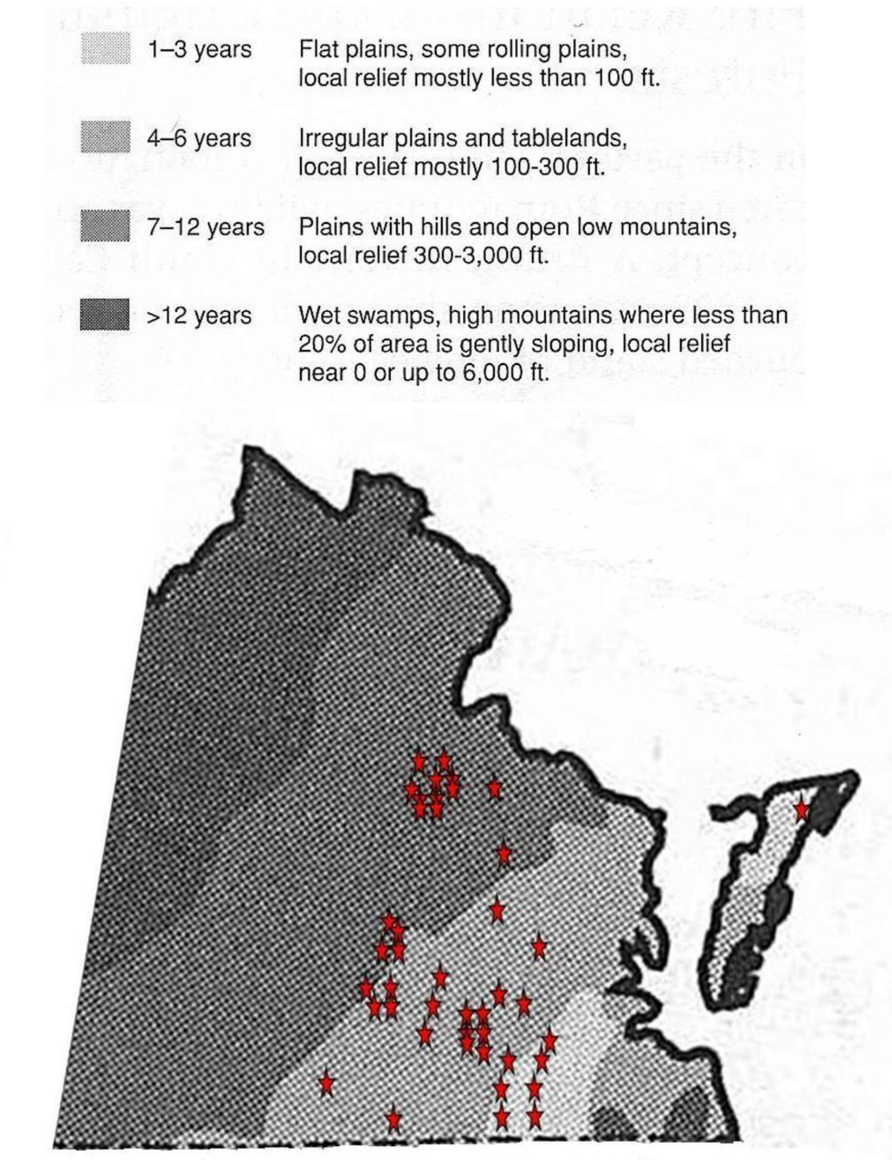

Figure 7. Historical *S. purpurea* distribution in Virginia and fire regimes. Fire regime map used with permission of Cecil Frost.

These fire regimes would have inhibited woody species, arrested succession, and prevented the extirpation of *S. purpurea*. The overlay of the historic, and current, distribution of longleaf pine (*Pinus palustris*) with that of *S. purpurea* in southern Virginia is striking. Longleaf pine forests are by nature fire maintained ecosystems and purple pitcher plant is part of that ecosystem. The western shore of Maryland purple pitcher plant populations occurred in pitch pine (*Pinus rigida*) and/or Atlantic white-cedar (*Chamaecyparis thyoides*) ecosystems that are also fire maintained. The central Virginia purple pitcher plant distribution is a little harder to explain since longleaf pine, Atlantic white-cedar, and pitch pine are absent from that area. However, the soils where purple pitcher plant occurs in central Virginia are sandy and gravelly mixtures with dominant ericaceous shrubs. These central Virginia pitcher plants habitats are stressful environments with flammable vegetation conducive to fire. If my hypothesis that fire disturbance is necessary to maintain *S. purpurea* populations is correct, then the small pitcher plant colony that was found on the impact range at Fort A.P. Hill (Site 10) should have increased in size if they have not been destroyed.

Where fire has been lacking in the modern era, powerline rights of way provided a suitable disturbance inhibiting woody competition and favoring the herbaceous community, including pitcher plants (Sheridan et al., 1997). In very rare cases, persistent natural gaps sustained pitcher plant populations long-term (Sheridan et al., 2000). I also suggest that beaver, perhaps in concert with fire, may have played a role in maintaining pitcher plant populations within intact, functioning ecosystems. In addition, low intensity browse of woody vegetation in pitcher plant bogs by cattle, or other browsers in historic times, may have had a beneficial effect on *S. purpurea* (Schnell, 2002).

Climate change effects and the subspecies question

All the blooming *S. purpurea* herbarium specimens, collected from a number of locations between 1883- 1901, were dated May 21 –June 1. In addition, Plitt (Sipple, 1999) recorded hundreds of purple pitcher plants blooming at the Glen Burnie bog on May 30, 1900 and May 17, 1902. In contrast, I recorded peak bloom of Virginia purple pitcher plant from May 17-20 during my 1995-1997 phenology study (Fig. 34). *Sarracenia purpurea* started blooming as early as May 8 and finished by June 12. In addition, my 2009 purple pitcher plant bloom phenology study matched peak bloom period of my earlier research. My observations are corroborated by Shetler and Wiser (1987) who recorded an average first flower date for *S. purpurea* of May 10 in the District of Columbia and vicinity. While the 1883-1901 purple pitcher plant blooming dates fall within the possible current flowering dates for this taxon I find it very unusual that only one of these historical records were from mid-May, the current peak of blooming. In fact, there a number of issues with the 1883-1901 purple pitcher plant collections and reports. First, it is very unlikely that almost all these early collections would have been flowering this late since I had only one year (1997) where there was any significant portion of the plants blooming after May 28. Second, the sheer numbers of purple pitcher plants recorded as blooming by Plitt in 1900 (Sipple, 1999) would require that the total population would have to have been in the many hundreds to thousands. While the Glen Burnie bog was apparently a very robust population the fact that so many purple pitcher plants were blooming this late in May is very unusual. Third, all of my field records are consistent with a mid-May peak in purple pitcher plant blooming followed by a quick decline: Site 4, Peatross bog, May 28, 1988, “past bloom and petals withered”; Site 20, Howerton bog, April 27, 1991, “*S. purpurea* a week from flowering”; Site 38, Wakefield Bog, May 18, 1991, “*Sarracenia* have dropped petals”; Site 40, Piney Grove Bog, May 15, 1993, “pitchers in bloom”. I also recorded (photographically) a site visit to Piney Branch Bog (Site 9) in Charles County, Maryland on May 11, 1991 where I observed, but did not make a written record, that the plants were in bloom. Cumulatively, all the current records for Maryland and Virginia clearly indicate a mid-May peak flower period for *S. purpurea*. On the other hand, Shreve (1906) appears to suggest an earlier flowering/pollination period for *S. purpurea* since he states “Pollination takes place, near Baltimore, during the first week in May.” However, Shreve (1906) appears to contradict his earlier statement by stating “A visit on May 24 to plants growing in the open found the anthers nearest the ovary to have shed their pollen. Material collected at the same locality two days later was found to show fertilization. The time of pollination of the particular flowers gathered and fixed may have been as much as five days before gathering, but was probably not earlier." I think it is odd for Shreve to claim *S. purpurea* pollination the first week of May since I have not even documented the flowers opening this early. In any case, the comparison of historic and current *S. purpurea* flowering data may suggest a shift to an earlier flowering period in the present era. If true, this shift in flowering time would be consistent with other studies of the effect of global warming on flowering times in the Washington, D.C. region (Mones et al., 2001). What is the consequence or significance of shifted flowering dates in *S. purpurea*? Late spring blooming plants, such as *S. purpurea*, have tightly choreographed bloom times which are resistant to seasonal changes in spring or late winter temperatures. Early blooming species, and their bloom phenology, are much more sensitive to changes in seasonal temperatures (Shetler and Wiser, 1987). Therefore, if there is a shift in *S. purpurea* flowering dates, purple pitcher plant may serve as a sensitive indicator species of global climate change. An earlier blooming period for *S. purpurea* also implies a generally longer growing season. A longer growing season may allow purple pitcher plant to increase starch reserves. *Sarracenia* is also pollinated chiefly by *Bombus* species (Schnell, 1983) but other pollinators such as small solitary bees (*Augochlorella aurata* Smith) and the sarcophagid fly (*Fletcherimyia fletcherii* Aldrich) have been identified (Ne'eman et al., 2006). Presumably, pollinator life cycles are similarly affected by climate change but these effects are unknown and further research is needed in that area (Shetler and Wiser, 1987). However, floral biology may be a secondary concern since the chief factors affecting pitcher plant extirpation in Maryland and Virginia are beaver flooding and succession. Pitcher plant sites that have been kept open in the study area receive enough pollinator visits to produce abundant seed.

If there are taxonomic differences between *S. purpurea* populations in Virginia and the western shore of Maryland I did not find a big difference in those populations ability to resist extirpation pressure. Hypothetically, different taxa might have expressed underlying differences through a physiological ability to resist habitat insults or succession. While

Maryland has suffered a greater percentage loss (71%) of purple pitcher plant populations than Virginia (67%) the difference is not great and is more likely due to the proximity of the Maryland populations to urban centers and the smaller geographic area. In addition, the likelihood that both Virginia and western shore Maryland purple pitcher plant populations will be extirpated is very similar. The phenomenon of purple pitcher plant extirpation is not unique to Maryland and Virginia but appears to be much more widespread. Bill McAvoy (pers. comm. Delaware Natural Heritage Program) reports that many of the twenty-two purple pitcher plant populations in Delaware inventoried between 1984 and 2007 are likely extirpated. Sixty percent of purple pitcher plant populations on Long Island, New York have also been extirpated since the late 1800's (Lamont, 2008). Estimates of pitcher plant habitat loss range as high as 97% along the Gulf Coast (Folkerts, 1982). Analysis of Florida pitcher plant herbarium collections over a 40 year period, and subsequent field examination of whether locations were still extant, revealed a 62% loss of pitcher plant habitat (Herman, 1988). Furthermore, of the remaining Florida sites, only 31% (12% of the original total) appeared to have not been damaged or altered by human activity. Clearly, the ecosystems in which *Sarracenia* pitcher plants reside are under widespread assault, stress, and destruction.

If there are not two subspecies of purple pitcher plant in the mid-Atlantic now, the forces driving extirpation in the region are going to separate northern and southern Atlantic coast populations and could ultimately lead to new species through allopatric speciation. I find it remarkable that anthropogenic disruption of natural habitat and ecosystem processes may ultimately be responsible for the selection of pitcher plant species by classic evolutionary biology processes.

GENETIC ANALYSIS OF PURPLE PITCHER PLANT, *SARRACENIA PURPUREA L., SUBSP*ECIES UTILIZING THE CHALCONE SYNTHASE INTRON

Introduction

Botanical treatments (McFarlane, 1908; Uphof, 1936; Bell, 1949; McDaniel, 1966) of the genus *Sarracenia* have led to a general acceptance of eight species: *Sarracenia alata* (Wood) Wood, *S. flava*, *S. leucophylla* Raf., *S. minor* Walt., *S. oreophila* Kearney (Wherry), *S. psittacina* (Michx.), *S. purpurea*., and *S. rubra* Walt.. Known flower colors are red, pink, yellow and cream. *Sarracenia alata*, *S. flava*, *S. minor* and *S. oreophila* have yellow flowers with *S. alata* variants producing cream flowers. *Sarracenia leucophylla, S. psittacina*, *S. purpurea* and *S. rubra* have red flowers with variants in all four species producing yellow flowers. *Sarracenia purpurea* subsp. *venosa* var. *burkii* has pink to cream flowers. Leaf shapes range from upright to decumbent. Upright-leafed species are *S. alata*, *S. flava, S. leucophylla, S. minor, S. oreophila* and *S. rubra*. Decumbent-leafed species include *S. psittacina* and *S. purpurea*.

Eight species are generally recognized within the genus *Sarracenia*. However, there has been considerable work and debate on the exact taxonomic status of populations within *S. purpurea* and *S. rubra*. Some taxonomists advocate splitting *S. rubra* into as many as three species with two subspecies (Case and Case, 1974, 1976), five species (McDaniel, 1986), one species with five subspecies (Schnell, 1977, 1979b) or lumped into one species (Bell, 1949).

Two subspecies of *S. purpurea* are generally accepted, *S. purpurea* ssp. *purpurea* and ssp. *venosa* (Wherry, 1933, 1972; Schnell, 1979a) although not all taxonomists accept this designation (Bell, 1949; McDaniel, 1966). *Sarracenia purpurea* subsp. *venosa* (Raf.) Wherry contains a recently described variety named *S. purpurea* ssp. *venosa* var. *burkii* (Schnell, 1993) which is endemic to the Gulf Coastal Plain. *Sarracenia purpurea* ssp.

venosa var. *montana* Schnell and Determan is only found in the mountains of North and South Carolina and Georgia (Schnell & Determann, 1997). *Sarracenia purpurea* subsp. *purpurea* has an anthocyanin-free mutation described as forma *heterophylla* (Eaton, 1822, 1833; Fernald 1922). *Sarracenia purpurea* ssp. *venosa* var. *burkii* has subsequently been upgraded to the level of a new species, *S. rosea* (Naczi et al., 1999). In addition, because of a lectotypification error (Reveal, 1993) the taxonomy of the subspecies *venosa* and *purpurea* is in contention. For clarity, and consistency with most authors, I refer to northern populations as ssp. *purpurea* and southern (e.g. Virginia to Georgia) populations as ssp. *venosa*. However, in order to maintain neutrality of opinion I use the generic term "*S. purpurea*" in the results and discussion to refer to mid-Atlantic purple pitcher plant populations. Mountain populations in North and South Carolina are identified as *S. purpurea* ssp. *venosa* var. *montana* and Gulf Coast populations as *S. rosea*.

Sarracenia purpurea ssp. *purpurea* is distinguished from *S. purpurea* ssp. *venosa* by glabrous rather than pubescent pitchers, a pitcher length greater than three times the width of the pitcher versus less than three times in ssp. *venosa*, and dark red versus light red petals in ssp. *venosa* (Wherry, 1933; Schnell, 2002). Reputedly *S. purpurea* ssp. *purpurea* occurs from either Maryland or Delaware (Schnell, 2002) or from somewhere within the Maryland, Delaware, or New Jersey area northward (Wherry, 1933). Most authors (Wherry, 1933; Naczi et al., 1999; Schnell, 2002) report *S. purpurea* ssp. *venosa* as occurring from Virginia south while Townsend (2009) lists both subspecies as occurring within Virginia. Wherry (1933) was known to assign larger ranges to *Sarracenia* taxa based on somewhat limited field experience and I think this explains his difference in range for *S. purpurea* ssp. *purpurea* compared to Schnell (2002). I have worked this transition area extensively, visiting many *S. purpurea* populations and observing morphological characteristics, and think the transition zone can be ascribed to the western shore of Maryland and Virginia.

Ostensibly, Maryland and Virginia represent the overlap area for the two subspecies and careful analysis and study should resolve whether there is a line of demarcation between the two taxa. Recent allozyme genetic studies (Godt and Hamrick, 1999) offer encouragement for resolving the *S. purpurea* subspecies question in the mid-

Atlantic region. Godt and Hamrick (1999) found more genetic differentiation between the *S. purpurea* taxa than they found in a previous study of *S. rubra* segregates (Godt and Hamrick, 1998). They (Godt and Hamrick, 1999) found that the Gulf Coast populations of *S. purpurea* are the most distinct infraspecific taxon of any *Sarracenia* they had studied, lending strong support to the species concept for the disjunct Gulf Coast populations (now known as *S. rosea*) when morphological and distributional data are also considered. Godt and Hamrick (1999) also found that the Atlantic coast populations (ssp. *venosa*) were most closely allied to the Georgia, North and South Carolina mountain group (var. *montana*). The var. *montana* and ssp. *venosa* groups were most closely related to northern ssp. *purpurea* rather than to the gulf coast entity *S. rosea*. Godt and Hamrick (1999) also suggested that infraspecific *S. purpurea* taxa may have experienced restricted gene exchange for a considerable period of time.

Unfortunately, there has been a lack of research to determine the taxonomic unit that *S. purpurea* represents in Maryland and Virginia. Accurate designation and delineation of the taxon is essential to identifying the contributions of an organism to the ecosystem. The proper naming of the entity is essential to a scholarly exchange of information. Therefore, a molecular approach utilizing the variability with the intron of chalcone synthase gene (*Chs*) was used to attempt to solve the subspesific question for *S. purpurea*. Molecular research on one of the genes of the anythocyanin biosynthetic pathway, the chalcone synthase gene, made sense for a number of reasons. First, previous biochemical research on *Sarracenia* anthocyanidins at the USDA labs in Beltsville, Maryland had been successful (Sheridan and Griesbach, 2001). Second, chalcone synthase is an important enzyme of anythocyanin synthesis. This molecular study would be a useful follow-up to my previous research on anthocyanidins in the same lab. Third, the technique employed was a relatively inexpensive method to use and could potentially effectively answer the question at hand. Fourth, both Godt and Hamrick (1999) and Ellison et al. (2004) encouraged extensive investigation of *S. purpurea* and the development of additional genetic markers and DNA sequencing to explain phylogenetic relationships in the taxon. My research met this need by offering the prospect of providing genetic markers for *S. purpurea* and performing field research on a critical part of the range of the species. The objective of the research was to use variability in the *Chs* intron to assess whether two purple pitcher plant subspecies occurred in the study region. Therefore, I proposed, that if there is a significant difference in variability of chalcone synthase introns between mid-Atlantic (specifically western shore of Maryland and Virginia) populations of *S. purpurea* then a separate sub specific identification of those populations will be supported.

Materials and Methods

Plant Material

Flower buds were collected from purple pitcher plant populations in Virginia and the western shore of Maryland. In addition *S. purpurea* populations, both north and south on the Atlantic and Gulf Coasts, were sampled to provide a comprehensive survey of diversity as relevant to the subspecies question. Where possible, material was obtained from the remaining natural sites. In many cases natural populations had been extirpated and there was no choice left but to obtain flower buds from purple pitcher plant in *ex-situ* conservation, back-up wild populations to the natural sites, or an introduced site (Table 3).

Table 3. Flower buds of *S. purpurea* obtained between 2005 and 2006.

*Outgroup comparative material was obtained from research beds at the Meadowview Biological Research Station in Woodford, VA and included *S. leucophylla* (n=13), *S. flava* (n=2), and *S. jonesii* (n=14).
Ex-situ material is designated by "[a]", back-up wild populations by "[b]", introduced by "[c]", and native populations have no superscript.

State	County	Site Name	Number of samples
Connecticut	Tolland	Ruby Rd. Bog	18
Delaware	Sussex	Hanson Pond	15
Florida	Liberty	Apalachicola National Forest	15
Maryland	Anne Arundel	Arden[a]	12
Maryland	Anne Arundel	Maryland Avenue[a]	1
Maryland	Charles County	Piney Branch[a]	13

Table 3. Continued

State	County	Site Name	Number of samples
Maryland	St. Mary's	Charlotte Hall[c]	8
Maryland	Wicomico	Sharptown Bog	15
Virginia	Caroline	Peatross[b]	16
Virginia	Caroline	Reedy Creek	16
Virginia	Caroline	Meadow creek*	29
Virginia	Chesterfield	Zion Church[b]	13
Virginia	Chesterfield	Swift Creek[a]	1
Virginia	Dinwiddie	Addison[b]	3
Virginia	Dinwiddie	Depot Rd[a]	1
Virginia	Essex	Howerton[b]	13
Virginia	Greensville	Dahlia[b]	8
Virginia	Isle of Wight	Zuni	6
Virginia	Prince George	Cherry Orchard II	6
Virginia	Prince George	Cherry Orchard II[a]	1
Virginia	Southampton	Seacock Swamp	1
Virginia	Sussex	Wakefield railroad[b]	14
Virginia	Sussex	Byrum's[b]	14
N. Carolina	Brunswick	Orton Plantation	13
N. Carolina	Henderson	McClures Bog[b]	13
N. Carolina	Hampstead	Hampstead County[b]	3
N. Carolina	Tyrell County	Tyrell County[b]	3
New Jersey	Ocean	NJ Pine Barrens	15
Pennsylvania	Westmoreland	Spruce Flats Bog	8
West Virginia	Tucker	Big Run Bog	8

Flower buds were collected either prior to the flower opening or within several days of opening. Up to 15 flower buds were collected per site for analysis. Flower buds have the most extractable DNA with the best resolution (Freudenstein, pers. comm.). Herbarium specimens were obtained from each population sampled (Appendix B). All necessary permits and landowner permissions were obtained to collect plant material. Plant tissue was placed on ice at the time of collection, transported to the laboratory, washed with distilled water to remove insect debris, labeled to site, and then frozen.

DNA Isolation

DNA was extracted by grinding flower buds (100 mg fresh weight) in liquid nitrogen and isolated using the DNeasy Plant Mini Kit (Qiagen Sciences, Inc.) as recommended by the manufacturer.

PCR amplification

The DNA sequences of the chalcone synthase genes (*Chs*) have been reported (Niesbach-Klosgen et al., 1987; Koes et al., 1987). The sequence from *Petunia* x *hybrida* "Roter Traum" was selected for creating primers to amplify the *Chs* intron. The forward primer sequence (5'-GAGAAATTCAAGCGNATGTG-3'), designated CHS-1, was selected from the region immediately before the intron. The reverse primer sequence (5'-AACCCTGCTGGTACATCATG-3'), designated CHS-4, was selected from a transcribed region of the gene 312 bp downstream from the intron. The sequences complementary to CHS-4 are highly conserved between unrelated species in different genera (Niesbach-Klosgen et al., 1987).

The PCR reaction was performed in a Perkin Elmer DNA Thermal Cycler Version 2.3 at the USDA lab in Beltsville, Maryland. The reaction mix (100 uL) consisted of 10 uL genomic DNA (1.0 mg;mL-1), 1.5 uL AmpiTaq Gold DNA polymerase, 10 uL of 10X buffer (500 mM KCl and 150 mM Tris, pH 8.0), 8 uL mixed dNTPs (each at 10 mM), 15 uL 10 mM MgCl2, 5 uL of 20 uM CHS-1 primer, 5 uL of 20 uM CHS-4 primer, and 45.5 uL of water. Each reaction mixture was overlain with 25 uL of mineral oil and preheated at 95 C for 12 min. The reaction mixture was incubated for 2-min. at 92 C, 40 cycles of 92 C (30 s each cycle), 60 C (2 min), 72 C for 10-min, and then held at 5 C.

Restriction analysis

Analysis of the published sequence of the *Chs* intron in *P.* x *hybrida* “V30” (Koes et al. 1987) shows that only *Rsa 1* will digest the intron into several large fragments. Therefore PCR products were initially digested with *Rsa* 1 at 37 C for 3 h. The restriction mixture (200 uL) consisted of 30 uL PCR product, 150 uL water, 20 uL 10X buffer (10 mM MgCl2, 1 mM dithiothreitol, and 10 mM TRIS, pH 7.0), and 1 uL (10 units) *Rsa* 1. Additional digestions were performed with *Alu 1* and *Dra 1* after no difference in PCR restriction digest products were detected in mid-Atlantic *S. purpurea* with *Rsa 1*. *Alu 1* was selected as the restriction enzyme to complete the study since it appeared to produce differential restriction fragments for systematic analysis.

The PCR products and restriction fragments were resolved by gel electrophoresis (50-V constant voltage) in 4% Amplisize Agarose in TAE. Gels were stained in 0.5 ug:mL-1 ethidium bromide for 15 minutes. The AlphaEase image analysis system was used to digitally record the resulting images and to determine molecular weights.

When pitcher plant flower extracts failed to produce PCR products with gel electrophoresis a positive control was performed. Positive controls consisted of extracting DNA, PCR amplification, and gel electrophoresis of several pitcher plant samples known to produce results done at the same time and on the same gels as samples that failed to produce PCR products. In this manner I could determine that the lack of PCR products was not a failure in lab technique but a systemic problem with the plant sample itself (e.g. inhibition of DNA extraction).

Genetic relatedness of the populations was inferred based on the molecular fragments and an assessment of the hierarchy of the respective taxa was made and placed in the context of work by other molecular researchers (Schwaegerle and Schaal, 1979; Bayer et al., 1996; Godt and Hamrick, 1999; Neyland, 2006) and taxonomists (Naczi et al., 1999; Ellison et al., 2004).

Results

A total of 304 flower buds were collected from 28 purple pitcher plant populations and four outgroup taxa. Flower buds could not be obtained from the State of Georgia due to the critical status of the few remaining indigenous purple pitcher plant populations in that state. Material was obtained from South Carolina but was improperly prepared for shipment and DNA could not be extracted. PCR and restriction digest gels (over 120 of each) were run to analyze the samples.

Comparison of outgroups

Four taxa were compared against *S. purpurea*: *S. leucophylla*, *S. rosea*, *S. jonesii*, and *S. flava*. Despite repeated attempts at DNA extraction and PCR amplification (four separate gel attempts consisting of a total of thirteen individual flower buds) no product was obtained for *S. leucophylla*. Genomic DNA of *S. leucophylla* was also combined (ten samples) and no detectable product was obtained on agarose gels. A positive PCR control of *S. purpurea* and *S. leucophylla* demonstrated that the lack of *S. leucophylla* product was not due to error in methods but rather due to inhibition of DNA extraction by *S. leucophylla*.

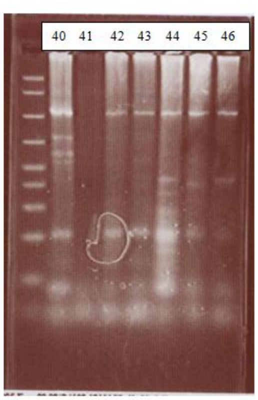

Figure 8. PCR products of the *Chs* intron of *S. rosea* (40-44) and *S. purpurea* (45-46).

Sarracenia rosea and *S. purpurea* produced *Chs* intron PCR products of approximately 1000 base pairs (bp)(Fig. 8.). *Sarracenia purpurea* typically produced several major *Chs* intron PCR products of approximately 1000, 700, 400, and 200 bp. *Rsa 1* restriction digest of the *Chs* PCR product from Connecticut *Sarracenia purpurea* produced inconsistent results (Fig. 9). However, after multiple digestions, I determined that both Connecticut *S. purpurea* and *S. rosea* produced a 750 bp restriction fragment. *Alu 1* restriction of the *Chs* PCR product from *S. rosea* did not produce a fragment while the PCR product from Connecticut *S. purpurea* produced a 900 bp fragment (Figs. 10-11). There was some evidence that both *S. purpurea* and *S. rosea* produced a restriction fragment of ca. 650 bp from the 750 bp PCR fragment when using *Alu 1* (Fig. 10). However, there is some evidence that the 650 bp fragment could be pre-existing in *Chs* intron PCR products for *S. rosea* (see sample 40, Fig. 8).

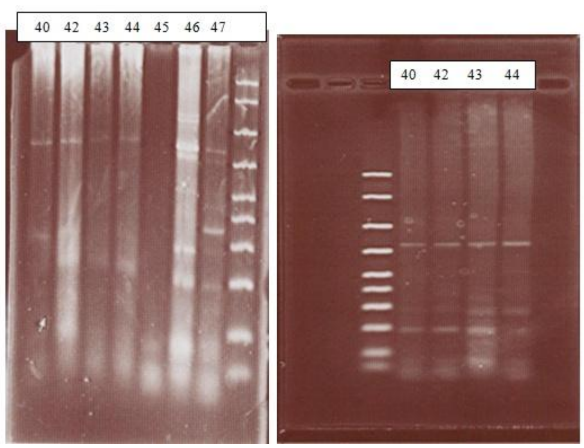

Figure 9. *Rsa 1* digestion of the *Chs* intron from *S. rosea* (40-44) and Connecticut *S. purpurea* (45-47).

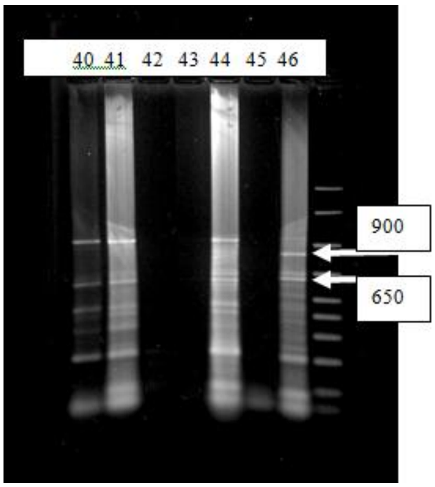

Figure 10. *Alu1* digestion of the *Chs* intron from *S. rosea* (40-44) and *S. purpurea* (45-46).

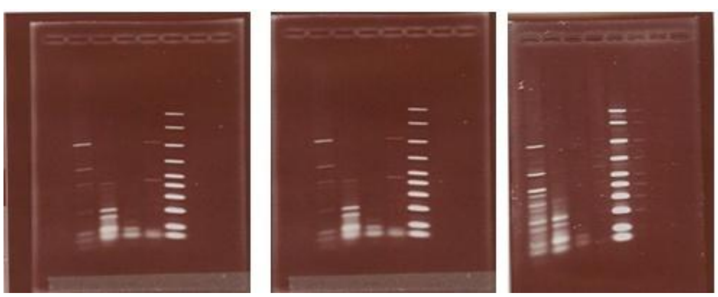

Figure 11. Repeated *Alu 1* restriction digests of the *Chs* intron from *S. rosea* samples 40, 42-44. Samples digested on 9/19/06, 10/5/06, and 10/24/06 and enzyme failed to digest chalcone synthase intron of ca. 1000 bp. 700 bp PCR fragment may have cut to 650 bp fragment.

Sarracenia purpurea typically produced a major PCR product for the *Chs* intron of around 1000, 700, 400, and 200 bp while *S. jonesii* produced PCR products around 1200, 700, 400, 300 and 200 bp (Fig. 12). I was not able to get satisfactory restriction digests of *S. jonesii* with restriction enzyme *Alu1* to assess genetic differentiation from *S. purpurea* (Fig. 13). While DNA was successfully extracted from *S. flava*, both PCR amplification of the *Chs* intron and its restriction enzyme digestion provided unsatisfactory results for interpretation.

There were a variety of reasons for unsatisfactory results. I took steps to improve existing lab protocols that increased efficiency and quality so that the results I achieved were the best possible. First, the preparation of agarose gels requires particular attention to detail. If agarose is not thoroughly dissolved and mixed in solution, PCR and restriction digest products will not properly migrate through the gel matrix and no, or poor, resolution is achieved. I worked on existing lab protocol, through consultation with other USDA molecular biologists, to achieve consistent, high quality gels that allowed PCR and restriction digest products to successfully migrate through the gel matrix and produce clear results. The factors to obtain good gels are proper melting of the agarose in hot buffer, mixing the hot agarose with a magnetic stirrer until completely clear, and smooth pour of the hot agarose into the mold. Second, gels can smear due to PCR fragments or stain due to contamination. I was not able to overcome smearing and staining of gels, which inhibited the ability to resolve the few *S. flava* samples. Third, the age and quality of pitcher plant samples may have negatively affected gel quality. I took great care to obtain my pitcher plant samples but given the broad geographic area covered, many people submitting and processing samples, and length of time to complete the project there may have been some sample degradation. Despite these difficulties, I had enough samples across the range and over taxa to discern any differences within the intron of the *Chs* gene in *Sarracenia*.

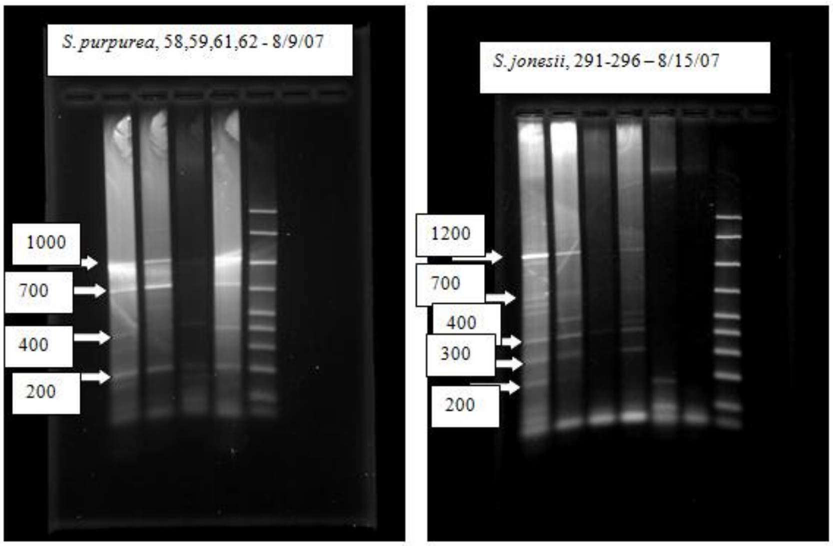

Figure 12. Comparison of *S. purpurea* var. *montana* and *S. jonesii* PCR *Chs* intron products. Note the larger *S. jonesii* PCR product of ca. 1200 bp vs. ca. 1000 bp of *S. purpurea* ssp. *venosa* var. *montana*. *Sarracenia jonesii* contains a product of 300 bp rarely seen in *S. purpurea*.

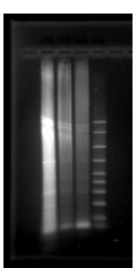

Figure 13. *Sarracenia jonesii Chs* intron digested with *Alu 1*.

Comparison within S. purpurea

Sarracenia purpurea typically produced several major *Chs* intron PCR products of approximately 1000, 700, 400, and 200bp. Restriction enzyme digests of *S. purpurea Chs* intron with *Rsa 1* routinely produced DNA fragments of approximately 750 and 250 bp, matching the approximate molecular weight of the chalcone synthase gene intron of around 1000 bp (Fig. 14).

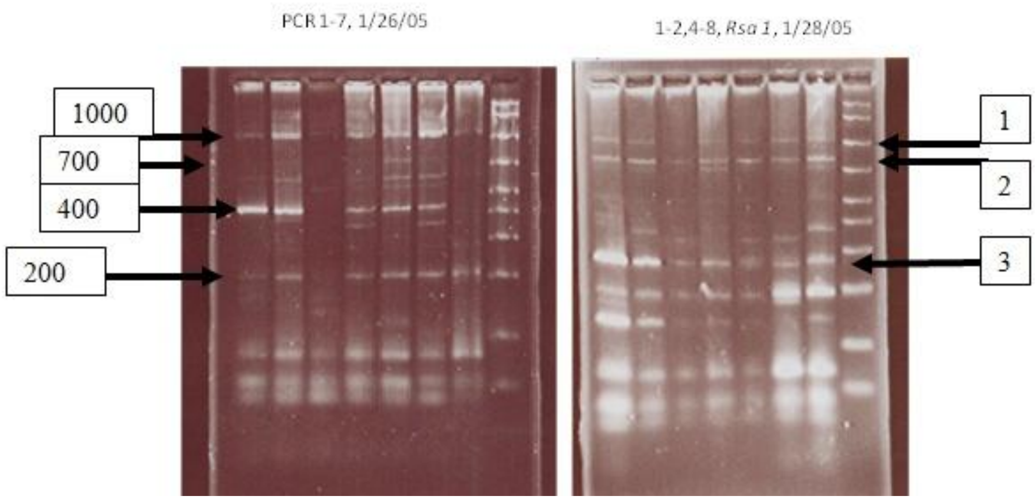

Figure 14. Comparison of *S. purpurea Chs* intron PCR product and its *Rsa 1* digestion. Samples 1-8. Gel on left highlights major PCR products. Gel on right is *Rsa 1* digest with 1 as PCR chalcone synthase gene intron product of ca. 1000 bp, 2 is digested fragment of ca. 750 bp, and 3 is digested fragment of ca. 250 bp.

All restriction digests of the *Chs* intron with *Rsa 1* (samples 1-62, eight populations) of *S. purpurea* and the outgroup *S. rosea* produced similar digestion fragments of approximately 750 and 250 bp. Restriction digests with *Alu 1* initially produced intriguing results since the enzyme repeatedly cut PCR products (Figs. 15-16). *Sarracenia purpurea* from Chesterfield County in south central, VA and Ocean County, NJ produced restriction fragments of 900 and 650 bp while *S. purpurea* ssp. *venosa* var. *montana* from the mountains of North Carolina generally did not (Figs. 17 and 18). *Alu 1* did not appear to cut the 1000 bp PCR fragment in *S. purpurea* ssp. *venosa* var. *montana* but appears to have cut the PCR fragment of 700 bp to 650 (Fig. 18).

In mid-Atlantic *S. purpurea*, *Alu 1* was able to digest the ca. 700 bp PCR product into a 650 bp fragment and the 1000 bp product into a 900 bp fragment. The main PCR product of ca 1000 bp in many instances did not produce a distinct banding pattern after digestion.

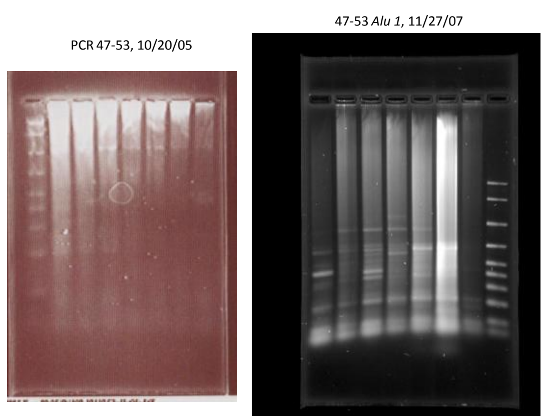

Figure 15. New Jersey *S. purpurea Chs* intron PCR products and their digestion with *Alu 1*.

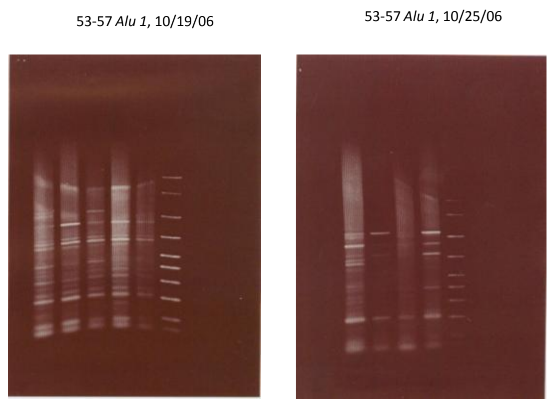

Figure 17. Repeated *Alu 1* digestions of Chesterfield, VA *S. purpurea*

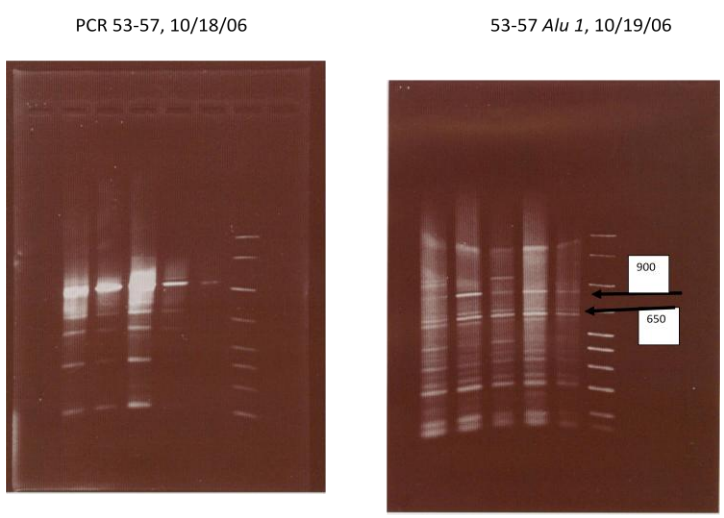

Figure 16. *Chs* intron PCR products and their *Alu 1* digestion of Chesterfield Co., VA *S. purpurea*. *Alu 1* fragments detected are ca. 900 and 650 bp.

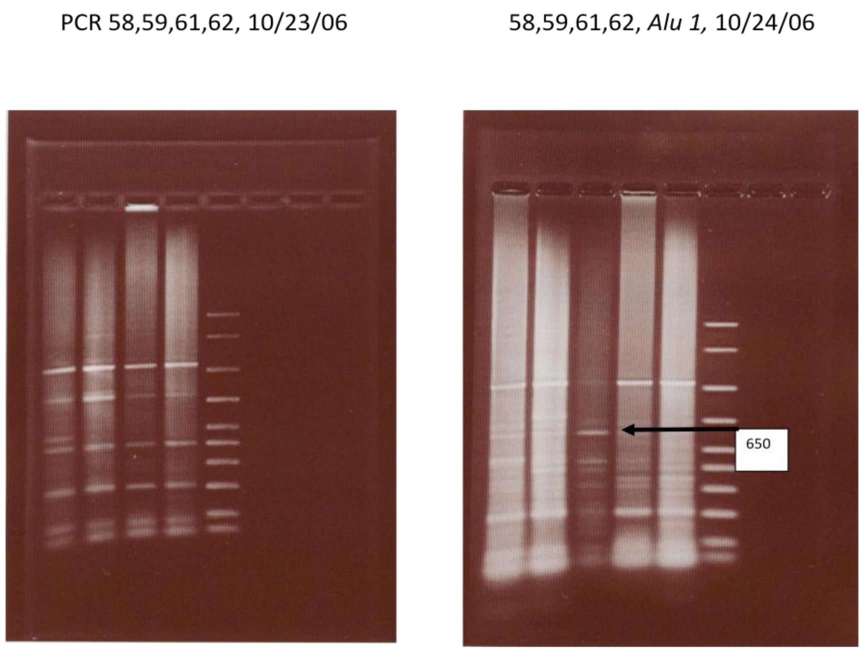

Figure 18. *Chs* intron PCR products and *Alu 1* digestions of *S. purpurea* var. *montana*. 1000 bp PCR fragment is not cut by restriction enzyme while 700 bp PCR fragment cut to 650 bp fragment by *Alu 1*.

Discussion

The genetic technique used in this study, restriction fragment length polymorphism (RFLP), was one of the first molecular techniques developed in the 1980's to assess genetic variation. While the subsequent development of DNA sequencing has proved effective at thoroughly characterizing DNA, the process is expensive. In contrast, RFLP's provide an efficient and effective way of addressing genetic difference between taxa. The restriction enzymes utilized in RFLP analysis target and cleave specific base sequences within the genome. For example, *Rsa 1* cleaves DNA in a location (5' - GT/ AC-3' and complementary strand 3'-CA/TG-5') different from restriction enzyme *Alu 1* (5'-AG/CT-3' and complementary strand 3'-TC/GA-5').

Introns are free to drift and evolve with minimal constraint since they do not share the strong selection pressure experienced by exons (expression sequences). Therefore, introns provide a way to assess divergence between taxa. If one taxon has diverged from another taxon those differences may be expressed in changes in base sequences which can be exploited for taxonomic purposes. The variation in both intron length and sequence as determined by restriction endonuclease digestion can be used as a molecular marker to separate taxa. Utilization of several restriction enzymes allows the researcher to select a restriction enzyme sensitive enough to detect molecular differences between taxa.

Chalcone synthase is a critical enzyme in anthocyanin biosynthesis. The intron of *Chs* has been used to differentiate species and varieties of *Petunia* (Griesbach et al., 2000; Griesbach and Beck, 2005). The gene for chalcone synthase has been sequenced for many species in a number of families with a 66% nucleotide similarity (Niesbach-Klosgen et al., 1987). The chalcone synthase gene has up to eight complete copies with intron lengths of 3776, 2438, 1346, 728, 694, 563, 406, and 123 base pairs (bp). Each intron in a complete gene is flanked by two exons. Only one of the chalcone synthase genes (*Chs A*) is transcribed to any degree in flowers (Koes et al. 1989; Griesbach et al., 2000). The chalcone synthase gene intron is an excellent candidate to explore taxonomic relationships, versus a coding sequence (exon), because of the accumulation of mutations within the highly conserved *Chs* gene. Those mutations allow differentiation of taxa by analysis of fragments produced by restriction enzymes.

Rsa 1 digestion of the 1200 bp *Chs* intron in *Petunia* was used to resolve the taxa. (Griesbach et al., 2000; Griesbach and Beck, 2005). In contrast, I found no difference between mid-Atlantic *S. purpurea Chs* intron PCR products or restriction enzyme digests of DNA with *Rsa 1* or *Alu 1*. I did detect differences between *S. purpurea* and the outgroups *S. leucophylla* and *S. jonesii*. These results suggest that only one taxon occurs in the study area specifically, and the mid-Atlantic generally. The recovery of multiple *Chs* intron PCR products in *S. purpurea*, as opposed to a single *Chs* intron PCR product for *Petunia*, was noteworthy in that it indicated *S. purpurea* may have multiple copies of the Chalcone synthase gene. The inability to extract DNA from *S. leucophylla* reflected a fundamental biochemical difference between that species and *S. purpurea* which is clearly reflected on a morphological level. *Sarracenia jonesii* seemed to produce a longer *Chs* intron PCR product (ca. 1200 bp) than *S. purpurea* and produced a *Chs* intron PCR product of 300 bp typically not seen in *S. purpurea*. Differences in *Chs* intron PCR products between *S. purpurea* and *S. jonesii* are not surprising since these are clearly different species and one might expect to find molecular differences. Differences in PCR products were found by Griesbach et al. (2000) between *Petunia* species and varieties. The discovery of molecular differences between *Sarracenia* species supports the utility of the chalcone synthase gene intron for systematic analysis.

RFLP comparison research of the chloroplast genome utilizing 10 restriction enzymes with 6 and 4 base recognition sites, conducted between 1988-1991, found very little variation in *Sarracenia* (Rob Naczi, pers. comm.). However, the chloroplast genome is highly conserved making interspecific analysis difficult (Palmer and Stein, 1986).

Restriction enzyme *Rsa 1* digestion of the *Chs* intron in *Sarracenia rosea* produced the same banding pattern as that found in *S. purpurea*. In contrast, the *S. rosea Chs* intron was not cleaved by restriction enzyme *Alu 1* while *S. purpurea* was cleaved into 900 and 650 bp fragments. *Sarracenia purpurea* ssp. *venosa* var. *montana* also responded differently than mid-Atlantic *S. purpurea* to digestion with *Alu 1* since only one PCR band (ca. 700 bp) was digested instead of two (ca. 1000 and 700 bp). These differences suggest that *S. rosea* and *S. purpurea* ssp. *venosa* var. *montana* are distinct from the mid-Atlantic *S. purpurea*.

The differences found in this study between *S. purpurea*, *S. purpurea* ssp. *venosa* var. *montana,* and *S. rosea* are consistent with other recent genetic studies on *S. purpurea* (Godt and Hamrick, 1999; Neyland, 2006). Both authors were able to differentiate the various *S. purpurea* taxa in a similar fashion despite using different techniques (allozyme electrophoresis for Godt and Hamrick and nuclear DNA sequencing for Neyland). Neyland (2006) expanded and improved upon the work of Bayer et al. (1996) and demonstrated that *S. purpurea* was "sister to all remaining species in *Sarracenia*". In addition, Neyland (2006) was able to resolve four infraspecific taxa (*S. rosea*, *S. purpurea* ssp. *purpurea*, *S. purpurea* ssp. *venosa*, and *S. purpurea* ssp. *venosa* var. *montana*) with *S. rosea* strongly supported as a separate species (my taxonomy not Neyland's for the respective taxa). The work of Godt and Hamrick (1999) also supported both the species concept for *S. rosea* and subspecies and varietal status of *S. purpurea* ssp. *purpurea*, *S. purpurea* ssp. *venosa*, and *S. purpurea* ssp. *venosa* var. *montana*. Neyland (2006) independently, and with different techniques, matched the distance and cladistic relationships reported by Godt and Hamrick (1999) for the respective *S. purpurea* taxa (including *S. rosea*).

This is the first molecular marker study comparing *Sarracenia* within the mid-Atlantic range, focusing on Maryland and Virginia, to determine if genetic differences warranted splitting the taxonomic unit found in this region. This region is where the two *S. purpurea* subspecies reputedly overlapped.

Godt and Hamrick (1999) sampled *S. purpurea* populations in Minnesota, Wisconsin, Georgia, and North Carolina. The Minnesota and Wisconsin populations were clearly differentiated from the Georgia and North Carolina populations. Furthermore, within the Georgia and North Carolina samples, coastal populations split as ssp. *venosa,* while mountain populations were discerned as ssp. *venosa* var. *montana*. Schwaegerle and Schaal (1979) investigated, via allozyme electrophoresis, eleven *S. purpurea* populations in Ohio, Michigan, Pennsylvania, New Jersey, and North Carolina. Schwaegerle and Schaal (1979) found that while there was substantial differentiation between populations, the suite of alleles was found throughout the study sites. In addition, Schwaegerle and Schaal (1979) determined that genetic variability in their study region did not have geographical correlates, that populations did not deviate significantly in their genetics from the norm, and there was no differentiation between the northern subspecies and the North Carolina coastal population. In short, they found no support for a subspecies concept between North Carolina and Michigan.

In this study, *S. purpurea* ssp. *venosa* var. *montana* could be distinguished from *S. purpurea* by the fact that only one of two *Chs* intron PCR products was digested by restriction enzyme *Alu 1* (*Alu 1* cleaves both PCR fragments in *S. purpurea*). Furthermore, coastal *S. purpurea* populations from North Carolina to Connecticut produced similar PCR products and restriction digests with both *Alu 1* and *Rsa 1* suggesting that plants in this geographic area are one taxon. Since Godt and Hamrick (1999) detected a clear genetic distinction between *S. purpurea* populations in coastal North Carolina and Wisconsin, and I found no difference between North Carolina and Connecticut, it could be suggested that the demarcation between the subspecies lies further north and west than previously thought. These results are consistent with the findings of Schwaegerle and Schaal (1979) who found no significant genetic difference in *S. purpurea* populations between North Carolina and Michigan. Schwaegerle and Schaal (1979) obtained a mean genetic identity function (Nei, 1972) for their populations of .97 (a value close to 1 is the same entity while a value of 0 is a different species). Godt and Hamrick (1999) obtained values between .91 and .99 for infraspecific population pairs and a mean of .80 between infraspecific pairs. Godt and Hamrick's results (1999) suggest divergence between *S. purpurea* taxa . The historical difficulty identifying *S. purpurea* subspecies in the mid-Atlantic region may therefore be due to a misdiagnosis of the range of the northern taxon, if it even exists. In contrast, our study could distinguish *S. rosea* from both *S. purpurea* ssp. *venosa* var. *montana* and *S. purpurea* by the fact that restriction enzyme *Alu 1* failed to digest the *Chs* intron PCR product.

Morphological and biometric attempts to separate *S. purpurea* taxa have had limited success. Naczi et al. (1999) were able to separate the Gulf Coast populations of *S. purpurea* as a distinct species, *S. rosea*, based on height of the flower scape, flower color, lip width, and geographic disjunction. The morphological and geographic justification for separating *S. rosea* as a distinct taxon have now been supported by two genetic studies (Godt and Hamrick, 1999; Neyland, 2006), a morphometric study (Ellison et al., 2004), and the present research.

Ellison et al. (2004) were unable to morphologically separate the two putative subspecies of *S. purpurea* (ssp. *purpurea* and ssp. *venosa*) despite a detailed project covering 39 sites across the range of the taxon. Ellison et al. (2004) analyzed the morphological features traditionally used to separate the two taxa, the ratio of pitcher length to mouth diameter and thickness of pitcher lip, and were not able to differentiate the two taxa. Ellison et al. (2004) proposed that introgression and hybridization between the two subspecies may be responsible for failure to distinguish the subspecies but this hypothesis is refuted by Godt and Hamrick (1999) who did not detect significant levels of hybridization in *S. purpurea*.

The failure to morphologically separate ssp. *purpurea* and ssp. *venosa* is at odds with allozyme and nuclear DNA studies which have differentiated the taxa. Godt and Hamrick's (1999) *S. purpurea* ssp. *purpurea* material from Wisconsin and Minnesota overlapped the northwestern extreme of the range sampled by Ellison et al. (2004), yet the latter research group could not morphologically separate this subspecies using alleged traits for that species identification. Either the taxon is a molecular cryptic species or characteristics have not been identified to successfully differentiate the taxon from ssp. *venosa*. It is difficult to reconcile that Schwaegerle and Schaal (1979) genetically identified with allozymes one *S. purpurea* entity residing between coastal North Carolina and Michigan while Godt and Hamrick (1999), using the same technique, identified a different genetic entity in Wisconsin. The difference in results could be due to greater sensitivity of technique since Godt and Hamrick (1999) resolved more than double the number of loci as Schwaegerle and Schaal (1979). Alternatively, only one entity of *S. purpurea* may reside from the Georgia coast to northern Canada. If so, this would support Gleason and Cronquist's (1991) characterization of the geographic variation of the taxonomic unit as one entity, *S. purpurea*.

Sarracenia purpurea basically has a continuous distribution from the mid-Atlantic and the northeast to the mid-west (Fig. 6). I think it unlikely that a plant with a continuous distribution would be undergoing selection for subspecies since the classic mechanisms to prevent interbreeding are absent. The flower design of *Sarracenia purpurea*, and pollinator behavior, is conducive to cross pollination. However, abundant fertile seed is also produced with self-pollination (Schnell, 2002). Geographic separation has supported at least varietal evolution in var. *montana* and speciation in the clearly disjunct *S. rosea* since the ranges of these taxa are separate from *S. purpurea*.

The ongoing loss of purple pitcher plant populations in Maryland and Virginia, and the predicted extinction of those populations (see Census chapter), is a serious conservation and genetics issue. Godt and Hamrick (1999) pointed out that *S. purpurea* taxa are highly differentiated and expressed concern about loss of varieties. Schwaegerle and Schaal (1979) suggested that founder effect and subsequent genetic drift reduced genetic variability in the *S. purpurea* populations they studied. In contrast, Godt and Hamrick (1999) determined that genetic drift was not playing a major role in the evolution of purple pitcher plant. The current extinction event occurring in the mid-Atlantic clearly has genetic implications for the future of *S. purpurea*. While this study could not assess what rare *S. purpurea* alleles are being lost through extirpation in Maryland and Virginia, it is clear from the literature that efforts should be made to prevent further loss of *S. purpurea* so as to preserve unique genetic features of the taxon.

In conclusion, this study found no support for the occurrence of two subspecies of *S. purpurea* in Maryland and Virginia. Since morphological methods cannot separate putative subspecies, and genetic studies are equivocal, the taxononomic unit residing within the study region should be ascribed to one entity which I would identify as *S. purpurea*.

SOILS AND VEGETATION OF PURPLE PITCHER PLANT, *SARRACENIA PURPUREA* L., SITES IN MARYLAND AND VIRGINIA

Introduction

Wetland soils can be inhospitable places for plants to grow due to inundation and subsequent lack of oxygen for roots, leaves, and stems. Many plants have overcome wetland environmental stress by evolving leaves and stems that can absorb oxygen either in or on the surface of the water and transport oxygen to the roots (Barbour et at., 1998; Niering, 1985). Wetland soils typically contain predominantly ammonia, instead of nitrate, and at high concentrations ammonia can be lethal to plants (Britto and Kronzucker, 2002). Some wetland soils, notably bogs or seepage wetlands, typically have acid soils and are low in macro- and micro-nutrients adding further stress to plant growth and development (Crum 1992; Johnson, 1985).

Sarracenia pitcher plants, and other associated carnivorous plants in the genera *Drosera*, *Pinguicula*, and *Utricularia*, are thought to have evolved carnivory to obtain limiting elements such as nitrogen and phosphorus, which are lacking in their native soils (Juniper et al., 1989). Carnivorous plants occur in sphagnum peat bogs and fens of the United States and Canada and mineral seeps, pocosins, Atlantic white-cedar swamps, and wet flat woods of the southeastern United States (McPherson, 2006; Schnell, 2002). Sphagnum peat bogs, typically formed in scoured glacial depressions of the northeastern United States and Canada, are typically ombrotrophic (rain water fed) systems and as a result are low in nutrients (Johnson, 1985). However, sphagnum peat bogs can also form in shallow depressions with impoverished soil and impeded drainage (Niering, 1985). Southeastern United States pitcher plant wetlands are typically minerotrophic or ground water fed systems (Bridges and Orzell, 1989). While the groundwater does carry some nutrients, the soils in which southeastern pitcher plant bogs occur are typically silica based sand or sandy loams that are leached of nutrients by the seepage waters (Folkerts, 1982).

There are several ecological phenomena that typically characterize pitcher plant wetlands, notably nutrient poor acid soil, arrested succession, low productivity, and a unique suite of plant species (Folkerts, 1982; Niering, 1985). There are exceptions to these general habitat conditions, for example high pH marl fens. *Sarracenia* are normally present in most sites where these requisite environmental factors are present and persistent. *Sarracenia alata*, for example, was documented in 68% of hillside seepage bogs (Bridges and Orzell, 1989), demonstrating that pitcher plants are a relatively predictable part of the bog flora. Conversely, environmental perturbation (e.g. pollution or fire suppression) can quickly eliminate *Sarracenia* and other rare plant taxa from these habitats. Therefore, pitcher plants wetlands typically occur in sub-climax ecosystems (fire maintained wetland longleaf pine savannas for example) where competition is limited by nutrient poor soils and/or a mechanism is present to prevent succession (e.g. natural fire regime). The strong natural selection pressure exerted by these environmental effects has resulted in the evolution of carnivory in some plant species such as *Sarracenia purpurea*, the purple pitcher plant. Pitcher plants may avoid nutrient competition with some plants in a stressed environment by obtaining limiting nutrients such as nitrogen and phosphorus from the bodies of captured insects (Folkerts, 1982). However, the unique ecological niche that pitcher plants have filled is not without cost. The resources invested in producing carnivorous leaves apparently make pitcher plants poor competitors in the face of woody invasion and succession. Conversely, the poor competitive ability of pitcher plants may have driven the evolution of carnivory in a stressed environment. A case can also be made that pitcher plants facilitate succession, in the absence of disturbance events or nutrient exporting phenomena such as fire, since they capture and import limiting nutrients into a nutrient deficient ecosystem.

Sarracenia purpurea, the purple pitcher plant, occurs within sub-climax fire maintained ecosystems in Maryland and Virginia. The purple pitcher plant colonizes habitat through hydrarch primary succession by invading pond edges or by secondary succession when it recruits on moist mineral or organic soil after fire or mechanical disturbance. The ability of *S. purpurea* to obtain limiting elements such as nitrogen and phosphorus through carnivory gives it a unique advantage in capturing sites through primary succession.

Sarracenia purpurea is extirpated from habitat primarily by autogenic factors, when fire regimes are suppressed and invading hardwoods dominate the canopy and block too much light (Schnell, 2002). Additional negative impacts of hardwood invasion on purple pitcher plant include decreased water availability, lowered water tables, burial by hardwood detritus and fungal/and or bacterial infection. Ongoing climate change, via summer droughts, may provide allogenic succession and elimination of *S. purpurea*.

Succession typically results in increased soil depth, C pool, N pool, P pool, litterfall and decreased pH. This process of progressive succession in the temperate zone also results in increased plant species diversity in early succession but decreased diversity in late succession (Barbour et al., 1998). Local disturbance can put succession back to an earlier seral stage and maintain maximum diversity. The longleaf pine/pond pine forests of Virginia and the southeastern United States, and pitch pine and Atlantic white cedar forests of Maryland where purple pitcher plant grow, are fire maintained sub-climax high diversity ecosystems (Platt, 1999). *Sarracenia purpurea* is most abundant in northern peat bogs where glacial activity provided a setting for primary succession and establishment of large pitcher plant colonies (my observations).

No investigator has specifically studied the soils and vegetation of *S. purpurea*, purple pitcher plant, habitats on the western shore of Maryland and Virginia. If *S. purpurea* is adapted to nutrient poor, acid wetlands with a unique suite of rare plant species, then soil nutrient characteristics and plant communities should be predictable. If population declines of purple pitcher plant are caused by succession and pollution, and those effects also impact rare seepage wetland plant diversity, there should be a concomitant effect on rare plant taxa that correlates with soil factors and pitcher plant abundance. I therefore conducted a comprehensive study of a variety of soil variables, site characteristics, and vegetation to obtain baseline information on the habitat of *S. purpurea* and to see if the general predictions of pitcher plant habitat were met. Furthermore, I investigated whether any site differences that were found correlated with suspected *S. pupurea* subspecies in the study region.

Materials and Methods

Eighteen sites in Virginia and three in Maryland were visited throughout the growing season and plants growing within the habitat of *S. purpurea* colonies were recorded and checklists compiled. Site characteristics, location, and history have been previously described (Sheridan, Ph.D. dissertation). In addition, previous lists by other investigators (Sipple and Klockner, 1984; Simmons et al., 2003; D. Loomis, W. Sipple and R. Wright pers. comms.) of selected sites were used to augment and cross check my lists. Checklist preparation focused on the immediate growing area (within several hundred meters) of *S. purpurea*, which typically encompassed most if not all of the bog area and all associate, characteristic flora of the purple pitcher plant habitat. The number of state rare plant species, and species richness, was compiled for each site visited. A rarity quotient was also calculated for each site by dividing the total number of rare plant taxa found by the sum of state plant rarity scores. The rarity quotient was used to assess rare plant quality since there could be many rare plants at a site but of a low state score.

Soil samples were collected within 25 cm of *S. purpurea* within the top 10 cm of the soil profile (the plant root zone). Soil samples were collected from 2005 – 2009 using a chrome plated auger during the months of May – August. For comparative purposes, a purple pitcher plant site (Sharptown) on the Eastern Shore of Maryland was also sampled for soil macro- and micro-nutrients. If soil samples were not delivered to the testing lab within one day they were frozen until they could be sent to the lab. Three soil samples were collected per site and measured for pH, soluble salts, CEC (cation exchange capacity), % base saturation, OM (organic matter), Na, pH, K, Mg, Ca, NH_4, S, Zn, Cu, Mn, Fe, and B by A&L Eastern Laboratories in Richmond, VA. Soil analytic techniques followed the Agricultural Experiment Station of the University of Delaware (1995) as follows. Soil samples were dried in the lab under gentle, heated, forced air at 90 degrees F. Soil samples were then crushed and sieved to remove coarse debris and then minerals (active P, exchangeable K, Ca, Mg, Na, sulfate-S, extractable Zn, Mn, Fe, Cu, and B) were extracted with the Mehlich 3 method and quantified with Inductive Coupled Plasma (ICP) spectroscopy. CEC was determined by summing exchangeable cations and base saturation determined by dividing the respective cation by CEC. Percent organic matter was determined using the routine colorimetric determination with chromic acid digestion. Soil pH was determined with a pH meter in a 1:1 soil to water ratio, while soluble salts were determined with a conductivity meter utilizing a fixed soil:solution ratio of 1:2. Soil ammonium was extracted with 1 N KCl and quantified colorimetrically. Soil data were analyzed with analysis of means, ANOM (alpha 0.05), using Mintab statistical software. Raw data were log transformed to normalize and establish homogeneity of variance. Slope and aspect were compiled for each site while climatic data were compiled utilizing NCDC (National Climatic Data Center) 1971-2000 normals and from actual data from the nearest weather station to the respective sites. Climate normals are the arithmetic mean of a climatological element computed over three consecutive decades (World Meteorological Organization, 1989). NCDC meteorological data were typically not directly measured at the weather stations in Virginia at Corbin, Emporia, and Wakefield or in Maryland at Baltimore-Washington Airport (AP) and LaPlata. Data were supplemented with statistical calculations by NCDC (Larry Brown, NOAA pers. comm.). Additional data were compiled from the regional weather stations in Virginia at Norfolk AP, Suffolk-Lake Kilby, Williamsburg, Richmond AP, Farmville, and Maryland at Baltimore-Washington AP where direct measurements were made. Site nutrient means, pitcher plant abundance, species richness, number of rare species, and rarity quotient were then analyzed with a correlation analysis on Minitab statistical software.

Results

There was significant variation (ANOM, alpha = 0.05) among sites in almost all soil characteristics tested (Tables 4 and 5) with the exception of potassium where no differences were found. Zuni had the highest organic matter content at 11.4% while Depot Rd. and rt. 601 were low in organic matter at 2.9% (Table 4). Sites that had been polluted or suffered other impairment exhibited elevated levels of macro- and micro-nutrients such as Mg

(Cattail Creek and Howerton), Ca (Cattail Creek, Howerton, and MD Ave.), Na (Cattail Creek and MD Ave.), S (Arden2 and MD Ave), Zn (MD Ave), Fe (MD Ave), B (MD Ave) and soluble salts (Arden2 and Md. Ave.). Unimpaired sites that had significant elevated nutrient levels were Reddy Creek (Mg), Piney Branch (Na), Zuni (NH_4), Wakefield powerline (Zn and Mn), Chester (Cu), and Wakefield railroad (Cu). Significantly low levels of nutrients occurred for P (Cherry Orchard 2 and Wakefield railroad), Na (Byrum, Reedy Creek, and Wakefield powerline), S (Meadow Creek, Rt. 601, and Wakefield powerline), Zn (Depot Rd and Rt. 601), Mn (Bains), Fe (Depot Rd.), Cu (Addison and Arden1), and soluble salts (Byrum, Meadow creek, Rt. 601, and Wakefield railroad). Significant site patterns for pH included lows of 3.5 at Zuni and Bains, 3.7 at Addison to a high of 4.9 at Howerton and Piney Branch. Three sites had significantly high CEC (Cattail Creek @ 10.9, Md. Ave. @ 10.1 and Zuni @ 8.0) while two sites were significantly lower (Piney Branch @1.8 and rt. 601 @ 1.6). Cation exchange capacity was typically dominated by over 50% hydrogen ions with two sites having significantly less hydrogen ions (Howerton at 44.7% and Piney Branch at 43.8%). Base cation exchange was low with a significant high mean for calcium at Piney Branch (29.6%) and a significant low mean for sodium at Zuni (1.1%).

Table 4. Soil parameters for *S. purpurea* sites in Virginia and Maryland. Values are means with one s.d in brackets. Means that are significantly higher than the population mean with ANOM are denoted with + while those that are significantly lower are denoted with –. Values are in ppm unless indicated as percent.

Site	% OM	P	K	Mg	Ca	Na	pH	Hydr	CEC	%K	%Mg
Rt. 656	9.7 (1.1)	17.3 (2.3)	91.3 (15.6)	58.3 (7.6)	106.7 (30.6)	19.3 (0.6)	3.8 (0.1)	4.4 (0.7)	5.7 (0.9)	4.0 (0.20)	8.5 (1.4)
Addison	5.3 (0.3)	7.7 (1.2)	35.7 (7.1)	31.7 (7.6)	73.3 (23.1)	23.3 (4.2)	3.7- (0.2)	2.7 (0.5)	3.6 (0.6)	2.7 (0.88)	7.4 (0.7)
Airfield	6.9 (2.4)	9.0 (1.0)	53.0 (21.9)	23.3 (5.8)	56.7 (5.8)	21.3 (5.1)	3.9 (0.2)	2.2 (0.7)	2.9 (0.8)	4.5 (0.70)	6.7- (1.0)

Table 4. Continued

Site	% OM	P	K	Mg	Ca	Na	pH	Hydr	CEC	%K	%Mg
Arden 1	7.0 (3.1)	8.0 (2.0)	30.0 (22.3)	28.3 (16.1)	146.7 (106)	25.3 (13.1)	4.5 (0.1)	1.7 (1.0)	2.8 (1.8)	2.47 (0.95)	8.6 (1.9)
Arden 2	5.3 (0.4)	13.0 (1.0)	22.0 (4.0)	43.3 (5.8)	140.00 (10.0)	25.00 (4.4)	4.3 (0.3)	2.6 (1.1)	3.9 (1.2)	1.57 (0.31)	10.0 (3.1)
Bains	7.7 (3.7)	15.0 (1.7)	67.7 (29.5)	35.0 (15.0)	66.7 (11.5)	21.7 (2.3)	3.5- (0.2)	3.0 (0.9)	3.8 (1.1)	4.37 (1.07)	7.4 (1.2)
Byrum	4.1 (0.7)	13.0 (1.0)	24.7 (5.1)	31.7 (12.6)	73.3 (15.3)	13.3- (1.2)	4.3 (0.1)	1.5 (0.6)	2.2 (0.9)	3.03 (1.02)	11.9 (1.4)
Cattail Creek	7.7 (1.8)	11.7 (1.5)	75.7 (42.2)	130.0 + (61.4)	570.0 + (130.0)	70.0+ (16.1)	4.5 (0.1)	6.4+ (1.5)	10.9+ (2.7)	1.70 (0.56)	9.6 (2.0)
Cherry Orchard	7.0 (1.4)	8.3 (2.1)	48.7 (12.5)	86.7 (24.7)	293.3 (66.6)	19.7 (2.5)	4.3 (0.1)	4.9 (2.0)	7.3 (2.6)	1.73 (0.25)	10.1 (0.8)
Chester -Swift Creek	6.1 (1.0)	20.7 (12.4)	59.7 (29.2)	45.0 (18.0)	293.3 (291.6)	18.7 (3.2)	4.0 (0.3)	4.7 (1.7)	6.8 (3.4)	2.37 (1.08)	5.7- (0.5)
Dahlia	7.4 (1.2)	10.3 (3.5)	59.0 (15.6)	33.3 (15.3)	80.0 (26.5)	17.0 (2.0)	4.3 (0.1)	1.6 (0.4)	2.6 (0.7)	5.97+ (0.81)	10.6 (2.0)
Depot Rd.	2.9- (1.6)	8.3 (1.2)	21.3 (7.4)	33.3 (7.6)	126.7 (15.3)	16.7 (2.1)	4.5 (0.3)	1.6 (0.9)	2.7 (1.6)	2.10 (0.63)	11.0 (1.8)
Howert on	7.1 (0.3)	20.3+ (4.0)	48.0 (41.6)	170.0+ (67.3)	330.0+ (127.7)	33.3 (6.8)	4.9+ (0.2)	2.6 (0.4)	6.0 (1.3)	2.17 (1.87)	23.6+ (6.1)
Md. Ave.	7.8 (1.2)	13.7 (12.4)	65.7 (32.3)	63.3 (51.3)	656.7+ (806.5)	158.3+ (53.8)	4.4 (1.1)	5.4 (3.4)	10.1+ (4.4)	1.67 (0.31)	4.8- (2.5)
Meado w creek	4.8 (1.2)	13.7 (3.8)	32.0 (3.6)	35.0 (5.0)	70.0 (0.0)	19.0 (2.0)	3.9 (0.1)	2.6 (0.1)	3.5 (0.2)	2.37 (0.25)	8.4 (0.9)

Table 4. Continued

Site	% OM	P	K	Mg	Ca	Na	pH	Hydr	CEC	%K	%Mg
Cherry Orchard 2	7.9 (0.6)	6.3- (3.5)	58.0 (16.6)	36.7 (7.6)	76.7 (11.5)	19.3 (7.5)	3.9 (0.4)	2.5 (0.3)	3.5 (0.2)	4.33 (1.29)	8.9 (2.2)
Piney Branch	4.0 (1.5)	9.7 (2.5)	28.3 (10.0)	30.0 (8.7)	106.7 (25.2)	37.3+ (9.9)	4.9+ (0.1)	0.8- (0.3)	1.8- (0.5)	3.97 (0.81)	13.7 (1.5)
Reedy Creek	6.5 (1.9)	15.3 (2.3)	47.0 (13.0)	101.7+ (22.6)	110.0 (17.3)	15.0- (1.0)	4.5 (0.3)	2.5 (0.8)	4.0 (0.6)	2.97 (0.65)	21.8+ (8.0)
Rt. 601	2.9- (1.8)	12.0 (3.6)	25.3 (8.7)	25.0 (8.6)	56.7 (11.5)	16.3 (1.2)	4.5 (0.2)	1.0- (0.6)	1.6- (0.7)	4.23 (0.59)	13.5 (1.1)
Sharptown	8.8 (2.3)	16.7 (6.8)	64.0 (15.7)	46.7 (12.6)	110.0 (45.8)	21.3 (2.1)	4.2 (0.0)	2.8 (0.8)	4.0 (1.2)	4.27 (1.42)	9.8 (0.6)
Wakefield Powerline	4.9 (0.47)	15.7 (2.9)	41.0 (11.4)	48.3 (8.1)	84.0 (36.6)	15.3- (2.5)	4.1 (0.1)	2.6 (0.8)	3.6 (1.1)	3.0 (0.6)	11.5 (1.6)
Wakefield RR	4.8 (1.1)	4.3- (1.2)	28.3 (7.2)	60.0 (27.8)	250.0 (135.3)	24.0 (0.0)	4.5 (0.2)	2.6 (0.9)	4.5 (1.7)	1.70 (0.26)	10.9 (1.6)
Zuni	11.4+ (0.5)	14.3 (2.5)	60.0 (12.8)	58.3 (2.9)	226.7 (15.3)	20.3 (0.6)	3.5- (0.1)	6.2+ (0.4)	8.0+ (0.5)	1.93 (0.32)	6.1- (0.1)

Table 5. Soil parameters for *S. purpurea* sites in Virginia and Maryland. Values are means with one s.d in brackets. Means that are significantly higher than the population mean with ANOM are denoted with + while those that are significantly lower are denoted with –. Values are in ppm unless indicated as percent.

Site	%Ca	%H	%Na	NH_4	S	Zn	Mn	Fe	Cu	B	SS
Rt. 656	9.2- (1.6)	76.7 (0.0)	1.5- (0.2)	3.7 (0.6)	23.0 (2.7)	1.4 (0.2)	7.0 (2.7)	216.3 (91.5)	0.37 (0.06)	0.17 (0.06)	0.13 (0.00)
Addison	10.2 (1.3)	76.7 (0.0)	2.9 (0.9)	1.9 (0.5)	18.0 (1.7)	0.9 (0.1)	7.3 (5.9)	187.3 (82.8)	0.17- (0.12)	0.10 (0.00)	0.09 (0.01)
Airfield	9.9 (1.7)	75.6 (1.9)	3.2 (0.2)	2.5 (1.0)	21.3 (4.9)	1.3 (0.6)	2.0 (0.0)	354.7 (118.1)	0.23 (0.06)	0.10 (0.00)	0.09 (0.02)
Arden 1	25.2 (2.7)	59.4 (2.5)	4.3 (0.9)	0.9 (0.5)	33.0+ (13.5)	1.6 (1.1)	4.3 (3.1)	612.7 (540.8)	0.13- (0.06)	0.20 (0.10)	0.09 (0.03)
Arden 2	19.5 (5.9)	66.0 (10.3)	3.0 (1.0)	2.8 (1.3)	81.3+ (41.9)	1.8 (0.6)	2.0 (0.0)	198.0 (42.9)	0.33 (0.06)	0.17 (0.06)	0.27+ (0.11)
Bains	9.0- (1.8)	76.7 (0.0)	2.5 (0.5)	3.1 (0.4)	16.0 (2.7)	1.3 (0.5)	1.0- (0.0)	215.00 (50.2)	0.27 (0.12)	0.10 (0.00)	0.10 (0.03)
Byrum	17.3 (2.8)	64.9 (4.5)	2.9 (1.0)	12.6 (7.8)	13.3 (3.8)	1.2 (0.2)	2.7 (1.2)	326.3 (262.7)	0.20 (0.00)	0.13 (0.06)	0.05- (0.02)
Cattail Creek	26.3 (1.4)	59.4 (2.5)	2.9 (1.1)	3.2 (1.0)	12.0 (1.0)	2.6 (0.7)	7.0 (6.1)	153.3 (59.1)	0.90 (0.00)	0.13 (0.06)	0.16+ (0.04)
Cherry Orchard	20.7 (2.7)	66.2 (3.9)	1.3- (0.3)	2.6 (0.9)	13.3 (3.2)	1.7 (0.4)	7.3 (1.2)	346.3 (58.8)	0.30 (0.10)	0.10 (0.00)	0.07 (0.02)
Chester	18.6 (9.7)	71.9 (8.3)	1.3- (0.47)	1.4 (0.3)	16.3 (3.5)	2.3 (1.3)	12.7 (15.0)	157.0 (59.2)	1.00+ (0.61)	0.17 (0.12)	0.13 (0.02)
Dahlia	15.6 (1.5)	64.8 (2.2)	3.0 (0.5)	3.7 (0.6)	16.3 (1.5)	1.4 (0.5)	4.0 (2.7)	396.0 (20.1)	0.30 (0.10)	0.13 (0.06)	0.08 (0.03)

Table 5. Continued

Site	%Ca	%H	%Na	NH_4	S	Zn	Mn	Fe	Cu	B	SS
Depot Rd.	25.9 (7.7)	58.1 (10.6)	2.9 (0.8)	2.1 (0.9)	13.3 (1.5)	0.7- (0.2)	7.3 (4.9)	109.7- (78.7)	0.17 (0.06)	0.10 (0.00)	0.07 (0.01)
Howerton	27.0 (4.5)	44.7- (6.4)	2.5 (0.7)	7.2 (4.5)	23.0 (10.4)	2.5 (1.0)	11.0 (5.0)	413.0 (113.3)	0.27 (0.06)	0.10 (0.00)	0.12 (0.03)
Md. Ave.	27.3 (28.8)	58.9 (30.8)	7.3+ (2.0)	6.2 (6.8)	156.0+ (83.8)	6.6+ (5.2)	12.0 (7.6)	2495.0 + (1345.6)	0.23 (0.15)	0.50+ (0.26)	0.37+ (0.03)
Meadow creek	10.1 (0.5)	76.7 (0.0)	2.4 (0.3)	1.7 (0.5)	9.7- (1.2)	2.4 (0.4)	2.3 (0.6)	186.3 (29.3)	0.33) (0.06)	0.30 (0.35)	0.06- (0.01)
Cherry Orchard 2	11.1 (0.5)	73.2 (6.1)	2.5 (1.1)	3.4 (1.2)	18.3 (5.1)	1.2 (0.3)	2.0 (1.0)	742.0 (408.4)	0.20 (0.10)	0.13 (0.06)	0.08 (0.02)
Piney Branch	29.6+ (1.3)	43.8- (2.9)	9.0+ (0.7)	37.2 (59.6)	15.7 (4.5)	0.9 (0.3)	5.0 (1.7)	168.0 (65.5)	0.40 (0.10)	0.10 (0.00)	0.08 (0.01)
Reedy Creek	14.0 (3.7)	59.7 (12.0)	1.6 (0.2)	2.0 (2.1)	12.7 (2.3)	3.2 (0.6)	4.3 (0.6)	393.7 (134.9)	0.33 ((0.06)	0.10 (0.00)	0.07 (0.00)
Rt. 601	19.0 (3.8)	58.2 (6.8)	4.9+ (1.6)	1.9 (1.2)	11.0- (0.0)	0.8- (0.3)	4.3 (0.6)	226.7 (95.3)	0.27 (0.06)	0.13 (0.06)	0.05- (0.02)
Sharptown	13.4 (1.9)	70.1 (0.0)	2.4 (0.7)	No sample	18.3 (4.9)	1.4 (0.4)	2.3 (0.6)	528.3 (189.7)	0.30 (0.10)	0.17 (0.06)	0.10 (0.00)
Wakefield Powerline	11.3 (2.1)	72.4 (2.0)	1.9 (0.3)	2.9 (0.8)	10.3- (1.2)	4.4+ (0.9)	13.3+ (4.5)	223.0 (40.6)	0.5 (0.2)	0.3 (0.3)	0.13 (0.02)
Wakefield RR	26.6 (6.5)	58.2 (7.1)	2.6 (1.3)	1.9 (0.3)	16.7 (1.2)	2.1 (0.9)	1.7 (0.6)	646.0 (76.9)	1.63+ (0.85)	0.23 (0.06)	0.06- (0.01)

Table 5. Continued

Site	%Ca	%H	%Na	NH_4	S	Zn	Mn	Fe	Cu	B	SS
Zuni	14.2 (0.3)	76.7 (0.0)	1.1+ (0.1)	13.3+ (8.1)	14.3 (1.2)	3.3 (0.5)	3.3 (0.6)	95.0- (10.8)	0.40 (0.10)	0.10 (0.00)	0.09 (0.01)

Site slope was 1-2%. Purple pitcher plant site aspects included 12 sites facing south, 3 facing east, 2 facing west, and 4 facing north (Table 6).

Table 6. Slope and aspect of Maryland and Virginia *S. purpurea* sites.

Site	Slope	Aspect
Addison	1-2%	East
Airfield	1-2%	South
Arden	1-2%	South
Bains	1-2%	South
Byrum	1-2%	South
Cattail Creek	1-2%	South
Cherry Orchard	1-2%	South
Cherry Orchard 2	1-2%	South
Chester-Swift Creek	1-2%	West
Dahlia	1-2%	South
Depot Rd.	1-2%	South
Howerton	1-2%	South
Md. Ave.	1-2%	North
Meadow creek	1-2%	North
Piney Branch	1-2%	South
Reedy Creek	1-2%	North
Rt. 601	1-2%	North
Rt. 656	1-2%	South
Sharptown	1-2%	East
Wakefield RR	1-2%	West
Zuni	1-2%	East

Ten weather stations were located in close proximity or within the general boundaries of all remaining purple pitcher plant sites in Virginia (Corbin in Caroline County, Emporia in Greensville County, Farmville in Prince Edward County, Norfolk International AP, Richmond International AP, Suffolk-Lake Kilby in the City of Suffolk, Wakefield in Sussex County, Williamsburg in James City County) and the western shore of Maryland (La Plata in Charles County and Baltimore Washington AP in Baltimore). Average mean temperature ranged from a low of 54.6 ^{o}F at Baltimore to a high of 60.9 ^{o}F at Norfolk (Tables 7 & 8). Average mean precipitation ranged from lows of 41.4 inches at Baltimore and 41.2 inches at Farmville to a high of 49.1 inches at Williamsburg (Tables 9 & 10). In short, southern Virginia pitcher plant habitats are typically warmer and wetter than Maryland sites.

Table 7. Temperature normals 1971-2000 (Degrees Fahrenheit)

NO.	STATION NAME	ELEMENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
030	Corbin	MAX	44.2	48.0	56.9	67.2	75.4	83.0	87.1	85.6	79.4	68.8	58.8	48.5	66.9
		MEAN	34.8	38.1	46.3	55.6	64.3	72.5	76.8	75.3	68.9	57.3	48.2	39.2	56.4
		MIN	25.3	28.2	35.7	44.0	53.2	62.0	66.4	65.0	58.3	45.8	37.5	29.8	45.9
039	EMPORIA,1,WNW	MAX	49.0	52.3	60.9	70.8	78.2	85.4	89.2	87.7	81.9	71.8	62.5	52.8	70.2
		MEAN	37.7	40.4	48.2	57.2	65.6	73.4	77.9	76.2	70.0	58.6	49.4	41.2	58.0
		MIN	26.3	28.5	35.5	43.6	53.0	61.3	66.5	64.6	58.0	45.3	36.3	29.5	45.7
114	WAKEFIELD,1,NW	MAX	48.5	51.6	60.4	70.1	77.3	84.6	89.0	87.0	81.4	71.8	62.3	52.1	69.7
		MEAN	38.7	41.3	49.0	57.6	65.6	73.6	78.6	76.2	70.8	59.6	50.9	41.9	58.7
		MIN	28.8	31.0	37.5	45.1	53.8	62.6	68.2	65.3	60.2	47.4	39.4	31.7	47.6
004	BALTIMORE-WASHINGTON,AP	MAX	41.2	44.8	53.9	64.5	73.9	82.7	87.2	85.1	78.2	67.0	56.3	46.0	65.1
		MEAN	32.3	35.5	43.7	53.2	62.9	71.8	76.5	74.5	67.4	55.4	45.5	36.7	54.6
		MIN	23.5	26.1	33.6	42.0	51.8	60.8	65.8	63.9	56.6	43.7	34.7	27.3	44.2
029	LA PLATA,1,W	MAX	44.0	48.5	57.8	68.4	74.6	81.2	84.8	83.4	77.9	68.0	58.6	48.2	66.3
		MEAN	35.0	38.5	46.6	55.8	63.9	71.6	75.8	74.4	68.3	57.6	48.4	39.2	56.3
		MIN	26.0	28.4	35.4	43.2	53.2	61.9	66.8	65.4	58.7	47.1	38.1	30.1	46.2

Table 8. Temperature averages 1971-2000 and 2001-2009 (Degrees Fahrenheit).

Station Name	Element	Year	JAN	FEB	MAR	APR	MAY	JUN
BALTIMORE-WASHINGTON, AP	MAX	1971-2000	41.5	45.2	54.3	64.9	74.3	83.0
		2001-2009	42.4	45.0	54.2	65.8	73.8	83.1
	MEAN	1971-2000	33.2	36.2	44.4	53.9	63.5	72.5
		2001-2009	34.1	35.5	44.0	54.9	63.0	72.8
	MIN	1971-2000	24.8	27.2	34.5	42.9	52.8	62.0
		2001-2009	25.8	25.9	33.7	44.0	52.1	62.6
NORFOLK INTERNATIONAL, AP	MAX	1971-2000	48.7	51.3	58.9	68.1	75.9	83.7
		2001-2009	49.7	51.3	58.8	68.5	75.5	83.8
	MEAN	1971-2000	40.5	42.6	49.7	58.1	66.8	75.0
		2001-2009	41.5	42.8	49.9	59.2	66.7	75.9
	MIN	1971-2000	32.4	33.8	40.4	48.2	57.8	66.3
		2001-2009	33.4	34.2	41.1	50.0	57.9	67.9
RICHMOND AP	MAX	1971-2000	46.7	50.7	59.8	70.2	77.6	85.1
		2001-2009	48.4	51.0	60.0	70.5	77.2	85.8
	MEAN	1971-2000	37.1	40.2	48.4	57.7	66.1	74.2
		2001-2009	38.9	40.4	48.7	58.7	66.3	75.5
	MIN	1971-2000	27.6	29.7	37.0	45.3	54.6	63.3
		2001-2009	29.5	29.8	37.4	47.0	55.4	65.2
WILLIAMSBURG 2N	MAX	1971-2000	48.9	52.4	61.0	71.1	78.2	85.1
		2001-2009	49.6	52.1	60.6	70.6	76.8	84.5
	MEAN	1971-2000	38.5	41.2	48.8	57.8	66.1	73.7
		2001-2009	40.2	41.7	49.5	59.3	66.4	75.0
	MIN	1971-2000	28.1	29.9	36.6	44.4	54.1	62.3
		2001-2009	30.9	31.3	38.6	48.1	56.0	65.5
FARMVILLE 2N	MAX	1971-2000	47.6	51.8	60.8	70.9	77.8	85.1
		2001-2009	48.5	51.1	59.8	70.0	75.8	84.6
	MEAN	1971-2000	36.4	39.6	47.6	56.6	65.0	73.0
		2001-2009	37.3	38.5	46.4	56.6	63.8	73.2
	MIN	1971-2000	25.3	27.3	34.4	42.3	52.1	61.0
		2001-2009	26.0	25.9	32.9	43.1	51.8	61.8
SUFFOLK-LAKE KILBY	MAX	1971-2000	48.8	52.3	60.4	69.5	76.9	84.2
		2001-2009	50.2	52.9	60.6	70.4	76.5	84.3
	MEAN	1971-2000	39.5	42.2	49.6	59.0	66.4	74.1
		2001-2009	41.0	42.8	50.2	59.7	66.6	75.3
	MIN	1971-2000	30.2	32.1	38.8	46.7	56.1	64.1
		2001-2009	31.9	32.6	39.8	49.0	56.7	66.2

Table 8 (cont.).

Station Name	Element	Year	JUL	AUG	SEP	OCT	NOV	DEC	ANN
BALTIMORE-WASHINGTON, AP	MAX	1971-2000	87.5	85.4	78.5	67.3	56.5	46.3	65.4
		2001-2009	86.6	86.3	78.5	67.1	57.9	46.7	65.7
	MEAN	1971-2000	77.4	75.6	68.6	56.6	46.7	37.7	55.5
		2001-2009	76.7	76.6	68.5	56.8	47.9	37.9	55.8
	MIN	1971-2000	67.3	65.7	58.7	46.0	36.9	29.1	45.7
		2001-2009	66.7	66.9	58.5	46.5	37.9	29.0	45.9
NORFOLK INTERNATIONAL, AP	MAX	1971-2000	87.8	85.8	80.5	70.4	61.8	53.1	68.8
		2001-2009	87.1	86.5	79.5	70.7	62.3	54.5	69.1
	MEAN	1971-2000	79.6	78.0	72.7	61.8	53.0	44.7	60.2
		2001-2009	79.4	79.2	72.9	62.9	53.6	45.9	60.9
	MIN	1971-2000	71.3	70.1	64.9	53.2	44.1	36.3	51.6
		2001-2009	71.7	71.9	66.4	55.1	45.0	37.2	52.9
RICHMOND AP	MAX	1971-2000	89.0	87.1	80.9	70.4	60.8	50.9	69.1
		2001-2009	89.0	88.7	81.3	71.1	62.4	52.4	69.8
	MEAN	1971-2000	78.7	76.9	70.4	58.8	49.6	41.0	58.3
		2001-2009	78.8	78.9	71.4	60.6	51.7	42.6	59.4
	MIN	1971-2000	68.3	66.8	59.9	47.2	38.4	31.1	47.4
		2001-2009	68.7	69.1	61.5	50.1	41.1	32.8	49.0
WILLIAMSBURG 2N	MAX	1971-2000	89.0	87.1	81.6	71.5	62.4	53.0	70.1
		2001-2009	87.6	87.3	79.9	70.8	62.7	53.8	69.8
	MEAN	1971-2000	78.1	76.5	70.8	59.7	50.9	42.4	58.7
		2001-2009	78.3	78.3	71.3	61.2	52.5	44.1	59.9
	MIN	1971-2000	67.2	65.9	60.0	48.0	39.2	31.9	47.3
		2001-2009	69.1	69.4	62.8	51.6	42.4	34.3	50.0
FARMVILLE 2N	MAX	1971-2000	88.9	87.0	80.7	71.2	61.1	51.0	69.5
		2001-2009	87.2	87.9	79.5	69.9	61.9	51.3	69.1
	MEAN	1971-2000	77.2	75.4	68.8	57.6	48.3	39.9	57.1
		2001-2009	76.3	76.7	68.5	57.7	48.9	40.0	57.1
	MIN	1971-2000	65.4	63.8	56.9	44.1	35.4	28.7	44.7
		2001-2009	65.3	65.6	57.5	45.4	35.8	28.7	45.1
SUFFOLK-LAKE KILBY	MAX	1971-2000	88.0	86.2	80.5	70.7	61.8	52.9	69.4
		2001-2009	87.2	87.5	80.7	71.6	63.1	54.5	70.1
	MEAN	1971-2000	78.5	76.9	71.2	60.4	51.5	43.3	59.3
		2001-2009	78.5	78.8	72.2	62.3	53.0	45.0	60.5
	MIN	1971-2000	68.9	67.5	61.9	50.1	41.0	33.7	49.3
		2001-2009	69.7	70.1	63.6	53.0	42.8	35.5	51.0

Table 9. Precipitation normals 1971-2000 (Total in Inches)

NO.	STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
030	Corbin	3.72	3.17	4.21	3.26	4.02	3.60	4.34	3.70	3.97	3.89	3.33	3.33	44.54
039	EMPORIA,1,WNW	3.96	3.14	4.16	3.34	3.88	3.30	4.54	4.34	4.21	3.46	2.98	3.05	44.36
114	WAKEFIELD,1,NW	4.14	2.87	4.32	3.39	4.23	3.62	4.51	4.35	4.74	3.28	2.76	2.84	45.05
004	BALTIMORE-WASHINGTON,AP	3.47	3.02	3.93	3.00	3.89	3.43	3.85	3.74	3.98	3.16	3.12	3.35	41.94
029	LA PLATA,1,W	3.42	2.85	3.96	3.11	4.13	3.81	4.12	4.60	4.31	3.36	3.21	3.16	44.04

Table 10. Precipitation averages 1971-2000 and 2001-2009.

Station Name	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
BALTIMORE-WASHINGTON, AP	1971-2000	3.5	3.0	3.9	3.0	3.9	3.4	3.9	3.7	4.0	3.2	3.1	3.4	41.9
	2001-2009	2.5	2.5	3.3	4.0	4.6	4.4	4.8	3.5	3.8	4.5	3.4	3.4	44.4
NORFOLK INTERNATIONAL, AP	1971-2000	4.1	3.6	4.4	3.3	3.9	4.0	5.0	5.6	5.0	3.6	3.1	3.3	48.6
	2001-2009	2.8	2.4	3.5	3.7	4.5	5.0	5.0	4.8	5.2	4.2	3.9	3.9	48.7
RICHMOND AP	1971-2000	3.6	3.0	4.1	3.2	4.0	3.5	4.7	4.2	4.0	3.6	3.1	3.1	43.9
	2001-2009	2.4	2.1	3.4	3.4	4.1	4.9	4.8	6.0	4.7	3.2	3.2	3.3	46.5
WILLIAMSBURG 2N	1971-2000	4.2	3.4	4.6	3.2	4.5	3.4	5.3	5.0	5.0	3.6	3.4	3.3	49.0
	2001-2009	2.7	2.5	3.4	4.6	3.8	3.7	5.8	5.9	5.3	4.6	3.2	3.7	49.1
FARMVILLE 2N	1971-2000	4.0	3.3	4.3	3.3	4.3	3.2	4.2	3.9	3.9	3.8	3.4	3.2	44.7
	2001-2009	2.4	2.0	3.6	3.2	3.9	3.6	3.9	3.8	4.3	3.8	3.3	3.2	41.2
SUFFOLK-LAKE KILBY	1971-2000	4.1	3.6	4.4	3.3	3.9	4.0	5.0	5.6	5.0	3.6	3.1	3.3	48.6
	2001-2009	2.8	2.4	3.5	3.7	4.5	5.0	5.0	4.8	5.2	4.2	3.9	3.9	48.7

While no sub specific differences were found in Maryland and Virginia for *S. purpurea*, there were differences in checklists (Appendices C and D), rare plant associates, and species richness in purple pitcher plant bogs. Maryland sites had 19 state listed rare plant taxa while Virginia purple pitcher plant bogs had 35 state listed and one federally threatened plant species (Table 11). Species richness and number of rare species ranged from lows of 11 and 0, respectively, at Cattail Creek in Dinwiddie County, Virginia to a high of 118 species at Piney Branch Bog in Charles County, Maryland and 14 rare species at Cherry Orchard Bog in Sussex County, VA. Average species richness in Virginia purple pitcher plant bogs was 31 versus 74 in Maryland. Rarity quotient ranged from a low of 0.0 at Cattail Creek and Byrums's in Virginia to a high of 0.67 at Zuni and Seacock Swamp. The Maryland purple pitcher plant sites had rarity quotients ranging from 0.44 to 0.48. (Table 12).

Table 11. Rare, threatened, and endangered plant species in Western shore Maryland and Virginia *S. purpurea* bogs.
*Global Rank: G2 = Imperiled - At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines or other factors; G3 = Vulnerable – At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread decline, or other factors; G4 = Apparently Secure – Uncommon but not rare, some cause for long term concern due to declines or other factors; G5 = Secure – common, widespread and abundant. G_T_ = Infraspecific taxa – Signifies the rank of a subspecies or variety.
State Rank; S1 = Critically Imperiled – At very high risk of extirpation from the state due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors; S2 = Imperiled – At high risk of extinction in the state due to a restricted range, very few populations (often 20 or fewer), steep declines, or other factors; S3 = Vulnerable – At moderate risk of extirpation from the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors, S_? = Inexact Numeric Rank. Federal Status: E = Endangered – A taxon is threatened with extinction throughout all or a significant portion of its range; T = Threatened – A taxon is likely to become endangered in the foreseeable future. State Status: E = state endangered; T = state threatened.

State and species	Global Rank*	State Rank*	Federal Status*	State Status*
Maryland				
Bartonia paniculata	G5	S3		
Bidens discoidea	G5	S3		
Carex exilis	G5	S1		E
Carex venusta var. *minor*	G4	S2		T
Carex vesicaria	G5	S1		T
Chamaedaphne calyculata	G5	S1		T
Drosera rotundifolia	G5	S3		
Eleocharis tortilis	G5	S3		
Epilobium ciliatum	G5	S1		E
Eriophporum virginicum	G5	S3		
Juncus caesariensis	G2	S1		E
Juncus longii	G3G4Q	S1		E
Platanthera blephariglottis	G4G5	S2		T
Platanthera ciliaris	G5	S2		T
Rhynchospora alba	G5	S3		
Sarracenia purpurea	G5	S2		T
Smilax pseudochina	G4G5	S2		T
Thelypteris simulata	G4G5	S2		T
Vaccinium macrocarpon	G4	S3		
Virginia				
Aletris aurea	G5	S1		
Asclepias rubra	G4G5	S2		
Carex collinsii	G4	S3		
Chelone cuthbertii	G3	S2		
Cirsium virginianum	G3	S2		
Ctenium aromaticum	G5	S1		
Drosera brevifolia	G5	S3		
Drosera capillaris	G5	S3		

Table 11. Continued				
State and species	Global Rank*	State Rank*	Federal Status*	State Status*
Eriocaulon decangulare	G5	S2		
Eriophorum virginicum	G5	S3		
Helenium brevifolium	G4	S2		
Helonias bullata	G3	S2S3	T	E
Iris prismatica	G4G5	S3		
Juncus abortivus	G4G5	S1		
Juncus caesariensis	G2	S2		T
Juncus longii	G3?	S3?		
Kalmia angustifolia	G5	S2		
Lachnocaulon anceps	G5	S2		
Lilium pyrophilum	G2	S1		
Ludwigia hirtella	G5	S1		
Ludwigia glandulosa	G5	S3		
Pinus palustris	G5	S1		
Platanthera blephariglottis	G4G5	S1		
Pogonia ophioglossoides	G5	S3		
Polygala cruciata var. *cruciata*	G5T4T5	S3?		
Rhexia petiolata	G5?	S1		
Rhynchospora fasicularis	G5	S2		
Rhynchospora rariflora	G5	S3		
Sabatia campanulata	G5	S2		
Sarracenia purpurea	G5T3T5	S2		
Scleria minor	G4	S2		
Solidago uliginosa var. *uliginosa*	G4G5T4T5	S2		
Utricularia geminiscapa	G4G5	S3		
Xyris difformis var. *curtisii*	G5T5	S1		
Zigadenus glaberrimus	G5	S1		

Table 12. Species richness and rare plant quality at *Sarracenia purpurea* sites in Virginia and Maryland.

Site	Species richness	Number of rare species	Total rare species score	Rarity quotient
Rt. 656	16	2	5	0.40
Addison	45	13	28	0.46
Airfield	12	2	5	0.40

Table 12. Continued

Site	Species richness	Number of rare species	Total rare species score	Rarity quotient
Arden	48	12	25	0.48
Bains	16	2	3	0.67
Byrum	19	0	0	0
Cattail Creek	11	0	0	0
Cherry Orchard	83	14	27	0.52
Chester-Swift Creek	52	5	10	0.50
Dahlia	47	3	8	0.38
Depot Rd.	42	5	11	0.45
Howerton	43	1	3	0.33
Md. Ave.	55	8	18	0.44
Meadow creek	22	2	4	0.50
Cherry Orchard 2	22	1	2	0.50
Piney Branch	118	11	23	0.48
Reedy Creek	39	9	20	0.45
Rt. 601	25	3	8.5	0.35
Wakefield Powerline	24	4	8	0.50
Wakefield RR	22	4	9	0.44

Table 12. Continued

Site	Species richness	Number of rare species	Total rare species score	Rarity quotient
Zuni	25	4	6	0.67

Correlation analysis of soil and vegetative characteristics revealed a number of significant interactions (Table 13). The most ecologically interesting relationships occurred between vegetative characteristics, pH, and percent nutrients on CEC. Species richness positively correlated with pH while the rarity quotient and acidity had a negative correlation. Species richness also positively correlated with percent calcium, percent sodium, and ammonium.

Table 13. Correlation analysis of soil and vegetative characteristics. Values are correlation coefficient and *p* value.

	% OM	P	K	Mg	Ca	Na	pH	Hydr	CEC	%K	%Mg	%Ca	%H	%Na	NH_4	S	Zn	Fe	B	Species richness
K	0.81																			
	0																			
Ca				0.596																
				0.003																
Na					0.818															
					0															
pH	-0.469																			
	0.028																			
Hydr	0.688		0.686	0.449	0.716	0.449														
	0		0	0.036	0	0.036														
CEC	0.59		0.625	0.613	0.894	0.634		0.946												
	0.004		0.002	0.002	0	0.002		0												
%K				-0.427	-0.593			-0.489	-0.562											
				0.048	0.004			0.021	0.007											
%Mg				0.584			0.645													
				0.004			0.001													
%Ca					0.594	0.452	0.831			-0.47										
					0.004	0.035	0			0.027										
%H							-0.955				-0.643	-0.872								
							0				0.001	0								
%Na						0.554	0.5						-0.578							
						0.008	0.018						0.005							
NH_4													-0.443	0.617						

Table 13. Continued

	% OM	P	K	Mg	Ca	Na	pH	Hydr	CEC	%K	%Mg	%Ca	%H	%Na	NH_4	S	Zn	Fe	B	Species richness
													0.039	0.002						
S					0.564	0.832								0.466						
					0.006	0								0.029						
Zn					0.652	0.701		0.536	0.628	-0.426						0.625				
					0.001	0		0.01	0.002	0.048						0.002				
Mn		0.492			0.504				0.45								0.525			
		0.02			0.017				0.035								0.012			
Fe					0.585	0.847								0.459		0.842	0.669			
					0.004	0								0.032		0	0.001			
B					0.454	0.682										0.702	0.768	0.747		
					0.034	0										0	0	0		
SS					0.648	0.8		0.447	0.561							0.916	0.67	0.662	0.642	
					0.001	0		0.037	0.007							0	0.001	0.001	0.001	
Number of plants											0.54									
											0.012									
Species richness							0.473					0.506	-0.516	0.536	0.615					
							0.03					0.019	0.017	0.012	0.003					
Rarity quotient							-0.454													
							0.039													
Number of rare species																				0.732
																				0

Discussion

No genetic differences were found in mid-Atlantic *S. purpurea* populations to warrant splitting the taxon into two subspecies within the study region. Soil, vegetation, and site characteristics were examined to determine if differences in these features would correspond with the two putative subspecies. Since no subspecies differences were found in mid-Atlantic *S. purpurea*, the secondary questions were rendered moot from a taxonomic standpoint. However, given the documented extinction vortex occurring within mid-Atlantic *S. purpurea* populations, analysis of soil, vegetation, and site characteristics take on new meaning in terms of what factors may be driving extirpation. In addition, comparing the data to research on similar wetland habitats in the region and pitcher plant habitats in general may shed light on the health of local pitcher plant habitats. This study is the first research to examine soil macro- and micro-nutrients in regional pitcher plant wetlands. Not surprisingly, polluted sites had significantly higher levels of some nutrients compared to non-polluted sites. In general, the soil nutrients I measured are consistent with conventional dogma that pitcher plants occur in nutrient deficient sites that are low in pH.

Soil/ plant relations

While a number of correlations were found between soil variables the important areas to emphasize are the interaction between soil and vegetation. Glaser (1992) found that sodium was significantly related to species richness in raised bogs of North America. My research found that species richness positively correlated with percent calcium, percent sodium, and ammonium. Species richness also positively correlated with pH while the rarity quotient and acidity had a negative correlation. Species richness positively correlated with the number of rare species while number of pitcher plants positively correlated with percent magnesium. These results suggest that as nutrient levels increase, species richness and number of rare species increase. However, the quality of rare species (rarity quotient) declines as pH increases and acidity decreases, indicating that the high value rare plants found in purple pitcher plant bogs are not only adapted to a unique niche in acidic conditions but are also adversely impacted by increasing nutrients levels. The correlation analysis therefore provided quantitative support for longstanding views on rare species quality in pitcher plant bogs. Rare acidophilic species have a specially adapted niche which is perturbed by increasing nutrients.

Comparison of soil characteristics

Significant differences in technique, equipment, and technological advances hinder direct comparison of some of my soil characteristics to the work of Plummer (1963) on pitcher plant soils in Georgia and Whigham and Richardson's (1988) research on Maryland bogs and Atlantic white-cedar soils. However, despite these differences various conversions can be made, in most cases, to provide a comparison of soil characteristics. Soil analyses by other researchers of pitcher plant habitats has also been summarized by Herman (1990) and allow me to prepare a regional table (some values corrected/added after reviewing original papers and additional publications) of southeastern U.S. pitcher plant soil characteristics (Table 14). Where necessary and possible, soil measurement units were converted to ppm for ease of comparison.

Table 14. Selected soil variables at pitcher plant sites throughout the Southeast. Nutrients converted to ppm for comparison unless otherwise noted.

Source	State	pH	Calcium	Magnesium	Nitrogen	Phosphorus	Potassium
Barker and Williamson 1988	LA	3.8-4.7	40-150	5-55	---	5	6-20
Eleuterius and Jones 1969	MS	4.0-5.5	---	---	9-45	30-35	42-63
Macroberts and MacRoberts 1988 and 1991	LA	4.5-5.2	80-410	13-176	---	1-4	20-82
Nixon and Ward 1986	TX	4.3-5.3	146-670	38-283		1-4	8-76

Table 14. Continued

Source	State	pH	Calcium	Magnesium	Nitrogen	Phosphorus	Potassium
Norquist 1984	MS	4.7-5.0	34-330	4-28	---	1-3	7-15
Plummer 1963	GA	3.9-5.0	34-72	157-253	---	1.4-4.0	8-43
Sheridan In Prep.	VA	3.5-4.9	56-657	23-170	---	4.3-20.3	21-91
Taggart, 1990	NC	4.2-4.4	47.2-56.5	15.4-22.1	---	1.9-2.9	24.1-24.9
Weiss 1980	GA	4.4-5.5	15-60	8-20	275-675	1-4	5-16
Whigham and Richardson 1988	MD	4.2-5.3	179-1808	211-1418	---	---	441-1622
Walker 1985	NC	4.0-4.5	380-394 mg/dm^3	181-187 mg/dm^3	---	4.5-4.8 mg/dm^3	.41-1.65 mg/dm^3

While nutrient extraction techniques may have differed among researchers there are several soil characteristics that can be compared. Organic matter is a relatively major component of pitcher plant soils since these are wetland habitats conducive to slow decomposition and accumulation of peat. Plummer (1963) measured organic matter with a range of means between 2 - 2.4% in his Georgia samples while MacRoberts and MacRoberts (1988, 1991) recorded a range of 0.6 – 2.1 % . The mean of organic matter in Maryland and Virginia purple pitcher plant bogs ranged between 2.9 – 11.4% , higher than the Georgia and Louisiana pitcher plant soils. Somewhat surprisingly, the highest organic matter in my study area was for Zuni at 11.4%. I thought that the quaking bog at Arden in Anne Arundel County, MD would have the highest organic matter but such was not the case. The higher organic matter content of Maryland and Virginia purple pitcher plant sites compared to Louisiana and Georgia is likely due to several factors. First, many sites in my study area are suppressed and undergoing succession where one would expect high organic content as opposed to fire maintained longleaf pine ecosystems in Georgia and Louisiana.

Second, even though Zuni is now fire maintained, the peaty pockets where purple pitcher plants are found burn infrequently and would typically be wetter historically than Georgia savannas. Third, Virginia and Maryland bogs tend to reflect a northern element of peat accumulation in pitcher plant wetlands. In particular, the Maryland pitcher plant bogs are topographically located where one would expect significant organic matter accumulations versus the mineral soil wetlands of southern pitcher plant bogs. Fourth, purple pitcher plant tends to grow in wetter sites than other pitcher plant species. Wetter sites may accumulate more organic matter.

Soil calcium, potassium, and phosphorus decrease in abundance in pitcher plant bogs during the growing season because of seasonal uptake and use by plants (Plummer, 1963). Growing season fire can release nutrients accumulated in biomass making these minerals available for uptake while winter burns can result in loss of nutrients and a temporary (one year) reduction of phosphorus and potassium in pitcher leaves and nitrogen, phosphorus, calcium, and magnesium in soil (Weiss, 1980). Fire in pine-wiregrass savannas can add significant quantities of nutrients such as PO_4, K^+, Ca^{++}, and Mg^{++}, although significant amounts of nutrients are lost to the atmosphere (Christensen, 1977). Soil pH slightly rises after a winter burn in pitcher plant bogs, while no change was detected with summer burns (Weiss, 1980). When I compare my soil nutrients to the results of other researchers (Table 13), phosphorus and potassium levels seem generally higher, but still within the range or slightly above that of the other researchers (except Whigham and Richardson to be discussed later). Purple pitcher plant bogs in my study area are almost all long-term fire-suppressed sites while most of the other pitcher plants bogs have a long-term fire history. Phosphorus and potassium levels may have increased in Virginia and Maryland pitcher plant bogs due to lack of fire. On the other hand, fire maintained sites may be able to recapture and mineralize nutrients and maintain nutrient pools (Christensen, 1977).

Plummer (1963) reported a mean range for available P_2O_5 of 6.5 – 19 lbs/acre (1.4 – 4.1 ppm P). I measured a mean range of 19.78 lbs/acre (4.3 ppm P) at Wakefield Railroad to 93.38 lbs/acre (20.3 ppm P) at Howerton. Eleuterius and Jones (1969) reported high P levels, for pitcher plant bogs, ranging from 140 – 160 lbs/acre (30-35 ppm). Typical phosphorus levels in southeastern bogs ranged from 1-5 ppm. Maryland and Virginia purple pitcher plant bog phosphorus levels start on the high end of most southeastern U.S. pitcher plant bogs. However, Maryland and Virginia pitcher plant site phosphorus levels are still considered low to very low by soil test standards and much lower than those reported by Eleuterius and Jones (1969). More importantly, at the pH ranges on my sites little or no phosphorus is available since it could precipitate with iron, aluminum, and manganese.

No significant difference in potassium levels was found between Maryland and Virginia purple pitcher plant sites. I recorded a mean range of 42 – 182 lbs/acre (21 – 91 ppm) for potassium with an overall mean of 93 lbs/acre (46.5 ppm). Plummer (1963) reported potassium in trace amounts of less than 40 lbs/acre (20 ppm) after June, which is considered deficient for the coastal plain. Eleuterius and Jones (1969) reported a range of 100 – 150 lbs/acre (42-63 ppm) potassium in *S. alata* bogs and reported that their bogs were not deficient in N-P-K. MacRoberts and MacRoberts (1988, 1991) reported a soil potassium range of 20 – 82 ppm. Potassium and phosphorus were typically found in higher concentration in mid-Atlantic pitcher plant bogs compared to Plummer's Georgia savannas but fell within the range for southeastern pitcher plant wetlands. Examination of my soil data disclosed that the overall site mean of 93 lbs/acre potassium (46.5 ppm) is considered a medium level of this nutrient and hence my purple pitcher plant soils are typically not K deficient. In contrast, Whigham and Richardson (1988) recorded relatively high potassium levels, ranging from 441-1622 ppm in their bogs.

Whigham and Richardson (1988) also reported the highest ranges for calcium (179-1808) and magnesium (211-1418) compared to any of the other pitcher plant bogs. Whigham and Richardson also found higher levels of sodium (89-841 ppm) compared to purple pitcher plant sites in Maryland and Virginia (13-158 ppm). Concentrations of calcium, magnesium, potassium, and sodium were typically an order of magnitude greater in Whigham and Richardson's study (1988) than in my purple pitcher plant sites. Only impaired sites such as Cattail Creek (657 ppm for calcium), Howerton (170 ppm for magnesium), and Md. Ave. (158 ppm for sodium) had measurements close or in the range of those reported by Whigham and Richardson. Two of the sites sampled by Whigham and

Richardson (1988), Cypress Creek and Angels Bog, were known historic purple pitcher plant sites. While purple pitcher plant has not been documented from all the bogs sampled by Whigham and Richardson, the associate plants found in those sites suggest their historic occurrence and comparison of soil nutrients was warranted. Elevated levels of nutrients at former purple pitcher plant sites in Maryland may reflect a history of environmental degradation, pollution, and succession. In fact, Whigham and Richardson (1988) suggested rising tidal waters were influencing cation levels at Cypress Creek. Whigham and Richardson (1988) also detected high lead levels in Atlantic white-cedar at Cypress Creek, which I ascribe to contamination from a nearby major road. Storm water from roads and attendant pollution from development could provide a source for elevated nutrient levels (pollution) of sensitive, former pitcher plant wetlands in Maryland. Alternatively, the slightly different extraction techniques used by Whigham and Richardson may have resulted in their higher reported nutrient levels in bogs. However, extraction technique does not have a major effect on potassium levels (Paul Chu, pers. comm.). Whigham and Richardson reported potassium levels ranging from 441 – 1622 ppm, far in excess of levels measured by any other researcher, with the upper level considered toxic to plants (Paul Chu, pers. comm.).

Plummer (1963) reported total cation exchange capacity (CEC) ranging from 5.57 to 9.17 (my calculation based on reported miliequivalents) in his moist pine barren pitcher plant bogs while my range was 1.8-10.9. CEC is determined by estimating the miliequivalents of exchangeable H, K, Mg, and Ca in a 100g air dried soil sample. My overall soil averages were 0.83 meq Ca, 0.13 meq K, and 0.48 meq Mg. while Plummer recorded averages of 0.29 meq for Ca, 0.051 meq for K, and 1.75 meq for Mg. Therefore, while my study sites have higher average cation exchange than Georgia pitcher plant wetlands for calcium and potassium they are lower for magnesium and tend to generally have a lower CEC. Obviously, most of the CEC is occupied by hydrogen ions in these acidic sites but it is important to point out the similarities and differences in other ions between Virginia, Georgia, and Maryland pitcher plant bogs. What seems to be rather consistent is that Virginia and Maryland pitcher plant study sites are closer chemically to the southeastern pitcher plant soils than they are to the bogs and white-cedar habitats studied by Whigham and Richardson (1988). However, the higher levels of nutrients found in the bogs studied by Whigham and Richardson may reflect ongoing anthropogenic inputs of nutrients in this heavily developed and urban part of Maryland since high lead levels were detected in plant tissue. The lowest levels of nutrients in Whigham and Richardson's sites (Eagle Hill Bog) also occurred in the least disturbed or impacted site (my observations).

Soil pH of my study sites ranged from 3.5 at Zuni to 4.9 at Howerton and Piney Branch. All of these pH measurements are consistent for pitcher plants occupying acidic wetland habitats in the southeastern United States. In contrast, raised bogs in eastern North America containing *S. purpurea* are all below pH 4.2 (Glaser, 1992).

Maryland. Ave. had high levels of sulfur, zinc, iron, and boron. High levels of sulfur were also found at Arden bog. The high levels of sulfur at two Maryland sites are not surprising since not only is this element detectable through smell at these habitats but sulfur bacteria have been isolated at Arden bog (Keith Underwood pers. comm.). High levels of copper were detected at both Wakefield railroad and Chester Swift Creek. The proximity of the railroad at the Wakefield site may provide a possible industrial contamination explanation while the Chester levels appear to be indigenous. Soluble salts were low to very low in all sites examined. Comparison between sites demonstrated that Arden, Cattail Creek, and Md. Ave. had significantly higher levels of soluble salts relative to average sites while Byrum, Meadow Creek, rt. 601, and Wakefield railroad were significantly lower. Soluble salts became significantly elevated at Arden Bog (Arden2) after the flooding event from late 2007-2008. Prior soluble salt measurements (Arden1) taken before flooding in 2007 were similar to overall average concentrations in my other study sites. There was no other chemical signature detected from the flooding event at Arden Bog other then elevated levels of soluble salt. The causes for elevated soluble salt are not clear other than downstream mineral transport from local development.

Chemical Fertilization and Pollution

Eleuterius and Jones (1969) reported a decrease in *S. alata* with two applications of 6-12-12 fertilizer at 1 lb/100 sq. ft. When their low and high base soil level of N-P-K is used (assuming P and K reported as P^2O^5 and K^2O), nutrient treatments added (assuming two applications per plot), and calculations made of final soil nutrient level, I estimated ranges as follows: N 35-71 ppm; P 53-58 ppm; K 85-106 ppm. These are conservative estimates since they assume equal distribution of the added nutrients within the first 15 cm of soil. However, they are important calculations to make since negative effects of this fertilizer application were observed on *S. alata*. I hypothesize that elevated nutrient levels are deleterious to *Sarracenia*. Furthermore, determining what nutrient levels are deleterious in pitcher plant bogs is essential to know from a management and conservation standpoint. Based on my manipulations of Eleuterius and Jones data, and comparing to the data of Plummer, Weiss (1980) and myself, the nutrient that appears to exceed natural levels and most likely to induce toxic effects was phosphorus. While phosphorus is likely a limiting nutrient in most southeastern pitcher plant bogs it was not in the Mississippi bog studied by Eleuterius and Jones (1969) and phosphorus additions apparently reached deleterious levels. This conclusion is further supported by the lack of toxic fertilizer effects in *S. flava* (Weiss, 1980). Weiss measured soil nutrient levels after several fertilizer applications and measured levels between treatments and controls as follows: N 400-1500 ppm; P 1-7 ppm; K 7-30 ppm. Phosphorus toxicity is known in other taxa, such as the Proteaceae (Hawkins et al., 2008), which are adapted to highly leached soils low in phosphorus. Pitcher plant bogs of the southeast are typically highly leached sandy loams, low in phosphorus, and it is not surprising that *Sarracenia* may not only have efficient phosphorus uptake but also sensitivity to this nutrient. Alternatively, Eleuterius and Jones may have detected potassium toxicity for *Sarracenia*. I think this is much less likely since I recorded potassium levels in one of my *S. purpurea* sites that would be in the presumed toxic zone for Mississippi *S. alata* yet did not observe mortality. A third possibility is that different *Sarracenia* species have differential susceptibility to elevated nutrient levels. Further research is needed on both the beneficial and negative levels of nutrients in *Sarracenia* horticulture and ecology.

I find it interesting that three sites (Cattail Creek, Howerton, and Md. Ave.) which have either lost their pitcher plant population, or are in the process of losing them, all have significantly higher levels of calcium, magnesium, and sodium than the rest of my study sites. Furthermore, levels of magnesium at Howerton and sodium at Md. Ave. are even high to very high by soil testing standards. I think the loss of pitcher plants at these sites and elevated nutrient concentration is not coincidental. All three sites adjoin primary or secondary roads and pollution from road activities or parallel power lines (salting of roads, herbicide spraying, general pollution, etc.) have apparently had a negative impact on these pitcher plant populations. This conclusion is consistent with the dogma that pitcher plants occur in low nutrient environments and are adversely impacted or eliminated when nutrient concentrations increase, as demonstrated by Eleuterius and Jones (1969). However, nutrient enrichment is not the only cause for purple pitcher plant extirpation since succession and competition may have an even greater negative effect. For example, Byrum bog has relatively low nutrient levels with no clear chemical perturbation signal yet the extirpation of this population was observed over only a short period of time from succession. Therefore, while chemical pollution may have a negative or lethal effect on *Sarracenia* populations, succession has a much more powerful negative impact and typically extirpates purple pitcher plant before pollution. Since increasing levels of nutrients in nutrient deprived bog systems would tend to enhance succession, there is also the possibility of a synergistic effect between succession and nutrient pollution eliminating *S. purpurea* from habitat.

Ellison and Gotelli (2002) and Gotelli and Ellison (2002) have shown that long term, annual increases in nitrogen deposition and direct application of ammonium pose both an extinction risk and can cause deformity in purple pitcher plant leaves. Both phenomena suggest that ammonium can be a toxic compound to *S. purpurea* at certain levels. Ammonium toxicity varies widely in plants, and within genera, but negative effects can generally be seen when soil concentrations rise above 0.1 – 0.5 mmol/L or 1.8 – 9.0 ppm (Britto and Kronzucker, 2002). *Sarracenia* are related to the Ericaceae (Bayer et al., 1992) which are considered tolerant of ammonium toxicity. Acid tolerant plant species are also typically ammonium tolerant (Britto and Kronzucker, 2002). Susceptibility to ammonium toxicity can co-occur with reduced photosynthetic rate while potassium can alleviate toxic effects. Co-application of nitrate with ammonium can alleviate ammonium toxicity but this synergistic effect is absent in the Ericaceae (Britto and Kronzucker, 2002). I found ammonium levels averaging 1.4 – 37.2 ppm in my study sites. Most of my sites were in the low end of a presumed toxic range but others (Byrum, Md. Ave., Piney Branch, and Zuni) had potentially damaging levels of ammonium for purple pitcher plant. While there is now evidence that ammonium may have deleterious effects on *S. purpurea*, future studies need to directly measure where lethal or deleterious effects occur in terms of soil ppm. Whigham and Richardson (1988) measured ammonium levels averaging 58-117 ppm in their study sites. Significantly, none of these sites contained *S. purpurea* at the time ammonium concentrations were measured. On the other hand, *S. purpurea* was subsequently introduced to one of the study sites, Round Bay Bog (Sipple, 1999). The introduced population of *S. purpurea* at Round Bay Bog flourished and reproduced suggesting that at least 85 ppm ammonia (the mean level reported by Whigham and Richardson) is not an inhibitory level for purple pitcher plant. Interestingly, Whigham and Richardson (1988) also reported relatively high potassium levels (1622 ppm) at Round Bay Bog. Could potassium have inhibited ammonium toxicity at Round Bay Bog? While Whigham and Richardson's methods were slightly different, and hence comparisons may be difficult, one may attempt to at least infer nutrient zones of tolerance for *Sarracenia*. Weiss (1980) recorded N levels as high as 1500 ppm in fertilized *S. flava* plots with no deleterious effects reported. The level at which soil nitrogen, and species of nitrogen, causes toxic effects in *Sarracenia* is open to question and future research. Based on the research to date, the ammonium concentrations in my study sites were not cause for concern.

Slope, aspect, and meteorological data

Purple pitcher plant bogs were located in gently sloping wetlands of 1-2% slope with the preponderance of sites facing south. Surrounding site contours frequently exceeded bog slope. However, seepage wetland conditions are typically favored in gentle grades due to the slow release of water and subsequent possibility for bog development on suitable soils. The occurrence of most *S. purpurea* populations on south facing slopes is not surprising considering the need for abundant light by these heliophytes.

While I observed and recorded drought conditions, and subsequent mortality and reduction in pitcher plant populations between 2000 and 2008, I did not see a major long-term water deficit in the meteorological record to explain this. The average precipitation between the 1971-2000 and 2001 – 2009 at the Suffolk weather station differed by only 0.03 inches. The Richmond station over the same contrasting periods differed by only 2.62 inches, with 2001-2009 having more precipitation than the previous average period (Suffolk and Richmond are the nearest direct weather measurement stations to my southern VA sites). One trend that was clear for both Maryland and Virginia weather stations was below average rainfall January – March over the 2001-2009 period. Even though annual precipitation over this period was average or above, the timing of the rain events was not. The deficit of precipitation in the winter, when water can more easily penetrate the soil, may have led to a lowered water table which could not be recovered during the growing season (when large rain events tend to run off the soil). While many bogs with adequate groundwater did not exhibit drought stress (the Maryland bogs and Reedy and Cattail Creek in VA for example) several seepage bogs in southern Virginia that were on shallow, rain-water fed aquifers exhibited extreme drought stress (Zuni, Depot Rd., Addison, Wakefield powerline, etc.). This is not to say there weren't drought years. For example, the Suffolk-Lake Kilby station recorded below average (avg. = 48.7 inches) precipitation of 32.13 inches in 2001 and 34.63 inches in 2007. Both 2001 and 2007 precipitation deficits were recorded at other weather stations. However, similar or worse droughts were recorded from 1971 – 2000 and *S. purpurea* apparently survived those episodes (especially true because this covers the period of my field exploration and discovery of *S. purpurea* sites in Virginia and Maryland). For example, both Norfolk and Suffolk-Lake Kilby recorded an average of 29 inches of precipitation in 1986 and below 36 inches in 1976 and 1980.

While it is initially tempting to associate pitcher plant drought stress and mortality with lowered water tables from succession and subsequent evapotranspiration, the fire maintained Zuni site suggests additional causes. I think it is also possible that a variety of factors have come into play to lead to drought stress on purple pitcher plant populations in any particular site. While prescribed fire at Zuni may have lowered competition and evapotranspiration, this is offset by lack of water due to changed precipitation patterns and drainage ditches in the sandy soil. Water tables may also be dropping due to general ditching, increasing rural populations and water withdrawals from wells, and other anthropogenic demands on shallow aquifers. In other cases such as Depot Rd., Addison, and Wakefield powerline, it is very clear that succession and woody competition are removing critical amounts of water during the growing season. One way I have been able to identify the linked problems of succession and evapotranspiration in bogs is through pitcher plant restoration at the Joseph Pines Preserve in Sussex County, VA. During the same period (2001-2009) that many southern Virginia bogs were drying up and losing pitcher plants, I cleared and removed woody competitors from Joseph Pines Preserve and established *S. flava*, *S. purpurea*, and other indigenous rare seepage wetland plant taxa. Not only have the plants flourished but I have seen natural regeneration and increased water tables while at the same time comparable natural sites were experiencing drought and reproductive adversity. While my observations are qualitative they do suggest the negative effect of woody competition on the hydrologic cycles of shallow aquifer pitcher plant bogs.

Rare plants and species richness

High quality, intact, pitcher plant bogs are known for their unique assemblage of rare plant and animal species (Folkerts 1982; Schnell 2002). Environmental degradation of pitcher plants bogs or succession, conversely, reduces species richness (Herman, 1990) and number of rare plant taxa in a site by altering the niche that specially adapted bog species occupy. There are a number of factors, including hydrology, topographic position, site and fire history, degree and frequency of succession, and anthropogenic impacts, that could result in the number of rare plants and species richness at purple pitcher plant wetlands in

Maryland and Virginia. Some of these factors can be directly measured (topographic position) while others, and their frequency, may be lost over time (site history, succession, anthropogenic impacts). The mosaic effect of these factors on the occurrence of rare species and species richness makes it difficult to discern why sites are floristically different.

Despite the difficulties in determining the cause of site species richness and number of rare plants, there were some general trends in my data. Typically, and not unexpectedly, bogs located on power line rights-of-way had some of the highest levels of species richness and rare species (Piney Branch, Cherry Orchard, Reedy Creek, Chester, and Depot Rd.). In other cases (Arden and Md. Ave.), rare natural gaps or sea level fens provided the open sunny conditions and edge habitat conducive to rare plants and enhanced species richness. Conversely, heavily shaded, advanced successional sites typically had both low number of rare species and low species richness (Cattail Creek and Byrum for example). These results are not surprising if one accepts the role that natural, lightning caused fire must have played historically in keeping pitcher plant bog sites open and enhancing diversity. In the absence of fire, anthropogenic disturbance such as mowing on power line rights-of-way, plays a vital role in maintaining seepage wetland flora (Sheridan et al., 1997).

Typically, purple pitcher plant habitat covered no more than one hectare so comparison of number of rare plants and species richness between sites represented equivalent units. Sipple and Klockner (1984) measured species richness at many of the sites chemically analyzed by Whigham and Richardson (1988) and offered the opportunity to compare my results to other similar, currently non-pitcher plant containing bog or wetland savanna habitats. In addition, the Maryland Natural Heritage Program (MHP) has recently completed a vegetation analysis of seepage wetlands containing *S. purpurea* (Harrison and Knapp, 2009). The Maryland Natural Heritage program recorded a range of 22-57 species in 10 x 10 plots in three community types containing *Sarracenia*, while non-pitcher plant plots ranged from 20-45 species in the same communities. Therefore, pitcher plant plots tend to be more species rich than non-pitcher plant plots in Maryland bogs. Species richness ranged from 19-47 species per site with an average of 38 species at the sites studied by Sipple and Klockner (1984). Higher species richness was found in more open, sunny sites by both research groups. The Delaware Natural Natural Heritage Program recorded a range of 66-85 vascular plant species at the two remaining exemplary pitcher plant sites (Bill McAvoy, pers. comm.). This compares with an average of 31 species in Virginia purple pitcher plant bogs (range 11 – 83) and 74 species (range 48-118) in western shore Maryland purple pitcher plant bogs in my study. The average high species richness for Maryland purple pitcher plant bogs is due to the large number of species found at Piney Branch Bog. In contrast, I tabulated 247 bog species in the south Mississippi *S. alata* bogs studied by Eleuterius and Jones (1969) while MacRoberts and MacRoberts (1988 and 1991) recorded 96, 106, and 104 taxa at the pitcher plant bogs they studied. Walker and Peet (1983) recorded between 22 and 35 species per 0.25 m^2 in savannas of the Green Swamp of North Carolina. Norquist (1984) found an average of 25 species per 0.25 m^2 plot in her Mississippi pitcher plant bogs. MacRoberts and MacRoberts (1991) stated that their sites were considerably less diverse than Walker and Peet's. Species richness ranged from 22-277 for pitcher plant bogs across the southeast (Herman, 1990) with a mean species richness of 140 (my calculation). These are gross levels of species richness in southeastern pitcher plant bogs since the expertise of the investigator and size of the bog may have varied. Nevertheless, it is apparent from the data that gulf coast pitcher plant bogs have greater species richness than Atlantic Coast bogs. Herman (1990) hypothesized that fire plays a significant role in maintaining species diversity in southeastern pitcher plant bogs.

Raised bogs in eastern North America containing purple pitcher plant ranged in species richness from 13-50 species (Glaser, 1992). The raised bogs consisted of four floristic regions with the southern-boreal continental region having the most impoverished flora in eastern North America at less than 20 species. Species richness was related to geographical region, mean annual precipitation, annual freezing degree days, and mean annual temperature, the concentration of sodium and magnesium in the surface water, and the number of wet-to-dry habitats. Fire return interval for this region is 100 years (Cogbill, 1985). In short, western shore Maryland and Virginia purple pitcher plant bogs are depauperate in flora compared to gulf coast and North Carolina pitcher plant bogs but richer than eastern North America purple pitcher plant bogs.

The discrepancy between the number of rare species found in purple pitcher plant bogs in Maryland (n = 19) and Virginia (n = 35) is probably largely due to the smaller geographic range and the fewer number of *S. purpurea* sites on the western shore of Maryland and the impact of the geographic range of the taxon on rarity. In contrast, 25 and 26 rare species were recorded at two Delaware purple pitcher plant sites (Bill McAvoy, pers. comm.). While some northern species are close to their southern limit and are rare in Maryland and Delaware and absent from Virginia pitcher plant bogs (*Carex exilis* Dewey, *Chamaedaphne calyculata*, *Thelypteris simulata* (Davenport) Nieuwland, and *Vaccinium macrocarpon*) a number of southern species reach their northern limit in southern Virginia as part of the longleaf pine ecosystem or are principally found in coastal Virginia (*Aletris aurea*, *Asclepias rubra* L., *Ctenium aromaticum*, *Drosera capillaris*, *Helenium brevifolium* (Nuttall) Wood, *Iris prismatica* (Pursch), *Lachnocaulon anceps*, *Lilium pyrophilum* M.W. Skinner & Sorrie, *Ludwigia hirtella* Raf., *Polygala cruciata* L., *Rhexia petiolata* Walter, *Rhynchospora fascicularis* (Michaux) Vahl, *R. rariflora* (Michaux) Ell., *Sabatia campanulata* (L.) Torrey, *Scleria minor* W. Stone, and *Zigadenus glaberrimus*). Some rare species are found in both Virginia and Maryland purple pitcher plant bogs (*Platanthera blephariglottis*, *Eriophorum virginicum*, *Juncus caesariensis*, *Juncus longii* Fern., and *Sarracenia purpurea*).

A historical perspective on species richness and rare species in purple pitcher plant habitats of Maryland and Virginia is necessary. A number of species (*Burmannia biflora* L., *Sarracenia flava*, and *Zigadenus densus* (Desr.) Fern. to name a few) recorded in Rhodora by M.L. Fernald from Virginia purple pitcher plant bogs are no longer present in any *S. purpurea* site. Therefore, many rare species may have been extirpated from remaining *S. purpurea* sites and the true character and tapestry of what species these bogs should contain may have been irrevocably lost.

Fernald (1937a) himself even lamented the loss of sites and diversity during his field days in Virginia. Poo Run was an exceptional pitcher plant bog (*S. flava*) documented by Fernald and offers the opportunity to compare historic pitcher plant bog species richness and rarity to extant sites in Virginia. While Poo Run was an excellent site, Fernald also described many other pitcher plant sites with numbers of rare plant taxa. I enumerated (Sheridan, 1993b) the number of state rare species at Poo Run based on Fernald's Rhodora papers (Fernald, 1937a, 1937b, and 1937c) and tabulated (unpublished) the total number of species found at the site. While Fernald probably didn't report every species he found at the site, since he was focused on rarities, his data provide a conservative measure of diversity (the rare species list certainly gives an indication of quality). The Poo Run data confirms that high plant diversity, high rare species pitcher plant sites were probably the norm in Virginia. While four species have been delisted from the state rare plant list since my original publication, 24 species are still state listed with several increasing in rarity. Also, of interest, total richness was 59 species at Poo Run (again probably a conservative number). This richness number is within the upper range that we have in Virginia purple pitcher plant bogs today. What is outstanding, however, is the number of rare species found at Poo Run. In contrast, Cherry Orchard Bog has 14 rare species, the highest number of rare bog species of any extant purple pitcher plant site in western shore Maryland or Virginia. Shands Bog, a *S. flava* site in Dinwiddie County, has (had) 10 state rare plant species (Sheridan et al., 1997). A conclusion that could be made from these historic data is that both species richness and species quality (rarity) may have changed dramatically in Virginia purple pitcher plant bogs (not a surprise considering overall environmental degradation). Herman (1990) commented that Virginia had many species of special concern since it was at the range limit of pitcher plant species (probably meaning *S. flava* and the longleaf pine ecosystem – the range of *S. purpurea* continues through Virginia to the north). Herman provided a list, prepared by state natural heritage programs, of rare species found in or near pitcher plant habitats. Analysis of Herman’s compiled data reveals that Virginia pitcher plant bogs could theoretically contain 61 state rare plant species, more than double any other southern state, and more rare taxa than are now contained in the total number of species in most extant Virginia purple pitcher plant bogs. While Herman’s list is a composite rare species list, and species rankings have changed over the intervening 19 years, it does give some indication of how diverse Virginia pitcher plant bogs might historically have been.

I have personally observed that some species may persist in the seed bank (*Drosera*, *Rhynchospora*, *and Xyris* at Addison bog) or as vegetative material (*Platanthera*, *Sarracenia* and *Zigadensus* at Addison bog and *Asclepias rubra* and *Lilium pyrophilum* at Joseph Pines Preserve) in heavily shaded or successional sites and are released when the site is mechanically cleared or burned. Release of certain rare seepage plant taxa with prescribed fire was documented at the Zuni Pine Barrens, including *Calopogon pallidus* Chapman, *Platanthera blephariglottis*, *Sarracenia purpurea* and *Zigadenus glaberrimus*. However, the duration of how long vegetative or seed material of different species can persist in pitcher plant bogs as succession proceeds and a site closes to hardwood forest is largely unknown. My *Sarracenia* cultivation experience indicates seed remains viable for no more than ten years. If my observations are correct, *Sarracenia* pitcher plants are one of the first species to be permanently lost from a bog if succession proceeds unchecked. There is probably a hierarchy of species persistence, refuge, and loss within the successional continuum which future research may be able to address. Herman (1988) observed that pitcher plants can persist through 15-40 years of succession while other genera, such as *Pinguicula*, become locally extinct. The present suite of rare species, and species richness, in *Sarracenia* habitats in general and purple pitcher plant sites in particular, must then be viewed with caution and an eye to the past, present, and future history of the site.

In conclusion, *Sarracenia purpurea* occupies a unique ecological niche characterized by acidic, nutrient poor soils, temperate climate, generally south facing sites, gentle slope, and a suite of rare plant associates. The ecosystem in which purple pitcher plant occurs has been under stress from environmental degradation for several centuries. The result is an altered habitat and depauperate flora from pre-settlement conditions. The degradation of purple pitcher plant sites can be measured in both the reduced quality of rare species found in these sites and elevated levels of macro and micro nutrients.

CONCLUSIONS

Sarracenia purpurea, the purple pitcher plant, is a rare obligate wetland plant in Virginia and a threatened species in Maryland. A changing environment, largely due to anthropogenic impacts, is having such a negative impact on purple pitcher plant that extinction of the taxon both at a local and regional scale can be predicted with a high degree of accuracy. A total of thirteen sites for *S. purpurea* were documented on the western shore of Maryland and District of Columbia while forty-two colonies were identified in Virginia. Four *S. purpurea* sites are extant on the western shore of Maryland while fourteen sites remain in Virginia. A total of forty six *S. purpurea* clumps remain on the western shore of Maryland while five hundred and thirteen clumps were counted in Virginia. Only 31% (four of thirteen) of the *S. purpurea* sites are extant on the western shore of Maryland and District of Columbia while 33% (14 of 42) remain in Virginia. Causes of regional *S. purpurea* extirpation include beaver flooding, succession and development. Disturbance, especially natural fire, played an essential role in maintaining purple pitcher plant historically in Maryland and Virginia. The large scale prevention of fire, land fragmentation, and lowered groundwater tables have cumulatively led to a combination of impacts from which purple pitcher plant may not be able to survive. Peak bloom period of *S. purpurea* may also have shifted as much as a week from historical dates, perhaps, due to climate change. *Sarracenia purpurea* now blooms from May 8 – June 12 in Maryland and Virginia with a peak between may 18-20. The phenomenon of purple pitcher plant extirpation is a call to action to prevent extinction. *Sarracenia purpurea* is a relatively easy plant to cultivate and methods to restore habitat and reintroduce this plant to suitable habitat within its range are known.

No genetic difference was found in mid-Atlantic *S. purpurea* populations while differences were found with other *Sarracenia* species and *S. purpurea* varieties. These results suggest that a single taxon, *S. purpurea*, occurs in Maryland and Virginia. The lack of support for the subspecies concept in *S. purpurea* does not detract from the value of those populations and their habitats. Pitcher plant bogs in southern Virginia currently contain many state rare plant species and historically may have been quite diverse. While Maryland pitcher plant bogs lack the number of rare species found in Virginia bogs they are fewer in number and have higher species richness. Maryland pitcher plant bogs exhibited rare flora such as leatherleaf (*Chamaedaphne calyculata*) and cranberry (*Vaccinium macrocarpon*) with affinities to New Jersey and Delaware while Virginia bogs had rare elements typically found in the southeastern United States such as yellow pitcher plant (*Sarraceia flava*), golden colic root (*Aletris aurea*), short-leaved sneezeweed (*Helenium brevifolium*), toothache grass (*Ctenium aromaticum*) and pink sundew (*Drosera capillaris*). Further value is found in southern Virginia pitcher plant bogs since they were historically part of a longleaf pine ecosystem. Longleaf pine reached its northern limit in southern Virginia and the preservation of the rare elements found within the pitcher plant community is paramount. Climatic data disclosed that southern Virginia purple pitcher plant populations are both warmer and wetter than those on Maryland.

Purple pitcher plant soils in Maryland and Virginia met expected conditions of low pH (3.5–4.9), and were low in almost all macro- and micro-nutrients. Pitcher plants evolved unique leaves to capture and concentrate insect mass for absorption in a nutrient poor environment. Perturbed or polluted sites exhibited elevated levels of the exchangeable cations magnesium, calcium, and sodium. The ability of pitcher plants to tolerate excess nutrients is unknown but circumstantial evidence suggests pollution, or over fertilization, can quickly overwhelm their systems and lead to death. Therefore, appropriate buffers (300+ feet) around pitcher plant wetlands are essential to prevent pollution from changing bog soil chemistry.

The host of requirements to preserve and restore the Virginia and Maryland purple pitcher plant bogs means that a dedicated effort is needed to prevent their extirpation. There is great value in the bogs where purple pitcher plant grows. These features include rare species, preservation of clean groundwater, and the enjoyment of seeing some of nature’s more interesting ecosystems.

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APPENDIX A. HISTORICAL REVIEW

A review of the historical record (Appendix B) on the distribution (Fig. 18) of *S. purpurea* in Virginia and the western shore of Maryland and District of Columbia is important for several reasons: 1) to provide the necessary historical context and how that relates to the current distribution and plight of *S. purpurea*; 2) to highlight the causes (suspected and documented) for historical extirpations; and 3) to demonstrate the extent of the taxon's range, limits to that range, and the robustness of field work supporting that range. The historical review inherently provides the people, places, and observations essential to proper documention of purple pitcher plant in the study area. Preceedent for this approach to Virginia and Maryland phytogeography was set by Fernald (1937a-c, 1938, 1939, 1942, 1947), Sipple (1999), and other biologists.

Historical Review – Maryland and the District of Columbia

Sarracenia purpurea is historic for four counties (Anne Arundel, Baltimore, Charles, and Prince George) on the western shore of Maryland and one site in the District of Columbia. Most of the populations occurred in only Anne Arundel and Prince George Counties (Fig. 1). This concentration of populations is largely due to the sand and gravel seepage wetland and bog habitat provided by the Magothy Formation in Anne Arundel County and the fall line gravel seeps of Prince George County. Isolated populations occur or occurred in gravel seeps of Baltimore and Charles County.

The Glen Burnie bog in Anne Arundel County (Site 1) was apparently a robust population of *S. purpurea* (Sipple, 1999) with several hundred plants and extensive flowering. Sipple (1999) reported Plitt's journal stating on May 30, 1900 "In the swamp [Glen Burnie Bog], hundreds of Pitcher-plants were still found in bloom, notwithstanding the depletion that is constantly going on." The site was well known to local botanists and numerous specimens were collected either as novelties or for personal or public herbaria. Forrest Shreve did his doctoral dissertation on *S. purpurea* from plants collected at Glen Burnie Bog (Shreve, 1906). Shreve also provided a photograph of the Glen Burnie bog in his book “Plant Life of Maryland” (Shreve et al., 1910), which is useful for comparison with extant purple pitcher plant sites. The bog was an open peat mat with encroaching red maple edges, very similar to the bog at Gumbottom Branch on the Severn River (Site 3). *Sarracenia purpurea* was very abundant at Glen Burnie bog, as both photographic and written accounts demonstrate. In my opinion the Glen Burnie bog was representative of a healthy, functioning pitcher plant population numbering in the hundreds to thousands of plants. Noteworthy rare, seepage wetland plant associates included *Juncus caesariensis*, *Drosera rotundifolia*, *D. intermedia* Hayne, *Eriocaulon decangulare* L., *Platanthera cristata* (Michx.) Lindl., *P. blephariglottis, Chamaedaphne calyculata*, *Xyris caroliniana* Walter, *Eriophorum virginicum,* and *Utricularia cornuta* (Michaux) (Waters, 1905; Smith, 1938; Sipple, 1999). Glen Burnie Bog was apparently fed by an exceptionally strong groundwater seepage flow since Waters (1905) commented on the swift stream exiting the bog. The Glen Burnie bog was apparently destroyed by flooding when the water level of a downstream pond was raised around 1920 (Sipple, 1999). Ultimately, the dam was breached and what remains is largely a weed infested, sediment laden, ravine (Sipple, 1999).

A noteworthy feature of written reports and herbarium collections from Glen Burnie Bog and Sites 9 & 10 in Prince George County is the flowering dates of the pitcher plants. These historical records indicate abundant purple pitcher plant flowering from late May into June in the early 1900’s. I have recorded flowering times of Virginia *S. purpurea* in study beds at the Meadowview Biological Research Station over several years. I recorded peak flower time at that rural location as mid-May. Very few *S. purpurea* plants are in bloom at the end of May and typically those remaining have their petals falling off. Could this be a signal of global climate change affecting flowering times of pitcher plants?

Purple pitcher plant occurred at Fresh Pond in Anne Arundel County (Site 2) which was apparently a flowering, robust population. Herbarium records from this site span a twenty-one year period (1939-1960) with credible observations of the plants in 1968 (Sipple, 1999). Clyde Reed used several different site names (Bog near Angels Store, South of Angels Store, Fresh Pond, Mt. Carmel Bogs, and Mt. Carmel Lakes) for his pitcher plant herbarium specimens that were collected over a 13 year period at Fresh Pond. I interpret all of these collections as one population. Multiple site names for the same collecting location is not unusual for botanists and I have personally found myself doing the same thing. My contention that Reeds collections represent one site is reinforced by Plitt's discussion of the Fresh Pond pitcher plant population and Sipple's (1999) analysis of the situation. Sipple (1999) also reports that Dr. Plitt visited the site frequently in the early 1900's and recorded *Sarracenia* in profusion with a second site on a "little pond". If Sipple's analysis is correct, this "little pond" was downstream of Fresh Pond and essentially was part of the Fresh Pond pitcher plant population. Apparently, the Fresh Pond pitcher plant population was robust enough to export propagules downstream and colonize new habitat.

Fresh Pond (Angel's Bog) was the most diverse bog in Anne Arundel County (Sipple, 1999) including rarities such as *Juncus arbortivus* Chapman, *Drosera intermedia*, *D. rotundifolia*, *Chamaedaphne calyculata*, *Rhynchospora alba*, *Eriocaulon sp.,* and *Pogonia ophioglossoides* (L.) Ker. Clyde Reed purportedly did his master's thesis on the pitcher plants at Fresh Pond (Sipple, 1999) but I have been unsuccessful in locating this potentially important historical document at Loyola College in Baltimore. I visited Fresh Pond in 1979 and while there was still a sphagnum edge with leatherleaf and cranberry no pitcher plants could be found. There was some siltation and bare earth on one side of the pond in 1979 from a hog farm and the north end (outflow) of the pond was a fairly dense red maple and sweet bay, *Magnolia virginiana*, forest. Water levels at Fresh Pond have fluctuated over the years due to a water control device at the outfall (Sipple, 1999) and I suspect that this formerly large pitcher plant population was destroyed by flooding between their observation by Reed in 1968 and my visit in 1979. A good case can be made for a flooding extirpation, as the discussion of Arden Bog to follow will demonstrate. Alternatively, succession, pollution, or poaching could have eliminated this pitcher plant population but I think these options are unlikely. Elimination of pitcher plants at Fresh Pond due to succession would have required complete canopy gap closure which did not occur and would be difficult in a large pond margin setting. While large-scale pollution could have eliminated the pitcher plants, many associate species would have been lost and this was also not evident.   Poaching could have been a factor in the elimination of *S. purpurea* at Fresh Pond since herbarium specimens were clearly made and the site was well known. However, I have no example of poaching extirpating any *Sarracenia purpurea* population in my study area and think this scenario is also unlikely. While poachers might heavily predate adult plants they are unlikely to eliminate a seedling cohort that could replenish a site.

The best natural purple pitcher plant site on the western shore of Maryland was discovered by Maryland Natural Heritage botanists Judy Maudlin and Kathryn McCarthy on June 1 1988 (Sipple, 1999) and is known as Arden Bog or Gumbottom Branch bog (Site 3). The site is a naturally open gap (Sheridan et al., 2000) within a forested wetland matrix (Fig. 19) and supports a number of state rare bog plant taxa such as *Sarracenia purpurea*,

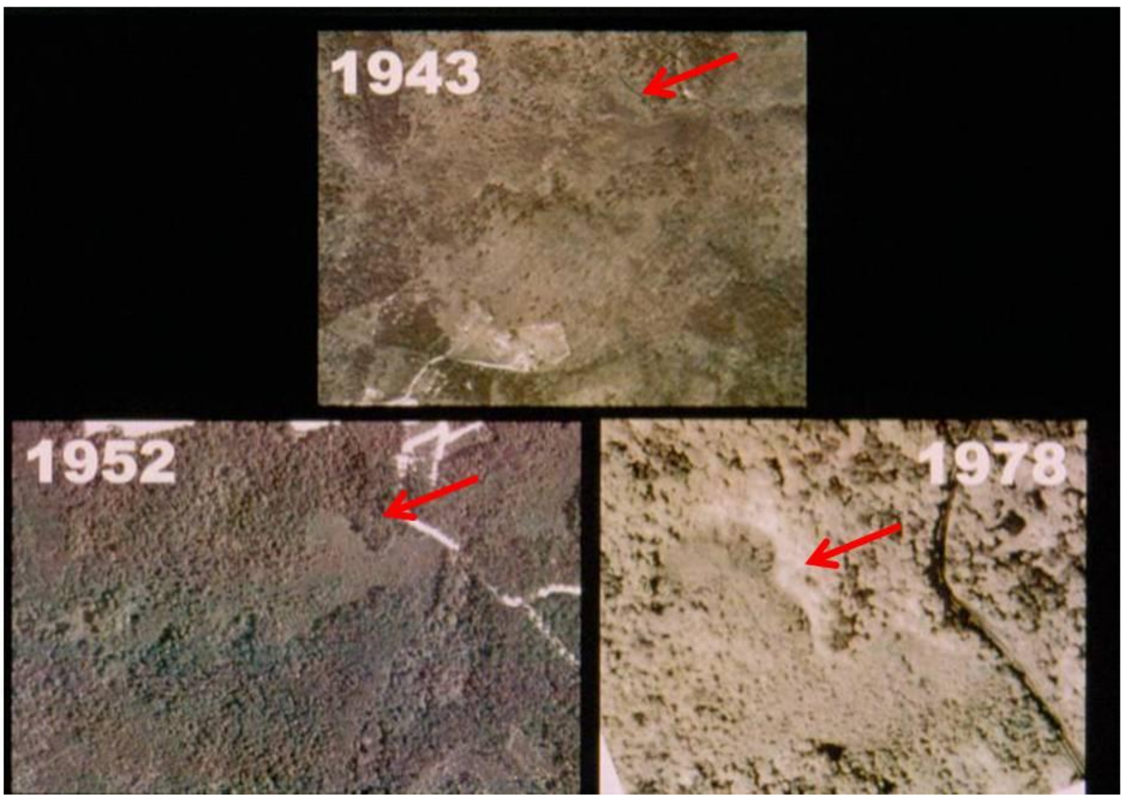

Figure 19. Aerial views of Arden bog from 1943 - 1978. Red arrow indicates bog location. Notice how site has remained open since 1943 and details of open pools in 1978 image.

Drosera intermedia, *D. rotundifolia*, *Chamaedaphne calyculata*, *Rhynchospora alba*, *Platanthera cristata*, *Eriophorum virginicum*, *Vaccinium macrocarpon*, and *Utricularia geminscapa* Benjamin (Fig. 20).

Figure 20. Arden bog before flooding, 1998.

Figure 21. Arden bog after flooding, July 2008.

Unfortunately, despite repeated warnings, no action was taken to stop beavers from flooding the site and the entire pitcher plant population of over 1000 plants was seemingly lost in 2008 (Fig. 21). The bog was a State Natural Area purchased specifically by the State of Maryland to protect the bog. To put this loss in perspective, Arden Bog contained more than double the number of pitcher plants that are left in all the remaining natural sites in Virginia and the western shore of Maryland. Both the Maryland Natural Heritage Program and staff from Arlington Echo Outdoor Education Center revisited Arden Bog in 2009 and counted 9 surviving pitcher plants.

Arden Bog provides some insight into the role of flooding on native *S. purpurea* populations. Flooding has played a large role in recent purple pitcher plant extirpations but I think historically beaver played an important regulatory role, combined with natural fire, in maintaining this taxon. Beaver induced flooding and suppression of woody competitors occurred within the matrix of *S. purpurea* metapopulations that could migrate locally by water between disturbed habitats. This kind of pitcher plant migration is no longer possible due to a highly fragmented landscape where natural disturbance regimes, such as fire, are prevented. In the case of the flooding of Arden Bog, it is already clear what species can survive inundation. Both leatherleaf and American cranberry survived the one year flooding event at Arden Bog. Interestingly, both leatherleaf and American cranberry were present at Fresh Pond in my 1979 visit and may be signature species which can survive flooding better than *S. purpurea*. Arden Bog will provide a "natural experiment" to investigate the effects of flooding on other rare seepage wetland plant taxa. Seed raised plants from the Arden Bog are in *ex-situ* conservation at both the Arlington Echo Outdoor Education Center in Millersville, Maryland and the Meadowview Biological Research Station in Woodford, VA.

Purple pitcher plant was rediscovered at Maryland Avenue (Site 4) on the Magothy River, not far from the historic Fresh Pond site (Sheridan et al., 2000). The flora of Maryland Avenue is similar to Arden Bog with key associates such as leatherleaf, American cranberry, and cotton grass but the site is more advanced in succession.

Plants that are conspicuously absent from the Maryland Avenue bog are *Drosera intermedia* and *D. rotundifolia*. Unfortunately, soon after discovery, the population was damaged by siltation from construction of a house on an adjoining slope. Pitcher plants were filled with mud and debris and were killed along with associates such as *Eriopohorum virginicum* and *Vaccinium macrocarpon*. The character of this sediment laden portion of the bog also changed from a hummock filled, sphagnous edge to a shaded, sediment laden thicket full of *Typha latifolia* L., *Celastrus orbiculatus* Thunberg, *Polygonum* sp., *Lonicera japonica* Thunberg and *Toxicodendron radicans* (L.) Kuntze. Unfortunately, the example of the decline of the pitcher plants at Maryland Avenue is a familiar theme in the extinction of these plants from our region. *Sarracenia purpurea* will not tolerate contaminated water from adjacent soil disturbance or pollution The Maryland Avenue pitcher plant population continues to decline, even in areas initially unaffected by the sedimentation event, and as of this writing I predict the population has been extirpated. The extirpation may have been hastened by pollution (winter salt application) from the road which bisects the bog. I am able to extrapolate based on my trend line (presented in Census chapter) that the Maryland Avenue population was about 20 clumps when I found it in 1999. Material from this population is in *ex-situ* conservation at Meadowview Biological Research Station and by Keith Underwood of Millersville, MD.

Sipple (1999) reported the occurrence of *S. purpurea* at two sites on Cypress Creek on the Magothy River (Sites 5 &6). One population was recorded by Plitt at what is now know as Cypress Creek Savanna and the other (a few plants) was observed by Sipple and Klockner in 1978 (Sipple 1999) at what is called Bonnie's Bog or the Dill Road site on Cypress Creek. Historically, these sites contained such rarities as *Pogonia ophioglossoides*, *Vaccinium macrocarpon*, *Chamaedaphne calyculata*, *Drosera intermedia*, *D. rotundifolia*, *Platanthera ciliaris* (L.) Lindl. and *P. blephariglottis*. All of the Cypress Creek pitcher plant populations have been extirpated. The degree of environmental degradation is evident in the fact that Atlantic white-cedar is almost extirpated at Cypress Creek Savanna. Plitt bemoaned the development and degradation to these habitats as early as 1909 (Sipple 1999). Both Sheridan et al. (1999a) and Sipple (1999) noted dramatic change and loss of rare species at Cypress Creek Savanna. Sipple (1999) records only a single stem of leatherleaf, *Chamaedaphne calyculata*, persisting at the Dill Road or Bonnie's Bog on Cypress Creek.

The Cypress Creek purple pitcher plant populations, and their important associate plants, have most likely been destroyed by pollution from adjoining major roads and intense urban development in close (50 feet) proximity to the bogs. The effect of these pollutants is not only simply visible to the observer but clearly manifested in the disappearance of rare species and in some chemical signatures such as elevated lead in Atlantic white-cedar tissue (Whigham and Richardson, 1988). In addition, Atlantic white-cedar mortality over the past 20 years at Cypress Creek Savanna and recent loss of rare plant taxa at that site may be compounded by increased salinity from rising tidal waters (Sipple, 1999; Walbeck et al., In Press). Extirpation of the Cypress Creek Savanna white-cedar population is predicted for 2013 based on population data trends over the past 13 years (Walbeck et al., In Press). The sensitivity of *S. purpurea* as a biological indicator is evident by its early and quick disappearance from the Atlantic white-cedar habitats on Cypress Creek. The hierarchy of rare species loss in these habitats proceeded as follows: *S. purpurea- Drosera-Platanthera-Vaccinium macrocarpon-Chamaedaphne-Chamaecyparis*. Several Atlantic white-cedar sites remain on the western shore of Maryland (Sheridan et al., 1999a) but none of these now contain *Sarracenia* and many of the sites lack a significant assemblage of rare seepage wetland plant associates. I maintain that these Atlantic white-cedar sites did in fact historically contain populations of *S. purpurea* and this claim is supported by documented loss from the few remaining sites. *Sarracenia purpurea* is routinely found in intact Atlantic white-cedar ecosystems and their lack of presence in remaining western shore of Maryland white-cedar stands is a demonstration of the degree of degradation to those ecosystems.

I located a specimen by Clyde Reed at MO that I first thought represented Plitt’s second pitcher plant colony near Fresh Pond. The label data states “Bodkin Creek” (Site 7). Reed was fairly consistent in identifying his Fresh Ponds collections as either Fresh Pond, near Angel’s Store, or Mt. Carmel Lakes – all of these monikers are consistent with the location of Fresh Pond while Bodkin Creek has no direct relation to Fresh Pond. In fact, three creeks enter into the Patapsco River from this estuary – Back Creek, Main Creek, and Bodkin Creek (Kirby and Matthews, 1973). Since Fresh Pond enters into Main Creek, Reed’s “Bodkin Creek” collection clearly indicates a separate tributary and previously unknown *Sarracenia* collection in Anne Arundel County. Intense urban development in Anne Arundel County, MD makes it highly unlikely that this population still exists.

Charlie Davis and the late Elmer Worthley both reported (pers. comm.) the occurrence of *S. purpurea* in Baltimore County, MD behind a church at a site called Westerman's Pond (Site 8). I heard about this site in the 1980's when Elmer Worthley mentioned that a population of pitcher plants occurred in the woods behind a church in Harford County, MD (incorrect county identification by Worthley). I visited the site with Charlie Davis and it is typical of a former pitcher plant occurrence. While the site for the pitcher plants was filled in and destroyed by the church for a parking lot the remainder of the site was an abandoned sand and gravel pit with pools of water. The white sand/gravel mix is typical of a pitcher plant location and remaining springs and ponds suggest the correct hydrology.

Bill Scholl and I discovered a population of robust pitcher plants in Charles County, MD (Site 9) and a host of rare plant associates including *Pogonia ophioglossoides*, *Rhynchospora alba*, *Platanthera blephariglottis*, *Solidago uliginosa* Nuttall, *Drosera rotundifolia*, and *Juncus caesariensis* (Sheridan, 1991). This pitcher plant site is significant because *Juncus caesariensis* had only been found in Maryland at the Glen Burnie bog almost a century earlier and had been presumed extirpated. The site was also characterized by large deposits of coarse gravel and typified what is known as a gravel bog (McAtee, 1918). The spring upon which the pitcher plants and bog occur is bisected by a PEPCO high voltage power line (Figs. 22 and 23).

Figure 22. The author at Piney Branch bog, May, 1991. Note white gravel in foreground and pitcher plants blooming to left.

Figure 23. Blooming *S. purpurea* at Piney Branch, May, 1991.

Power line habitats are known refugia for rare seepage wetland taxa (Sheridan et al., 1997). I censused the population on May 11, 1991 and counted 84 clumps of pitcher plants on both the power line (17 clumps) and in the woods (67 clumps). Within a few years the woodlands were logged and gravel deposits mined on the south side of the bog. During the mid-1990's commercial development intensified in this part of Maryland. What had been an old dirt road above the bog became a main, paved two lane thoroughfare called Billingsley Road and ground clearing upstream of the bog commenced for an industrial business (Fig. 24). Some of the land clearing violated wetland laws in Maryland and further land clearing was halted (Sheridan et. al, 1996; Collins, 1997a & b; Wheeler, 1997).

Figure 24. Cleared land on headwater of Piney Branch bog.

Ultimately, The Nature Conservancy received a $500,000 grant to manage the bog and the State of Maryland received seven acres on the northeast side of Piney Branch Bog. The pitcher plant population has declined from 84 robust, reproducing clumps in 1991 to 31 single-stem, non-reproducing clumps in 2008. All woodland pitcher plants are gone at

Piney Branch Bog, Billingsley Road has expanded to four lanes and there is sediment entering the headwaters of the bog, and the power line right-of-way is overgrown with shrubs up to 15 feet tall (Fig. 25).

Figure 25. Shrubs and saplings dominate Piney Branch bog, October, 2009.

Additional decline is evident in the disappearance of clear, spring fed gravel pools lined with *Drosera rotundifolia* and the *Juncus caesariensis* population is seriously diminished in size. Predicted extinction of purple pitcher plants at Piney Branch Bog, unless quick action is taken to restore the bog, is 2018. Fortunately, The Nature Conservancy partially cleared the bog in 2009 (Deborah Landau, pers. comm.). The Nature Conservancy plans annual bog clearing and I think this management strategy may reverse the population decline in *S. purpurea* and prevent extirpation.

Historic collections from Prince George County, Maryland (Sites 10 & 12) don't offer much in terms of specific locality data or habitat information. However, an unusual feature of the Laurel, MD collections (Site10) is the listed flowering dates of July 11, 1895 and June 1, 1903. *Sarracenia purpurea* was rediscovered (Site 11) in Prince George County, MD (Terrell et al., 2000) and is now in propagation at the USDA labs. While there is some speculation this might be an introduced population on a power line right-of-way (Terrell et al., 2000), the habitat and morphological features of the plants themselves indicate a natural population. The population consists of two plants growing in an open mineral soil seep in a remote, infrequently accessed part of the USDA property. Heavy deer browse prevented reproduction of the population but a fence has been installed and the plants are now reproducing.

One location was recorded for *S. purpurea* within the District of Columbia (Site 13). I have previously mentioned how botanists may use several different locality names for the same location (one example was the Clyde Reed collections at Fresh Pond). The collections of *S. purpurea* by Lester Ward illustrate this point and it took time to discern if there was one collecting site, several populations, or whether the site(s) were in Maryland or the District of Columbia. I have concluded that there was one population based on the following rationale. Lester Ward made a total of five *S. purpurea* collections: May 18, 1878, *In vicinis* Washington, D.C.; May 21, 1878 at District of Columbia, Mitchell Estate, Eastern Branch; 1878 in the Bladensburg vicinity; May 27, 1883 at District of Columbia, Mitchell Estate, Eastern Branch; May 28, 1884 at District of Columbia, Beaver Dam Branch, Bennings Race Track vicinity. Ward (1881) stated “It will suffice here to mention a wet meadow between the National Driving Park and Bladensburg, where, in a very diminutive spot *Sarracenia purpurea*, *Viola lanceolata* L., and *Carex bullata* Schkuhr, the first two wholly unknown elsewhere, have been discovered”. Ward’s comments, written in 1881 by his own account, establish that his three 1878 collections must have been from the same location since he states the pitcher plants where known from only one site. Ward’s 1883 collection from the Mitchell Estate obviously is the same location as his earlier 1878 collection. The 1884 Ward collection from “Beaver Dam Branch, Bennings Race track vicinity” also match the original collection since Ward (1881) stated the site was “near Beaver Dam Branch”. Ward also clearly indicated that the *S. purpurea* location was within the District of Columbia. In addition, McAtee (1918) listed a *S. purpurea* population at "*Sarracenia* swamp". McAtee provided a detailed U.S. Coast and Geodetic Survey map of the District of Columbia and vicinity with coordinates for the location of the pitcher plant colony. The coordinates match the general location described by Lester Ward and I think these are one and the same population. Ward's population may have matured over time into a swamp habitat due to inundation. Indeed there is evidence of impoundment when comparing 1882 and 1917 USGS maps for this location since there appear to be larger pools on the Anacostia River (Eastern Branch) by 1917. Alternatively, McAtee and Wards sites may have been part of a metapopulation but I would be surprised if Lester Ward would have missed such a notable botanical feature in the District of Columbia. The cause for the demise of the District of Columbia *S. purpurea* population are unknown but the most likely options are flooding or urban development.

Historical Review – Virginia

Reed collected a specimen of *S. purpurea* in Accomac County, Virginia (Site 1) – a range extension for the taxon in the state (Appendix B). There have been no other collections of *Sarracenia* from the Eastern Shore of Virginia. The pond edge where the pitcher plant collection was made is now dominated by water loose-strife, *Decodon verticallatus* (L.) Elliott (Bill McAvoy, pers. comm.). No *Sarracenia* have been found at Reed's collecting site in Accomac County, Virginia despite botanical investigations of the site by McAvoy of the Delaware Natural Heritage Program and Wieboldt of Virginia Tech. McAvoy reported that this former *Sarracenia* location is in an area of rich soils but that the drainage on which the pond is located contains unusual, pitcher plant indicator species such as *Kalmia angustifolia* L. and *Drosera rotundifolia*. *Decodon* is indicative of flooded conditions and I propose that the pond edge habitat for *Sarracenia* was probably eliminated by flooding due to an increase in pool level.

Sarracenia purpurea was reported in the Piedmont of Brunswick County, VA in 1932 (Lewis, 1934) (Site 2). Research by Wright (pers. comm.) has revealed that the pitcher plant population occurred on a headwater tributary of Sandy Branch 0.5-0.75 mile NE of present-day Brunswick High School. Wright (pers. comm.) also found the notes of J.B. Lewis about this pitcher plant population, which state "not known from the Seward Forest area to date. Up until the spring of 1931, there was a colony in a wooded swamp south of the Southern RR about half way between Lawrenceville and Edgerton. On visiting this swamp in the spring of 1941, not a plant could be found. I attribute the extinction of these plants to the increase in density of the shade of the young *Acer rubrum* and several less numerous species of trees and shrubs in this swamp. There is an open swamp in southern Greensville County where this species, *S. flava* and another race of this species is growing in considerable numbers…" (Lewis, 1940 and 1944b). Wright (pers. comm.) also reports that the Brunswick County purple pitcher plant colony contained *Smilax laurifolia* L., *Melanthium virginicum* L., and *Iris prismatica* (Lewis, 1944a). While this population was technically on the piedmont of Virginia, it occurred within the confines of an outlier of sandy, coastal plain soils and associate acidophilic species. The observations of Lewis are profound in many ways and support my conclusions on why many indigenous purple pitcher plant sites have been extirpated in Maryland and Virginia. Not only did Lewis identify red maple as a significant competitor, he provided a time scale between discovery of the pitcher plant population and extirpation. Lewis recorded a ten year interval between discovery of this pitcher plant population and extirpation. Lewis also identified that red maple and other trees and shrubs increased shade density. The current study also demonstrates that purple pitcher plant populations not only quickly decline from woody competition but can be extirpated within as little as ten to twenty years by species such as red maple. Folkerts (1982) also noted that succession could eliminate the Gulf Coast pitcher bog community within 20 years.

Caroline County, VA is a rural county in central Virginia that largely occupies the Coastal Plain province with a small portion of the county crossing the fall line into the Piedmont. All purple pitcher plant populations located in Caroline County have been found in the coastal plain soils. Caroline County is noteworthy for its extensive sandy soils and gravel deposits which give rise to the basic hydrogeomorphological conditions which can support *Sarracenia purpurea*. Purple pitcher plant was first discovered in Caroline County by Alton and Barbara Harvill on floating mats on the edge of a small pond near Peatross (Site 3) and subsequently about a mile to the east on the north side of rt. 656 in a sphagnum/gum/red maple swamp (Site 4). Site 3 was apparently destroyed by flooding (Harvill pers. comm.) while Site 4 continues to persist. I had originally thought that *S. purpurea* could persist for long periods of time in the woodland phase as exemplified by my original observations of flowering and successful regeneration at Site 4. However, after 20 years of observing Site 4, I now see decreased plant vigor, fewer plants, reduced flowering, and sparse regeneration. Site 4 is apparently experiencing increased successional pressure and woody plant competition. Site 4 has been successfully introduced by seed to a power line hill-side seepage bog feeding PoleCat Creek. The introduced population is several hundred clumps of pitcher plants with robust flowering and active reproduction and represents what a healthy, functioning purple pitcher plant colony should look like.

The best, natural purple pitcher plant population was discovered by Sheridan in May 1987 under power lines on a hillside seepage bog (Figs. 26 and 27) feeding Reedy Creek (Site 5). The site is botanically diverse with such pitcher plant associate rarities as *Juncus caesariensis*, *Platanthera blephariglottis*, *Eriophorum virginicum*, *Pogonia ophioglossoides*, *Scleria minor,* and *Utricularia geminiscapa*. There was also a woodland pitcher plant colony on the same south slope of Reedy Creek about a quarter mile from the powerlines in the forest. I recorded thirty three clumps of pitcher plants and two seedlings at the Reedy Creek powerline site on April 27, 1991 and twelve plants in the woodland colony. The woodland colony contained six plants with flower stalks and six with no flower stalks. I re-censused the power line colony in April 4, 2007 and counted four hundred and ten pitcher plant clumps and numerous seedlings. I had searched for the woodland colony a few years earlier but the colony had been extirpated, apparently by woody succession. This woodland site is another demonstration of the loss of purple pitcher plant colonies occurring during the period of the current study.

Figure 26. Reedy Creek bog, May, 2009. Seepage slope is on far side (south side) of depression. Beaver impoundment is at left.

Figure 27. Reedy Creek bog looking north, May, 2009. Seepage slope with blooming *S. purpurea* intersects beaver created pond. Pitcher plants are colonizing hummocks in pond.

The woodland and powerline pitcher plant colonies at Site 5 also allow me to compare and contrast different management/environmental effects. Two native pitcher plant seed spreading interventions by a local naturalist resulted in the population going from thirty one clumps in 1991 to four hundred and ten clumps in 2007. In contrast, the nearby woodland colony was extirpated without intervention. These outcomes are not at all surprising since *S. purpurea* responds well to management of its habitat (through clearing or burning) and through enhanced seed dispersal to appropriate habitat. What is important to point out is that with two interventions one purple pitcher plant site in Virginia now contains four times more plants than remain within the entire state. Furthermore, those interventions brought this site to population levels normally seen in historic pitcher plant colonies in Virginia. Clearly, purple pitcher plant requires intervention not only at the site level but regionally if it is going to persist as part of the flora of the region. An unfortunate aspect of intervention was the deliberate introduction of several non-native species to the site such as *Drosera intermedia*, *D. rotundifolia*, and *D. filiformis* Raf.

A remarkable occurrence of purple pitcher plant in Caroline County, VA occurred at Site 6, floating sphagnum mats on a small farm pond (Figs. 28 and 29). The plants were

Figure 28. The author on floating mats with *S. purpurea*, 1985. Note beaver activity on left side of mat (gnawed sticks).

Figure 29. Detail of floating mat at site 6. Note *S. purpurea* amongst *Hypericum* sp. and sphagnum moss.

growing on floating peat mats covered with sphagnum in association with *Drosera rotundifolia*. Within a few years, beavers moved into the site, wallowed all over the mats, and completely destroyed the colony of pitcher plants. I recorded damage to the pitcher plant population from beavers on March 10, 1985 (Phil Sheridan field notes). Site 6 has been one of the more interesting pitcher plant occurrences to explain. Prior to my discovery of the site the pond had been a shallow body of water with floating mats and grass/sedge meadow. The landowner decided to increase the height of the dam and create more open water habitat (Steve Carneal, pers. comm.). Apparently, during the raising of the pond level a few pitcher plants were able to survive on floating peat mats and persist. The pond itself is at the very head of an intermittent drainage, precisely the headwater seepage system where I typically find relict pitcher plant colonies in Virginia. Site 6 exemplifies a typical series of events for a pitcher plant colony in Virginia and Maryland as: 1) persistence in semi-woodland seepage wetland system or open gap; 2) disturbance enhances habitat (fire, partial flooding, clearing for power line, etc.); 3) release of pitcher plant colony; and 4) destruction of colony through anthropogenic or natural means.

The suggestion that partial flooding could enhance a pitcher plant habitat may seem inconsistent with my assertion that flooding is typically fatal to purple pitcher plant. However, flooding can be a positive feedback for creating pitcher plant habitat depending on the degree and frequency of flooding. Site 6 is perhaps an example of how beaver flooding historically may have worked to enhance pitcher plant populations in an unfragmented landscape with intact ecosystem processes. While purple pitcher plant populations may have been enhanced by beaver in the past they were also destroyed by their actions. The key would have been to have had more pitcher plant colonies to begin with and the means for them to migrate locally via water between sites. An example of a functioning, beaver maintained pitcher plant habitat is the Big Run Bog in Monongahela National Forest of West Virginia (an introduced population from a nearby native colony that was destroyed for creation of a lake – an early example of rare plant conservation) . Big Run Bog has a series of beaver weirs with actively maintained ponds and inactive grass/sedge meadow. Purple pitcher plants, and other rare acidophiles, are able to migrate between disturbed beaver created habitats at Big Run Bog. Finally, in 2008, interns from Meadowview Biological Research Station and I performed a reintroduction of indigenous Caroline County *S. purpurea* to Site 6 on the Carneal property (Simmons, 2008).

Meadow Creek Pond, in Caroline County, VA has long been known to harbor many rare seepage wetland plant species (Strong and Sheridan, 1991) such as *Juncus caesariensis*, *Drosera rotundifolia*, *Eriophorum virginicum*, *Eleocharis tortilis* (Link) Schultes, *Utricularia purpurea* Walter, and *Pogonia ophioglossoides* (Fig. 30). I was not able to find purple pitcher plant on the upper

Figure 30. Open spring-fed pools on upper end of Meadow Creek Pond, 1984. *Drosera rotundifolia* occupies hummocks in this photograph.

reaches of Meadow Creek Pond and thought this somewhat odd since not only was there good sphagnous, seepage habitat on the pond but there was the presence of significant, rare plant associates highly indicative of the presence of *Sarracenia*. My experience has been that this plant association almost always includes *Sarracenia*. I therefore concluded there must be a pitcher plant population somewhere on the Meadow Creek drainage. I mounted an investigation, starting downstream at Dalton Millpond, and worked my way up to Meadow Creek Pond. I found very little if any seepage on most of the slopes. The soils were typically an orange loam, not good soil for *Sarracenia*. I finally found one wetland which was a unique gravel hillside spring that contained a small population of purple pitcher plants. An important point here is that my initial proposition that associate acidophiles could be used to determine the presence of purple pitcher plant was valid. I counted eight pitcher plants at Site 7 in 1990 and found an additional two in 1992 bringing the total population to ten. The population size stayed at this number for several years but sometime after 2002 apparently started to dramatically decline, apparently from advancing dominance by broad-leaved hardwoods. In 2007 there were four plants, only one with normally formed pitchers, and within the next year one vestigial plant disappeared. I got permission from the landowner and in 2008 volunteers and I cleared the area within twenty feet of the plants. We carefully hand cleared leaves from around the remaining plants which were literally smothered by these broad-leaved hardwoods. Even this intervention wasn’t enough since I watched as one small plant died and decayed within a month in early summer. I obtained one division from the two remaining plants (only one was large enough to divide) and this material is under *ex-situ* conservation at Meadowview Biological Research Station. One purple pitcher plant bloomed at site 7 in 2009, because of our clearing efforts in 2008, and the flower was bagged and hand-pollinated for conservation efforts.

The situation at Site 7, Meadow Creek, illustrates a number of important points about *S. purpurea* populations in Virginia and the western shore of Maryland. First, I had underestimated the power of succession to quickly eliminate purple pitcher plant from habitat. The data from Site 7 demonstrates how quickly succession can eliminate purple pitcher plant from habitat. Second, succession operates in a number of ways on purple pitcher plant including blocking light, lowering water tables, and literally smothering the plants with a layer of decaying broad leaves. Broad leaves on the pitcher plants may facilitate extirpation through direct blockage of light and facilitating fungal and bacterial infection. I have documented infection and death of *S. purpurea* leaves and plants by the fungus, *Colletotrichum gloeosporioides* (Virginia Tech Plant Disease Clinic, report dated 11/21/08, specimen number 1522), which causes necrosis (anthracnose) on the leaves (Fig. 31). This infection typically occurs in fire suppressed sites dominated by hardwoods. Is fire playing a role of not only preventing woody invasion of bogs but also inhibiting disease in *Sarracenia purpurea*?

Figure 31. Infection and death of *S. purpurea* leaves with *Colletotrichum gloeosporioides*.

Site 8 in Caroline County, VA was originally discovered by Mo Stevens who found a colony of swamp pink, *Helonias bullata* L., but not *Sarracenia*. I recorded sixty seven clumps of swamp pink at the site and discovered six clumps of purple pitcher plant on one edge of the seep system on July 15, 1990. The site is located on route 601, just west of route 301, on a north facing slope and is on a high ridge sloping into the Mattaponi floodplain. The seepage drains out of the steep hillside with clear, perennial, spring water. I have revisited the *Helonias* population over the years and it seemed to be declining. The decline of *Helonias* was verified when I reinventoried the site in August 2007 and counted only eighteen non-flowering swamp pink and no *Sarracenia*. The *Sarracenia* population was on the eastern end of the seepage system and the plants were single stem, shaded plants. On my 2007 visit I did note some sediment in one portion of one seep and some mechanical disturbance upslope including some bulldozing of a road and a small dug-out pond at the head of one seep. I attribute the loss of the *Sarracenia* at this site chiefly to succession with possible interaction from siltation. However, I did not find direct evidence of damage from siltation where the pitcher plants used to occur.

Site 9 in Caroline County was a small population of a couple of clumps on sphagnum hummocks in a red maple/gum headwater spring system. I searched the whole spring system and this was the extent of the pitcher plant colony. The population persisted for a number of years but had been eliminated by beaver flooding when I visited in 2007. Site 9 is part of a cluster of populations in rather close proximity on the Reedy and Polecat Creek drainages. Sites within this cluster included sites 3, 4, 5, and 6. Further intense botanical work in this area on headwater seepage wetlands may locate additional *Sarracenia* colonies. However, the ongoing demographics for *S. purpurea* populations indicate both local and regional extirpation by 2055 (presented in Census chapter). These extirpation forces (chiefly succession and including but not limited to flooding, urban development, herbicide spraying, poaching, stochastic events such as hunt clubs tilling and fertilizing game plots with runoff into bogs) are powerful and are likely to eradicate any pitcher plant populations that may be found.

Two populations of *S. purpurea* have been found on Fort A.P. Hill in Caroline County, VA (Sites 10 & 11). One population was found on the impact range and consisted of a couple plants in shady conditions and the other is under a small power line near Anderson Camp. The Anderson Camp population has declined from twelve to six clumps and flower stalks are apparently being browsed by deer. Several points should be made about the pitcher plants on A.P. Hill. First, they are one of the few populations in Virginia on government or state land that could receive protection and management. Second, Fort A.P. Hill has received a fairly thorough inventory by Virginia Dept. of Conservation and Recreation botanists and only two pitcher plant populations have been found on over 70,000 acres. The low frequency of pitcher plant populations on Fort A.P. Hill is probably due to a combination of underlying geologic position (the base is adjacent to the Rappahannock River and the terrain becomes dissected and seepage bog habitat is lost) and former agricultural history (the land was intensively farmed prior to base formation).

Historically, *S. purpurea* occurred in Chesterfield County, VA just north of the town of Chester in a wetland along the Atlantic Coast Rail Road line (Site 12). Scholl and I were able to track down one of the collectors, W.H. Matheny, who still lived in Chester and interviewed him in 1985 (Bill Scholl and Phil Sheridan field notes 1/5-6/85). Mr. Matheny originally could not remember where he collected the plants but in a subsequent interview on March 10, 1985 he mentioned that the pitcher plant colony was along the rail road tracks north of Chester in association with golden club, *Orontium aquaticum* L. We relocated this site but the wetland was completely degraded and silted in. The degree of wetland degradation was so great that I would never have thought pitcher plants would have occurred at that location. We focused our efforts near the town of Chester since we had found in our field work that if there had been a historic pitcher plant population there usually was an extant population in the vicinity. Our insights were validated by the discovery of several pitcher plant populations south of Chester (Sites 13, 14, and 15) in a large area of sandy soil with headwaters feeding Timsbury and Swift Creeks. The first site we found was a copious seepage bog bisected by a power line and feeding Swift Creek (Site 14). We found purple pitcher plants in the woods in 1986 but also turned up a large colony of *Platanthera blephariglottis* in both the woods and power lines. Four pitcher plants were moved to the power line on March 28, 1987 to aid the colony in reproduction and a couple plants were collected for *ex-situ* conservation. Additional finds were *Asclepias rubra* and the only known extant station in Virginia for pinelands nerveray, *Tetragonotheca helianthoides* L. We counted ten purple pitcher plants at Site 14 in 1990, with nine in the woods and one reproducing clump on the powerline. Purple pitcher plants were also found in the woods on a seep near Zion Church feeding Swift Creek (Site 13) where we found approximately 25 clumps of pitcher plant on February 15, 1987 (Bill Scholl and Phil Sheridan field notes). We also found a colony of sheep laurel, *Kalmia angustifolia*, with the pitcher plants. The *Kalmia* collection was significant since it was an intermediate station between disjunct populations in southern Virginia and central Virginia in Caroline County. Eight pitcher plants were moved from the Zion Church bog to a nearby sphagnous power line to ensure reproduction on February 4, 1987. Bill Scholl and I returned to Site 13 on May 1, 1988 and installed metal labels at the base of each pitcher plant (n=20) and collected divisions (where possible) for *ex-situ* conservation. Therefore, the original pitcher plant population at Site 13 was 28 plants. Our final discoveries of purple pitcher plant in Chesterfield County were two sub-populations on headwaters of Timsbury Creek: two plants discovered by Robert Wright (Bill Scholl and Phil Sheridan field notes 2/11/92) and two plants found by Bill Scholl and I in sphagnous woods on January 8, 1989.

There are several important points to be made regarding the Chesterfield County purple pitcher plant populations. First, these populations are only eight miles away from Site 17 in Dinwiddie County where both *S. flava* and *S. purpurea* co-occurred. Why was *S. purpurea* able to cross the Appomattox River while *S. flava* could not? Second, Bill Scholl and I recorded a firsthand account by a life-long resident near the Chester seeps (Mr. Holtz) of railroad engine generated fires sweeping the bogs and woods in the 1930's (Bill Scholl and Phil Sheridan field notes March 28, 1987). The railroad right-of-way went through this prime sand country in Chesterfield. Obviously, anthropogenic fire disturbance was an important reason the Chesterfield pitcher plant populations persisted and may be interrelated to the beneficial effects provided by mowing on the north south powerline bisecting the bogs. Powerline rights of way are known refugia for rare seepage and pineland plant taxa (Sheridan et al., 1997). Third, what caused the extirpation of the Chesterfield purple pitcher plant populations and what are the remedies to prevent extirpation? In the 23 years since the discovery of the three Chesterfield pitcher plant populations only a single native pitcher plant remains in the woods on the seep feeding Swift Creek (Site 14), all other native populations having been extirpated. The Chesterfield purple pitcher plant extirpations illustrate the strong influence exerted by succession and the time scale over which it acted. On a more basic level my twenty-three year temporal view of the Chesterfield seeps has provided insight into how I can justify why pitcher plants were much more widespread in Virginia and occupied many more sphagnous habitats than today. This deep insight was crystallized by a revisit of the Chester seeps in the summer of 2008. Bill Scholl and I found two purple pitcher plants in an excellent, spring fed, wooded seepage bog on Timsbury Creek (Site 15) in 1989. At that time we were perplexed that the site did not support more pitcher plants. In 2008, we reinventoried the bog at Swift Creek (Site 14) and counted one remaining pitcher plant (Fig.32).

Figure 32. *Sarracenia purpurea* in habitat in Chesterfield County, VA. The sole surviving native plant at Swift Creek bog, August 2008.

Is Swift Creek a reflection of what we witnessed twenty years ago at Timsbury Creek? Having the perspective of time combined with continued field work at these pitcher plant sites I can now see that I was witness to the extirpation though succession of a pitcher plant colony at Timsbury Creek and now at Swift Creek. If the Swift Creek purple pitcher plant population went from ten plants in 1990 to one in 2008 is it unreasonable to presume that the Timsbury Creek population of two in 1989 might have been ten or more in 1968? Furthermore, if we move ahead in time to 2020 we might predict (as I have done) that all purple pitcher plants will be gone from the Chester seeps. Taking this logic a step further, if we never had botanical surveys in this part of Chesterfield, and came upon these seeps in

2020 we might conclude that purple pitcher plant never occurred in Chesterfield County despite the fact that we would find excellent sphagnous seeps with noteworthy associate species such as *Platanthera blephariglottis* and *Asclepias rubra*. This is not a trivial issue since some biologists are against introducing native *Sarracenia*, and other associate acidophiles, to suitable habitat within their historic range unless they can be documented from the specific site. I think this is an unfair burden of proof for ecological restoration and maintain that the presence of certain acidophiles, which are more resistant to successional pressure, is a strong indication that *Sarracenia* once occupied that specific site. I am presenting numerous examples of *S. purpurea* extirpation from what would be considered healthy, wooded, sphagnous seeps. Clearly, this extirpation phenomenon is happening regionally to sites no botanist has visited.

I can also compare and contrast conservation methods in the case of the Chester seeps. Bill Scholl and I moved eight purple pitcher plants from Site 13 to a nearby powerline. This turned out to be a wise move since Site 13 was flooded by beaver and the transplanted power line colony is up to forty four plants with numerous seedlings in 2008. The purple pitcher plants moved from the woods to the power line at Site 14 did not survive (the site was disturbed by new power line construction in 2008) but we fortunately removed a few plants in 1986 for *ex-situ* conservation. The *ex-situ* plants from Site 14 are now in the care of Bill Scholl in a sphagnum bog on his property in Caroline County, VA. If we had not intervened and either transplanted or gotten back-up material for *ex-situ* conservation we would have lost virtually all the purple pitcher plant germplasm from a critical part of its range in central Virginia. The opportunity for conservation, molecular, and biological research on these important plants would have been lost.

Site 16. "The day Townsend took us to the stations where his grandfather had shown him many local and rare species, we saw, sadly and impressively, an example of what is more and more happening to the bogs and swamps of the Coastal Plain. He had not visited these spots for some years; in the meantime deep ditching has lowered the water-table and what were once splendid bogs are now dried-out remnants, invaded by aggressive pines and oaks, with the open bogs he remembered now quite ruined and most of the then interesting plants now extinct. In these young invading pine woods southwest of Petersburg, in Dinwiddie Country, a few struggling and hopelessly shaded plants of the two species of *Sarracenia*, *S. flava* and *S. purpurea*, var. *venosa*, still lingered and with them their obvious hybrids, x *S. Catesbaei* Ell., which had not been known in Virginia." (Fernald, 1937a). Fernald's comments reveal several facts about Site 16 and southern Virginia bogs in general. First, bogs were once much more widespread in Dinwiddie County in the early 1900's and they were damaged by lowering of water tables and subsequent woody invasion. Pitcher plant bogs in Dinwiddie County were located on both coastal plain flat woods habitat and fall line seepage bogs. Both habitats would be jeopardized by drainage. Fernald's report that these bogs were more open, prior to drainage, is consistent with the inhibition that high water tables would have had on woody growth. In addition, regular burning was a consistent practice in this part of Virginia at that time. Regular fire, combined with impeded drainage and high water tables, would have favored the high diversity herbaceous flora found in southeastern wetlands. Second, Fernald observed the negative effects of shading and succession on pitcher plants.

Site 17 is less than a mile from the banks of the Appomattox River and is where Bill Scholl and I discovered the northern most population of *S. flava*, along with a colony of *S. purpurea*, on Jan. 18, 1986 (Figs. 33). The site is one mile N.E. of Addison and was

Figure 33. *Sarracenia flava* at Addison bog in Dinwiddie County, VA. Note persistent linear greenish-red phyllodia. *Sarracenia* are difficult to detect in suppressed conditions as this photograph illustrates.

an overgrown mass of *Smilax laurifolia* in pond pine, *Pinus serotina* Michaux F., woods. The *S. flava* was down to vestigial flat leaves while *S. purpurea* was still recognizable with inflated, green, etiolated, pitchers. The site originally would have been a pond pine pocosin or flat woods, and still was to some extent, but there was the inevitable drainage ditch (as discussed by Fernald) through the center of the site. An important point to make here is that drainage ditches, however apparently shallow they may appear (Site 17 had a one to two foot deep ditch), have a significant effect lowering both the water table and water storage in pitcher plant bogs. These effects may not be immediately obvious during the winter time when evapotranspiration is low but can have a profound negative effect on the seepage community during summer droughts. In short, drainage ditches decrease soil water storage during the summer months when seepage plants need water most. This decrease in water storage not only enhances woody invasion but imposes inordinate physical stress on seepage wetland plant physiology. The effects of lowered water tables will be discussed in how it relates to the collapse of *S. purpurea* populations at Sites 22 and 39 later in this appendix. The population of *S. flava* and *S. purpurea* at Site 17 was fifty and twenty six clumps, respectively. Fearing incoming development, pitcher plants were removed from Site 17 for *ex-situ* conservation at Meadowview and Bill Scholl's property in 1989. Our fears were fairly justified since the upper portion of the bog was scraped for a housing development and the bog logged (Fig.34).

Figure 34. Upper end of Addison bog cleared for development. Note drainage ditch through center of wetland and white sandy loam soil in background.

Several important observations were made as a result of the pitcher plant removal, scraping for the housing development, and clear-cut of the bog. First, our pitcher plant removal and subsequent logging of the pitcher plant site allowed us to perform a "natural experiment" testing the pitcher plant seed bank hypothesis (Sheridan and Scholl, 1999). If pitcher plant seeds were active in the seed bank they should be expressed after logging. We were skilled and thorough in our pitcher plant removal and the result of the logging was that we had only one mature *S. flava* quickly appear after logging and no pitcher plants in years following. There are a variety of reasons why we might not have seen the release of a *Sarracenia* seed bank such as decades since seed deposited, low numbers of seed in soil, and viability of that seed. My personal experience with pitcher plant seed is that it will not germinate after ten years of refrigerated storage. Therefore, I think *Sarracenia* is not a long-term resident of bog seed banks nor are rhizomes lying dormant during the growing season in suppressed conditions. Suppressed *Sarracenia* can be difficult to locate in overgrown conditions and the poorly developed leaves can be missed by inexperienced field workers. I have robust, long-term *Sarracenia* seed bank experiments planned for the future which should determine the longevity of *S. purpurea* and *S. flava* seed banks *in-situ*. The logging operation did release *Platanthera blephariglottis*, *Zigadenus glaberrimus*, and *Scleria minor*. We had not seen these species in the overgrown woodland phase but on the other hand we hadn't looked for them either. One plant we did look for, and did not initially find, was *Drosera capillaris*. We never found *Drosera capillaris* in the logged area but found hundreds of plants in the area that was scraped for the housing development. I have observed the release of *Drosera* seed banks at other suppressed pitcher plant sites in Virginia when the organic layer has been removed during logging or urban development. In brief, *Drosera capillaris* is persistent in the seed bank but the organic layer must be removed to mineral soil to expose that seed bank. *Drosera* is an early, pioneer species that would normally grow on moist mineral soil. Years of fire suppression result in a deep organic layer over the mineral soil that inhibits the life cycle of *Drosera capillaris*. The persistence (years) of the *Drosera capillaris* seed bank is unknown but I suspect it is in the multiple decade to century scale. Site 17 has regrown since the logging operation and in 2007 the site was dry. Many other pitcher plant sites in southern Virginia experienced a similar degree of drought in 2007 with negative consequences. Whether these growing season droughts are part of a natural cycle or a result of global climate change, the detrimental effects they are having on purple pitcher plant are amplified by lowered water tables from ditching, shallow well withdrawals, and evapotranspiration from now dominant hardwoods.

In contrast to the pond pine flat woods at Addison Bog (Site 17), *S. purpurea* occurred in two seepage springs in Dinwiddie County at Sites 18 & 19 (Depot Rd. and Cattail Creek). I found the Depot Rd. site sometime around 1987 (when I made my herbarium collection of *Lachnocaulon anceps* #422 GMUF) and recorded/discovered five clumps of *S. purpurea* in a seepy, sphagnous *Myrica cerifera* L. glade just off the edge of the powerline on January 20, 1991 (Phil Sheridan field notes). I found the pitcher plants prior to 1991 when they were in bloom in the springtime. I revisited Depot Road numerous times over the years. On August 3, 1994 I noted (Phil Sheridan field notes) that the population of pitcher plants was down to three clumps and they had senesced since my 1991 visit. I also noted the clumps had no flowers, were leggy, and overgrown by *Clethra alnifolia* L. On my August 3, 1994 visit I also took divisions off the pitcher plant clumps, planted three divisions along the power line, and took two pieces home for *ex-situ* conservation. I made a few more visits to Depot Rd. between 1994 and 2007 and found *Eriocaulon decangulare* and *Helenium brevifolium* in the woods. The pitcher plants that had been moved to the power lines were flourishing. In my later visits, particularly starting with the summer drought in 2002, things were changing hydrologically in the Depot Road Bog. Seepage slopes on the power line had dried out considerably, only one pitcher plant remained on the wettest slope on the powerline, and both *Eriocaulon* and *Helenium* had disappeared from the woodland bogs along with the original purple pitcher plants. When I visited Depot Road in the summer of 2007 to obtain soil samples from the original pitcher plant location I noted considerable change. The woodland seepage bog was completely dry, virtually all the sphagnum had disappeared in the woodland seeps, the canopy was dominated by red maple, and the single pitcher plant on the powerline had disappeared (possibly from herbicide application on the right-of-way). The phenomenon of some native purple pitcher plant bogs becoming extremely dry from 2000 to 2008, and their subsequent population declines or extirpation, is noteworthy. While purple pitcher plant is persisting in exceptionally well watered springs I think it is cause for concern that drought, combined with succession, has managed to eliminate them from other native sites.

In contrast to the degree of drought that afflicted the headwater seeps at Depot Road, Site 19 (Cattail Creek) was seemingly unaffected. The seeps on Cattail Creek are topographically positioned lower down the drainage on side slopes feeding the main creek and apparently receive greater seepage flows that can resist drought. Unfortunately, despite better hydrology, the purple pitcher plants at Cattail Creek could not resist urban development or succession. Site 19 was discovered by Catherine Harold in 1992 and reported to me in 1996 (Catherine Harold pers. comm.). Harold reported finding two colonies of about a dozen plants each 300 feet south of a road in Walker's Landing subdivision. I located two small plants (Phil Sheridan field notes 6/13/96) and when I returned in 2007 a landowner had expanded their fenced yard and destroyed the colony. Unfortunately, while I did obtain a leaf off the struggling plants as a herbarium specimen, I did not collect a division for *ex-situ* conservation and as a result the germplasm from this site has been lost. Interestingly, the Cattail Creek population of *S. purpurea* was just south of Fernald's collection on Old Town (now Rohoic Creek), and south of the Addison population. There were also a number of *S. flava* populations documented for this immediate area (Sheridan and Karowe, 2000) of Dinwiddie County. This cluster of pitcher plant populations is noteworthy and may be due to a number of factors. While the fall line runs south through other counties in Virginia, this frequency of pitcher plant populations was not recorded by botanical investigators in those areas despite similar levels of field work. First, seepage bogs located on the fall line of Dinwiddie County and flat woods habitat apparently provided exceptional hydrology for pitcher plant bog development. The character of these historic local bogs was reported by Fernald (1937a). Second, there were a number of major Native American settlements along the Appomattox River which may have provided increased fire frequency conducive to persistence of pitcher plant habitat. Third, the American Civil War provided an exceptional disturbance event with at least two yellow pitcher plant sites either immediately in front of breast works or between major engagement lines. Purple pitcher plant sites likely benefitted from the local disturbance of Civil War activities.

An unusual quaking bog was discovered by Robert Wright (Site 20) in Essex County, Virginia (1990) while he was investigating a report of ballonvine (*Cardiospermum*). The site even had ombrotrophic character since the headwater spring wetland had been impounded by a county road resulting in a deep peat, quaking sphagnous habitat containing such rare elements as *S. purpurea*, *Carex collinsii* Nuttall, *Carex leptalea* Wahlenberg, *Eleocharis tortilis*, *Eriophorum virginicum*, *Aster novi-belgii* L., *Platanthera cristata*, and *Drosera rotundifolia* (Fig. 35).

Figure 35. Howerton bog in Essex County, VA, Nov. 1988. Photograph courtesy of Robert Wright.

I started noticing beaver damage to this site sometime in the late 1990's and by the time I returned to collect soil samples in 2007 the pitcher plant population, and many of the rare acidophiles, had been completely eliminated by beaver activities. This was an exceptional loss of a pitcher plant site in Virginia. Fortunately, seed was collected from this population and sown on the sphagnous borders of Bowies Pond on Fort A.P. Hill in Caroline County. I sowed this seed in the early 1990's when Fort A.P. Hill was an open base and the public could freely drive in around Bowies Pond from route 2. Native purple pitcher plant germplasm was preserved from loss and is flourishing on protected property. In the summer of 2008 hundreds of mature purple pitcher plants and seedling recruitment was recorded at Bowies Pond.

Sarracenia purpurea and *S. flava* were reported from Greensville County, VA by Fernald (Fernald, 1939; Site 21). This site, known as the sphagnous bog one mile northwest of Dahlia, was apparently a botanical gem for Virginia with such rarities as *Burmannia biflora*, *Utricularia juncea* Vahl, *Zigadensus densus, Lachnocaulon anceps*, and *Drosera capillaris* to name a few. There is a slight problem with the location given by Fernald and the physical location of what is presently known as the Dahlia or Skippers bog. Fernald described the site as "about one mile NW of Dahlia" while what is currently known as the Dahlia bog is two miles NW of Dahlia. Tom Wieboldt, Bill Scholl, and I have all investigated locations one mile NW of Dahlia without locating a seepage bog containing the rarities described by Fernald. Either Fernald poorly described the actual location of the bog or botanical investigators have failed to locate a site of major biological significance in Virginia. I think the former description is the most likely and supported by an additional piece of evidence. Lewis (1940 & 1944b) commented that "There is an open swamp in southern Greensville County where this species, *S. flava* and another race of this species is growing in considerable numbers". Lewis meant *S. purpurea* when he referred to "this species" and his "another race" would have referred to the *Sarracenia* x *catesbaei*. Lewis knew Fernald and joined him in some field work. Dahlia bog contained all three *Sarracenia* species and hybrids as recently as 1990. Therefore, I think the most likely explanation for the discrepancy in physical location is an error on Fernald's part correctly listing the location of the site. Alternatively, Fernald may have deliberately adjusted the locality data to protect the site. In any case, the current Dahlia bog is in a steady state of decline. Almost all the rarities mentioned by Fernald are gone (including *S. flava* and *S.* x *catesbaei* which have been extirpated since my 1990 visit to the site) and I am predicting extirpation of *S.*

purpurea by 2011. The decline in *S. purpurea* at Dahlia bog has been predictable and is largely due to succession with some additional impacts from hydrological manipulation of a pond at the head of the spring. The pool level of the pond has been raised, and in the process, there appears to have been some sedimentation into part of the pitcher plant habitat.

Fernald (1937a) discovered *S. purpurea* in pine barrens south of Zuni (Site 22). Fortunately this site is now owned by Old Dominion University and is a preserve (The Blackwater Ecologic Preserve) managed with natural processes such as prescribed fire. While one would initially think that such a situation would bode well for a pitcher plant population such is not now the case. Initial restoration efforts at the Blackwater Preserve released the pitcher plants from competition and resulted in flowering, seed set, and seedling establishment. However, ongoing monitoring of the pitcher plant population (Marc Milne pers. comm.) has documented the loss of all seedlings and the decline of the original pitcher plant population from twenty-four clumps in 2005 to twelve in 2009. If current trends continue the population will be extirpated by 2014. The cause for concern here is that we are losing a native pitcher plant population on a preserve managed with natural processes such as fire.

How do we explain this population decline and what can be done to reverse it? First, summer droughts are clearly having a negative effect on the native pitcher plant population at Blackwater. Purple pitcher plant clumps are drying up and dying from lack of precipitation at Blackwater, a fate being shared by pitcher plants at other natural sites in Virginia. While droughts are a natural process, the fact that they are extirpating purple pitcher plant from their last refuges is unusual. The remaining refugia for pitcher plants in Virginia should be precisely those sites least likely to be extirpated (provided ecosystem processes and management are in place) under environmental stress such as drought. The fact that we are losing pitcher plants at Blackwater Preserve suggests either unusual climate change or habitat altered in a negative way. I think there is an interaction of both factors. While climate change can not be immediately addressed, altered habitat can. Shallow drainage ditches from former silvicultural operations at the Blackwater Preserve subtly drain the site to the Blackwater River. If those drainage ditches could be plugged enough residual water may remain and/or accumulate in the sandy soil to mitigate summer droughts and provide the purple pitcher plants groundwater at a critical time in the growing season. Folkerts (1982) noted that ditches as shallow as 2 dm (7.87 inches) were enough to eliminate bog species such as *Sarracenia* and commented that while these bogs initially appeared healthy the ditches spelled their ultimate demise. In addition, prudence would dictate *ex-situ* conservation of plants and/or seed propagated material to prevent further loss of this important population. It is hard to imagine how purple pitcher plants at Blackwater could survive fire suppression and subsequent woody invasion for fifty years (from 1936 to 1986) only to succumb to drought after release. Whether shrubs provided some protection from desiccation and/or mycorrhiza provided groundwater during past stressful times is unknown.

Additional purple pitcher plant populations were located in Isle of Wight County at Sites 23 and 24. Site 23 has not been located and is presumed extirpated through either large scale clearing of land and pond formation for a pulp plant. The Site 24 pitcher plant colony was reported to me by Chris Ludwig of the Department of Conservation and Recreation on July 7, 1990. I visited the site near Joyner's Bridge on Jan 1, 1993 (Phil Sheridan field notes) and counted twelve purple pitcher plant clumps. I returned to the site around 2006 and no pitcher plants could be located. Site 24 is a wooded, sphagnous seepage bog on the banks of the Blackwater River. While seepage flow is excellent and can resist summer droughts the pitcher plants could not resist the influence of succession in this woodland habitat. Alternatively, flooding of the Blackwater River during Hurricane Floyd in September 1999 could have played a significant role, along with succession, in the demise of this population as well. During Hurricane Floyd the Blackwater River flooded near-by Franklin, VA and overflowed the river banks for days. Purple pitcher plants are particularly susceptible to rot after this kind of inundation, particularly when floodwaters are laden with silt and other agricultural and urban pollutants.

The location of *S. purpurea* in James City County (Site 25) may represent an extirpation due to succession. Fernald (1942) reported searching for this population at a fairly specific location but was unable to locate it. No further information was given by

Fernald on the state of the habitat but I think it highly likely that succession claimed this population in a similar fashion to that mentioned by J.B. Lewis for the Brunswick County, Virginia occurrence. No pitcher plant population has since been located in this area despite local botanical investigation.

Sites 26 and 27 in King and Queen and New Kent County are also presumed extirpated. No site information was provided by the unknown collector for King and Queen County and I could not substantiate the record for New Kent in the Atlas of the Virginia Flora (Harvill et al., 1992).

Sarracenia purpurea was collected at two sites in Prince George County, VA (Sites 28 & 29). Wood and Loving recorded the plant as abundant in boggy depressions at Site 28 on August 5, 1937. There is no more detailed site information on the Wood and Loving collection and I am somewhat surprised that Fernald did not know of this important population. The specimen is at the University of Richmond where Fernald's student, Robert Smart, should have known about the collection. Perhaps the specimen was in an unmounted pile of student plant collections and could not be observed by Fernald or Smart. In any case, the site is presumed extirpated given the age and demographics for historical purple pitcher plant sites. I think it is important to point out that Wood and Loving recorded the pitcher plants as abundant, in contrast to the small populations we typically see today. I discovered a new population of purple pitcher plant in Prince George County on the south side of route 35 on a headwater of Cherry Orchard Branch on June 7, 1996 (Site 29, Cherry Orchard Bog II). Part of the site had just been logged and the open view was characterized by gentle relief of the landscape, light sprinkles of beige sand mixed with organic matter, springheads gently meandering through the base slopes, and a veil of *Arundinaria gigantea* (Walter) Muhl. next to the springs. All of these factors, and perhaps others hard to convey, suggested the possibility of a pitcher plant occurrence and led to my search of the property and subsequent discovery. I did not record the numbers of pitcher plants at the time I found the population but the woodland colony seemed fairly robust, had flowered, and I would estimate there were somewhere around thirty plants. Around 2000 the other side of the creek was logged and I saw a definite decline or loss of the pitcher plant population. Some of this loss might simply have been due to the plants being buried in the logging operation. When I performed my original census on May 17, 2005 I counted eight clumps. I returned on May 17, 2007 and counted only five live clumps; one flagged clump from 2005 was dead.

Three locations were recorded for *S. purpurea* in Southampton County (Sites 30-32). Fernald collected purple pitcher plant in a bottomland swamp of the Nottoway River at Smith's Ferry (Site 30). I have looked for Fernald's pitcher plants at Smith's Ferry but was unable to locate them in this unfavorable spot. In fact, I find it interesting that Fernald recorded the plant as occurring in a bottomland swamp which is an unlikely habitat for *S. purpurea*. In contrast, Tom Wieboldt found a population of *S. purpurea* not far away on hummocks in a white cedar swamp along the Blackwater River (Site 32). Atlantic white-cedar habitat is much more conducive for *Sarracenia* and perhaps Fernald's collection was a remnant of a former white-cedar swamp. In either case, no *S. purpurea* could be located in either location despite diligent search and the populations are presumed extirpated from succession and/or pollution. A new colony of *S. purpurea* was located by Bill Scholl and me, (Site 31) on sphagnous hummocks in a gum swamp on April 9, 1989 (Bill Scholl and Phil Sheridan field notes). The population occurred with a relict colony of old-growth longleaf pine and turpentine stumps and was an important botanical and forestry find in Virginia (Sheridan, 1993a). We recorded at least thirty *S. purpurea* in an area of five by ten feet on April 9, 1989 and more *S. purpurea* upstream in gum swamp on hummocks with numerous plants on April 23, 1989. I counted sixteen clumps with only one flower bud in my May 17, 2005 census.

Duffield and I visited site 31 during the drought of 2002 and the pitcher plant population was in great distress. The gum swamp was at a low water level and the pitchers on hummocks were experiencing drought stress. We were trying to sample invertebrates in the pitchers but the drought was so bad that the pitcher leaves lacked water to support the invertebrate community. Perhaps, not coincidentally, the pitcher plant population had declined at Site 31 due to both drought and woody competition.

Within the past few years the woodlands surrounding the bog have been clear-cut for longleaf pine restoration and additional light is penetrating the gum swamp borders. If competition has been a significant factor in the decline of pitcher plants at this site then the clearing that has occurred should result in an increase in size, flowering, seed set, and regeneration of this pitcher plant population. In addition, competition from hardwood and softwood trees may be manifest in reduced groundwater levels that would support the seepage wetland plant community. If the competing and dominant canopy layer is removed, and the amount of evapotranspiration greatly reduced, than groundwater levels should rise within the seepage wetland pitcher plant habitat. Competition apparently has a negative effect on purple pitcher plant through shade and lowered groundwater levels.

While Fernald and others collected *S. purpurea* in the pine barrens south of Franklin, VA along the Blackwater River in Suffolk, VA (Site 33), I have been unable to locate a colony despite 20 years of field work in that area. This site has been heavily impacted not only by the construction of a large waste pond for a paper mill but also by drainage ditches associated with forestry operations. Inventory of this area by the Virginia Dept. of Conservation and Recreation also failed to turn up a *S. purpurea* population (J. Townsend pers. comm.). Land alteration, drainage, succession, fire suppression, logging, and recent herbicide application have undoubtedly exterminated this population along the Blackwater River.

All historic Surry County, VA populations of *S. purpurea* are extirpated (Sites 34 & 35). I have examined the site where Bernard Mikula collected *S. purpurea* in 1949 (Site 34) and it is still a wooded swamp with sphagnum moss. The Mikula specimens appear to be typical of woodland *S. purpurea* with green, somewhat etiolated leaves. The pitcher plant population was most likely eliminated by succession since Alton Harvill looked for Mikula's purple pitcher plant population north of Beachland (Site 34) in the 1960's and did not find any pitcher plants. These observations are consistent with succession eliminating purple pitcher plant populations within 10-20 years (1949-1960). Tom Wieboldt reported "a very few *S. purpurea* in a seasonally wet area one mile north of Barham on route 602 in Surry County" (Bill Scholl and Phil Sheridan field notes 3/15/86). Bill Scholl and I searched the area in 1986 looking for *S. purpurea*, without success. I returned in August of 2008 to search for *Sarracenia* again and observed that the site had been clear-cut within the past year. No *Sarracenia* could be found. As Tom Wieboldt had noted, the site was seasonally wet, and by August the site was extremely dry with some water only found in tire tracks from forestry equipment about two to three feet deep. Hummock habitat that might have supported pitcher plants was dried up. The extirpation of the Barham purple pitcher plant population illustrates the effects of lowered water tables and summer drought.

Sussex is the second best county in Virginia (Caroline is the first with nine sites) for number of purple pitcher plant sites with a total of seven populations recorded. Fernald (1937a) documented a purple pitcher plant site (Site 36) just across the Prince George/Sussex County line on the Jerusalem Plank Rd. (present day rt. 35) called Coddyshore. Fernald stated "Passing without too much temptation through Chesterfield and Prince George County, we were just crossing the line into Sussex County, when, tiring of the monotonous ride, we got out to stretch our legs by going down an open pastured slope to a bit of boggy woods. This spot, on a small tributary of the Nottoway running through Jones Hole Swamp, at once stopped our southward progress. Fed by cold springs breaking through the plastic clay and marl, it was the last remnant of a truly wet, wooded sphagnous bog, the best we have yet explored in Virginia. Cows and pigs had almost a monopoly of the place and, although the clumsy and intimately inquisitive sows had wallowed everywhere and had uprooted most of the clumps of *Sarracenia flava* and *S. purpurea*, var. *venosa* (Raf) Fern., they had not wholly destroyed everything. Tumbling, slipping, and wallowing through the saturated clay and *Sphagnum*, we could find all we could handle in typical species of southern bogs…" Fernald's prose is a remarkable account of a native purple pitcher bog in southern Virginia. Bill Scholl and I rediscovered this site on 9/28/85 (Bill Scholl and Phil Sheridan field notes). We had a hard time initially finding the site because "Coddyshore" no longer appeared on maps. We researched older maps and located Coddyshore and the site. I think that "Coddyshore" is a typographical error on maps and originally meant "Coddy's Store" for the old, wooden, store that used to be along route 35. In any case when we found the site it was still much as Fernald described since it was wooded, had copious seepage with sphagnous hummocks, and hogs in a pen with the purple pitcher plants. We were amazed the pitcher plants could survive fifty years with hogs (Figs 36 and 37).

Figure 36. Hog pen within *S. purpurea* habitat at Coddyshore.

Figure 37. Large clumps of *S. purpurea* at Coddyshore.

Note how vegetation has been browsed by low intensity hog farming. Old country store is visible at upper left of photograph and may have been Coddy's Store which was transcribed to Coddyshore.

Unfortunately, many of the other rare plant taxa such as *Drosera capillaris* and *S. flava* were extirpated from Coddyshore bog. *Sarracenia flava* is much rarer than *S. purpurea* in southern Virginia because it is at the northern limit of its range, occupies a slightly different niche (purple pitcher plant tends to occur on hummocks while yellow pitcher plant tends to grow on the flats), and it is much less tolerant of competition and shading than *S. purpurea*. In the case of Coddyshore, *S. purpurea* survived the hog operations on hummocks while *S. flava* was eradicated from the intervening flat seeps. Bill Scholl and I counted about thirty clumps of *S. purpurea*, two being very large, and one hummock containing many pitcher plant seedlings (Bill Scholl and Phil Sheridan field notes September 28, 1985). The *Sarracenia* were still in good shape with 6 clumps and 32 flowers in 1991 but hog operations had ceased (Phil Sheridan field notes 5/18/91). However, I noted things were changing since I recorded poison ivy invading the site. I returned again sometime around 2003 with Mike Rasnake and the plants were clearly in trouble. I did not see any flowers, the pitcher plants were down to single stems, and poison ivy was starting to dominate the understory. I obtained permission to get some pitcher plants for *ex-situ* conservation work at Meadowview Biological Research Station. The 6 clumps from 1991 had disintegrated to multiple single stem plants by 2003. I didn't count the plants in 2003 but there were a substantial number, perhaps as many as thirty. When I returned for census on May 17, 2007 the poison ivy had totally captured the understory and not a single pitcher plant remained. While we did remove pitcher plants for *ex-situ* work on 2003 I by no means defoliated the site and was careful in the proportion of plants removed (ca. ten stems). The significant point here is that the purple pitcher plants were extirpated within four years. While competition played a significant role in this extirpation there may have been exacerbating factors from pollution and sedimentation. The landowner has an excavating business and piled wood, concrete, and other debris just above the wetland. I think it is noteworthy that the historic Fernald Coddyshore pitcher plant site persisted almost sixty years only to quickly succumb to succession and pollution in the present era (Figs. 38 and 39).

Figure 38. View of Coddyshore bog from upland, May, 2007. Note debris to right and closure of canopy in bog.

Figure 39. View within Coddyshore bog, May, 2007.

The area around Wakefield, VA in Sussex County was a major cluster of purple pitcher plant populations (Sites 37-40). Fernald (1938) found a population just outside the town of Wakefield (Site 37) that was being destroyed by road expansion. Mike Lane discovered a population of purple pitcher plant along the Norfolk & Western Railroad tracks northwest of Wakefield in 1978 (Mike Lane pers. comm. to John Hall) which is the same site independently found by White and Sheridan in 1985 and investigated by Fleming in 1992 (Site 38). The site was originally quite robust with large clumps of purple pitcher plants and numerous flowers (Fig. 40).

Figure 40. Wakefield bog, south side of railroad tracks, May, 1986.

The railroad tracks bisected the spring that contained the pitcher plants and they were found on both sides of the tracks. I recorded fifty-seven flowers on the northeast side of the railroad tracks in 1991, all of which had dropped their petals by this date (Phil Sheridan field notes May 18, 1991). Beaver colonized the wetland in 2003 and completely flooded the pitcher plant population on the northeast side of the railroad tracks. Mike Rasnake and I rescued some of the plants in 2003, pulling plants out from under a foot of water, with most of the plants introduced to the nearby Joseph Pines Preserve and some planted in sphagnous habitat on the Rasnake property near Zuni, VA. The pitcher plants on the south side of the railroad tracks were not flooded but had been in decline from competition since 1985. I managed to find three, spindly purple pitcher plants on September 22, 2005. On my June 11, 2007 site visit I was unable to locate the three plants and I would not be at all surprised if they have not been extirpated from competition. The beaver dam on the north side of the railroad tracks was removed or collapsed by 2007 but not a single pitcher plant survived the flooding event at this site. I know we did not rescue every plant in 2003 from inundation and this demonstrates the power of beaver flooding to eradicate purple pitcher plant populations.

An important point to make about the Wakefield purple pitcher plant population cluster is that all the populations were either along the railroad grade or within a half mile of the grade. In fact, the pitcher plant population along the railroad tracks (Site 38) was in the midst of old loblolly pine containing red-cockaded woodpeckers. Red-cockaded woodpeckers are a signature species indicating a frequent fire regime that would sustain pitcher plant populations. The railroad right of way provided anthropogenic fire at this bog both by accidental fire from steam engines, sparks from the wheels of diesel train engines (Phil Sheridan field notes May 18, 1991), and deliberate, annual, maintenance burning/clearing of the right- of- way (Fred Turck VDOF pers. comm.). I checked with the Norfolk and Western Historical Society (Garry Rolih pers. comm.) and could not confirm that this right-of-way did indeed receive prescribed fire but it was kept clear by brush-cutting. However, steam engines were used on this line until 1960 and could easily spread incendiary cinders into adjoining territory. In addition, the sulfur in coal ash dust that was deposited along the right-of-way inhibited plant growth (Garry Rolih pers. comm.). I have also personally seen the results of two fires at this site over the past 25 years. Did accidental and prescribed fire along the railroad right-of-way provide a high enough fire frequency, locally, to explain the Wakefield purple pitcher plant cluster? The Surry Lumber Company was performing railroad right-of-way maintenance burning in the late 1800's in the Wakefield area (Crittenden, 1967). The Chesterfield purple pitcher plant cluster (Sites 12-15) was also associated with documented, frequent anthropogenic fire. In addition, Dahlia and Addison bog (Sites 17 & 21) are immediately adjacent to railroad rights-of-way. If purple pitcher plant requires a high fire frequency, and natural fire frequencies have been disrupted through general development and regulation, than frequent fires on railroad rights-of-way may provide a causal mechanism for historic maintenance of some purple pitcher plant populations in Virginia. If this hypothesis is correct it would suggest that purple pitcher plant may require a similar fire frequency to that of red-cockaded woodpeckers and longleaf pine.

Site 39 (Wakefield power line bog) was discovered by Bill Scholl and Phil Sheridan on April 6, 1986 (Bill Scholl and Phil Sheridan field notes). Six clumps of purple pitcher plants were found in a seepage bog feeding a gum pond under the power lines (Fig. 41)

Figure 41. Wakefield powerline bog, May, 1986.

and more plants were found in the forest. On May 19, 1991 we recorded nine clumps of purple pitcher plant under the power lines, one clump in flower, and seventy-five clumps in the forest (none with flowers). The site was noteworthy for not only pink sundew, *Drosera capillaris*, but it also contained one of the two remaining populations of toothache grass (*Ctenium aromaticum*) in Virginia. In 2008, with several interns, I counted the purple pitcher plant clumps, cleared locally around the remaining pitcher plants, and obtained divisions of rare plant material for *ex-situ* propagation and reintroduction. We were able to count only eleven spindly, dried up pitcher plants in the forest (Fig. 42).

Figure 42. Pitcher plants withering at Wakefield Powerline bog, July, 2008.

All the pitcher plants on the powerline were extirpated (I presume by herbicide spraying of the power line – I had seen several applications) and the seventy-five plants we counted in the woods in 1991 had dwindled to eleven plants. At this rate I predict this pitcher plant population will be extirpated by 2011. To forestall this apparent inevitable loss of germplasm we removed four pitcher plants for *ex-situ* conservation at Meadowview Biological Research Station with the landowner's permission. Aside from the major loss of pitcher plants at site 39 the soil was incredibly dry in the woodland habitat in 2008. The soil at the pitcher plant root zone was powder dry, not a favorable environmental condition for a hydrophyte, and the leaves of most plants were shriveling. Once again, a native pitcher plant bog in Virginia was displaying major water stress during the growing season.

Site 40, Piney Grove Bog, was discovered by Chris Ludwig of the Virginia Dept. of Conservation and Recreation Division of Natural Heritage. Chris was following-up on some of my power line work and asked if I had explored further north on the line. I had not yet investigated that area and Chris had the opportunity to get into this property on May 30, 1990. At least three hundred purple pitcher plants were found on a large powerline right-of-way with such choice species as *Drosera capillaris*, *Zigadenus glaberrimus*, *Pogonia ophioglossoides*, *Asclepias rubra*, *Carex barrattii* Schweinitz & Torrey, *Scleria minor*, and *Platanthera blephariglottis*. I also located a few purple pitcher plants off the powerline right-of-way in the forest. I can still recall my May 15, 1993 visit to this site with Jim Robinson and the view we had of hundreds of purple pitcher plant in bloom (Fig. 43).

Figure 43. Piney Grove bog, May 15, 1993. Note maroon flowers of *S. purpurea* in left foreground and rutting from bush-hog operations. The maroon flowers are difficult to see

from any distance, in contrast to the yellow blooms of *S. flava*. Photograph courtesy of Jim Robinson.

Sometime after 1993 the landowner at Piney Grove Bog intensified cattle operations and there was visible damage to the pitcher plant and acidophile population from trampling and compaction. The final blow to Piney Grove Bog was delivered by the beavers which completely flooded the pitcher plant bog by September 24, 1997. Not a single pitcher plant survived the inundation and a biologically diverse bog habitat was lost in Virginia. I never obtained any pitcher plant material for *ex-situ* conservation.

One positive conservation event in Virginia is preservation of one of the purple pitcher plant sites discovered by Bill Scholl and me on November 18, 1990 (Site 41). Bill and I found only a couple purple pitcher plants in pond pine woods but did note some important associates on the nearby power line such as *Drosera capillaris* and *Lachnocaulon anceps*. This 354 acre property was acquired by the Virginia Department of Conservation and Recreation and is called the Cherry Orchard Bog. I censused the purple pitcher plant population on May 18, 2007 and our original two clumps had grown to four clumps. I presume the increase in numbers was through vegetative division. While this is not a large population increase for this pitcher plant colony, it is certainly better than the extirpation fate shared by many other pitcher plant sites in Virginia over this same time period. In fact, if the site had not been acquired and prescribed burning implemented I would have expected that this purple pitcher plant population would have been extirpated by succession. Some additional notes on this pitcher plant population are that the plants are regularly blooming but there is no seedling recruitment. The pitcher plants are still in fairly heavy shrub competition and I think this is limiting regeneration.

The final purple pitcher plant site in Virginia (Site 42) is located on the property of the Airfield 4-H Center in Wakefield, VA. I received a lead on this population from Sussex County Soil Scientist Jim Clausen who told me pitcher plants were “in the woods in the first depression to the west of the lodges” (Phil Sheridan field notes 6/3/93). I looked in this area, was unable to locate any pitcher plants, and thought this was probably a misidentification. A small pitcher plant colony of five clumps was discovered on March 16, 1998 by Marvin Heinbach and me east of the lodges near the edge of the millpond. In subsequent visits from 2005 to 2008 my population count has ranged between six to seven clumps reflecting the vegetative division of the plants. The population continues to bloom (Fig. 44) and produce seed which is unfortunately being largely eaten by a parasite.

Figure 44. *Sarracenia purpurea* at Airfield 4-H Center, May, 2008.

Two divisions of the Airfield pitcher plants were made in 2008, authorized by the 4-H center, and brought into *ex-situ* conservation at Meadowview Biological Research Station. I have done some limited clearing around this population and predict that without further intervention this population will ultimately succumb to succession.

I located an additional purple pitcher plant collection from the Airfield 4-H center in the fall of 2008 at the College of William and Mary herbarium collected by P.R. Cabe on May 27, 1983 “In swampy stream bottom just above “Swamp Road”; Growing in sphagnum with *Trillium pusillum*; Single plant.” While I consider this collection part of the 4-H population as a whole this specific plant has not been located despite searches by me and the 4-H staff. The co-occurrence of the pitcher plant and *Trillium* is noteworthy since I have never found the two plants growing together elsewhere.

I should mention a potential pitcher plant population that was not included in the official enumeration. In March 2009 I interviewed Tom Woodacre, a former forester with Gray Lumber Company. I mentioned pitcher plants to him and he stated there were two populations, one near Wakefield and the other northwest of Waverly in Sussex County. He said the Waverly plants were in the pine woods where the Murphy Brown plant had been built (about 4 miles n/w of Waverly). I found the site had been badly silted and degraded. I did find a good indicator plant, *Iris prismatica*, in the railroad ditch which could have been a clue to this former population. Further, I found a great deal of support for the possibility of this pitcher plant population since Fernald (1937a) found *Aletris aurea*, *Iris prismatica*, *Tofieldia racemosa*, and *Zigadenus glaberrimus* in depressions in pinelands about 4 miles northwest of Waverly. The spring that starts near the railroad tracks flows eastward towards route 460 where Fernald would have collected. Tom Woodacre is a keen observer (Mike Lane pers. comm.) and that combined with the historic occurrence of key associate plants at this general location is a strong indication of the credibility of this report. The report (if true), and literature, in this case highlight several things. First, pitcher plant bogs have tight community structure and predictable rare plant associates.   Second, historic railroad operations were beneficial to the persistence of the pitcher plant community. Third, further botanical work is needed in the Waverly area to search for additional pitcher plant populations. The last known population of *Tofieldia racemosa* was recently destroyed in Greensville County (Phil Sheridan pers. obs.) and the chance to rediscover this extremely rare plant, with associate species, in the Waverly area is worth the botanical effort.

Finally, this historical review does not cover introduced populations of pitcher plants. I have mentioned the few relevant cases where natural populations were rescued and inoculated into nearby back-up sites. There has been a long history in Maryland and Virginia of out planting pitcher plants. Most, if not all of these plantings have been either documented in the literature, with herbarium records at local universities, or were outright failures by inexperienced horticulturalists. A discussion and enumeration of introduced pitcher plant populations is a work that merits additional scholarly effort. I am comfortable stating that the sites I have catalogued in this historical review are the single most complete compilation of natural purple pitcher plant sites on the western shore of Maryland and Virginia. My contention is based both on the veracity of the historical record and my expertise in identifying natural populations based on location, physiognomy, and rare plant associates.

APPENDIX B. HERBARIUM, LITERATURE DATA, AND CREDIBLE REPORTS FOR *S. PURPUREA* IN THE DISTRICT OF COLUMBIA, WESTERN SHORE OF MARYLAND, AND VIRGINIA

Maryland

Anne Arundel County: **1.)** *Waters, C.E. 20 Aug 1910* Glen Burnie, abnormal plants found in shade of low dense thicket on edge of bog (US); *Waters, C.E. 28 Aug 1912* Glen Burnie, normal plants in sun, in bog (US); *Plitt, Charles C. 190 30 May 1900* Saw Mill Pond, Glenburnie, bogs (MO) : **2.)** *Reed, C. 316 19 November 1939* Mt. Carmel Bogs (MO); *Reed, C. 4583 29 June 1941* Mt. Carmel Lake (MO); *Reed, C. 3651 23 May 1943* Fresh Pond, Mt. Carmel (MO); *Reed, C. 29194 & 29195 12 June 1952* South of Angels Store, Mt. Carmel Lake, edge of bog (MO); *Reed, C. 33226 7 May 1954* Bog near Angels Store, near Mt. Carmel Lake (MO); *Hotchkiss, N.and E.C.Leonard 21294 18 Aug 1960*, In swamp at head of Fresh Pond near Mt. Carmel. Remarks: Occasional. (US); *Killip, E.P. 43312 27 May 1953*, Fresh Pond, 3 mi. NW of Gibson Island. Remarks: Naturalist's Center #10569. Flowering. (US): **3.)** MDANNE001 - *Sheridan, P., K. Underwood, and J. Cole 1969 9 August 1996* Gumbottom Branch bog at head of Severn River (not yet deposited): **4.)** MDANNE002 - *Sheridan, P., K. Underwood, and J. Cole 2136 18 June 1999* Pitch pine bog on west side of Maryland Avenue near Gibson Island Marina (not yet deposited): **5.)** Sipple (1999) – Cypress Creek: **6.)** Sipple (1999) – Bonnie's Bog: **7.)** *Reed, C. 4122 7 October 1945* Bodkin Creek, bogs (MO).

Baltimore County: **8.)** Charlie Davis credible report – sphagnum hummocks on Westerman's Pond – St. Joseph Church, 8420 Belair Rd – site filled in.

Charles County: **9.)** MDCHAR006 - *Sheridan, P. and W.* Scholl 394 18 November 1989 Sphagnum bog under power lines and wooded acid seep forest 1 ¼ miles s/e of Piney Church, Charles County, MD on headwaters of Piney Branch (specimen lost at GMUF?); *Sheridan, P. and J. Hummer 536 12 May 1990* Power line bog on headwaters of Piney Branch 4 miles south of Waldorf (FTG); Strong, *M.T. and P. Sheridan. 1164 23 Jul 1994* Piney Branch, S of Piney Church, S of Waldorf, NE of La Plata, N of Brice.Vegetative. (US); Sheridan, *P. and M. Strong 1748 23 July 1994 Sarracenia* bog at headwaters of Piney Branch under power line (FTG)

Prince George County: **10.)** *Marshall, G. 11 Jul 1895*, Laurel. flowering (US); *Bartsch, P. s.n. 01 Jun 1903* Laurel. flowering (US): **11.)** MDPRGE001 - Terrell et al (2000) – power line bogs on USDA Beltsville Agricultural Research Station: **12.)** McAtee (1918) – Silver Hill

District of Columbia

13.) *Ward, L.F. 18 May 1878*, in vicinis Washington, D.C. (MO); *Ward, L.F. 21 May 1878*, District of Columbia Mitchell Estate, Eastern Branch. (US); *Ward, L.F. 1878*, Bladensburg vicinity. Flowering. (US); *Ward, L.F. s.n. 27 May 1883*, District of Columbia Mitchell Estate, Eastern Branch. Flowering. (US); *Ward, L.F. 28 May 1884*, District of Columbia Beaver Dam Branch, Bennings Race Track vicinity, flowering (US); McAtee (1918) – *Sarracenia* swamp.

Virginia

Accomac: **1.)** *Reed, C. 5 June 1955 86111*, Just E of Wattsville, edge of pond (MO)

Brunswick: **2.)** *Virginia Academy of Sciences Party 15 May 1932* The northernmost known occurrence in the chief area of the subspecies (PENN)

Caroline: **3.)** *Harvill, A.M.; B.J. Harvill 21874 9 July 1969* Sphagnous border of pond near Peatross (FARM): **4.**) VACARO023 - *Sheridan P. 3 June 1985* N. side of rte. 656 just east of Peatross (GMUF): **5.)** VACARO013 - Sheridan, *P. 378 25 May 1987* Under power lines, 1.5 miles nnw of Bagdad (GMUF); *Sheridan, P. and T. Darling 318 16 September 1989* Power line bog 2 miles n/w of Bagdad feeding Reedy Creek and west of rt. 690 (FTG): **6.)** VACARO026 - *Sheridan, P 379 2 June 1987* just n. of rte. 656, floating sphagnum mats (GMUF): **7.)** VACARO007 - *Sheridan, P. and W. Scholl 461 27 January 1990* Gravelly and sandy bog in woods ¾ mile s/w of Phil Sheridan residence on springs feeding Meadow Creek Pond (FTG): **8.)** VACARO017 - *Sheridan, P., W. Scholl, T. Bradley, M. Strong, C. Kelloff, R. Curlee, L. Peterson 598 15 July 1990* Seepage hillside bogs 1.4 miles s/e of Penola, west of rt. 301 (FTG): **9.)** VACARO025 - *Sheridan, P. and J. Hummer 1156 24 May 1992* Acid seep forest on south side of logging road ca. 0.5 miles west of powerline and ¾ mile south of Colemans Mill Crossing or rt 656 (FTG): **10.)** VACARO027 - *Fleming, G.P., A. Belden, and N. Van Alstine 7715 14 October 1992* Fort A.P. Hill (WILLI): **11.)** VACARO024 - Fleming and Van Alstine (1994) Anderson Camp, Fort A.P. Hill

Chesterfield County: **12.)** *Wilmouth, G; 6 June 1936* Near Chester (US); *Wilmoth, G; 6 June 1936* Bog along A.C.L. (Atlantic Coast *Line*) R.R. tracks (VDAC) ; *Matheny, W.H. 13 October 1957* near Chester (VDAC): **13.)** VACHES004 - *Sheridan, P. and W. Scholl 634 17 November 1990* Zion Church Bog, located ¾ mile west of Zion Church and south of rt. 10 and rte. 631 – some plants moved to nearby power line (FTG): **14.)** VACHES001 - *Sheridan, P and W. Scholl 638 18 November 1990* Swift Creek bog, located 3 miles south of rte 10, 1 mile west of rte 625 and 1.2 miles s/e of Zion Church (FTG): **15a and b.)** VACHES006 and 002 - Phil Sheridan and Robert Wright credible report – two small (1 and 2 plants respectively) populations recorded in 1988 and 1992 on headwaters of Timsbury Creek, south west of Chester, on seeps in mixed oak/pine woods on east and west sides of power lines.

Dinwiddie County: **16.)** *Fernald, M.L.; B. Long, 6211 22 July 1936 Boggy* woods near head of Old Town Creek southwest of Petersburg (GH) (NY) (PENN): **17.)** VADINW002 - *Sheridan, P. and W. Scholl 2 18 January 1986* Swamp in pine woodland, 1 mile n.e. of Addison (GMUF): **18.)** VADINW003 - *Sheridan, P. R. Curlee, and L. Peterson 644 20 January 1991* Wooded *Myrica* heterophylla seepage bog just south of power lines on headwaters of Hatcher Run south of Depot Road n/w of Carson (FTG): **19.)** VADINW005 - *Sheridan, P. 1900 13 June 1996* Catharine Harold Bog; Located on south side of subdivision road in Walkers Landing on seepage, sphagnous edge of Cattail Run. Very local, 2 clumps. Walkers Landing off route 226 and ca. 2 miles east of Addison – *Amianthium muscatoxicum* in bog as well (not yet deposited)

Essex County: **20.)** VAESSEX001 - Wright (1990) – Howerton Bog, along rt. 684 between Howetons and Upright, VA ca. ½ mile ENE of Dragon Run and near the intersection with rt. 611.

Greensville County: **21.)** VAGREE019 - *Fernald, M.L. and B. Long 8715* 15 *July 1938* sphagnous bog about 1 mile NW of Dahlia (GH); Fernald*, M.L. and B. Long 9326 18 September 1938 leaves* essentially green. Deep sphagnum, wooded swamp about 1 mile northwest of Dahlia (GH); *Fernald, M.L, H.E. Moore, 15090 7 June 1946* sphagnum bog 1 mile northwest of Dahlia (MO, US); *Fernald, M.L, H.E. Moore, 15091 7 June 1946* Form with narrow sepals. Sphagnum bog 1 mile northwest of Dahlia (GH); *Harvill, A.M. 17609 28 August 1967* Bog 2 miles north of Dahlia (FARM) (WILLI); *Wieboldt, T., 4107 23 June 1981* Skippers *Sarracenia* bog, west of U.S. 301, 1.2 mi. south of Skippers (VPI)

Isle of Wight: **22.)** VAISLE002 - *Fernald, M.L. and B. Long 6600 24 August 1936* sphagnous depression in sandy pine woods south of Zuni (GH); *Harvill, A.M. and B.J. Harvill 21875 30 September 1969* Boggy flat 5 miles south of Zuni (FARM); *Musselman, L.J., 7090 27 Feb. 1986* Plants in dense stand of Vaccinium spp. Ca. 0.05 mi. south of main entrance of preserve on Union Camp property (ODU): **23.)** *Fernald, M.L. and B. Long 12087 8 June 1940* Swampy depressions in sandy pine barrens and open woods, south of Lee's Mill (GH): **24.)** VAISLE003 - credible report by Chris Ludwig and Phil Sheridan, sphagnous seepage woodland bog feeding Blackwater River near Joyner's Bridge

James City: **25.)** Fernald (1942) "Grimes had reported *Sarracenia purpurea* from "Swampy woods, at Chisel's Run, near Williamsburg-Centerville Road"…we could not locate the *Sarracenia*"

King and Queen: **26.)** *Unknown collector 2 January 1926* (VDAC)

New Kent: **27.)** Harvill et al., 1992.

Prince George: **28.)** *Wood and Loving 5 August 1937* Boggy depression, abundant (URV): **29.)** VAPRIN003 - *Sheridan, P. 1895 7 June 1996* Sphagnous pine woods on headwaters of Cherry Orchard Branch. Just south of route 35 and ca. 1.25 miles north of Sussex County line (not yet deposited)

Southampton. **30.)** *Fernald, M.L. and B. Long 7860 9 April 1938* bottomland swamp of Nottoway River, Smith's Ferry (GH): **31.)** VASOUT001 - *Sheridan, P. and W. Scholl 387 9 April 1989* sphagnous borders of gum pond swamp ¾ mile n/e of Beulahland Church (FTG): **32.)** VASOUT002 - Wieboldt, T. credible report – on hummocks in white cedar swamp along Blackwater River on east side of rt. 258, 2 miles north of road crossing of Nottoway River.

Suffolk (Nansemond): **33.)** *Fernald, M.L. and B. Long 10659 26&28 July 1939* Wet peaty pine barrens, east of Cox landing, south of South Quay (GH); Fernald, *M.L. and B. Long 10660 27 July 1939* Sphagnous savannah-like swale east of Cherry Grove, south of South Quay (GH); *Ahles (with Coker and Morgan) 58181 Pocosin*, Blackwater River about 2.5 mi. n. of VA-NC state line (NCU)

Surry County: **34.)** *Mikula, B. 2240 4 July 1949* Wooded swamp 1 mile north of Beachland. (FARM) (WILLI): **35.)** *Wieboldt, T.* credible *report 3/15/86* – "a few *Sarracenia purpurea* in a seasonally wet area 1 mile north of Barham on rt. 602 in Surry County"

Sussex County: **36.)** *Fernald, M.L. and B. Long 20 July 1936 6210* Spring-fed argillaceous sphagnous bog, headwaters of Jones Hole Swamp, n. of Coddyshore (GH); *Sheridan, P. and W. Scholl 1 31 August 1986* Sphagnum bog n. of Coddyshore (GMUF);): **37.)** *Fernald, M.L. and B. Long 7441 11* September *1937 Sphagnous* argillaceous boggy depression just northwest of Wakefield (GH): **38.)** *White, R. 14 May 1985,* two and one half miles W of Wakefield Diner on route 460 Open pine woods on left, in boggy area along dirt road paralleling railroad tracks (ODU); *Sheridan, P. 4 & 5 5 October 1985* near Wakefield

(GMUF); *Fleming, G.P., 6426 11 May 1992* Open boggy sphagnous swale along N&W railroad NW of Wakefield (VT): **39.)** *Sheridan, P. and A. Harvill 334 23 September 1989* Wooded seepage bog and open power line bog under power lines about ½ mile w. of 460 and ¾ mile n/w of Wakefield (FTG): **40.)** *Sheridan, P. and W. Scholl 553 1 July 1990* Powerline bogs 1 mile n/w of route 604 and just west of rt. 460 (FTG); *Sheridan, P. 715 19 May 1991* Piney Grove Bog – n/w of route 604 under power lines just west of 460 – n/w of Wakefield (FTG); *Sheridan, P. and R. Curlee 1191 14 June 1992* Piney Grove Bog (FTG): **41.)** *Sheridan, P. and W. Scholl 640 18 November 1990* Acid seep forest and power line bog ½ mile west of rt. 627 on headwaters of Cherry Orchard Branch near Prince George County line (FTG): **42a.)** *Cabe, P.R. 202 27 May 1983* Airfield 4-H Camp, south of Wakefield. In swampy stream bottom just above "Swamp Road", growing in sphagnum with *Trillium pusillum*, single plant (WILLI); **42b.)** *Sheridan, P. and M. Heinbach 2005 16 March 1998* Seepy slope edge of Airfield Millpond in mixed pine/hardwoods – 5 clumps present (not yet deposited)

APPENDIX C. PLANT CHECKLIST FOR MARYLAND PURPLE PITCHER PLANT BOGS.

SPECIES	MD SITE ARDEN	MARYLAND AVE.	PINEY BRANCH
Acer rubrum	X	X	X
Alnus serrulata	X		X
Amelanchier canadensis			X
Andropogon glomeratus	X	X	X
Apios americana		X	
Arisaema triphyllum			X
Aronia arbutifolia	X	X	X
Arundinaria gigantea		X	
Asclepias incarnata		X	
Aster lateriflorus			X
Bartonia virginica			X
Bartonia paniculata	X		
Bidens discoidea			X
Calamagrostis coarctata			X
Carex albolutescens			X
Carex atlantica ssp. *capillaceae*			X
Carex collinsii			X
Carex exilis	X		
Carex folliculata		X	X
Carex intumescens			X
Carex leptalea ssp. *harperi*			X
Carex lurida			X
Carex serosa			X
Carex stricta	X	X	X
Carex venusta var. *minor*			X
Carex vesicaria	X	X	
Carex spp.	X	X	X
Celastrus orbiculatus		X	
Chamaedaphne calyculata	X	X	
Chionanthus virginicus			X

SPECIES	MD SITE		
	ARDEN	MARYLAND AVE.	PINEY BRANCH
Clethra alnifolia	X	X	X
Cuscuta compacta var. *compacta*			X
Cuscuta gronovii			X
Cuscuta spp.	X		
Cyperus esculentus			X
Decodon verticillatus		X	
Desmodium paniculatum		X	
Dicanthelium clandestinum			X
Dicanthelium dichotomum			X
Dicanthelium ensifolium	X	X	X
Dicanthelium scoparium			X
Dioscorea villosa			X
Drosera intermedia	X		
Drosera rotundifolia	X		X
Dulichium arundinaceum		X	X
Eleocharis tortilis			X
Epilobium ciliatum			X
Erechtites hieraciifolia			X
Eriophorum virginicum	X	X	
Eupatorium album		X	
Eupatoriadelphis fistulosus		X	
Euthamia graminifolia			X
Gaultheria procumbens	X		
Gaylussacia frondosa		X	X
Glyceria obtusa		X	
Glyceria striata		X	X
Gratiola virginiana			X
Hypericum canadense			X
Hypericum mutilum			X
Ilex laevigata			X
Ilex opaca	X	X	X
Ilex verticillata	X	X	X
Juncus abortivus	X		

SPECIES	ARDEN	MD SITE MARYLAND AVE.	PINEY BRANCH
Juncus caesariensis			X
Juncus canadensis		X	
Juncus debilis			X
Juncus effusus	X		X
Juncus longii			X
Juncus subcaudatus			X
Kalmia angustifolia			X
Kalmia latifolia			X
Leersia oryzoides	X		X
Lespedeza cuneata			X
Leucothoe racemosa	X		X
Lindera benzoin			X
Ludwigia alterniflora			X
Ludwigia palustris			X
Lycopodiella appressa			X
Lycopus virginicus			X
Lyonia ligustrina var. *ligustrina*	X	X	X
Magnolia virginiana	X	X	X
Medeola virginiana			X
Mikania scandens		X	
Mitchellia repens	X		
Myrica cerifera	X		
Nyssa sylvatica	X	X	
Onoclea sensibilis			X
Orontium aquaticum			X
Osmunda cinnamomea	X	X	X
Osmunda regalis		X	X
Oxypolis rigidior			X
Panicum verrucosum			X
Panicum virgatum		X	
Parthenocissus quinquefolia		X	
Phragmites australis		X	X
Pilea pumila			X
Pinus rigida	X	X	
Pinus virginiana	X		X
Platanthera blephariglottis			X
Platanthera ciliaris	X		
Platanthera clavellata			X
Polygala cruciata			X
Polygonum arifolium	X		

SPECIES	MD SITE ARDEN	MARYLAND AVE.	PINEY BRANCH
Polygonum punctatum			X
Polygonum sagittatum			X
Polygonum sp.		X	
Polytrichum commune			X
Pogonia ophioglossoides			X
Rhexia virginica			X
Rhododendron pericylmenoides			X
Rhododendron viscosum	X	X	X
Rhododendron viscosum var. *glaucum*			X
Rhus coppalina			X
Rhus vernix	X		X
Rhynchospora alba	X	X	X
Rhynchospora gracilenta			X
Rosa palustris	X		X
Rubus hispidis		X	X
Rubus spp.		X	
Salix nigra			X
Sarracenia purpurea	X	X	X
Schizachyrium scoparium			X
Scirpus polyphyllus			X
Smilax glauca			X
Smilax pseudochina			X
Smilax rotundifolia	X	X	X
Solidago canadensis			X
Solidago gigantea			X
Solidago odora			X
Solidago rugosa ssp. *rugosa* var. *villosa*			X
Solidago uliginosa			X
Solidago spp.		X	
Sphagnum spp.	X	X	X
Symphyotrichum lateriflorum var. *lateriflorum*			X
Symplocarpus foetidus	X		X
Thelypteris palustris			X

SPECIES	ARDEN	MD SITE MARYLAND AVE.	PINEY BRANCH
var. *pubescens*			
Thelypteris simulata			X
Thelypteris thelypteroides		X	
Toxicodendron radicans		X	
Triadenum virginicum		X	X
Typha latifolia		X	X
Utricularia geminiscapa	X		
Utricularia gibba	X		
Utricularia juncea			X
Vaccinium corrymbosum	X	X	X
Vaccinium formosum			X
Vaccinium fuscatum			X
Vaccinium macrocarpon	X	X	
Viburnum dentatum	X		X
Viburnum nudum	X	X	X
Woodwardia areolata	X	X	X
Woodwardia virginica		X	X
Xyris torta		X	X
Xyris spp.			X

APPENDIX D. PLANT CHECKLIST FOR VIRGINIA PURPLE PITCHER PLANT BOGS.

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Acer rubrum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Aletris aurea														X				
Aletris farinosa					X													
Alnus serrulata						X			X	X		X		X				
Amianthium muscatoxicum								X										
Andropogon glomeratus		X			X	X	X					X	X					

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Andropogon virginicus													X					
Aralia spinosa											X							
Arisaema triphyllum					X			X										
Aronia arbutifolia		X			X				X			X		X				X
Aronia melanocarpa							X											
Arundinaria gigantea						X				X	X			X				
Asclepias rubra					X		X								X			

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Bartonia paniculata	X					X	X			X								
Calamagrostis cinnoides							X											
Campsis radicans									X									
Carex atlantica		X		X									X					
Carex collinsii			X	X	X					X							X	
Carex crinita					X													
Carex debilis					X													
Carex folliculata	X				X													

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Carex glaucescens												X						X
Carex intumescens					X													
Carex lurida								X		X			X			X		
Carpinus caroliniana				X														
Cephalanthus occidentalis						X			X	X								
Chelone cuthbertii					X		X											
Cirsium virginianum							X											

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Clethra alnifolia	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
Conium maculatum					X													
Cyrilla racemiflora										X								
Ctenium aromaticum															X			
Cuscuta spp.				X														
Cyperus pseudovegetus							X											
Dicanthelium dicotomum									X									

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Dicanthelium spp.		X										X		X				
Drosera brevifolia							X			X		X						
Drosera capillaris						X	X					X			X			
Drosera rotundifolia		X	X						X									
Dulichium arundinaceum										X								
Echinochloa crusgalii							X											
Eleocharis acicularis					X													

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Eleocharis tortilis									X									
Eleocharis tuberculosa		X				X	X			X		X						
Eriocaulon decangulare						X												
Eriophorum virginicum		X							X									
Eupatorium pilosum							X											
Eupatorium rotundifolium														X				
Eupatorium purpureum									X									

Virginia Site

Gratiola virginiana	*Gaylussacia dumosa*	*Gaultheria procumbens*	*Fuirena squarosa*	*Fagus grandifolia*	*Eupatorium* spp.	*Eupatorium rotundifolium*	Species
							MEADOWCREEK
					X		REEDY CREEK
							PEATROSS
				X			RT. 601
							SWIFT CREEK
			X				DEPOT RD.
							ADDISON
							CATTAIL CREEK
X			X				HOWERTON
			X			X	SKIPPERS (DAHLIA)
		X					ZUNI
					X		CHERRY ORCHARD
	X						CHERRY ORCHARD II
							WAKEFIELD RR
							WAKEFIELD POWERLINE
							BYRUMS (CODDYSHORE)
	X						AIRFIELD
							SEACOCK SWAMP (BAINS)

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Helenium brevifolium						X												
Helonias bullata				X														
Hexastylis virginiana									X									
Hexastylis spp.				X							X						X	
Hypericum canadense							X		X	X								
Hypericum spp.						X												
Ilex glabra		X			X							X			X			X
Ilex opaca			X	X		X			X	X	X	X	X			X	X	

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Ilex verticillata									X									
Iris prismatica												X		X				
Iris verna		X			X													
Isotria verticillata												X						
Juncus abortivus		X																
Juncus caesariensis	X	X																
Juncus canadensis	X					X	X		X			X						
Juncus longii		X																

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Juncus effusus									X	X		X						
Juncus scirpoides	X						X											
Juniperus virginiana																X		
Kalmia angustifolia											X							
Kalmia latifolia			X	X	X													
Lachnocaulon anceps						X						X						
Leersia oryzoides									X									
Leucothoe racemosa						X			X	X								

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Ligustrum sinensis																X		
Lilium pyrophilum												X						
Lilium superbum				X								X						
Liquidambar styraciflua			X		X	X				X	X	X		X	X			
Liriodendron tulipifera	X		X		X	X		X		X		X	X	X		X		
Lobelia nutalii					X	X	X					X						
Lobelia puberula												X						
Ludwigia alternifolia												X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Ludwigia hirtella												X						
Ludwigia glandulosa							X											
Ludwigia linearis												X						
Lyonia ligustrina var. *ligustrina*					X							X						
Lyonia lucida					X													
Lycopodium aleopecuroides					X		X					X			X			
Lycopodium appressum		X				X									X			

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Lyonia ligustrina							X		X				X					
Lyonia mariana													X					
Magnolia virginiana	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Medeola virginiana						X						X						
Melanthium virginicum											X							
Mitchellia repens				X								X			X			
Myrica cerifera						X			X	X		X		X		X		
Myrica heterophylla							X											

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Nuphar luteum									X									
Nyssa sylvatica var. *biflora*	X			X	X	X	X		X	X	X	X		X	X	X	X	X
Onoclea sensibilis					X													
Osmunda cinnamomea	X	X	X	X	X	X		X	X	X		X	X	X	X			
Osmunda regalis	X	X			X			X		X		X			X			
Oxypolis rigidior					X							X						
Panicum ensifolium					X													
Panicum verrucosum									X			X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Parthenocissus quinquefolia																X		
Peltandra virginica										X								
Pinus palustris											X							X
Pinus serotina					X		X				X	X						
Pinus taeda	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pinus virginiana	X																	
Platanthera blephariglottis		X			X		X					X						
Platanthera ciliaris										X						X		

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Platanthera clavellata				X				X		X								
Pogonia ophioglossoides		X		X								X		X				
Polygala cruciata							X											
Polygala incarnata					X													
Polygala lutea		X			X	X				X		X						
Polygala mariana							X											
Prenanthes autumnalis												X						
Pteridium aquilinum		X	X		X						X	X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Quercus alba										X		X	X	X				
Quercus nigra					X					X		X			X			
Quercus phellos						X						X						
Quercus rubra																	X	
Rhexia mariana							X			X								
Rhexia nashii												X						
Rhexia petiolata												X						
Rhexia virginica		X										X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Rhododendron viscosum	X	X	X	X	X	X			X		X	X	X	X				X
Rhus coppalina											X	X						
Rhus vernix					X	X						X						
Rhynchospora capitellata							X					X						
Rhychospora cephalantha var. *attenuata*												X						
Rhynchospora fascicularis							X											

Virginia Site

Species	*Rhynchospora globularis*	*Rhynchospora glomerata*	*Rhynchospora gracilenta*	*Rhynchospora inexpansa*	*Rhynchospora microcephala*	*Rhynchospora rariflora*
MEADOWCREEK						
REEDY CREEK						
PEATROSS						
RT. 601						
SWIFT CREEK						
DEPOT RD.						
ADDISON	X	X	X	X		X
CATTAIL CREEK						
HOWERTON		X			X	
SKIPPERS (DAHLIA)						
ZUNI						
CHERRY ORCHARD			X	X	X	
CHERRY ORCHARD II						
WAKEFIELD RR						
WAKEFIELD POWERLINE					X	
BYRUMS (CODDYSHORE)						
AIRFIELD						
SEACOCK SWAMP (BAINS)						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Rhynchospora recognita												X						
Rhynchospora torreyana							X											
Rhynchospora spp.	X	X							X									
Rubus hispidus		X										X						
Rubus spp.						X			X									
Sabatia campanulata						X												
Sacciolepis striata												X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Salix caroliniana						X												
Salix nigra												X						
Sambuccus canadensis									X									
Sarracenia purpurea	X	X	X		X					X	X	X	X	X	X		X	X
Saururus cernuus										X								
Sassafras albidum		X				X					X	X			X			
Scleria minor							X					X						
Scleria triglomerata	X	X																

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Scirpus cyperinus									X	X			X					
Scutellaria integrifolia															X			
Smilax bona-nox					X							X						
Smilax glauca					X													
Smilax laurifolia					X	X				X	X	X			X			X
Smilax rotundifolia									X	X	X	X		X		X		
Smilax walterii					X					X								
Solidago odora var. *odora*					X		X					X						

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Solidago uliginosa		X																
Solidago spp.																		
Sorbus arbutifolia						X												
Sparganium americanum		X							X									
Sphagnum spp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spiranthes cernua									X									
Symplocus tinctoria																	X	

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Toxicodendron radicans						X										X		
Typha latifolia						X												
Utricularia geminiscapa		X																
Utricularia subulata	X																	
Utricularia gibba										X								
Utricularia inflata										X								
Vaccinium corymbosum		X	X	X					X	X	X		X		X	X	X	X

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Viburnum dentatum						X												
Viburnum nudum	X			X	X				X	X		X	X		X			X
Viola primulifolia					X													
Woodwardia areolata				X	X					X		X	X			X		
Woodwardia virginica		X		X	X							X						X
Xyris ambigua							X			X								
Xyris difformis var. *curtisii*							X											

Virginia Site

Species	MEADOWCREEK	REEDY CREEK	PEATROSS	RT. 601	SWIFT CREEK	DEPOT RD.	ADDISON	CATTAIL CREEK	HOWERTON	SKIPPERS (DAHLIA)	ZUNI	CHERRY ORCHARD	CHERRY ORCHARD II	WAKEFIELD RR	WAKEFIELD POWERLINE	BYRUMS (CODDYSHORE)	AIRFIELD	SEACOCK SWAMP (BAINS)
Xyris difformis var. *difformis*							X											
Xyris jupicai																X		
Xyris torta		X				X				X								
Xyris spp.	X	X			X				X									
Zigadenus glaberrimus							X				X	X						

VITA

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Education

Bachelor of Science in Biology from Virginia Commonwealth University, Richmond, VA granted in May 1994.

Master of Science in Biology from Virginia Commonwealth University, Richmond, VA granted in August 1996.

Doctorate of Philosophy in Ecological Sciences from Old Dominion University, Norfolk, VA granted in May 2010.

Professional Experience

Director and President: 1995 – Present. Meadowview Biological Research Station. Run a non-profit, 501(c)(3), conservation organization.

Adjunct Faculty: Fall 2001. University of Mary Washington, Fredericksburg, VA. Taught general biology.

Teaching Assistant: 1998 – 2000. Old Dominion University, Norfolk, VA, Taught general biology and botany.

Field Botanist: 1998-1999. Georgia Dept. of Natural Resources, Social Circle, GA. Identified, described and mapped occurrences of rare plant species and exemplary natural communities in the west central Georgia Fall Line Sandhills with standard Nature Conservancy methodology.

Professional Memberships

Virginia Academy of Science
The Longleaf Alliance
Quail Unlimited

Publications

Eberhardt, T., P. Sheridan, and J. Mahfouz. 2009. Monoterpene persistence in the sapwood and heartwood of longleaf pine (*Pinus palustris* Mill.) stumps: assessment of differences in composition and stability under field conditions. Canadian Journal of Forest Research 39: 1357-1365.

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Sheridan, P. and R. Griesbach. 2001. Anthocyanidins of *Sarracenia* L. flowers and leaves. HortScience 36: 384.

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