Pennsylvania Statewide Seasonal Pool Ecosystem Classification

Description, mapping, and classification of seasonal pools,

their associated plant and animal communities, and the surrounding landscape

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Pennsylvania Natural Heritage Program

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I. INTRODUCTION

Study Purpose

This study was the first state-wide effort focused on documenting and classifying the plant, amphibian, and invertebrate communities of upland seasonal pool wetlands across multiple ecoregions in Pennsylvania. Past research in Pennsylvania has focused on assessing and classifying seasonal pool plant or animal communities on a local or regional basis (see the list of Pennsylvania-specific research in the Conservation section). Prior to this research, little quantitative data existed to elucidate and refine seasonal pool community types across Pennsylvania. We focused on habitats that met the United States Environmental Protection Agency's definition of a seasonal pool wetland based on four distinguishing features: surficial hydrologic isolation, periodic drying, relatively small size and shallow depth, and distinctive biological community (Brown and Jung 2005).

The purpose of this study was to add to a knowledge base that can be used to address national priorities developed by the U.S. EPA Wetland Program Development Grants. Core elements of comprehensive wetland programs addressed within this study include:

- Regulations: Summarize the current regulations protecting seasonal pools and identify potential gaps in those regulations identified by this and other research (e.g. protection of isolated wetlands, appropriate buffer sizes).
- Wetland monitoring and assessment: Establish reference condition seasonal pools by ecoregion, describe the plant, animal, and invertebrate communities and assess the water chemistry and landscape context of those pools.
- Wetland mapping: Contribute new seasonal pool locations to the Pennsylvania Seasonal Pool Registry, explore use of aerial photography and NWI maps to identify pools, identify vernal pools that were successfully mapped by NWI and record the NWI habitat code they received.
- Restoration: Describe the plant and animal communities and the natural range of environmental conditions found in reference condition pools across multiple ecoregions of the state which can be used to develop restoration goals and gauge success.
- Compensatory mitigation effectiveness: Explore the effectiveness of recreating forested seasonal pool habitats with naturally fluctuating hydroperiods.
- Prioritization of vulnerable wetlands: Identify seasonal pool types that may be most valuable ecologically or sensitive to threats and disturbance and identify important considerations for their protection (buffers, corridors, best management practices).

The Pennsylvania Natural Heritage Program (PNHP) was primarily responsible for the data collection, analysis and production of this report. The Department of Conservation of Natural Resources provided administration, consultation, and reviewed the report and analyses. Occurrence data of types deemed rare or high quality were entered into the Pennsylvania Natural Diversity Inventory (PNDI) database maintained by the PNHP. This information can be combined with that generated from future studies of seasonal pools in Pennsylvania to fully represent and classify the range of pool types found within the state. These data are available to state agencies, conservation groups and environmental consultants for use in a variety of research, management, conservation, and planning applications.

Study Goals

To assist with meeting the purpose listed above, the following goals were defined for this study:

1) Advance scientific understanding of vernal pools and their ecological functions as seasonal wetland habitats by gathering quantitative information on their plant, animal, and physiochemical qualities and landscape context.
2) Characterize the plant, amphibian, and invertebrate communities of upland isolated seasonal pools across multiple ecoregions in Pennsylvania.
3) Relate plant, amphibian, and invertebrate communities to each other and to environmental and landscape variables.
4) Identify easily measured environmental and landscape variables that may predict presence or dominance of plant, amphibian and invertebrate taxa in a particular seasonal pool.
5) Identify environmental and landscape indicators of amphibian and invertebrate taxonomic richness in seasonal pool habitats.
6) Provide a revision of seasonal pool plant communities for an eventual update of the "Terrestrial and Palustrine Plant Communities of Pennsylvania" (Fike 1999). This classification currently describes one seasonal pool community type, the Herbaceous vernal pond. This habitat type is described as often occurring with "Buttonbush wetland" or "Red maple – mixed shrub palustrine woodland" community types.

Seasonal Pool Ecosystems

Seasonal pool definition

Names and definitions for seasonal pools are as variable as the habitat. Seasonal, temporary, ephemeral, vernal, and autumnal are all terms used to describe these wetlands. While "vernal" is a term commonly attached to these temporary wetlands, it is not always accurate. A vernal pool is technically a water body that experiences a dry phase in the fall and winter, and a wetted phase in the early spring and summer. In contrast, an autumnal pool fills in the fall and retains water through the winter and spring (Wiggins et al. 1980; Williams 1987; Batzer and Sion 1999). For the remainder of this report, the terms pool and pond will be used interchangeably, as will the terms vernal, temporary, seasonal, and ephemeral.

Seasonal pools occur along a gradient of flood duration and frequency. On one end of the spectrum are rain puddles that hold water for a few weeks. At the other end of the spectrum are pools with water levels that fluctuate seasonally, but only dry down completely during drought years. The definition of a vernal pool may vary based on geographic region and even upon the interest of the researcher or management agency. The U. S. Environmental Protection Agency uses four criteria to define a vernal pool: surficial hydrologic isolation, periodic drying, small size and shallow depth, and a distinctive biological community (Brown and Jung 2005). Colburn (2004) proposed five indicators for vernal pools in the glaciated northeastern United States: a forested landscape context, physical isolation, relatively small size, seasonally fluctuating water levels, and a distinctive, specialized fauna.

Factors shaping seasonal pool animal assemblages

Vernal pools are relatively small, fishless, still-water environments found within forest depressions. They generally have an impermeable substrate such as hardpan or clay, and have a fluctuating hydroperiod characterized by an annual or semi-annual dry phase (Wiggins et al. 1980; Thompson and Sorenson 2000). Temporary pools within a region share a backdrop of climatic and geomorphologic conditions, and share the same potential assemblage of organisms adapted to withstanding those particular environmental conditions (Schneider and Frost 1996). Processes such as habitat duration or habitat disturbance largely determine invertebrate community structure (Schneider and Frost 1996). In a temporary pool, the habitat is disturbed by the seasonal, cyclic pattern of flooding and drying. The physical stress exerted by a fluctuating hydroperod and the adaptations of the temporary pool organisms to this stressful environment are therefore dominant factors in determining the insect community composition (Sharitz and Batzer 1999, Zimmer et al. 2000). While a temporary hydroperiod is a significant obstacle for an aquatic organism to overcome, there is a good evolutionary reason to do so. Fish are major predators of invertebrate fauna, but are typically unable to tolerate temporary aquatic environments. When fish are present in an aquatic habitat, they become one of the most significant variables affecting the composition and abundance of the insect community (Zimmer et al. 2000). Temporary pools provide a place for immature animals to develop without the threat of predation from fish.

Physiochemistry

The physiochemical environment directly influences biota. Components of the physiochemical environment include size and depth of the wetland, the substrate, soils, nutrient availability, pH, oxygen, and temperature. Many of these components are interrelated, dependent variables; for example as temperature increases, dissolved oxygen and oxidation-reduction potential (ORP) decreases. Most temporary pond species have fairly broad tolerances for the conditions found in seasonal pools including low pH and dissolved oxygen (Schneider and Frost 1996). On the other hand, mollusk species richness and abundance is positively correlated to calcium availablilty (Dillon, 2000). Therefore mollusk species that use seasonal pools such as pond snails and fingernail clams may be limited to pools with sufficient calcium available for them to use in building their shells.

Hydroperiod

Hydroperiod plays an important role in the plant and animal life of a vernal pool. In temporary pools, hydroperiod includes the length of time a pool has standing water in it (flood duration), and the frequency at which the pool is flooded in a given period of time (Sharitz and Batzer 1999). The duration of flooding in a temporary pool is related to the size and depth of a pool (Higgins and Merritt 1999, Zimmer et al. 2000), and the composition of the underlying substrate (Sharitz and Batzer 1999, Falkenstein 1999). Temporary pools tend to be located on soils that greatly restrict surface water infiltration. This slow permeability rate through the soil creates a seasonally high (perched) water table, allowing water to remain ponded on the surface for unusually long periods of time. The accumulation of organic material in the ponds also increases the water-holding ability of the pools compared to pools with more mineral soils (Falkenstein 1999). As a result vernal pool hydrology is driven by seasonal precipitation patterns and subject to fluctuating hydroperiods.

Hydroperiod is linked to several trends in water chemistry and species occurrence. Schneider and Frost (1996) examined the invertebrate and amphibian communities present in seven seasonal pools with varying hydroperiod duration in Wisconsin. In general all of the ponds had low pH and conductivity compared to other aquatic habitats. But as pond duration increased, pH, dissolved oxygen, and conductivity also increased. Long hydroperiod ponds had higher invertebrate predator diversity and abundance. Predator consumption was found to be significant in regulating prey abundance and distribution only in long-duration ponds. Short duration ponds had a greater proportion of taxa with life history adaptations to dry spells. Decomposition of organic detritus that takes place during the dry phase of a vernal pool is important because it increases the nutrient availability (Wiggins et al. 1980). Short hydroperiod pools typically do not support taxa requiring longer larval development such as backswimmers (Notonecta), mole salamanders (Ambystoma) and dragonflies (Anisoptera).

In a study of six wetlands in a developed region of western Australia, Balla and Davis (1995) found that wetlands that seasonally dried had higher macroinvertebrate species richness compared to permanent wetlands. Coleoptera were found to be the most diverse taxa, with higher diversity in wetlands with seasonal drying and low nutrient enrichment. This trend of increased richness in wetlands that undergo a period of dryness may be explained by rarefaction.

Rarefaction is density-independent elimination of species, which in this case is a period of drought in a wetland environment. This severe environmental disturbance suppresses population sizes of all species but increases overall diversity by creating more opportunity for less competitive species or species specially adapted to the seasonal cycles of a temporary pool (Connell 1978, Outridge 1987).

Studies of amphibians have found a similar trend. For example a study of 103 wetlands ranging in size from 0.01 to 3.27 ha in New Hampshire found that wetland size and hydroperiod were correlated, with smaller wetlands having shorter hydroperiods. Overall, amphibian species richness was influenced by hydroperiod rather than wetland size, with less diversity in wetlands with short hydroperiods (< 4 months) than those with intermediate (4-11 months) and long (permanent) hydroperiods. Occurrence of eight out of nine individual amphibian species was also significantly influenced by hydroperiod rather than wetland size. However, when species richness and wetland size within hydroperiod categories were examined, species richness patterns were found to relate to wetland size in wetlands with short and, to a lesser extent, intermediate hydroperiods, but not in wetlands with long hydroperiods (Babbitt 2005).

Pool Size

The size of a wetland has been shown to affect insect community composition. As mentioned previously, the size of a pool affects hydroperiod, and therefore the biota. In a study of Dytiscidae beetles, the size of a pool was found to be significant with respect to larval development and population survival (Nilsson and Soderstrom 1988). The smaller pools were found to have fewer species than larger pools. Species excluded from the smaller pools included larger bodied beetles of the *Agabus* genus. Since larger bodied species must consume more prey to complete larval growth, it is thought that the smaller pools lacked a sufficient food supply to support a successful population of the larger bodied *Agabus* larvae. It was shown that stable populations of the smaller bodied *Agabus* species were able acquire enough food from the smaller sized pools that did not support the larger bodied species. Another study (Roth and Jackson 1987) found that both the density of predatory insects and mortality of tadpoles were directly related to pool size. They surmised that predators were less likely to discover small pools during dispersal, or that the insects may selectively choose larger pools to colonize.

A study of invertebrate biomass of seven temporary ponds in southern Quebec found that trends in total animal biomass were explained by water temperature, volume of the water body, and the season (Aubin and Leblanc 1986). They found that pool size correlated to total biomass, with smaller ponds exhibiting a greater total biomass than an equivalent volume of larger ponds. Smaller pools have a higher perimeter to volume ratio, which increases the amount of shallow shoreline habitat which is a highly productive zone. Fairchild et al. (2003) also found that of nearly 4,000 aquatic beetles collected from temporary and permanent ponds, 85% were collected from along the pond’s margin.

Temperature

Temperature is an important factor that can influence insect community composition. In general, larval growth and water temperature are positively correlated. The Aubin and Leblanc (1986) study found that total biomass was correlated closely to temperatures, with the most abundant biomass in the spring. However, within a study of the local guild composition of *Agabus* (Coleoptera: Dytiscidae) beetles in a vernal pond, it was found that four species differed in their relative food consumption at varying temperatures. This disparity is probably due to differing thermal growth responses that cause species to develop at a particular time in the season. This study also found that shading from perimeter and interior vegetation lowered water temperatures, which excluded certain insect species (Nilsson and Soderstrom 1988).

Seasonality

Many species using a temporary pool have just one generation per year, unlike many terrestrial or permanent pond species that can produce multiple generations in one year. Because of the impermanence of the aquatic habitat, there is a narrow window of time in the spring when the temporary pool is present at its full size on the landscape. Spring is the time of high productivity, before the pool starts to dry and environmental conditions in the pool deteriorate. Aubin and Leblanc (1986) documented this trend, as did Balla and Davis (1995) who found that overall, the highest numbers of taxa and maximum biomass occurred in the spring at peak water levels.

Oxygen

The availability of oxygen is an important factor influencing aquatic communities. Flooding leads to a depletion of oxygen in water and soil, preventing plants from respiring through normal metabolic pathways, and alters the availability of nutrients to plants. Anoxic conditions also cause electrochemical reduction in the wetland soils. This causes an increase in concentrations of toxic materials such as ferrous and manganous salts, ammonia, and sulfides (Sharitz and Batzer 1999). Availability of oxygen can be a limiting factor for aquatic insects. Insects that are typically found in well-aerated aquatic environments such as lakes, rivers, and streams, tend to be absent or poorly represented in temporary pool environments. Vernal pools have relatively low dissolved oxygen levels (Battle and Golladay 2002, Colburn 2004). The insects of temporary pools have the ability to cope with the low oxygen and some species have evolved unique methods of obtaining oxygen (Sharitz and Batzer 1999).

Some invertebrates take advantage of oxygenized pockets in the substrate created by wetland plants. Wetland vascular plants developed pore space in the cortical tissues to compensate for the anoxic conditions commonly found in temporary pools. This allows oxygen to diffuse from the leaves of the plants down to the roots to provide them with oxygen needed for their functions. This diffusion of oxygen into the roots eventually spreads into the surrounding anoxic soil, creating an oxidized rhizosphere (NRC 1995). The oxidized rhizosphere can create a buffer from the toxic reduced ions in the soil, and can create microhabitats where invertebrates can obtain oxygen (Sharitz and Batzer 1999).

pH

pH is a measure of the amount of active acid in a body of water. Vernal pools not located on carbonate bedrock typically have soft, acidic water because they are fed by surface water rather than ground water. Acidic waters generally have fewer nutrients available for plant and animal growth. Highly acidic pools have been found to increase deformities and lower survival of amphibian embryos, although the thresholds for species varies geographically with populations of regions with naturally more acidic soils and waters more tolerant of lower pH (Colburn 2004). Certain functional groups of invertebrates are more likely to be intolerant of low pH and associated higher concentrations of metals such as aluminum. Kok and Van der Velde (1994) found that macroinvertebrate detritivores who shred or graze and scrape on decomposing organic matter were less diverse and less abundant in acidic still water habitats compared to alkaline ones. The decline in detritivores was shown to be partially a response to a decline in the nutritional quality of detritus in acid waters due to decreased microbial activity. Microbes play an important role in making decaying organic matter more palatable to detritivores (Mehring 2003).

Conversely, many vernal pool invertebrates are adapted to lower pH waters (Batzer and Wissinger 1996, Schneider and Frost 1996). Acid tolerant invertebrate predators such as the *Ptilostomis postica* caddisfly may in fact contribute to poor amphibian recruitment, especially in acidic waters where amphibian larvae may already be stressed (Rowe et al. 1994). Several studies of water beetles have also concluded that water beetle communities are not strongly structured along a pH gradient (Juliano 1991, Nilsson and Soderberg 1996, Arnott et al. 2006).

Nutrients

Seasonal pools in the northeastern United States, because of their small size, are typically surrounded by trees. The surrounding forest buffers vernal pools, shades them, moderates water temperatures, and in closed canopy settings can prevent or reduce growth of vegetation and algae. Trees also stabilize the soil and reduce sediment input into wetlands. Seasonal pools located in settings where trees have been removed for agriculture or development tend to become eutrophied due to increased water temperatures and input of sediments and nutrients. These changes lead to degraded water quality with lower oxygen levels and increased algae production. Hydrologic patterns change as well. For example, after periods of rain pool levels increase more rapidly and to higher levels due to increased surface runoff.

Several studies have found increasing biomass and abundance but decreasing taxa richness with increasing nutrient enrichment. Permanent and enriched wetlands tend to have the highest macroinvertebrate biomass consisting of species more tolerant of hypertrophic conditions such as chironomids, cladocerans, copepods, and amphipods, while seasonal, less enriched wetlands tend to have more unique species (Davis et al. 1993, Balla and Davis 1995).

Vegetation

Another important variable shown to affect invertebrate community structure is the vegetative community (Zimmer et al. 2000). The abundance of aquatic plants is influenced by many of the same factors that influence the invertebrate community. For example, the shading of a pond by overarching upland trees can limit or prevent plant colonization of pools by limiting light availability. Temporary pools may be vegetated to varying degrees with a variety of vegetation types. The vegetative community may include shrubs, marsh grasses and sedges, floating leaved aquatic plants, algae, and even flood resistant trees (Falkenstein 1999). When plants colonize a temporary pool, their presence can change the physiochemical environment. Vascular plants influence pool hydrology through evapotranspiration while at the same time lowering pool temperature through shading. Plant growth and decay builds up the organic layer and traps sediment (Sharitz and Batzer 1999). The accumulation of organic soil affects length of flooding because the accumulated organic matter helps the pool hold water longer (Falkenstein 1999).

Vegetation provides decaying organic matter, a valuable food source which forms the foundation of the aquatic insect food web (Wiggins 2000). The detritus originates either from dead aquatic macrophyte leaf and stem material from within the pool (*in situ* inputs), or from leaves and woody material entering the pool from surrounding trees (allochthonous inputs) (Smock and Stoneburner 1980, Batzer and Wissinger 1996). Studies have shown that abundance of insects feeding on detritus increases as leaf decomposition progresses (Campeau et al. 1994). This is likely due to the increased nutrient availability as microbes break down the detritus and make it more palatable. The dense growth of fungi and bacteria that break down the organic material are themselves another key food source to many aquatic insects. Algae colonizing the decaying vegetation provide another important food source, particularly to midge larvae (Campeau et al. 1994). Finally, the small invertebrates feeding on the detritus become prey items for other invertebrate and vertebrate predators.

Since detritus is the major source of food for the aquatic insects of temporary pools, it could potentially become a limiting factor if in short supply. This is uncommon however, as the amount of detritus is typically more than can be processed by the invertebrate community (Batzer and Wissinger 1996). In wetlands, plant decomposition is primarily achieved through microbial processing and leaching, rather than by insect shredding and consumption (McArthur et al. 1994). An interesting limitation to the population size of some detritivorous mosquitoes occurs when the population becomes so dense that some of the individuals are physically unable to access the plentiful detritus on the substrate (Batzer and Wissinger 1996).

Live macrophytic vegetation serves an important role in the pool environment besides providing organic detritus. Live macrophytes, both during and after seasonal flooding, are a food source for a variety of terrestrial insects such as aphids, leaf beetles, weevils and moth caterpillars. Fewer aquatic insects utilize live macrophyte tissue as a food source, but they do rely on the habitat structure the plants provide (Smock and Stoneburner 1980; Bergey et al. 1992). Live vegetation increases the amount and variety of habitats and substrates. Vegetated aquatic habitats have been found to have different insect guilds as well as greater insect diversity and abundance versus unvegetated aquatic habitats (Hargeby 1990; Bergey et al. 1992). Vegetated habitats provide more abundant food resources by creating physical attachment sites for periphytic algae and insects, and by contributing detritus. Some of the most productive wetland areas occur where open water is interspersed with emergent and submerged vegetation (Bergey et al. 1992, Batzer and Wissinger 1996). Vegetation also provides protective cover that hides insects from their predators. Complex habitats have been shown to lower vertebrate predation rates (Hargeby 1990). Batzer and Resh (1992) found that certain mosquito, epiphytic midge, and brine fly larvae reached their highest numbers in pools with 100% cover, while predators such as water boatmen and hydrophilid beetles preferentially colonized and reached their highest numbers in pools with 50% vegetation. Living macrophytes also are important for insects with aerial adult forms such as dragonflies and damselflies, serving as emergence and oviposition sites (Bergey et al. 1992).

Seasonal fluctuations in vegetative communities can influence insect communities. A study by Hargeby (1990) compared invertebrate abundance in plant stands, one that died back annually and one that was evergreen. Chironomidae with the ability to disperse and recolonize quickly dominated in the plant stand that died off each winter. Quick dispersal and recolonization enables these Chironomidae to tolerate frequent disturbances to their habitat. In the evergreen plant stand, Isopoda were found to dominate. In this habitat, Isopoda found the habitat permanence they needed to support their life history of slow colonization and low recruitment. As their numbers increase, they begin to overtake the Chironomidae by outcompeting with them for food resources, and by consuming Chironomidae as part of their diet. While die-back of macrophytes in the fall increases detrital and microbial food bases, this process can be detrimental to insects that depend on living plants as food material, rely on the physical habitat created by the plants for shelter from predators, or cannot adapt to a fluctuating environment.

Landscape condition

The condition of the surrounding landscape is often an important factor influencing the condition of a wetland or vernal pool. Disturbances from activities such as logging, mining, agriculture and development can lead to nutrient enrichment, sedimentation, runoff, wetland basin alteration, hydrology alteration, habitat fragmentation, and other changes which can negatively impact the health of vernal pool ecosystems (Rader et al. 2001, Colburn 2004, Calhoun and deMaynadier 2008

II. METHODS

Site Selection

Emphasis for site selection in this study was placed on regions containing a high concentration of pools and diversity in pool types. An effort was also made to select pools across a wide range of geographical locations and physical and biological characteristics. Eighty-nine study pools were ultimately selected that met the United States Environmental Protection Agency's definition of a seasonal pool wetland based on four distinguishing features: surficial hydrologic isolation, periodic drying, relatively small size and shallow depth, and distinctive biological community (Brown and Jung 2005).

Data from PA Natural Program Biotics Database (PNHP 2008a) and the Pennsylvania Seasonal Pools Registry Program (PNHP 2008b) were reviewed at the beginning of this study in 2007. These data indicated that the highest concentration of seasonal pools occur in several ecoregions or ecoregion sections, including: the Low Glaciated Section of the Western Allegheny Plateau, the Pocono section of the High Allegheny Plateau, The Ridge and Valley and Blue Mountain sections of the Central Appalachian Forest, and the Delaware River Valley (from the Delaware Water Gap to Milford, Pennsylvania). These areas are characterized by either rolling, glaciated terrain with poor developed drainage networks, poorly drained valley bottoms and lowlands, or perched pools along ridgetops.

Lesser concentrations of vernal pools were identified in the Piedmont which has undergone high levels of anthropogenic disturbance such as development and intensive agriculture. The ephemeral wetlands typical of the Great Lakes Plain ecoregion adjacent to Lake Erie were not utilized in this study because of their strong connection to groundwater and other wetlands. The North Atlantic Coastal Plain ecoregion is heavily urbanized and no natural seasonal pools were identified in this region.

Aerial photo interpretation was used to attempt to locate additional pools in areas of the state where existing data was lacking. Data gaps in the existing data were especially apparent in the southwest corner of the state in the Waynesburg Hills and Allegheny Mountain Physiographic Province Sections. Aerial photo interpretation did not yield any new seasonal pool sites in this region. Topography and geology of the southwestern corner does not favor development of seasonal pools in upland settings. Ephemeral wetlands that support seasonal pool indicator species in this region occur most commonly along the floodplains for streams and rivers.

The opposite corner of the state in the northeastern region of the Glaciated Low Plateau Physiographic Province Section also lacks documented seasonal pools. Aerial photo interpretation of this region yielded a handful of new potential seasonal pool sites, two of which were included in the study. Pools in this region tended to occur singly or as small groups and were widely distributed across the landscape. In forested areas with high evergreen canopy, pools may have been present but were very difficult to detect using aerial photography.

Water Chemistry and Pool Dimension Measurements

A variety of environmental variables were measured to look for correlations with invertebrate and herptile abundance, richness, and distribution. This sampling was done in conjunction with the invertebrate and herptile surveys. In 2007 the faunal surveys were conducted between April 4 and May 17. In 2008 they were conducted between April 2 and May 21. One pool (EPASP73) was dry at the time of the visit and no water chemistry data was collected.

Water temperature, conductivity, dissolved oxygen, water pH and ORP were recorded using the YSI meter. The probe was placed in the water approximately 2 dm below the surface and at least 1 meter from the edge. The meter was allowed to stabilize for at least 5 minutes before readings were recorded. A water sample was collected in the field for use in measuring total hardness, calcium hardness, magnesium hardness and total alkalinity. These values were determined in the lab using LaMotte test kits. Air temperature was also recorded in degrees Celsius using the Kestrel 4000 Pocket Weather Tracker. Instrument readings were taken approximately 4 feet above the ground.

The length and width of each pool basin was measured using a Bushnell yardage pro range finder. Often the pools would appear to be fully inundated. Other times, there were signs that the pool basin was not completely inundated. Indications that the pool was drying down includes presence of an exposed ring of leaf litter of different color than upland forest litter, a ring of mosses or high blush blueberry bushes set back from the current water's edge, and water marks on trees no longer standing in water. If the pools appeared to be less than fully inundated, the potential maximum length and width was measured using the above indications to estimate pool dimensions. The actual flooded pool length and width was also measured and used to calculate the number of d-frame net samples to be taken from the pool.

Invertebrate and Herptile Surveys

The invertebrate and reptile and amphibian fauna of each pool was surveyed during the spring. In 2007 these surveys were conducted between April 4 and May 17. In 2008 they were conducted between April 2 and May 21. One pool (EPASP73) was dry at the time of the visit and no invertebrate or herptile data was collected.

Amphibian Call Surveys

Surveyors approached the pool quietly and stood far enough away to avoid detection by the amphibians. Surveyors listened for 3 minutes and recorded the species calling and the call code. Additional species heard during the pool sampling were added to the list. The calling code was adapted from protocols used by the USGS Amphibian Research and Monitoring Initiative, Northeast Region (http://www.pwrc.usgs.gov/nearmi/).

Calling Codes:0) = No frogs or toads calling
1) = Individual calls can be heard and counted. Calls do not overlap.
2) = Calls overlap but individual calls still discernable.
3) = A full chorus. Cannot distinguish individual calls.

Amphibian egg mass surveys

A visual count of all egg masses within the pool was conducted. Surveyors walked transects through the pool as needed to cover the pool basin. When wood frog egg masses were too many to count individually, the area they occupied was estimated in square meters. A single egg mass of wood frog eggs was considered to occupy $0.02m^2$.

Herptile upland pool edge survey

One individual conducted a ten-minute survey (or two people conducted a five-minute survey), for herptiles around the perimeter of the pool. Searchers turned over logs and rocks and inspected sphagnum hummocks in an area up to 10 meters from the pool edge.

D-frame dip netting for invertebrates and larval amphibians

A 12 inch rim d-frame dip net with a canvas bag approximately 6.5 inches deep was used to take invertebrate samples. The number of samples collected was based on the inundated pool size. A Bushnell yardage pro range finder was used to measure the length and width of the pool and the area of the pool was calculated using the equation A = 3.14 (1/2L) (1/2W). The total area was divided by 150 to yield a survey effort of one sweep per 150 m^2. This number represented the number of samples preserved as macroinvertebrate samples. The total area was again divided, this time by 100. The difference between this number and the number calculated when the area was divided by 150 represented the number of scoops that were quickly processed in the field. These scoops were intended to increase sample effort for amphibian larvae to one sweep per 100 m^2 without increasing collected samples for later processing.

Samples were distributed around the pool by walking approximately five d-frame pole lengths between sample points. The rich shallow zones of the pool were targeted more heavily than very deep zones. Samples were alternated between the shallow perimeter and deeper waters up to a depth of approximately 0.75 m, and an effort was made to sample a variety of microhabitats. Amphibian egg masses were avoided.

The contents of each d-frame dip designated as a macroinvertebrate sample were cleaned of leaves and other pieces of detritus were rinsed and removed. Larval amphibians were counted and released. Samples from a given pool were then combined into a large whirl-pack, preserved in 75% ethanol, and returned to the laboratory for macroinvertebrate identification.

Samples designated to increase survey effort for larval amphibian larvae were examined in the field in a white pan. Any amphibian larvae or adults were counted and released and any new macroinvertebrate taxon not observed in previous samples were picked out by hand and kept. A few amphibian larvae were kept when needed and preserved in order to verify their identification in the lab.

Invertebrate Sample Processing

The contents of each whirl pack bag were dumped into a large (25.4 x 34.3 cm) white sorting tray and larger debris removed. Using a pair of fine forceps, all macroinvertebrates were removed from the sample and placed into vials by broad taxonomic groupings. Much of this work was done under a dissecting scope with a magnification range of 10 – 30 x in order to locate even quite small specimens. This methodology typically resulted in a total or near total pick of macroinvertebrates from each d-frame net sample. Small micro-invertebrates (zooplankton) were also removed, but the total number removed from any one sample was capped at 100 individuals for microinvertebrate taxa. For the purposes of this study, taxa considered to be macroinvertebrates were: Amphipoda, Anostraca, Bivalvia, Coleoptera, Collembola, Diptera, Ephemeroptera, Gastropoda, Hemiptera, Hirudinea, Isopoda, Megaloptera, Nematoda, Odonata, Oligochaeta, and Trichoptera, Bivalves, Mollusca, Snails. Taxa categorized as microinvertebrates were: Cladocera, Copepoda, and Hydrachnida, Ostracoda, and Planaria.

Invertebrates were placed in 8 ml specimen vials with a screw cap and O-ring for long term reliable storage of alcohol-preserved specimens. Each vial was labeled with the site name and number, date of collection, and collector. Determinations were written on labels placed in the vial with the specimens. Locality and determination data were entered into a spreadsheet.

Invertebrate Specimen identification

All identifications were made to the most detailed taxonomic level possible given available keys, equipment, and time available for identification. Early instars were typically only identified to order or family as most keys require mature larvae or adults for identification. Keys used to identify organisms included Belk (1975), Burch (1975), Burch (1980) Burch and Tottenham (1980), Darsie and Ward (2005), Dillon (2000), Epler (1996), Epler (2001), Hutchinson (2003), Jokinen (1992), Larsen et al. (2000), Merritt and Cummins (1996), Needham et al. (2000), Peckarsky et al. (1990), Pennak (1989), Smith (2001), Thorp and Covich (2001), Westfall and May (1996), Williams (1972),Wiggins (2000).

Vegetation and Physical Site Surveys

Vegetation composition and structure were recorded for 89 pools following accepted Natural Heritage sampling protocols developed for the quantitative characterization of plant communities (Strakosch-Walz 2000). Sampling took place in late summer and early fall in order to capture late season development of the vegetative community.

For each pool, a sketch was made of the pool and surrounding habitat on graph paper. General vegetation zones were drawn based on dominant cover of plant forms (i.e. herbaceous-dominated, shrub-dominated). Plots were established within homogeneous vegetation patches that were representative of the community (Mueller-Dombois and Ellenberg 1974). Within each zone, a $1m^2$ relevé sampling plot was established to document the cover of each plant species.

In total, there were 269 $1m^2$ relevé sampling plots within the 89 pools. Each plot was sampled one time during the growing season between June and September. The bulk of the vegetation data were collected during intensive sampling windows of several consecutive weeks, between July and August, of each year.

The vegetation was visually divided into eight strata: emergent trees (variable height), tree canopy (variable height), tree subcanopy (>5m in height), tall shrub (2-5m), short shrub (<2m), herbaceous, non-vascular, and vines. The percent cover was estimated for each species in each stratum using modified Braun - Blanquet cover classes (Strakosch-Walz 2000). Specimens of species that were not identifiable in the field were collected for later identification. Collected specimens were deposited in the herbarium of the Carnegie Museum of Natural History in Pittsburgh.

Total bryophyte cover recorded for each plot and representative bryophytes were collected and specimens packaged and sent to John Atwood at the Missouri Botanical Garden in St. Louis, Missouri.

A soil core was excavated near each plot and soil characteristics including depth to clay, rock, or hardpan; thickness of muck (organic material), and presence of gleying/mottling were recorded. Field texture, color, and pH were determined for each soil horizon. Soil color was determined using a Munsell Soil Color Chart. Soil color can be a clue to its mineral content. Soil colors defined by the Munsell system allows for direct comparison with soils from other sites. Field pH was obtained using a Lamott Morgan Soil Test Kit (model ST-M) or Hellige-Truog Soil Reaction tester. These tests measure the amount of ionic material dissolved in a suspension of soil and water. A pH <7.0 is acid and a pH >7.0 is alkaline.

A digital photograph of each plot was also taken. The location of each plot was recorded with a Trimble GeoXM global positioning system (GPS) unit, with the datum set to North America 1983 (Conus) and the coordinate system set to Universal Trans-Mercator (UTM) zone 17, or 18. All data points were post-processed using Trimble GEO Correct Software.

Surrounding Plant Community Sampling

The plant community was described for a 100 m radius around each pool during the site visit. Notes were taken on the area surrounding each pool including the quality and dominant species at each stratum. Based on the composition, each vegetation patch surrounding the pool was assigned to a plant community type described in the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999). In addition, notes were taken on any significant environmental information, such as landscape context, herbivory, stand health, recent disturbance, fragmentation, or evidence of historic disturbance.

Landscape Analyses

The GPS-recorded location of each pool was used to create a layer in ArcMap 9.2 (ESRI Inc. 1999-2006). The following spatial attributes of each pool were calculated from a series of base layers. Complete data tables of this information are found in Appendices 3-5.

- TNC Ecoregion and Subsection
- Physiographic Province and Section
- County
- Bedrock geology and primary lithosome
- Elevation

Additional analyses were conducted on each pool to evaluate the condition of the surrounding landscape. Landscape qualities were assessed using publicly available state-wide based layers available through the Pennsylvania Spatial Data Access (http://www.pasda.psu.edu/) such as roads, topographic maps, National Wetland Inventory, PA Map aerial photography, and Department of Environmental Protection watershed layers (PASDA 2008). Measured landscape variables included the amount of forested buffer in increasing concentric circles around each pool, and the distance and type of nearest disturbance, road, stream, and wetland. Complete data tables of this information are found in Appendix 6.

Several multivariate statistical techniques were employed to classify the pools based on environmental data. The physiochemical data of eighty-eight pools was examined in cluster analysis and . The invertebrate cluster groupings were based on base 10 log transformed abundance data at the greatest taxonomic resolution and including rare species. Data from eighty-eight pools were used for the invertebrate community analysis with EPASP 73 excluded because it was dry during the spring faunal visit. The amphibian cluster groupings were based on base 10 log transformed abundance data at the species level and included rare species. Data from eighty pools were used for the amphibian analysis with pools EPASP 7, 9, 11, 28, 30, 70, 73, 78, 81 excluded because no aquatic amphibians were observed during the spring faunal visits.

Invertebrate and Herptile Data Analyses

Line and curve fitting on bivariate scatterplots: The Fit Y by X platform was used in the JMP software (SAS Institute Inc., version 4.0.4, copyright 1989-2001) to examine relationships between continuous variables such as taxon abundance and richness and environmental variables. Invertebrate and herptile abundance data were base 10 log transformed prior to analysis. Taxon richness was calculated by summing the number of taxa identified to the lowest level of resolution reached, which varied by taxon.

Invertebrate and herptile abundance and taxon richness were treated as the dependent response variable (Y) while measured environmental variables were treated as the independent variable (X). Simple least-squares method linear regressions fit a line through the resulting scatterplot using the least squares criterion. Unimodal concave / convex relationships were also sought by fitting a parabola (quadratic polynomial fit degree = 2) curve to the data. The relationship that best described the data (linear, parabola) was selected based on the highest significant probability and r^2 value and verified by viewing a graph of the data. On occasion single pool outliers were removed to allow for a better fit.

Pearson product-moment correlation coefficients were calculated using the JMP software for pairs of environmental variables and for pairs of invertebrate and herptile taxa. This coefficient provides an estimate of how much two variables covary with each other.

One-way Analysis of Variance (Anova) was used to test if two or more sample means belong to a population with the same parametric mean. Anova was conducted using JMP software to determine if there was a significant difference ($p < 0.05$) among group means for herptile and invertebrate taxon density and richness within a variety of pool classes. Environmental grouping variables were county, ecoregion and physiographic sections and subsections, surficial geology, glacial history, largest disturbance type within 600 m buffer, nearest road, stream, and wetland type. Plant and animal community classification grouping variables were based on the results from cluster analyses on vegetation, amphibian, and invertebrate data. A post-hoc comparison of means using Tukey-Kramer was used to look for significant differences between pairs of means. The Tukey-Kramer test is used when the group sample size is not equal, and identifies which group sample means did not belong to the same parametric mean.

Multivariate Analyses: Several multivariate statistical techniques were employed to classify the invertebrate data from eighty-eight pools. The invertebrate cluster groupings were based on base 10 log transformed abundance data at the greatest taxonomic resolution and including rare species. Data from eighty-eight pools were used for the invertebrate community analysis with EPASP 73 excluded because it was dry during the spring faunal visit. The amphibian cluster groupings were based on base 10 log transformed abundance data at the species level and included rare species. Data from eighty pools were used for the amphibian analysis with pools EPASP 7, 9, 11, 28, 30, 70, 73, 78, 81 excluded because no aquatic amphibians were observed during the spring faunal visits.

Cluster Analysis in PC-ORD was used to arrange the pools into hierarchical groups and subgroups based on their invertebrate and aquatic amphibian communities (excluding terrestrial amphibians and terrestrial/semiaquatic reptiles not commonly encountered in vernal pools). This analysis was run using log transformed taxon abundance data. Rare taxa were not eliminated because a major goal of this analysis was to examine patterns in taxon diversity (McCune and Grace 2002). The Sorensen (Bray-Curtis) distance measure was used with the group average linkage method, which is compatible with a city-block distance measure such as Sorensen's and conserves the original distance matrix space.

Cluster analysis first groups together pools that have the most similar suites of invertebrate or amphibian taxa. Then it adds additional individuals or groups to those initial groups based on similarity of the invertebrate or amphibian communities. The results of the cluster analysis can be coded with any number of grouping variables that describe an environmental quality of the pool such as ecoregion or vegetation structure. The grouping variables can illustrate possible reasons why the pool groups share similar invertebrate or amphibian communities.

Multi-response permutation procedure (MRPP) was run in PC-ORD on the invertebrate and amphibian pool community types identified through cluster analysis. MRPP is a non-parametric procedure that tests the hypothesis that there is no difference between two or more groups. The distance matrix was constructed using the Sorensen (Bray-Curtis) distance measure. The average within-group distances were compared with a Pearson type III continuous distribution of all possible groupings of the data.

Non-metric multidimensional scaling (NMS) was used to examine relationships between pools and invertebrate taxa. NMS uses rank order rather than metric information in a dissimilarity matrix. This method avoids the assumption of linearity of species response curves to biotic or abiotic gradients (McCune and Grace 2002). NMS was conducted using PC-ORD with algorithms developed by Mather (1976) and Kruskal (1964a,b). The primary matrix contained log transformed invertebrate abundance data from the d-frame dip net samples. Rare taxa were not eliminated because a major goal of this research was to examine patterns in taxon diversity (McCune and Grace 2002). Secondary matrices containing vegetation, environmental, and landscape variables were created to lay over the invertebrate and aquatic amphibian ordinations to look for important environmental gradients that may shape the invertebrate community.

The Sorensen (Bray-Curtis) distance measure was used to create a distance matrix based on the invertebrate abundance data. NMS was run on the data set five times for a six dimensional solution, each time from a different random starting configuration, with 250 runs on the real data. This ensured that the analysis yielded consistent results before a final solution was chosen for interpretation.

The number of dimensions used in the final solution was chosen after examining the NMS stress tests for a potential six dimensions. Stress in NMS is "a measure of departure from monotonicity in the relationship between the dissimilarity (distance) in the original p-dimensional space and distance in the reduced k-dimensional space" (McCune and Grace 2002). The only assumption in NMS is monotonicity in the rank order of the data series. An increasing monotonic series has values that don't change or increase, but do not decrease. The number of dimensions chosen for the final solution should capture most of the variation in the data as evidenced by reduction in stress, but exclude additional dimensions that capture only small amounts of variation that would be difficult to interpret.

Indicator species analysis (ISA) in PC-ORD was used to look for species that best indicate a-priori groups. The analysis calculates taxon relative frequency and relative abundance. The product of these is the indicator (importance) value (Dufrene and Legendre 1997). The significance of the observed maximum indicator value for each taxon-group association was evaluated with 4,999 permutations of a Monte Carlo randomization test.

Vegetation Data Analyses

Data from 269 1m^2 vegetation plots within the 89 pools were entered into the NatureServe PLOTS Database System on a Microsoft Access platform. In the PLOTS database, species were assigned standardized codes based on the PLANTS database developed by the Natural Resource Conservation Service in cooperation with the Biota of North American Program (Kartesz 1994). Environmental variables and species percent cover data were exported from the PLOTS database into Excel in order to be manipulated into a format compatible with PC-ORD version 5.0 Multivariate Analysis software (McCune and Mefford 1999).

Vegetation data from all plots within a single pool were aggregated to compare the 89 pools; because the number of plots taken did not reflect the area of each vegetation zone within the pool, the value of the maximum percent cover of each species was used in the analysis. Plot data were analyzed using several multivariate statistical techniques available in PC-ORD software. Different techniques were employed to provide multiple lines of evidence from which to interpret the results. Plant species occurring in less than five percent of the plots were removed from the analysis. For a detailed discussion of the statistical techniques used in this study, refer to McCune and Grace (2002).

To classify the plot data into vegetation communities, a hierarchical agglomerative cluster analysis was performed on the species' percent cover data using the Flexible Beta method (-.25) and Sorenson (Bray-Curtis) distance measure. Cluster analysis creates groups by sequentially merging sample units into larger groups (McCune and Grace 2002).

A non-metric multidimensional ordination analysis (NMS) was also performed using both the species' percent cover data and the environmental variables from the plots. NMS is an ordination technique well suited to non-normal data sets (Kruskal and Wish 1978). In this analysis, Sorensen distance measure, a random starting configuration, and a stability criterion of 0.005 were employed. There is not a statistical criterion developed for selecting the appropriate number of dimensions (Kruskal and Wish 1978), but a stress test of 20 or below indicates a stable solution (McCune and Grace 2002). Two hundred and fifty runs were performed with the real data, with a maximum of 400 iterations.

Indicator Species Analysis (ISA) (Dufrêne and Legendre 1997) was used to determine the percent affinity of species in each cluster group. Mean indicator values resulting from the ISA were used as an index to evaluate patterns found in cluster groups and ordination. Analysis Monte-Carlo simulation p-values from the ISA were compared using classification types. The p-values generated from Monte-Carlo simulations in ISA tell us whether the indicator species are statistically significant and are a metric of how well the dataset is classified.

While the analyses above produced relatively understandable groupings, best professional judgment ultimately determined the most appropriate groupings of sample locations and community types. We described communities by the strongest significant species indicators and their site environmental variables, as well as commonly occurring species in the plots. A multi-response permutation procedure (MRPP) was also performed on the plots' environmental variables to determine if the differences between the vegetation communities classified by the Cluster and NMS analyses were statistically significant. Sorensen distance measure was used to analyze the groups determined from above-mentioned analyses.

III. RESULTS

Site Selection

Eighty-nine seasonal pools spread across forty-three sites were selected for this study and were sampled for water chemistry, aquatic macroinvertebrates, and amphibians, and vegetation (Figure 1). These pools met the United States Environmental Protection Agency's definition of a seasonal pool wetland based on four distinguishing features: surficial hydrologic isolation, periodic drying, relatively small size and shallow depth, and distinctive biological community (Brown and Jung 2005). Descriptions of each site are provided in Appendix 1.

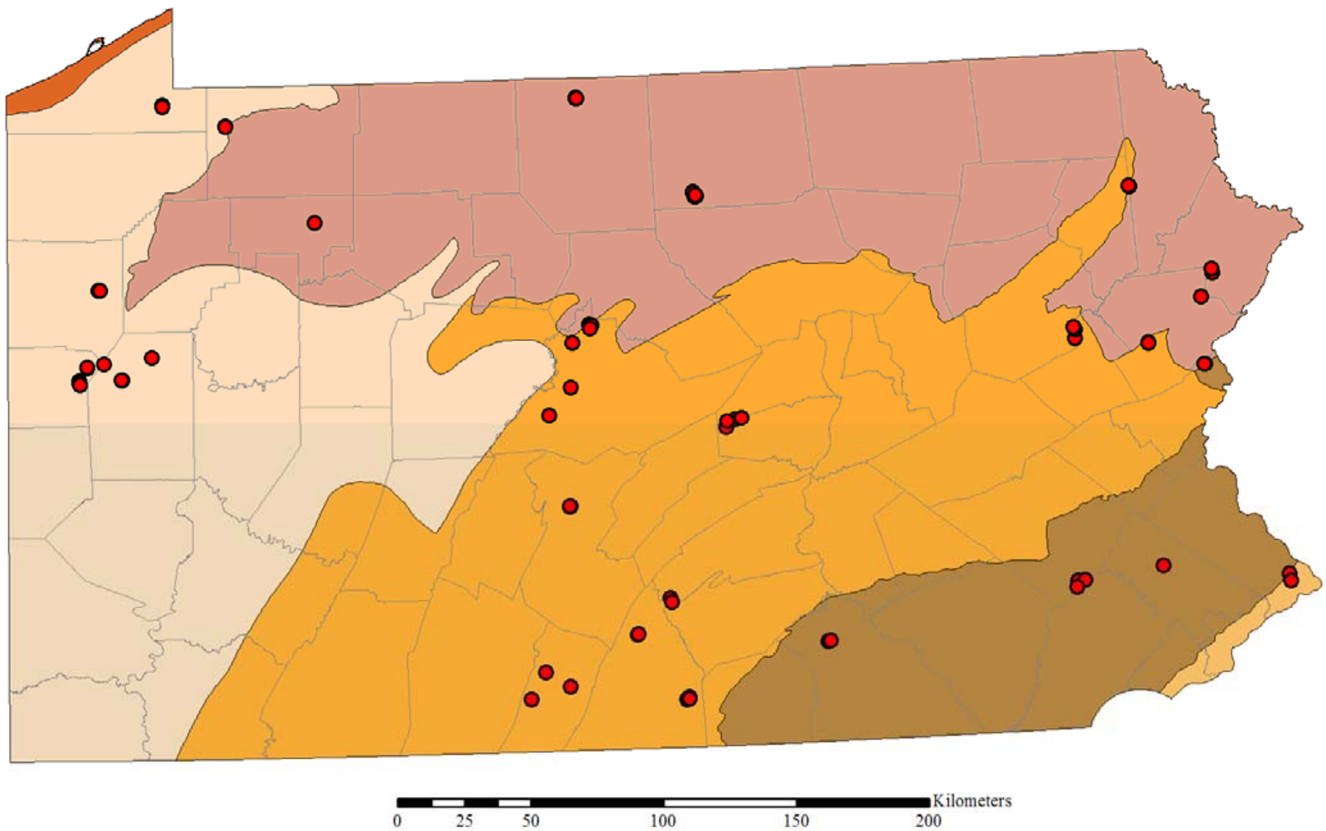


Figure 1. Location of 89 seasonal pools studied in Pennsylvania; presented by PA County and TNC ecoregion

Landscape, Physical, and Chemical Characteristics

Tables 1-5 present a summary of the spatial distribution of the eighty-nine seasonal pools included in this study across ecoregions, physiographic provinces, surficial geology types, and counties. Tables 6-10 present a summary of the landscape context variables evaluated for each pool in GIS. The results are preceded by definitions for each variable. Full data tables showing individual pool distributions and landscape context are presented in Appendices 3-6. Measurements of pool dimensions, substrate qualities, and water chemistry variables were measured and reported in Appendices 7 and 8. Figures 2-13 present the pool landscape setting, dimensions, substrate qualities, and water chemistry variables in a series of graphs presented by ecoregion. All graphs show the average values for each variable by ecoregion. Graphs for area, depth, oxidation-reduction potential, pH, and amphibian egg mass abundance and density also show the minimum and maximum value recorded for a pool in each region.

Table 1. Study pools tallied by ecoregions as designated by The Nature Conservancy.

TNC ecoregion	Subsection	Sub-section code	# pools
LOWER NEW ENGLAND / N. PIEDMONT	Gettysburg Piedmont Lowland	221.41	5
	Piedmont Upland	221.42	2
	Total		**7**
HIGH ALLEGHENY PLATEAU	Allegheny Deep Valleys	212.72	6
	Allegheny High Plateau	212.71	1
	Cattaraugus Highlands	212.61	4
	Eastern Allegheny Plateau	212.63	5
	Kittatinny-Shawangunk Ridges	221.24	3
	Total		**19**
WESTERN ALLEGHENY PLATEAU	Allegheny Plateau	221.61	15
	Pittsburg Low Plateau	221.51	5
	Total		**20**
CENTRAL APPALACHIAN FOREST	Allegheny Mountain Plateau	221.26	7
	Northern Blue Ridge Mountains	221.44	5
	Northern Great Valley	221.14	1
	Northern Ridge and Valley	221.13	30
	Total		**43**

Table 2. Study pool distribution and tally by physiographic province and section.

Physiographic province	Section	Section code	# pools
APPALACHIAN PLATEAUS	Allegheny Front	17	3
	Glaciated Low Plateau	4	4
	High Plateau	5	1
	Northwestern Glaciated Plateau	3	15
	Pittsburgh Low Plateau	14	6
	Total		**29**
PIEDMONT	Gettysburg-Newark Lowland	29	5
	Piedmont Upland	38	2
	Total		**7**
RIDGE AND VALLEY	Anthracite Upland	19	3
	Anthracite Valley	11	1
	Appalachian Mountain	18	24
	Blue Mountain	20	3
	Deep Valleys	6	13
	Great Valley	21	9
	Total		**53**

Table 3. Study pool distribution and tally by county.

Site names	Cnty num	County	# pools
SGL 102	25	Erie	2
Spring Creek	61	Warren	2
Lisica Property	43	Mercer	4
Plain Grove, SGL 216	37	Lawrence	6
Jennings, SGL 95, Wolf Crk Narrows	10	Butler	6
ANF Marienville	27	Forest	1
Ellisburg	52	Potter	4
West Rim North and South	58	Tioga	6
Black Moshannon, Sproul, Wolf Rocks	14	Centre	7
Warrior Ridge	31	Huntingdon	4

Site names	Cnty num	County	# pools
Grass Mtn, Kreb Tr, Little Mtn, Mulls Gap	54	Snyder	9
2nd Narrows, 3 Square Hollow	50	Perry	5
Butler Knob, Mount Cydonia	28	Franklin	9
Roaring Run, Meadow Grounds	29	Fulton	3
Gifford Pinchot State Park	66	York	2
French Creek State Park	6	Berks	3
Five Mile Woods	9	Bucks	2
Minsi Lake	48	Northampton	3
Bowers Crk, Delaware SF	45	Monroe	4
Irishtown Run, Kidder Run	13	Carbon	3
Delaware SF	51	Pike	2
SGL 300	35	Lackawanna	1
SGL 300	63	Wayne	1

Table 4. Study pool distribution on surficial geology and primary lithosome with a tally on occurrences of pools by surficial geology.

Surficial geology	Primary lithosome	Geo num	# pools
Allegheny Formation	Sandstone	31	15
Bryn Mawr Formation	Gravelly sand	4	2
Burgoon Sandstone	Sandstone	36	4
Clinton Group	Shale	94	4
Diabase	Diabase	8	2
Duncannon Member of Catskill Formation	Sandstone	53	2
Hammer Creek conglomerate	Quartz conglomerate	18	2
Huntley Mountain Formation	Sandstone	45	4
Juniata and Bald Eagle Formations, undivided	Sandstone	96	4
Juniata Formation	Sandstone	97	2
Long Run and Walcksville Members of Catskill Formation, undivided	Sandstone	67	3
Long Run Member of Catskill Formation	Sandstone	63	3
Martinsburg Formation	Shale	100	3
Mauch Chunk Formation	Shale	34	4
Pocono Formation	Sandstone	37	4
Pottsville Formation	Sandstone	33	8
Reedsville Formation	Shale	99	7
Rockwell Formation	Argillaceous sandstone	44	1
Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided	Limestone	83	4
Stockton Formation	Arkosic sandstone	20	1
Tomstown Formation	Dolomite	154	6
Venango Formation	Siltstone	50	4

Table 5. Study pool tally by primary lithosome

Primary lithosome	# pools
Argillaceous sandstone	1
Arkosic sandstone	1
Diabase	2
Dolomite	6
Gravelly sand	2
Limestone	4
Quartz conglomerate	2
Sandstone	49
Shale	18
Siltstone	4

Table 6. Study seasonal pools grouped and tallied by percent forest in increasing concentric circular buffers around each pool.

Landscape Analysis (Code)	Description
Forest Buffer 1 (FrstBuf1)	% forest within a 0-30.5 m (0-100 ft) radius around pool. Based on the EPA defined vernal pool envelope & the PA Bureau of Forestry no cut zone (Brown and Jung 2005)
Forest Buffer 2 (FrstBuf2)	% forest within a 30.5-61 m (100-200 ft) radius around pool. Based on the PA Bureau of Forestry 50% cut zone (PA DCNR-BOF 2003).
Forest Buffer 3 (FrstBuf3)	% forest buffer within a 0-305 m (0-1000 ft) radius around pool. Based on the EPA-defined terrestrial upland (Brown and Jung 2005)

% Forest in buffer 1 (0-30.5 m)	# pools	% Forest in buffer 2 (30.5-61 m)	# pools	% Forest in buffer 3 (0-300 m)	# pools
90-100	85	90-100	85	90-100	63
80-89	1	80-89	1	80-89	5
50-79	1	50-79	2	50-79	18
0-49	2	0-49	1	0-49	3

Table 7. Study seasonal pools grouped and tallied by distance to nearest stream and stream type.

Landscape Analysis (Code)	Description
Stream Distance (StrmDist)	Distance to nearest stream (m). In regression and correlation analyses, a positive relationship indicates that with increasing distance from the nearest stream, abundance of x variable also increases.
Stream Type (StrmType)	Nearest stream type: intermittent (1) or permanent (2).

Distance to nearest stream	# pools
0 - 31 m	14
32 - 61 m	3
62 - 300 m	30
301 - 600 m	14
601+ m	28

Nearest stream type	# pools
Intermittent	63
Permanent	28

Table 8. Study seasonal pools grouped and tallied by distance to nearest wetland and type.

Landscape Analysis (Code)	Description
Wetland Distance (WetDist)	Distance to nearest wetland (m). In regression and correlation analyses, a positive relationship indicates that with increasing distance from the nearest wetland, abundance of x variable also increases.
Wetland Type (WetType)	Nearest wetland type (used National Wetland Service wetland types if identified)
Wetland Code (WetCode)	Grouping code for wetland types: known vernal pool (1); wetland (2); pond or lake (3)

Distance to nearest wetland	# pools
0 - 31 m	5
32 - 61 m	30
62 - 300 m	37
301 - 600 m	7
601+ m	10

Nearest NWI wetland	# pools	# verified as vernal pools
Palustrine Emergent Wetland (PEM)	9	9
Palustrine Forested Wetland (PFO)	22	8
Palustrine Open Water (POW)	7	1
Palustrine Scrub Shrub (PSS)	11	9
Palustrine Unconsolidated Bottom (PUB)	9	0
Lake (L)	2	0
Not identified in NWI	29	28

Table 9. Study seasonal pools grouped and tallied by distance to nearest road and road type.

Landscape Analysis (Code)	Description
Road Distance (RoadDist)	Distance to nearest publicly accessible dirt or paved road (m). In regression and correlation analyses, a positive relationship indicates that with increasing distance from the nearest road, abundance of x variable also increases.
Road Type (RoadType)	Nearest road type: dirt (1) or paved (2)

Distance to nearest road	# pools
0 - 31 m	10
32 - 61 m	14
62 - 300 m	40
301 - 600 m	15
601+ m	10

Nearest road type	# pools
Dirt	63
Paved	26

Table 10. Study seasonal pools grouped and tallied by distance to nearest disturbance, amount of disturbance, and largest type of disturbance in the upland area around each pool.

Landscape Analysis (Code)	Description
Distance to disturbance (DistDist)	Distance to the most significant disturbance (largest and/or most likely to impact water quality) within a 0-610 m (0-2000 ft) radius around pool.
Disturbance type (DistTyp)	Most significant disturbance type within a 0-610 m (0-2000 ft) radius around pool.
	1 = Clearing (e.g. old field, pasture, food plot)
	2 = Right of ways (e.g. powerline, forestry road not open to public)
	3 = Dirt or paved road
	4 = Logging
	5 = Oil & gas development
	6 = Abandoned mine lands
	7 = Agriculture
	8 = Residential / urban development
	9 = Quarry / mining
Disturbance amount (DistAmt)	Cumulative amount of disturbance within a 0-610 m (0-1000 ft) radius around pool: 0-33% low (1); 34-66% medium (2); 67-100% high (3).

Distance to nearest disturbance	# pools
0 - 31 m	11
32 - 61 m	18
62 - 300 m	42
301 - 600 m	15
601+ m	3

Largest disturbance type within 600 m of pool	# pools
Clearing (old field, pasture, food plot)	11
Low use ROW (powerline, gated forestry road)	7
Regular use dirt or paved road	43
Logging	6
Oil & gas development	1
Abandoned mine lands	5
Agriculture	12
Residential / urban development	3
Quarry / mining	1

Amount of disturbance within 600 m of pool	# pools
0-33% low	75
34-66% medium	14
67-100% high	0

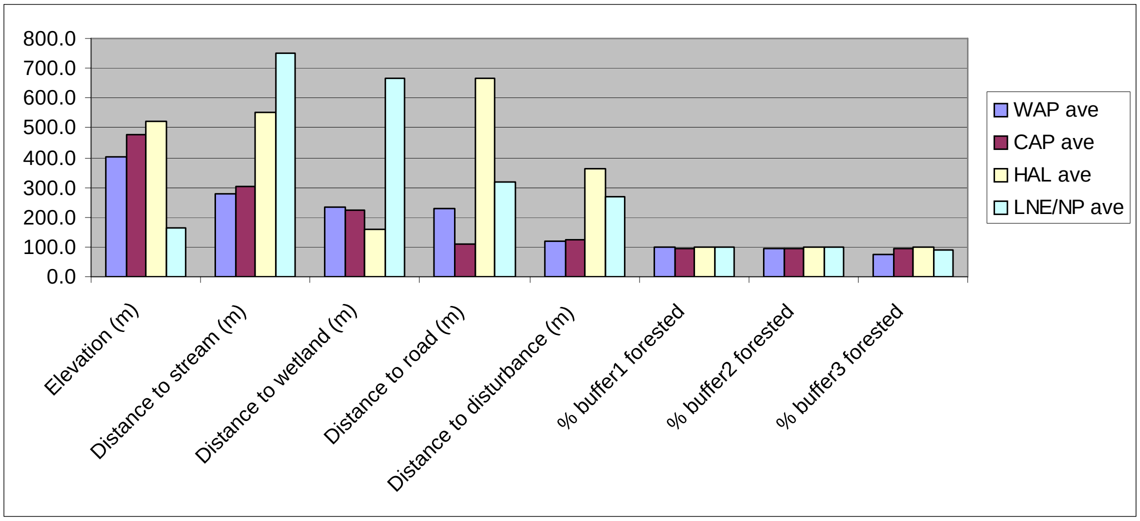


Figure 2. Average landscape values shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

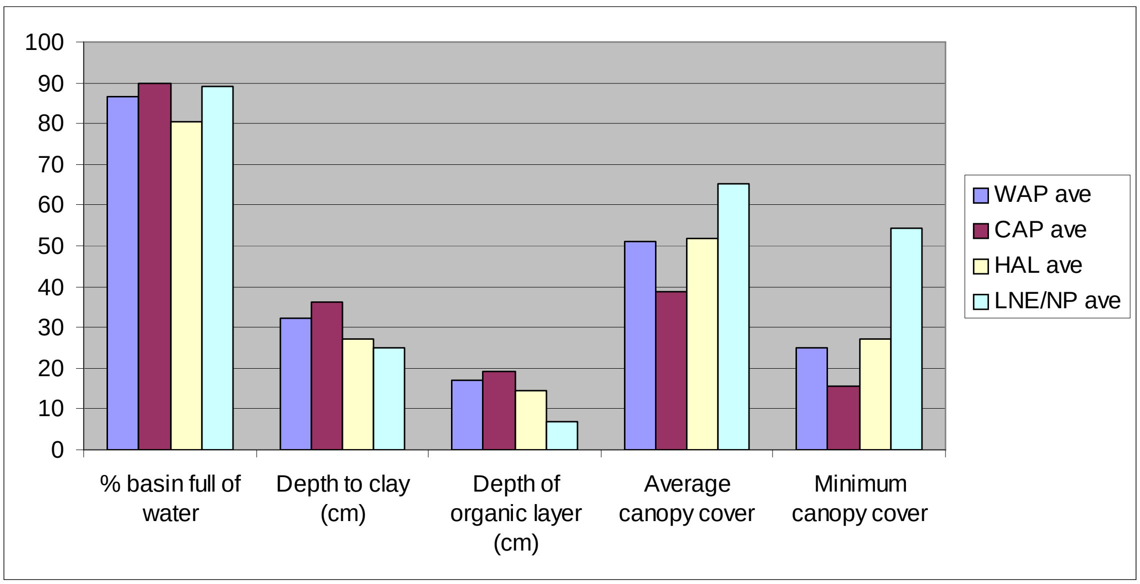


Figure 3. Average pool basin features shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

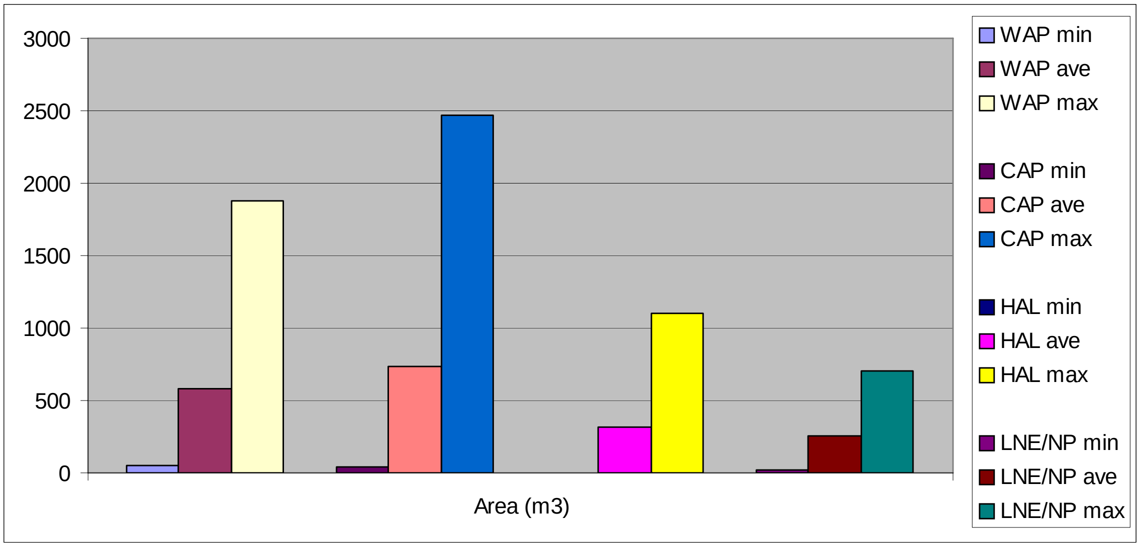


Figure 4. Minimum, average, and maximum pool area shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

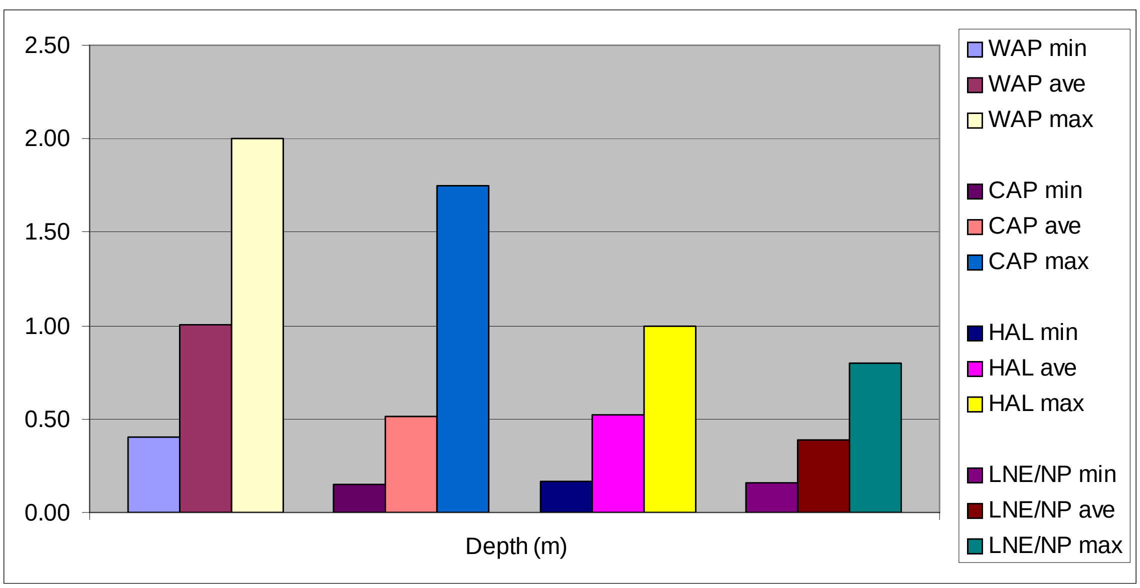


Figure 5. Minimum, average, and maximum pool depth shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

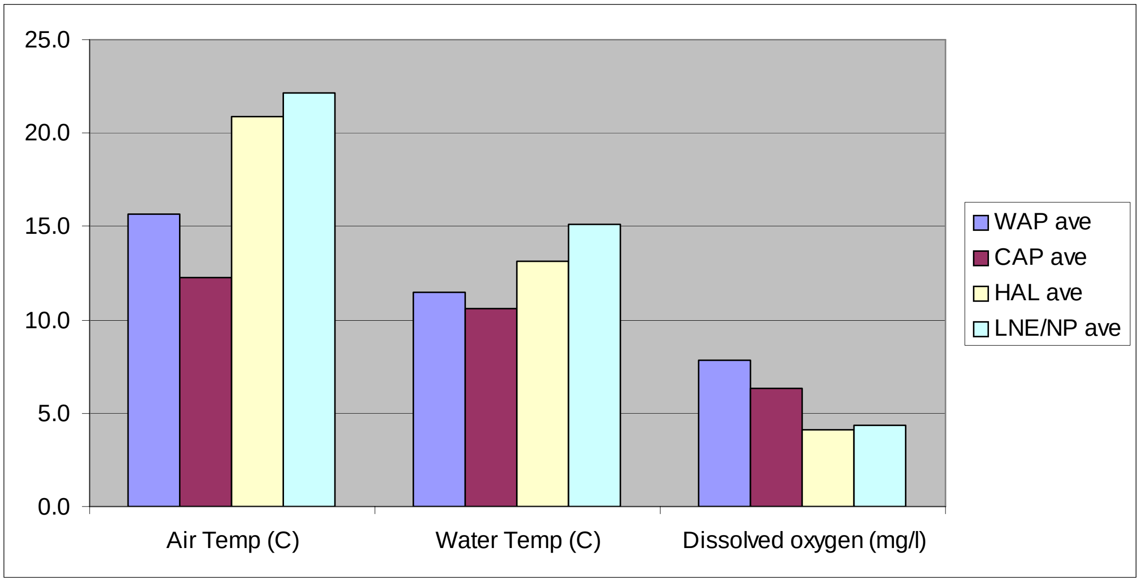


Figure 6. Average air and water temperature and dissolved oxygen (recorded during spring faunal survey) shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP) High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

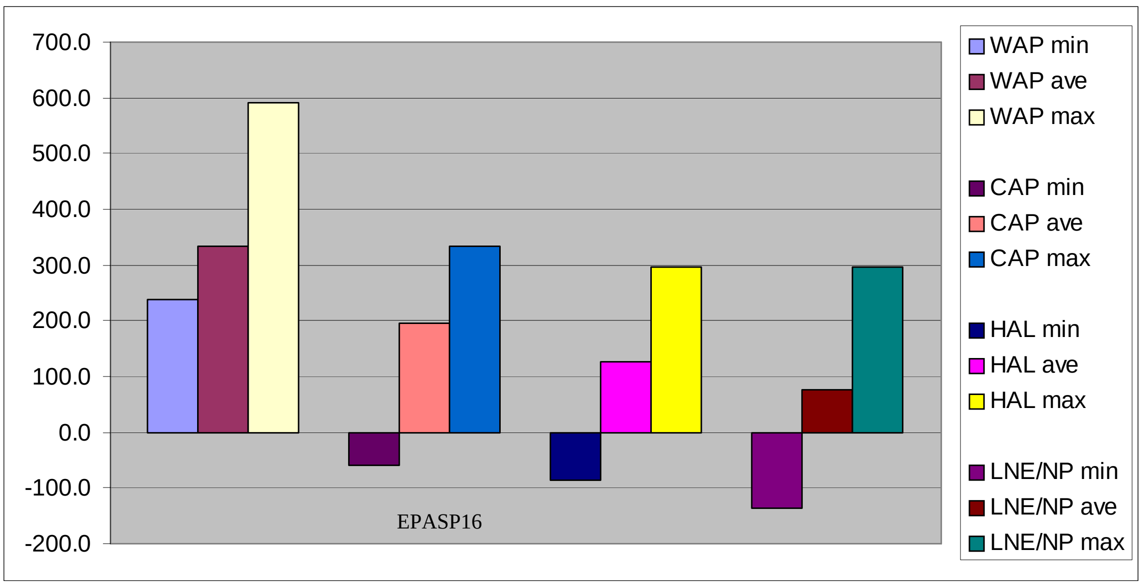


Figure 7. Minimum, average, and maximum oxidation-reduction potential (ORP) shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP) High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

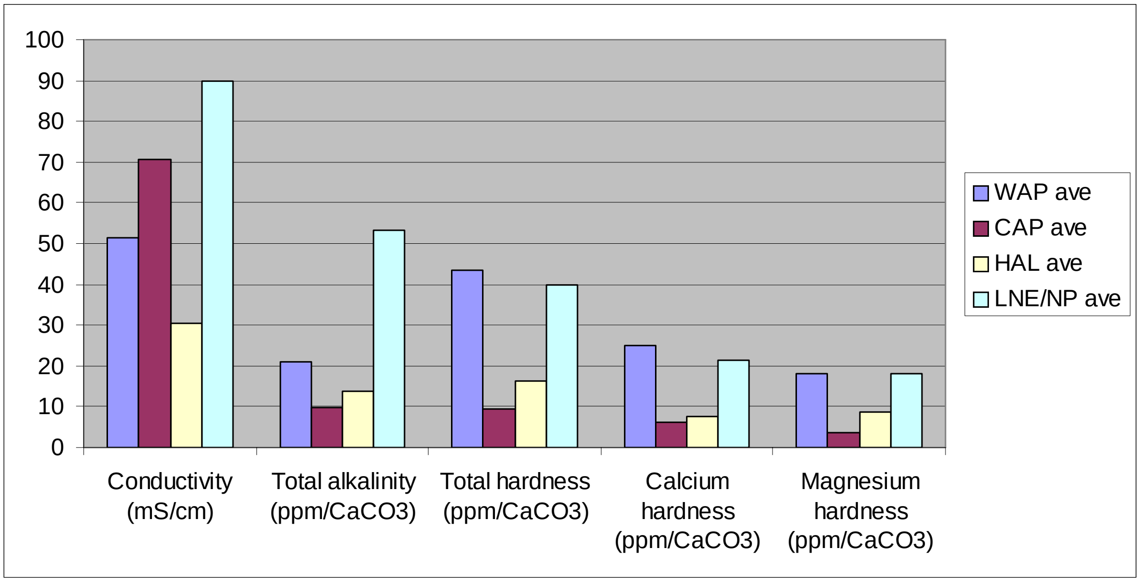


Figure 8. Minimum, average, and maximum dissolved ions per ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

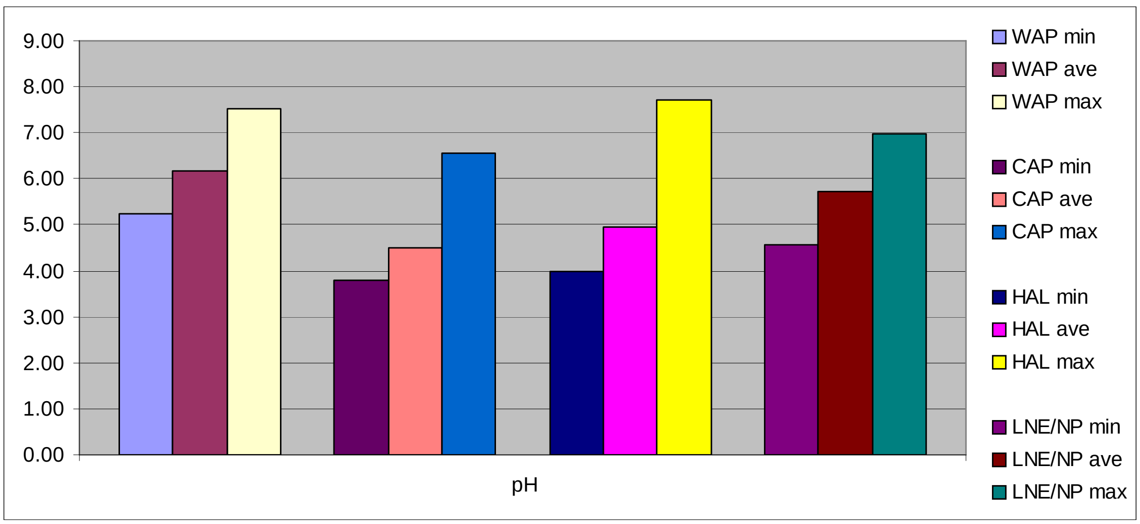


Figure 9. Minimum, average, and maximum pH shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

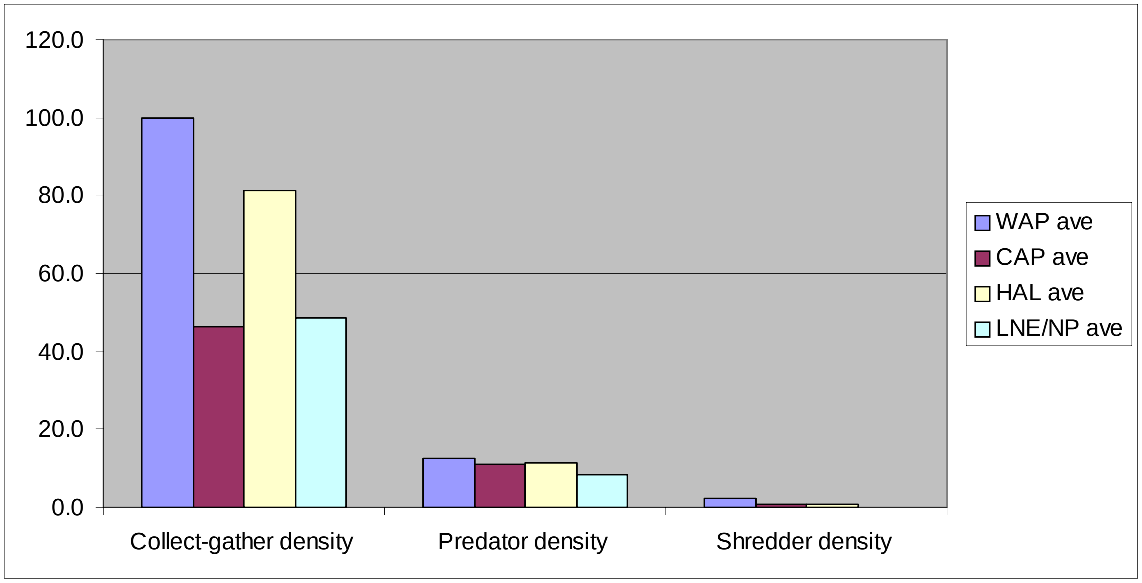


Figure 10. Average density (# per d-frame sample) of invertebrate trophic group shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

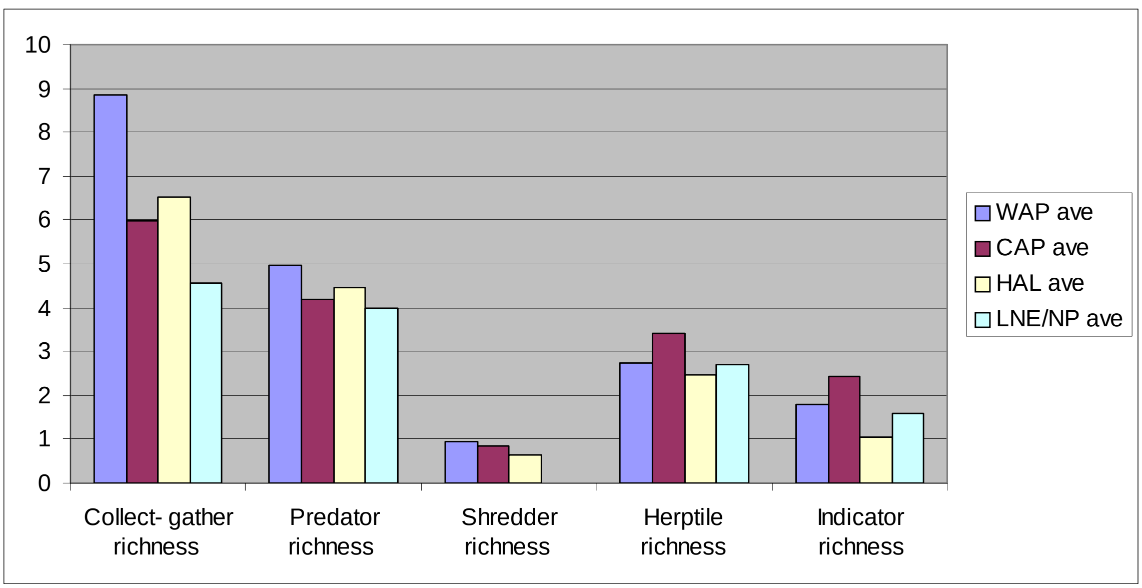


Figure 11. Average invertebrate trophic grouping richness, total herptile richness, and seasonal pool indicator species richness shown by ecoregion.

Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

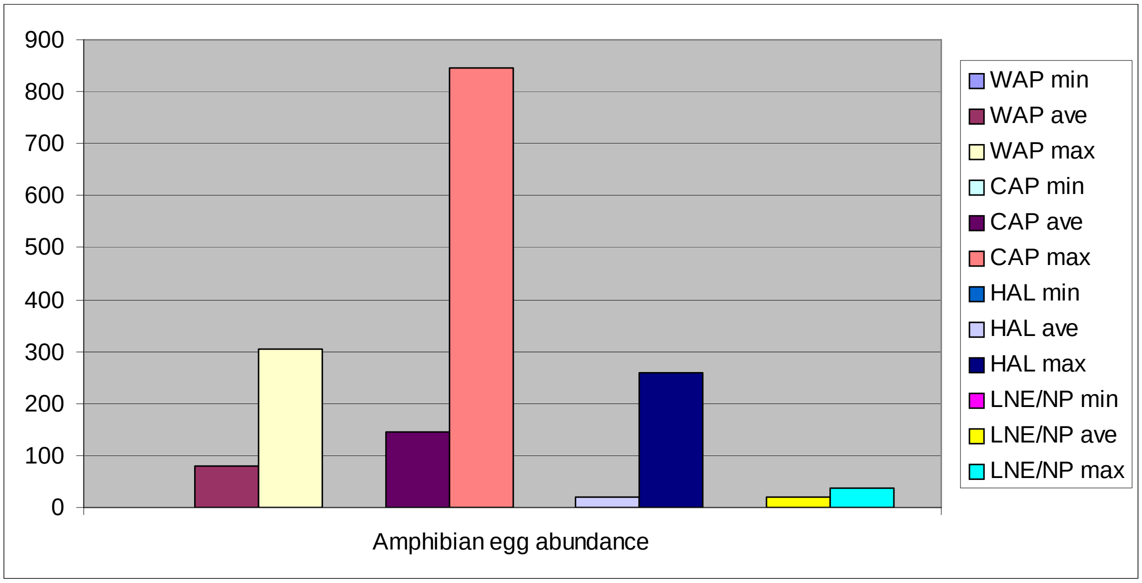


Figure 12. Minimum, average, and maximum amphibian egg abundance shown by ecoregion.

At least one pool in each ecoregion had no egg masses observed.
Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

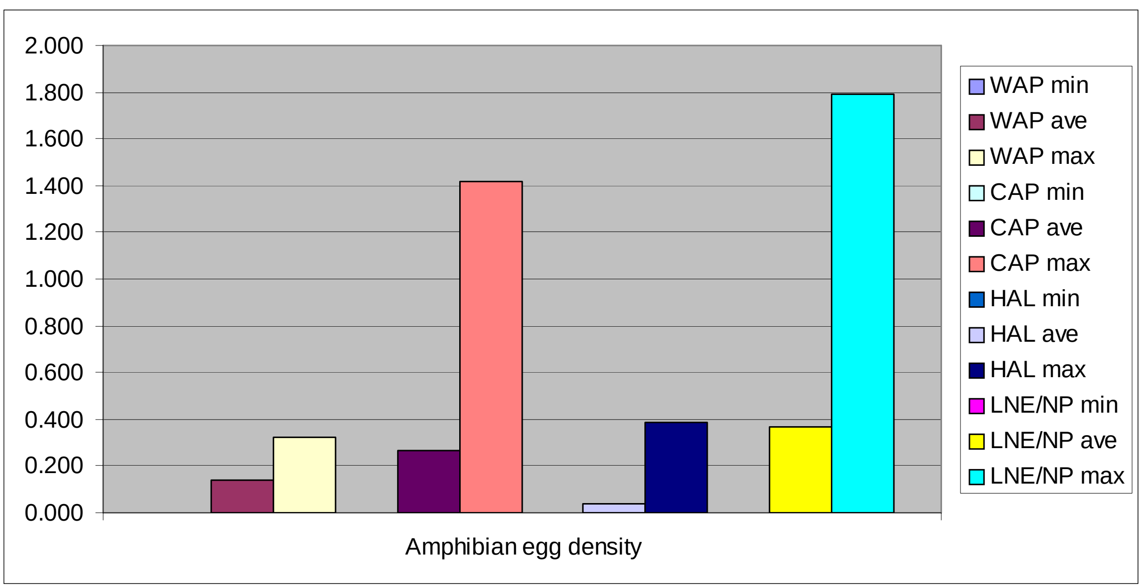


Figure 13. Minimum, average, and maximum amphibian egg density (# per m^3) shown by ecoregion

At least one pool in each ecoregion had no egg masses observed.
Codes: Western Allegheny Plateau (WAP), Central Appalachian Forest (CAP)
High Allegheny Plateau (HAL), Lower New England / Northern Piedmont (LNE/NP)

Ordinations of environmental data: A non-metric multidimensional scaling ordination (NMS) was conducted on the environmental matrix with in-pool and landscape conditions. Repeated ordination runs yielded 1 or 2 dimensional solutions indicating the data structure was not strong. Final minimum stress for a two dimensional solution was 21.9 with a p value of 0.0476. The cumulative r^2 for two axes was 0.749 (axis 1 $r^2 = 0.406$, axis 2 $r^2 = 0.343$). Each dimension of the ordination is graphed with an overlay of environmental variables and faunal richness and density values (Figure 14). Area, invertebrate shredder richness and aquatic herptile richness were positively correlated with axis one. Canopy cover, distance to nearest disturbance, and distance to nearest road were negatively correlated with axis one. Axis two was strongly positively correlated with distance to the nearest stream or wetland. Definitions of all analysis codes can be found in Appendix 2.

A second NMS run reduced the environmental matrix to only those variables reflecting in-pool conditions (surface geology, pool dimensions, water chemistry, pool substrate and canopy cover, and the three forest buffers which reflect conditions close to the pool). The remaining continuous variables for landscape qualities (distance to nearest roads, streams, wetlands, and disturbances) were removed. The resulting data structure was very weak. Repeated ordination runs yielded mostly 1 dimensional solutions and occasionally two dimensional solutions. Final minimum stress for a two dimensional solution was 18.9 with a non-significant p value of 0.1429. An overlay of environmental values showed a number of correlated variables. Area ($r^2 = 0.895$) and depth of the organic layer ($r^2 = 0.153$) were positively correlated with axis one, while minimum vegetation cover was negatively correlated ($r^2 = 0.172$). Axis two was positively correlated with elevation ($r^2 = 0.207$) and negatively correlated with total alkalinity ($r^2 = 0.201$).

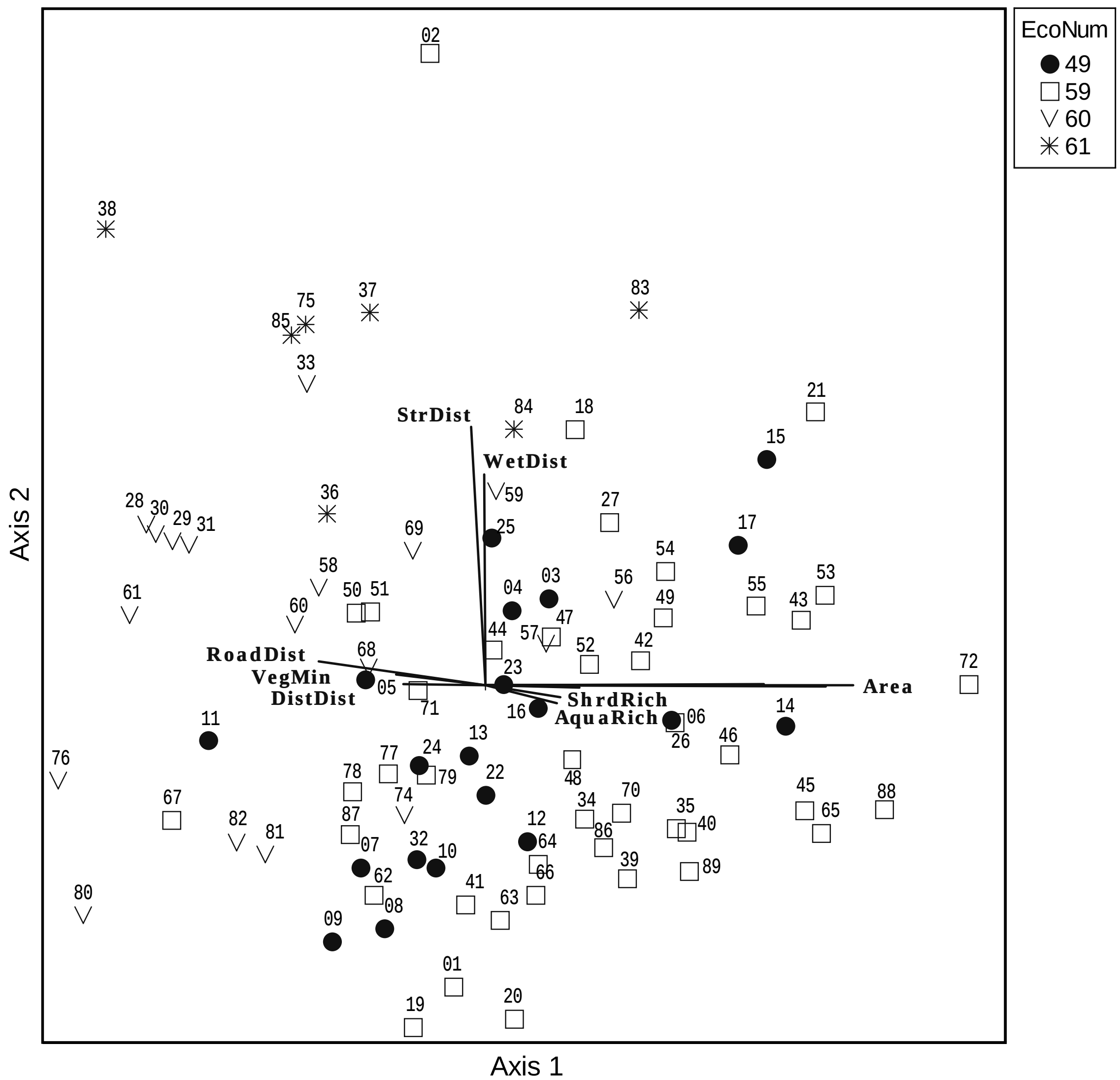


Figure 14. Axes 1 and 2 of an NMS ordination of pools based on in-pool environmental variables and landscape conditions.

Ecoregions are used as the grouping variable. An overlay of environmental variables and faunal richness and density values show that area (r^2 = 0.758), invertebrate shredder richness (r^2 = 0.151) and aquatic herptile richness (r^2 = 0.153) were positively correlated with axis one. Canopy cover (r^2 = 0.183), distance to nearest disturbance (r^2 = 0.168), and distance to nearest road (r^2 = 0.341) were negatively correlated with axis one. Axis two was strongly positively correlated with distance to the nearest stream (r^2= 0.530) or wetland (r^2 = 0.433).

Symbol	Ecoregion name	Symbol	Ecoregion name
●	Western Allegheny Plateau	∨	High Allegheny Plateau
□	Central Appalachian Forest	✳	Lower New England / Northern Piedmont

Invertebrate Sampling

A total of ninety-five invertebrate taxa were identified from the eighty-nine study pools. A table of invertebrate taxa encountered along with tallies of occurrences by pool and ecoregional distribution is presented in Appendix 11. Invertebrate taxonomy follows that used in the various identification keys (see the section on ‘invertebrate specimen identification’ in the methods). Figure 15 charts raw abundance data for invertebrate taxonomic groupings for all study pools combined, and Figure 16 charts the same data after undergoing a base 10 log transformation. These data were transformed prior to data analyses to allow for a more balanced comparison of taxonomic groups whose life history traits lead to vastly different abundances within the pool community. Transformations help statistical analysis by normalizing the data and reduces the influence of highly abundant species by equalizing the relative importance of rare and common taxa (McCune and Grace 2002).

The invertebrate taxa were also assigned to a trophic group to calculate the relative abundance and richness of several different feeding guilds (Appendix 13). Table 11 lists the trophic groups of vernal pool invertebrates along with the analysis code which represents condensed groupings used for data analysis. For example in data analysis the ‘CG’ group incorporated several trophic groups including collector gatherers, detritivores, filterers, herbivores, and scrapers. This group was composed largely of macro- and micro-crustaceans and diptera larvae. The shredder group was composed largely of caddisflies plus several beetle taxon. The predator group was largely composed of predaceous diving beetles, dragonfly and damselfly larvae, and true bugs. Figure 17 charts raw abundance and base 10 log transformed data for each trophic group.

Table 11. Invertebrate trophic groups and grouping code used in data analyses.

Trophic group description	Analysis code
Collector-gatherer (CG)	CG
Detritivore (D)	CG
Filterer (F)	CG
Herbivore (H)	CG
Predator (P)	P
Parasite (Pa)	P
Scraper (Sc)	CG
Shredder (Sh)	Sh
Scavenger (Sv)	P

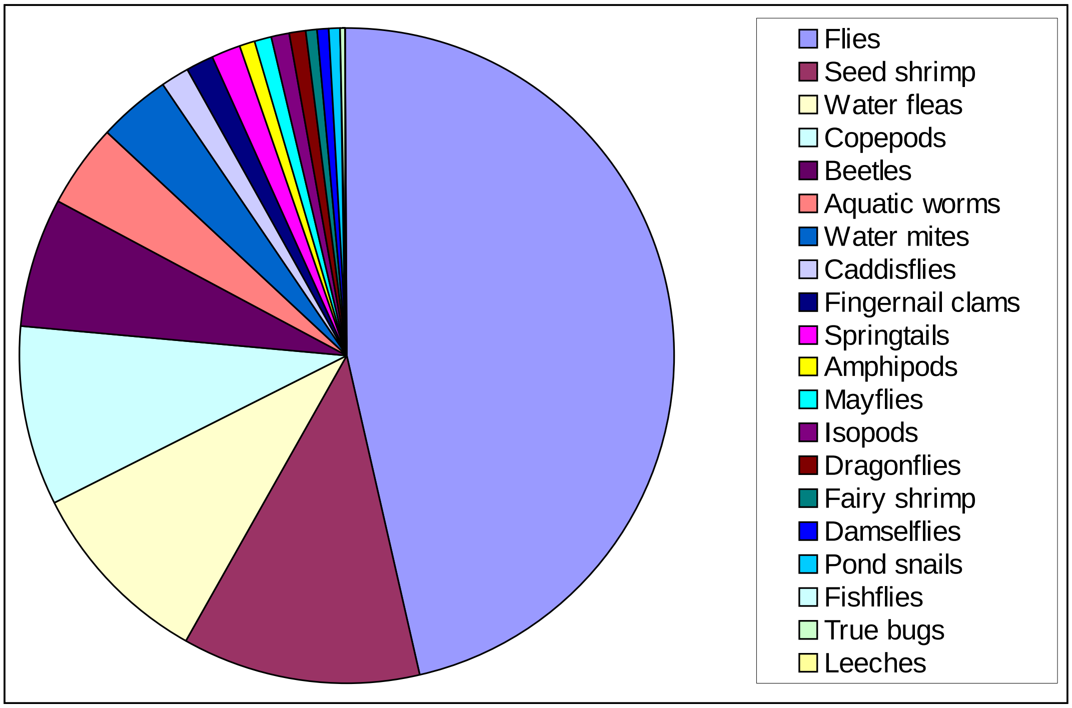


Figure 15. Raw abundance data for invertebrate taxonomic groupings shown for all study pools combined.

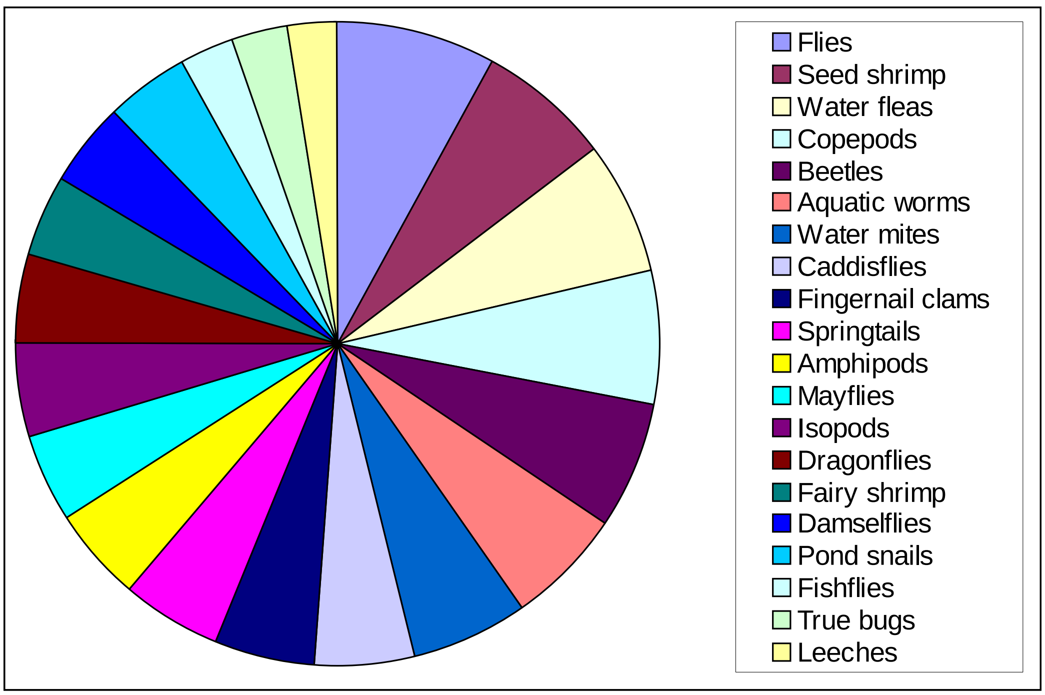
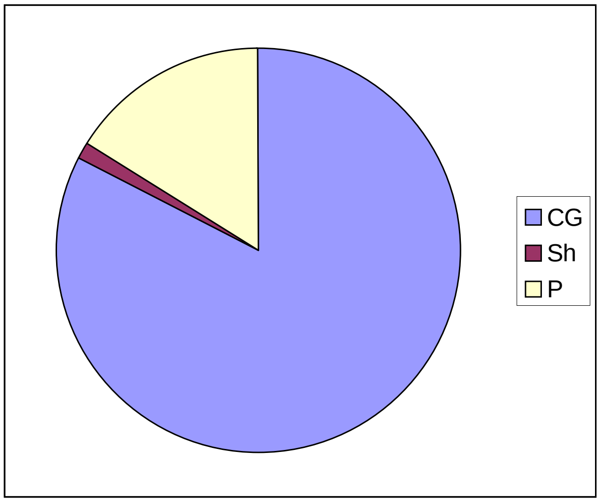


Figure 16. Abundance data base 10 log transformed for invertebrate taxonomic groupings shown for all study pools combined.



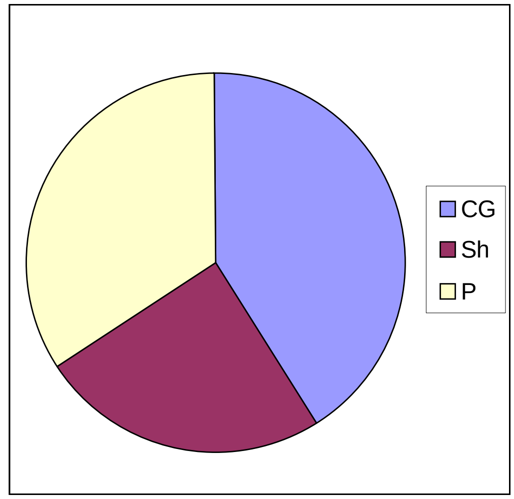


Figure 17. Raw abundance data (left) and base 10 log transformed abundance data (right) for invertebrate trophic groupings shown for all study pools combined.

Codes: CG = Collector gatherer grouping (for analysis includes collector gatherers, detritivores, herbivores, and/or filterers); Sh = Shredder grouping; P = Predator grouping

Rare invertebrate taxa

Of the 95 invertebrate taxon identified, 54 occurred in fewer than 5 pools. Ephemeral species such as phantom midges (Chaoboridae) undergo rapid development from larvae to adult. Other taxon buried in sediments such as cranefly larvae (Tipulidae) are difficult to sample. A complete inventory of the invertebrate community of a vernal pool is simply not possible with one visit utilizing one sampling method. Collecting samples from widely distributed sites across the state at different times throughout the season also makes it difficult to evaluate and compare the data. Most of the rare taxa found in this study are likely just underrepresented by sampling effort.

Several uncommon invertebrates were identified in the dragonfly group (Anisoptera). This group is relatively well understood compared to most invertebrates. There are excellent species level keys to the adults and larvae (Needham et al. 2000, Westfall and May 1996), which allow for relatively confident identifications of last instar nymphs. Three dragonfly species of special concern were potentially identified in this study: the Green-striped Darner (*Aeshna verticalis*), the American Emerald (*Cordulia shurtleffii*), and the Taiga Bluet (*Chromagrion resolutum*). The identifications of the latter two are tentative since the identifications were based on specimens that may not have been final instars. Surveys for adults at the localities where the nymphs were collected to confirm presence of these species are recommended.

Only one invertebrate taxon is commonly considered an indicator species for seasonal pools, the fairy shrimp (Anostraca). The most common species in Pennsylvania is the Springtime Fairy Shrimp (*Eubranchipus vernalis*). This species was found at ten sites throughout the Western Allegheny Plateau and the Central Appalachian Forest. A second species (*Eubranchipus holmani*) was found at a single pool within a vernal pool complex in Franklin County. E. holmani co-occurs with *E. vernalis*, and was documented in the same pool in 2002. *E. holmani* has not been found in other pools in the complex despite sampling in three different years. This species is also known from Centre County (Leppo and Evans 2003). While *E. holmani* is clearly not as common as *E. vernalis*, additional surveys for fairy shrimp in seasonal pools throughout PA should yield additional occurrences of this and perhaps other species.

Invasive invertebrate species

No invasive invertebrate species were documented in the seasonal pools during this study. However many taxon were not identified past higher taxonomic levels such as Order and Family. A lack of comprehensive species level keys and life history information makes identification of species not native to these systems very difficult.

Herptile Sampling

A total of seventeen species of reptiles and amphibians (together called herptiles) were documented in the eighty-nine study pools (Appendix 12). These species included one toad, five frogs, three mole salamanders, three plethodon salamanders, one newt, two snakes, and two turtles. Herptile taxonomy follows the Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico (Moriarty 2008).

The herptile species were assigned to a functional group based on their usage of the seasonal pool habitat to calculate relative abundance and richness. Most species encountered were either seasonal pool indicator or facultative species. Four species, the Jefferson Salamander (*Ambystoma jeffersonianum*), Spotted Salamander (*A. maculatum*), Marbled Salamander (*A. opacum*), and the Wood Frog (*Lithobates sylvaticus*) are together with the fairy shrimp crustaceans (*Eubranchipus* spp.) considered indicator species. Seasonal pool indicators rely heavily upon temporary, fishless wetlands for some portion of their life cycle.

Facultative species will utilize seasonal pool habitats opportunistically for feeding and or breeding, but they can also use other habitats. Facultative species encountered in this study included American toads (*Anaxyrus americanus*), Gray Treefrogs (*Hyla versicolor*), Bull Frogs (*Lithobates catesbeianus*), Green Frogs (*L. clamitans*), Four-toed Salamanders (*Hemidactylium scutatum*), Red-spotted Newts (*Notophthalmus viridescens*), Water Snakes (*Nerodia sipedon*), Snapping Turtles (*Chelydra serpentine*), and Spotted Turtles (*Clemmys guttata*). Three terrestrial species were encountered during surveys of the immediate upland: Redback Salamanders (*Plethodon cinereus*), Slimy Salamanders (*Plethodon glutinosus*), and Garter Snakes (*Thamnophis sirtalis*).

Data analyses focused on aquatic amphibian species that typically use seasonal pools for feeding and/or breeding. Insufficient numbers of aquatic turtles or snakes were observed to use in analysis. Aquatic amphibian abundance data were transformed prior to data analyses to allow for a more balanced comparison of species whose life history traits lead to vastly different abundances within the pool community. For example only adult red-spotted newts utilize a seasonal pool while eggs, larvae, and adults of the wood frog can be found in a pool. Transformations help statistical analysis by normalizing the data and reduces the influence of highly abundant species by equalizing the relative importance of rare and common taxa

(McCune and Grace 2002). Figure 18 charts raw abundance data of the aquatic amphibian species for all study pools combined, and Figure 19 charts the same data after undergoing a base 10 log transformation.

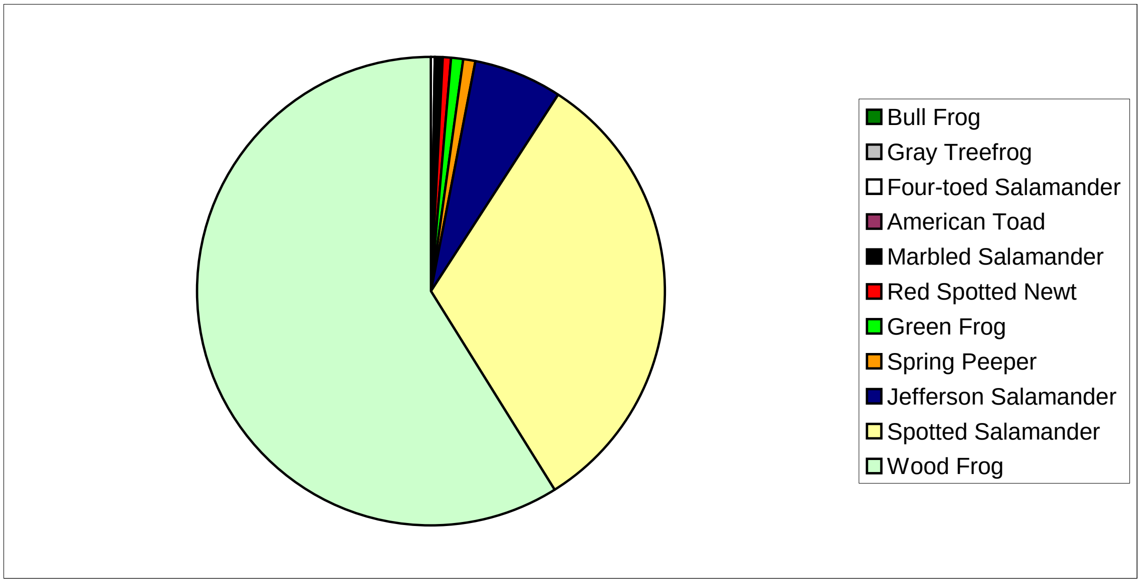


Figure 18. Raw abundance data for seasonal pool aquatic amphibian species shown for all study pools combined.

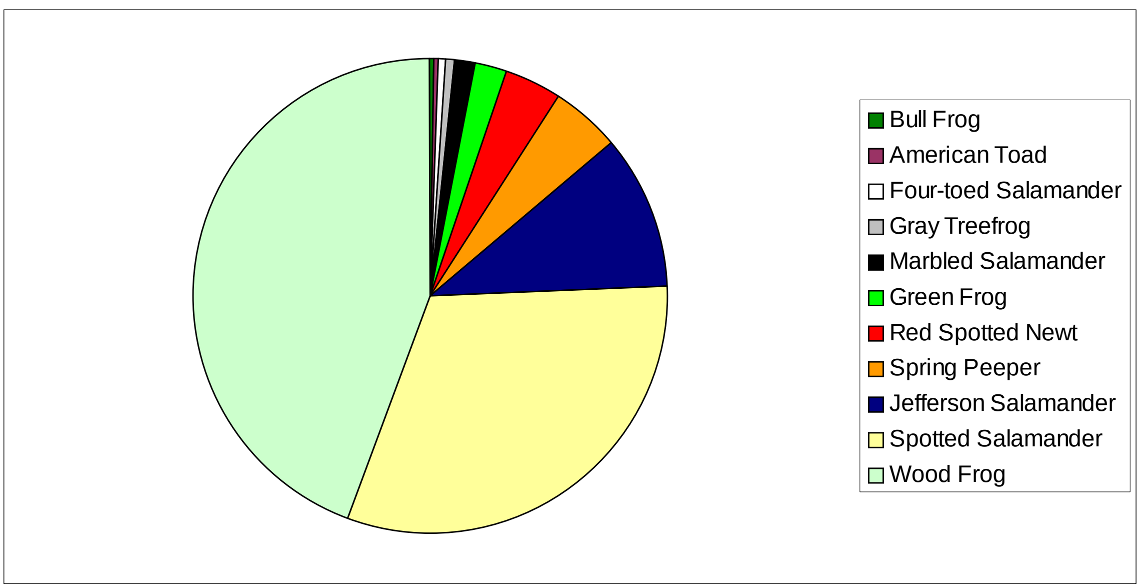


Figure 19. Aquatic amphibian abundance data base 10 log transformed and shown for all study pools combined.

Invertebrate and Amphibian Community Classification

Line and curve fitting on bivariate scatterplots:

Amphibian species and invertebrate taxon grouped at the family level or higher were plotted against continuous water chemistry, physical qualities, and landscape context variables measured for each pool (Tables 12 and 13 respectively). Linear regressions were used to seek relationships between dependent Y variables (base log 10 transformed taxon abundance) and independent X variables (environmental measurements). Linear positive or negative relationships are based on fitting a line using least squares linear regression. Unimodal concave or convex relationships were also sought for the amphibian species data and are based on fitting a parabola (quadratic polynomial fit degree = 2). The inflection point is where the parabola reaches its highest (convex) or lowest (concave) point.

Linear regressions and parabolic curve fitting were also used to seek relationships between herptile and invertebrate taxon density and richness and amphibian egg mass abundance and continuous environmental variables (Table 14).

Graphs were visually inspected, and significant relationships were reported for both linear and parabolic line fitting. Results are presented for results with a significant p value <0.05 and an r^2 value over 0.15. R^2 values are a measure of the degree of fit, from 0 (no fit) to 1 (exact fit). Parameters are defined in Appendix 2.

Table 12. Response of amphibian species abundance to environmental parameters.

Species	Parameter	p	r^2	Relation-ship*	Description
Ambystoma jeffersonianum	Area	0.0333	0.157	negative	
	Depth	0.0102	0.297	concave	inflection point 1.3 m
	Depth	0.0090	0.227	positive	
	pH	0.0058	0.327	concave	inflection point 6.1 pH
	pH	0.0135	0.205	positive	
Ambystoma maculatum	Area	0.0067	0.156	concave	inflection point 1200 m^2
Notophthalmus viridescens	Width	0.0083	0.313	positive	
Pseudacris crucifer	Calcium hardness	0.0281	0.186	positive	
	Elevation	0.0007	0.382	negative	
	Magnesium hardness	0.0002	0.457	positive	
	Total alkalinity	0.0046	0.289	positive	
	Total hardness	0.0016	0.345	positive	
Ambystoma opacum, Hyla versicolor, Lithobates clamitans					Insufficient data to process
Lithobates sylvaticus					No parameters with r^2 > 0.15

*Linear positive or negative relationships are based on fitting a line using least squares linear regression. Unimodal concave or convex relationships are based on fitting a parabola (quadratic polynomial fit degree = 2). The inflection point is where the parabola reaches its highest (convex) or lowest (concave) point.

Table 13. Response of invertebrate abundance (at family or higher taxonomic level) to environmental parameters.

by Variable	Variable	p	r^2	Relation-ship*
Aeshnidae	Distance to disturbance	0.0324	0.287	positive
	Distance to road	0.0199	0.330	positive
Ceratopogonidae	Width	0.0054	0.374	positive
Chirocephalidae	Distance to stream	0.0536	0.390	positive
	pH	0.0150	0.543	negative
Cladocera	Julian day	<.0001	0.241	positive
Copepoda	pH	0.0029	0.161	positive
	Total hardness	0.0021	0.171	positive
Gastropoda	pH	0.0208	0.689	positive
Hemiptera	pH	0.0442	0.346	negative
	Water temperature	0.0524	0.326	positive
Hydrophilidae	Distance to stream	0.0559	0.253	positive
	Water temperature	0.0285	0.318	positive
Isotomidae	Conductivity	0.0238	0.335	positive
	Elevation	0.0114	0.400	negative
	Oxidation-reduction potential	0.0306	0.312	negative
	Total alkalinity	0.0050	0.471	positive
Lestidae	Minimum canopy cover	0.0452	0.241	positive
Libellulidae	Calcium hardness	0.0022	0.433	negative
	Julian day	0.0377	0.230	positive
	Oxidation-reduction potential	0.0125	0.315	negative
	Total hardness	0.0512	0.206	negative
Limnephilidae	Distance to road	0.0016	0.264	positive
Malacostraca	Magnesium hardness	0.0304	0.511	positive
Megaloptera	Area	0.0049	0.443	positive
	Distance to disturbance	0.0393	0.270	negative
	Length	0.0157	0.350	positive
	Magnesium hardness	0.0094	0.393	negative
	Minimum canopy cover	0.0060	0.428	negative
	Width	0.0099	0.388	positive
Phryganeidae	Distance to road	0.0018	0.261	positive
Sphaeriidae	Distance to stream	0.0358	0.370	positive

*Linear positive or negative relationships are based on fitting a line using least squares linear regression.

Table 14. Response of amphibian and invertebrate taxon density, richness, and abundance to environmental parameters.

Taxon	Parameter	p	r^2	Relation-ship*	Description
Aquatic herptile richness	Area	<.0001	0.206	concave	inflection point 1250 m^2
	Length	0.0003	0.176	concave	inflection point 60 m
	Width	<.0001	0.196	concave	inflection point 25 m
Indicator species richness	Distance from nearest road	0.0001	0.156	negative	richness decreased as distance to nearest road increased
	Julian day	<.0001	0.173	negative	
	Width	0.0006	0.150	concave	inflection point 25 m
Invertebrate richness	Area	0.0012	0.147	concave	inflection point 1250 m^2
	Length	0.0006	0.161	concave	inflection point 65 m
Shredder density	Oxidation-reduction potential	<.0001	0.206	convex	inflection point 150 ORP
Shredder richness	Area	<.0001	0.296	concave	inflection point 1250 m^2
	Average canopy cover	<.0001	0.197	concave	inflection point 40%
	Depth of organic layer	0.0002	0.186	concave	inflection point 50 cm
	Depth of organic layer	0.0002	0.151	positive	
	Length	<.0001	0.259	concave	inflection point 60-70 m
	Minimum canopy cover	<.0001	0.222	negative	
	Width	0.0002	0.184	concave	inflection point 25 m
Predator richness	Area	0.0014	0.143	concave	inflection point 1250 m^2
	Length	0.0011	0.148	concave	inflection point 80 m
	Oxidation-reduction potential	<.0001	0.222	convex	inflection point 200-250 ORP
Collector gatherer & predator density, amphibian egg abundance					No parameters with $r^2 > 0.15$

*Linear positive or negative relationships are based on fitting a line using least squares linear regression. Unimodal concave or convex relationships are based on fitting a parabola (quadratic polynomial fit degree = 2). The inflection point is where the parabola reaches its highest (convex) or lowest (concave) point.

Product moment correlation coefficients: Associations among environmental variables and landscape variables and among herptile and invertebrate taxa were assessed using Pearson's product moment correlation coefficient. Variable definitions are provided in Appendix 2. Results significant at p <0.0001 and correlations greater than +0.390 or less than -0.390 are reported in Tables 15-19. Analyses of taxa were conducted on those occurring in eight or more pools.

Table 15. Pearson's product moment correlation coefficients among environmental variables.

Variable	by Variable	p	Correlation
Air temperature	Julian day	0.0001	0.528
	Oxidation-reduction potential	0.0000	-0.404
	Water temperature	0.0000	0.708
Area	Length	0.0000	0.871
	Width	0.0000	0.827

Canopy cover average	Minimum canopy cover	0.0000	0.811
Canopy cover minimum	Average canopy cover	0.0000	0.811
	Width	0.0001	-0.395
Calcium hardness	pH	0.0000	0.432
	Total alkalinity	0.0000	0.815
	Total hardness	0.0000	0.900
Depth	Oxidation-reduction potential	0.0000	0.426
Depth to clay	Depth of organic layer	0.0000	0.427
Depth of organic layer	Depth to clay	0.0000	0.427
	Length	0.0001	0.396
Elevation	Total alkalinity	0.0001	-0.407
Julian day	Air temperature	0.0000	0.528
	Dissolved oxygen	0.0000	-0.483
Length	Area	0.0000	0.871
	Depth of organic layer	0.0001	0.396
	Width	0.0000	0.565
Magnesium hardness	pH	0.0000	0.605
	Total hardness	0.0000	0.681
Minimum canopy cover	Average canopy cover	0.0000	0.811
	Width	0.0001	-0.395
Oxidation-reduction potential	Air temperature	0.0001	-0.404
	Depth	0.0000	0.426
	Dissolved oxygen	0.0000	0.451
Dissolved oxygen	Julian day	0.0000	-0.483
	Oxidation-reduction potential	0.0000	0.451
pH	Calcium hardness	0.0000	0.432
	Magnesium hardness	0.0000	0.605
	Total hardness	0.0000	0.608
Total alkalinity	Calcium hardness	0.0000	0.815
	Elevation	0.0001	-0.407
	Total hardness	0.0000	0.751
Total hardness	Calcium hardness	0.0000	0.900
	Magnesium hardness	0.0000	0.681
	pH	0.0000	0.608
	Total alkalinity	0.0000	0.751
Water temperature	Air temperature	0.0000	0.708
Width	Area	0.0000	0.827
	Length	0.0000	0.565
	Minimum canopy cover	0.0001	-0.395

Table 16. Pearson's product moment correlation coefficients among amphibians. Taxa occurring at fewer than eight pools were excluded from analysis.

By Variable	Variable	p	Correlation
Lithobates sylvaticus	*Notophthalmus viridescens*	0.0270	-0.569

Table 17. Pearson's product moment correlation coefficients among amphibians, and between amphibians and invertebrates.

Variable*	by Variable*	p	Correlation
Ambystoma jeffersonianum	Dytiscidae, *Agabus*	0.0545	-0.946
	Dytiscidae, *Liodessus*	0.0403	-0.654
Ambystoma maculatum	Ceratopogonidae	0.0396	-0.555
	Culicidae (spp not ID'd past family)	0.0246	0.527
	Dytiscidae, *Hydroporus*	0.0226	-0.520
Lithobates clamitans	Cladocera	0.0094	-0.878
	Ostracoda	0.0034	-0.980
Lithobates sylvaticus	Libellulidae	0.0017	-0.718
	Sphaeriidae	0.0224	0.676
Notophthalmus viridescens	Ceratopogonidae	0.0538	0.624
	Hydrachnida	0.0218	0.586
	Phryganeidae	0.0373	0.783
Pseudacris crucifer	Cladocera	0.0419	0.459
	Limnephilidae	0.0207	0.655
	Limnephilidae, *Limnephilus*	0.0314	0.647

*Invertebrate taxa reviewed at finest taxonomic level reached and also grouped at the family level. Taxa occurring at fewer than eight pools were excluded from analysis.

Table 18. Pearson's product moment correlation coefficients among invertebrates.

Variable*	by Variable*	p	Correlation
Ceratopogonidae	Chaoboridae, *Mochlonyx*	0.0121	0.563
	Chironomidae morpho A pupae	0.0110	0.913
Chaoboridae, *Mochlonyx*	Ceratopogonidae	0.0121	0.563
Chironomidae morpho A pupae	Ceratopogonidae	0.0110	0.913
	Culicidae, *Ochlerotatus excrucians*	0.0051	0.804
Culicidae (spp not ID'd past family)	Culicidae, *Ochlerotatus excrucians*	0.0060	0.621
	Dytiscidae, *Agabus*	0.0432	0.682
	Lestidae, *Lestes*	0.0083	0.924
Culicidae, *Ochlerotatus canadensis*	Hirudinea	0.0489	0.951
	Ostracoda	0.0138	0.495
Culicidae, *Ochlerotatus excrucians*	Chironomidae morpho A pupae	0.0051	0.804
	Culicidae (spp not ID'd past family)	0.0060	0.621
	Dytiscidae, *Agabus*	0.0172	0.670
Dytiscidae, *Agabus*	Culicidae not ID'd past family	0.0432	0.682
	Culicidae, *Ochlerotatus excrucians*	0.0172	0.670
Dytiscidae, *Liodesus*	Limnephilidae, *Limnephilus*	0.0367	0.698
	Oligochaeta	0.0531	-0.450
Hirudinea	Culicidae, *Ochlerotatus canadensis*	0.0489	0.951
Lestidae, *Lestes*	Culicidae (spp not ID'd past family)	0.0083	0.924
Limnephilidae, *Limnephilus*	Dytiscidae, *Liodessus*	0.0367	0.698
	Oligochaeta	0.0376	-0.402

Oligochaeta	Dytiscidae, *Liodessus*	0.0531	-0.450
	Limnephilidae, *Limnephilus*	0.0376	-0.402
Ostracoda	Culicidae, *Ochlerotatus canadensis*	0.0138	0.495
	Scirtidae, *Cyphon*	0.0253	0.639
Scirtidae, *Cyphon*	Ostracoda	0.0253	0.639

* Invertebrate taxa reviewed at finest taxonomic level reached and also grouped at the family level. Taxa occurring at fewer than eight pools were excluded from analysis.

Table 19. Pearson's product moment correlation coefficients among invertebrates grouped at the family or higher taxonomic level. Taxa occurring at fewer than eight pools were excluded from analysis.

Variable	by Variable	p	Correlation
Ceratopogonidae	Chaoboridae	0.0121	0.5631
	Chironomidae	0.0104	0.6029
Chaoboridae	Ceratopogonidae	0.0121	0.5631
Chironomidae	Ceratopogonidae	0.0104	0.6029
	Cladocera	0.0013	0.4387
	Libellulidae	0.0110	0.5836
Cladocera	Chironomidae	0.0013	0.4387
	Hydrophilidae	0.0519	0.5493
	Isotomidae	0.0082	0.7208
	Malacostraca	0.0006	-0.9362
Dytiscidae	Poduridae	0.0127	-0.6919
	Sphaeriidae	0.0409	-0.7274
Hydrachnida	Sphaeriidae	0.0292	-0.6840
Hydrophilidae	Cladocera	0.0519	0.5493
Isotomidae	Cladocera	0.0082	0.7208
Libellulidae	Chironomidae	0.0110	0.5836
Malacostraca	Cladocera	0.0006	-0.9362
Ostracoda	Scirtidae	0.0373	0.6046
Poduridae	Dytiscidae	0.0127	-0.6919
Scirtidae	Ostracoda	0.0373	0.6046
Sphaeriidae	Dytiscidae	0.0409	-0.7274
	Hydrachnida	0.0292	-0.6840

<u>Cluster analysis</u>: Cluster analysis was used to arrange the pools into hierarchical groups and subgroups based on similarity in their invertebrate or aquatic amphibian communities. Percent chaining is a way of evaluating whether natural groups are present in the data. High chaining gives the dendrogram the appearance of stair steps and occurs when individual sample units (in this case pools) are added one at a time to pre-existing groups. Data with inherent groups will typically have percent chaining of less than 25%, higher percent chaining indicates that natural groups could not be found. The invertebrate cluster analysis yielded 10.96% chaining and the aquatic amphibian analysis yielded 13.24% chaining.

Six main invertebrate groups, accounting for 25 percent of the information were initially identified. The largest of the initial invertebrate groupings was further analyzed independently with cluster and indicator species analyses and nineteen subgroups accounting for 50 percent of the information were identified (Figure 20). Two of these subgroups (7 and 8) consist of a single pool. One pool could not be classified because it was dry at the time of the spring visit and no invertebrate samples were taken.

Three initial amphibian groups accounting for 25% of the information were identified. The largest of the initial amphibian groups was further analyzed independently with cluster and indicator species analyses. Seven amphibian subgroups accounting for 75 percent of the information were ultimately identified from eighty pools (Figure 21). Of the remaining nine study pools, six pools had no amphibians identified in or around the pool and an additional three only had terrestrial species found around the pool.

A table showing each pool's group membership in the plant, invertebrate, and amphibian cluster analysis groups are found in Appendix 16. Distribution of the amphibian and invertebrate groups in Pennsylvania within ecoregions, vegetation community types, and vegetation structure types are presented in Tables 25 - 28.

Indicator Species Analysis (ISA):

ISA was used to look for taxa that best indicate a-priori groups of pools. Indicator taxa were sought for pool groups based on amphibian and invertebrate community groups developed through cluster and NMS analyses. The ISA results are presented in Table 20 for the invertebrate subgroups. Indicator values over 15 and significant p values under 0.05 are reported.

Seventeen invertebrate community groupings encompassing eighty-eight pools were identified. The most ubiquitous taxa occurring at over fifty study pools included the microcrustaceans (Cladocera, Copeopda, and Ostracoda), non-biting midges (Chironomidae), phantom midges (Chaoboridae, *Mochlonyx*), a mosquito (Culicidae, *Ochlerotatus excrucians*), predaceous diving beetles (Dytiscidae), water mites (Hydrachnida), and aquatic worms (Oligochaeta).

Indicator species analysis indicated that eight groups were characterized primarily by species in the collector-gatherer trophic group, which for the purposes of these analyses included collector-gatherers, detritivores, filterers, herbivores, and scrapers. Collector gatherers include all of the microcrustaceans and two out of three dominant fly families (Chrionomidae and Culicidae). Three groups were primarily characterized by predatory species including the Anisoptera (dragonflies and damselflies), Ceratopogonidae (biting midges), the third dominant fly family (Chaoboridae), Dytiscidae, and Hydrachnidia. Three groups had indicators across several trophic groups including predators, shredders, and collector-gatherers.

Table 20. Indicator species for invertebrate groups identified through cluster analysis. Trophic codes are defined in Table 11.

Indicator	Trophic Group	Cluster group	Indicator values	p*
Megaloptera, *Chauliodes*	P	1	57.7	0.0186
Chirocephalidae, *Eubranchipus vernalis*	CG/F	2	55.2	0.0050
Oligochaeta	CG	3	40.8	0.0012
Culicidae, *Ochlerotatus abserratus*	CG/F	41	24.0	0.0286
None		42	na	na
Dytiscidae, *Liodessus*	P	43	32.4	0.0256
Dytiscidae, *Agabus*	P	43	28.6	0.0572
Culicidae, *Ochlerotatus excrucians*	CG/F	43	19.7	0.0002
Limnephilidae, *Limnephilus*	Sh/D/H/CG	44	24.0	0.0286
Cladocera	CG/P	51	15.7	0.0002
Ostracoda	CG/D	52	17.2	0.0002
Hydrophilidae, *Hydrochus*	Sh/H	53	36.4	0.0494
Libellulidae	P	53	28.4	0.0544
Culicidae, *Aedes vexans*	CG/F	54	40.9	0.0298
Isotomidae	CG/Sv	55	43.7	0.0096
Sminthuridae	CG/Sv	55	33.9	0.0506
Physidae, *Physa*	D	56	60.3	0.0038
Sphaeriidae, *Sphaerium*	F	56	44.8	0.0154
Dytiscidae, *Hydroporus*	P	56	25.1	0.0478
Planorbidae	D	57	66.5	0.0050
Limnephilidae, *Hesperophylax*	Sh/D/H	57	55.3	0.0074
Hirudinea	P/Pa	57	30.4	0.0408
Culicidae, *Ochlerotatus canadensis*	CG/F	57	20.9	0.0338
Copepoda	CG/P/Sc	57	14.6	0.0230
Dytiscidae, *Dytiscus*	P	58	87.7	0.0014
Phryganeidae, *Banksiola*	Sh	58	68.1	0.0012
Aeshnidae, *Aeshna verticalis*	P	58	44.9	0.0272
Coenagrionidae	P	58	42.2	0.0356
Dytiscidae, *Desmopachria*	P	58	41.0	0.0216
Dytiscidae, *Copelatus*	P	61	42.9	0.0300
Gyrinidae, *Dineutus*	P/Sv	62	66.7	0.0068
Gerridae	P/Sv	62	58.0	0.0106
Corixidae	P	62	46.2	0.0190

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs >= observed)/(1 + number of randomized runs)

The ISA results are presented in Table 21 for the amphibian subgroups. Indicator values over 15 and significant p values under 0.05 are reported. Seven aquatic amphibian community groupings encompassing eighty pools were identified. An additional two types were assigned to pools with only terrestrial species or with no herptile species found during the surveys. Wood frogs and spotted salamanders were most ubiquitous species and comprised a significant component of the aquatic amphibian community for seventy-five out of the eighty pools with aquatic amphibians observed.

Table 21. Indicator species for amphibian groups identified through cluster analysis.

Indicator	Cluster group	Indicator value	p*
Lithobates sylvaticus	20	89.3	0.0002
Ambystoma maculatum	20	82.7	0.0006
Ambystoma maculatum	21	29.1	0.0006
Ambystoma jeffersonianum	22	62.9	0.0002
Ambystoma maculatum	23	100	0.0002
Notophthalmus viridescens	24	38.2	0.0262
Pseudacris crucifer	25	65.8	0.0004
Rana clamitans	26	72.3	0.0010

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs >= observed)/(1 + number of randomized runs)

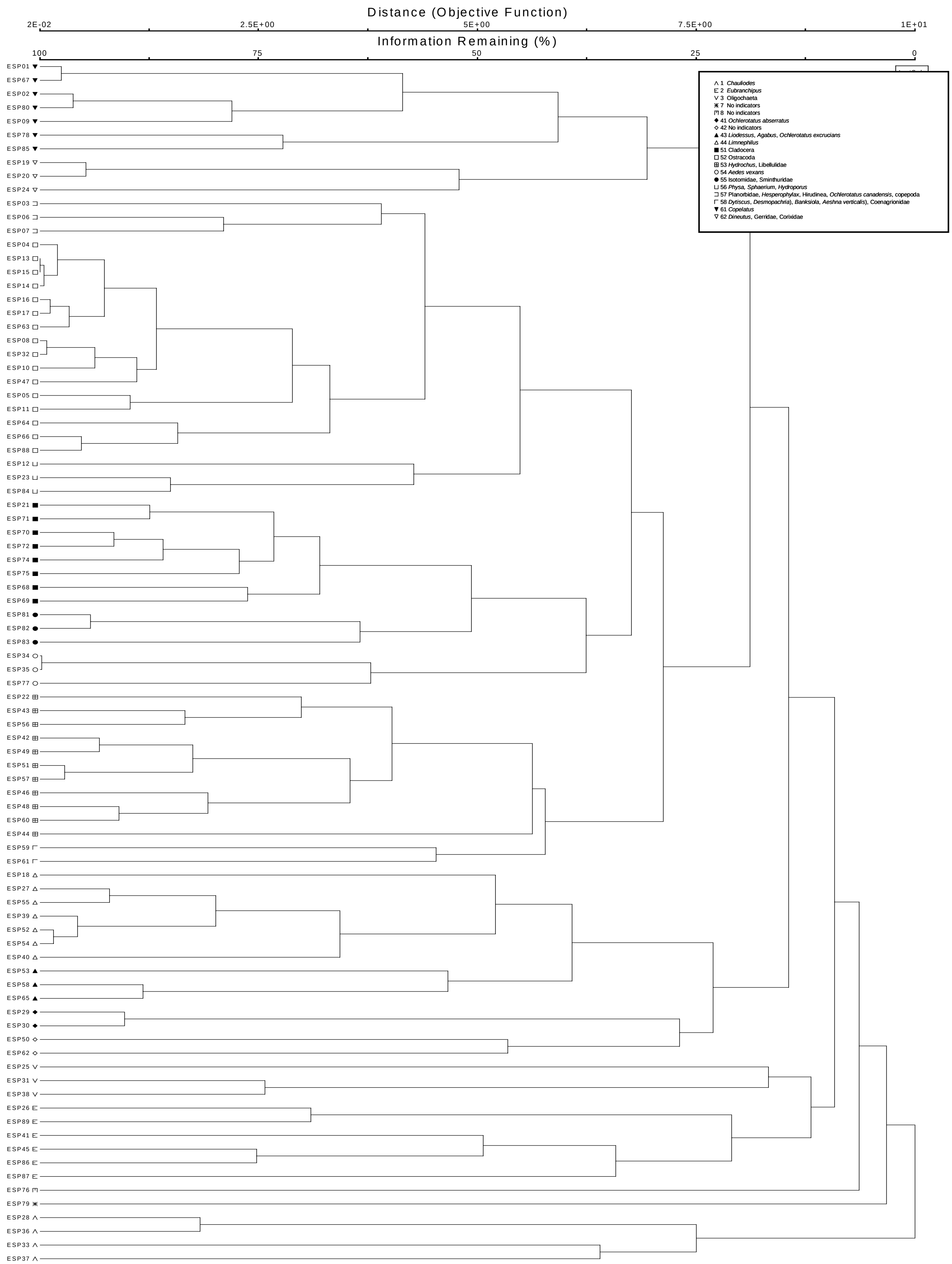


Figure 20. Cluster analysis of invertebrate abundance data showing nineteen subgroups.

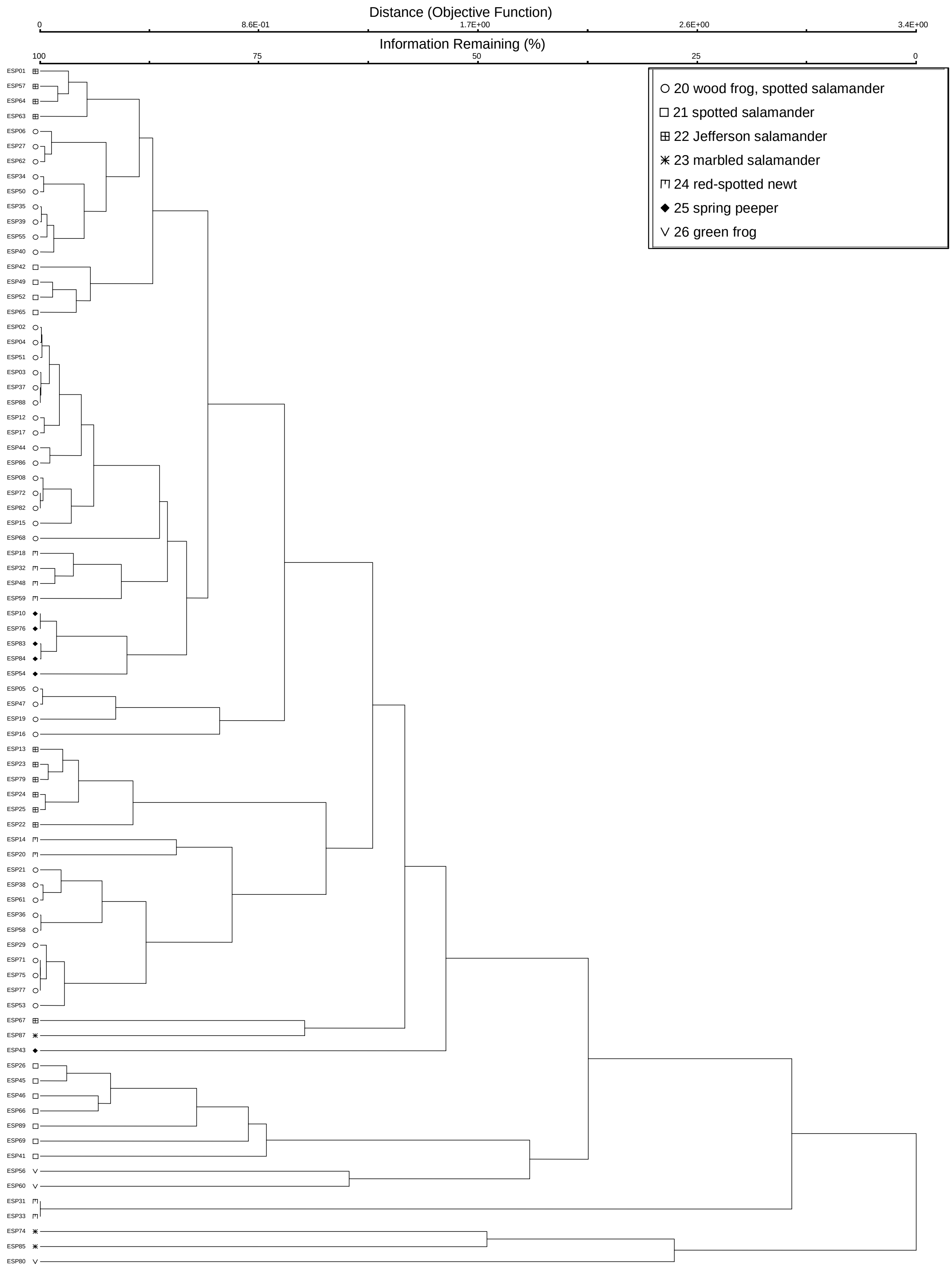


Figure 21. Cluster analysis of aquatic amphibian abundance showing seven subgroups.

Multi-response permutation procedure (MRPP): MRPP analyses were run on the invertebrate and amphibian subgroups identified in the cluster analyses. MRPP is a non-parametric procedure that tests the hypothesis that there is no difference between two or more groups. The key numbers in the output for interpretation are the test statistic (T) and the chance-corrected within-group agreement (A). As T values become more negative they indicate greater separation between groups. As A values become more positive they indicate more within-group consistency when compared to the random expectation. Values for A in community ecology are often below 0.1, and a finding greater than 0.3 would be on the high end (McCune and Grace 2002). The invertebrate and amphibian subgroups defined were found to differ significantly from one another (invertebrate MRPP T = -22.7, A = 0.27, p = 0.00000; amphibian MRPP T = -21.5, A = 0.30, p = 0.00000).

Ordinations of invertebrate and aquatic amphibian abundance data: Non-metric multidimensional scaling (NMS) was used to examine relationships between pools, invertebrate and aquatic amphibian taxon abundance, and other biotic and abiotic factors. The NMS analysis for the invertebrate data recommended a three-dimensional ordination. The NMS analysis for the aquatic amphibian ordination alternated between recommending two and three-dimensional ordinations. The stress reduction for three axes in the invertebrate dataset is shown in Table 22, and the amphibian dataset in Table 23. Most of the stress reduction occurred in the first three dimensions. In each case the addition of dimensions four through six yield increasingly smaller reductions in stress. Therefore three dimensions were chosen as the final solution for interpretation of the invertebrate and aquatic amphibian ordinations (final minimum stress of 17.67 and 11.71 respectively). Monte Carlo tests using 250 randomized runs were used to evaluate whether a similar final stress could be obtained randomly. Significant p values for three dimensions in the invertebrate and amphibian ordinations (p of 0.0040 and 0.0476 respectively) indicates that the final stress for three dimensions could not have been obtained by chance. As a rule of thumb, a stress value between 5 and 10 indicates a good ordination that can be interpreted with confidence, although higher values are commonly obtained with community data. Values between 10 and 20 can still illustrate useful trends and groupings, although details of the plot should not be over-interpreted (Kruskal 1964a and Clarke 1993). The cumulative r^2 for all three axes of the invertebrate ordination equaled 0.778 (axis 1 r^2 = 0.273, axis 2 r^2 = 0.252, axis 3 r^2 = 0.253). The cumulative r^2 for all three axes of the amphibian ordination equaled 0.935 (axis 1 r^2 = 0.323, axis 2 r^2 = 0.418, axis 3 r^2 = 0.195).

Table 22. Invertebrate NMS stress shown in relation to dimensionality (3 axes)

	Stress in real data 250 runs			Stress in randomized data Monte Carlo test, 250 runs			
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	41.127	49.26	57.078	46.027	52.017	57.077	0.0040
2	26.085	26.848	41.099	28.37	30.552	33.139	0.0040
3	17.676	18.001	31.889	20.309	21.745	22.938	0.0040

p = proportion of randomized runs with stress < or = observed stress
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)

Table 23. Amphibian NMS stress shown in relation to dimensionality (3 axes).

	Stress in real data 250 runs			Stress in randomized data Monte Carlo test, 250 runs			
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	31.796	42.73	57.037	31.88	46.03	57.573	0.0476
2	17.01	25.44	44.623	16.341	27.24	42.221	0.0952
3	11.707	17.53	42.683	11.964	19.75	33.95	0.0476

p = proportion of randomized runs with stress < or = observed stress
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)

Several configurations of the ordination for the invertebrates (Figures 22 and 23) are shown with an overlay of environmental variables and taxonomic richness and density values. In the invertebrate ordination, axis one is positively correlated with pH and negatively correlated with elevation and percent forest in the 300 meter upland buffer around the pool. Axis two is positively correlated with dissolved oxygen and negatively correlated with Julian Day and invertebrate predator density and richness. Axis three is positively correlated with richness of the collector-gatherer and shredder invertebrate trophic groupings.

One configuration of the NMS ordination of eighty pools based on aquatic amphibian abundance is shown in Figure 24. Axis 1 is positively correlated with indicator species richness and oxidation-reduction potential. Axis three is positively correlated with aquatic herptile richness, indicator species richness, water temperature, magnesium hardness, and Julian day.

Additional ordinations of invertebrate abundance data

Levels of stress found in the final NMS were higher than what is desired for ease of interpretation of the data. This may be due to the large numbers of zeros in the data set, the relatively large sample size, and the wide range of environmental conditions in which the pools were found. Several additional NMS runs were performed on different treatments of the data to see if the stress could be reduced, but both attempts yielded similar final stress and weaker p values.

The first attempt was to run base 10 log transformed invertebrate abundance data with taxa grouped to family or higher taxonomic level. This eliminated genus and species level identifications and compressed the number of taxa from 95 to 31. Final stress at an optimal configuration of three axes was selected for the final ordination. The final stress was 17.684 and p for three axes was 0.0196.

The second attempt was to limit the ordination to pools within a single ecoregion. An NMS run using base 10 log transformed invertebrate abundance data at the greatest taxonomic resolution and including rare species. Analysis was limited to pools in the Central Appalachian Forest ecoregion (43 pools). An optimal configuration of three axes was selected for the final ordination. The final minimum stress was 16.86 and p value for three axes was 0.0476.

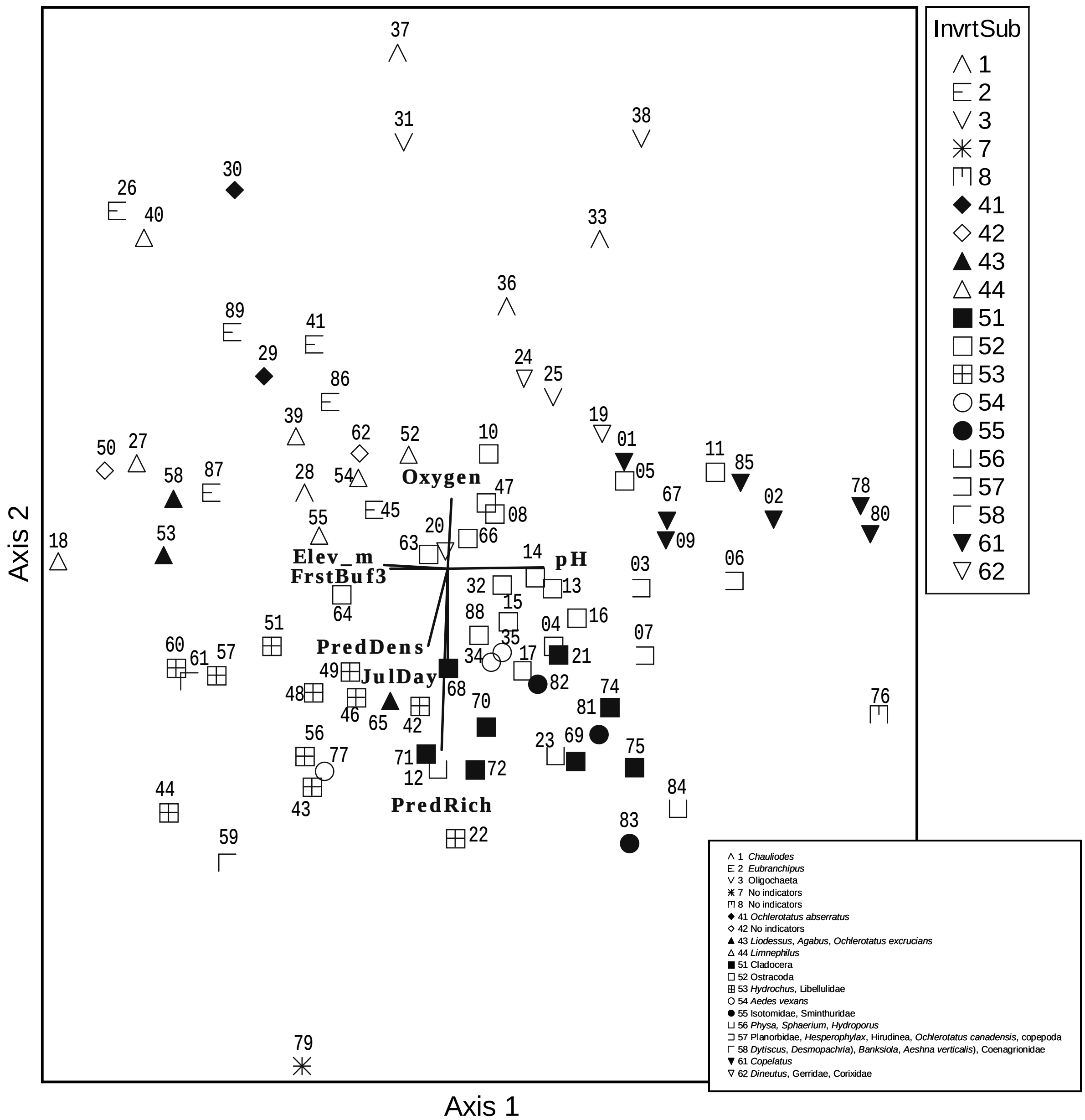


Figure 22. Axes 1 and 2 of an NMS ordination of eighty-eight pools based on invertebrate abundance.

Nineteen invertebrate community subgroups identified in cluster analysis are used as the grouping variable. An overlay of environmental and taxonomic richness and density values shows correlations with each axis. Axis 1 is positively correlated with pH ($r^2 = 0.191$) and negatively correlated with elevation ($r^2 = 0.126$) and percent forest in the 300 meter upland buffer around the pool ($r^2 = 0.113$). Axis 2 is positively correlated with dissolved oxygen ($r^2 = 0.138$) and negatively correlated with invertebrate predator richness and density ($r^2 = 0.358$ and 0.153 respectively) and Julian day ($r^2 = 0.204$). Definitions of analysis codes are listed in Appendix 2.

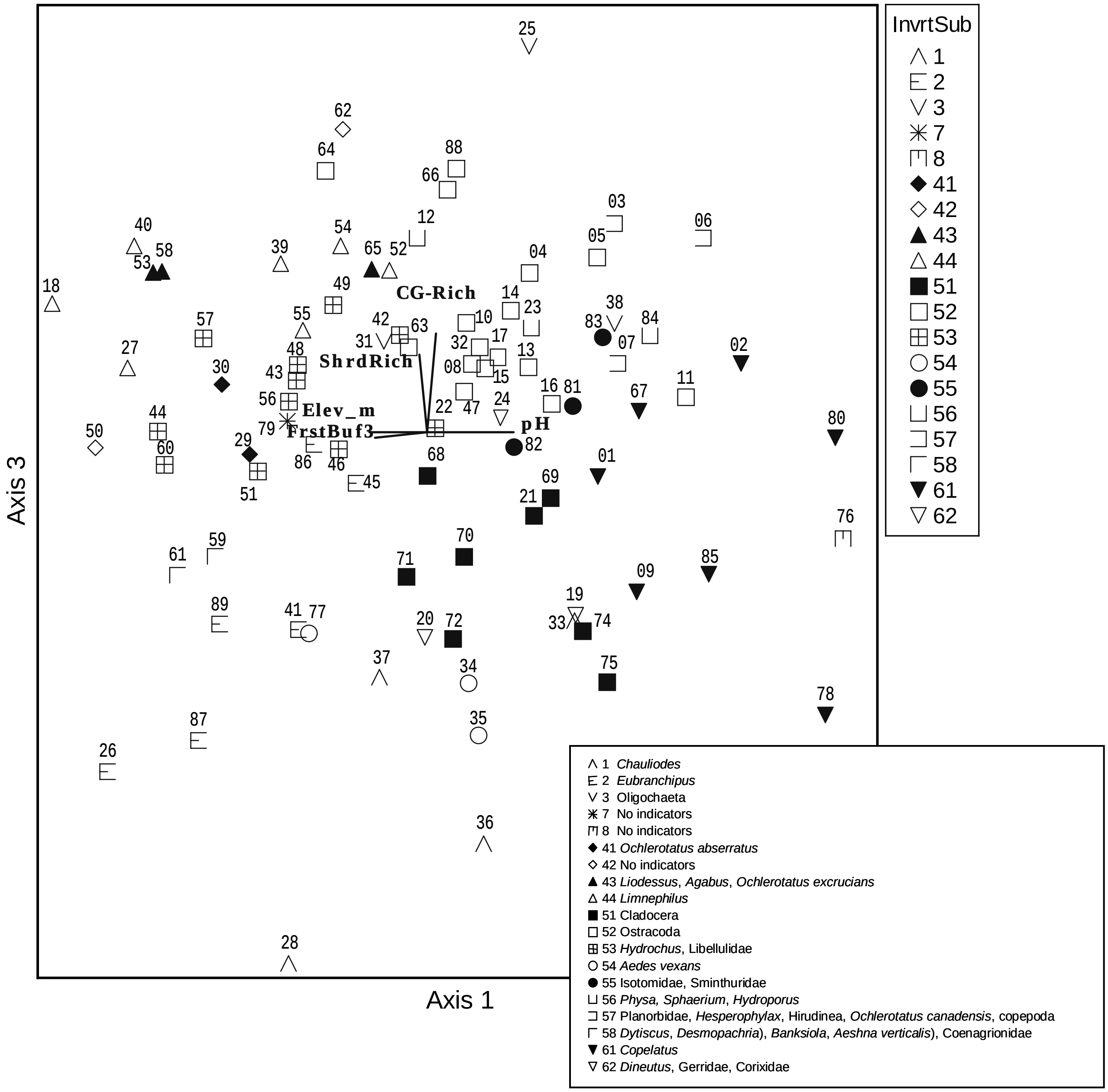


Figure 23. Axes 1 and 3 of an NMS ordination of eighty-eight pools based on invertebrate abundance.

Nineteen invertebrate community subgroups identified in cluster analysis are used as the grouping variable. An overlay of environmental and taxonomic richness and density values shows correlations with each axis. Axis 1 is positively correlated with pH ($r^2 = 0.191$) and negatively correlated with elevation ($r^2 = 0.126$) and percent forest in the 300 meter upland buffer around the pool ($r^2 = 0.113$). Axis 3 is positively correlated with richness of the collector-gatherer and shredder invertebrate trophic groupings ($r^2 = 0.215$ and 0.169 respectively). Definitions of analysis codes are listed in Appendix 2.

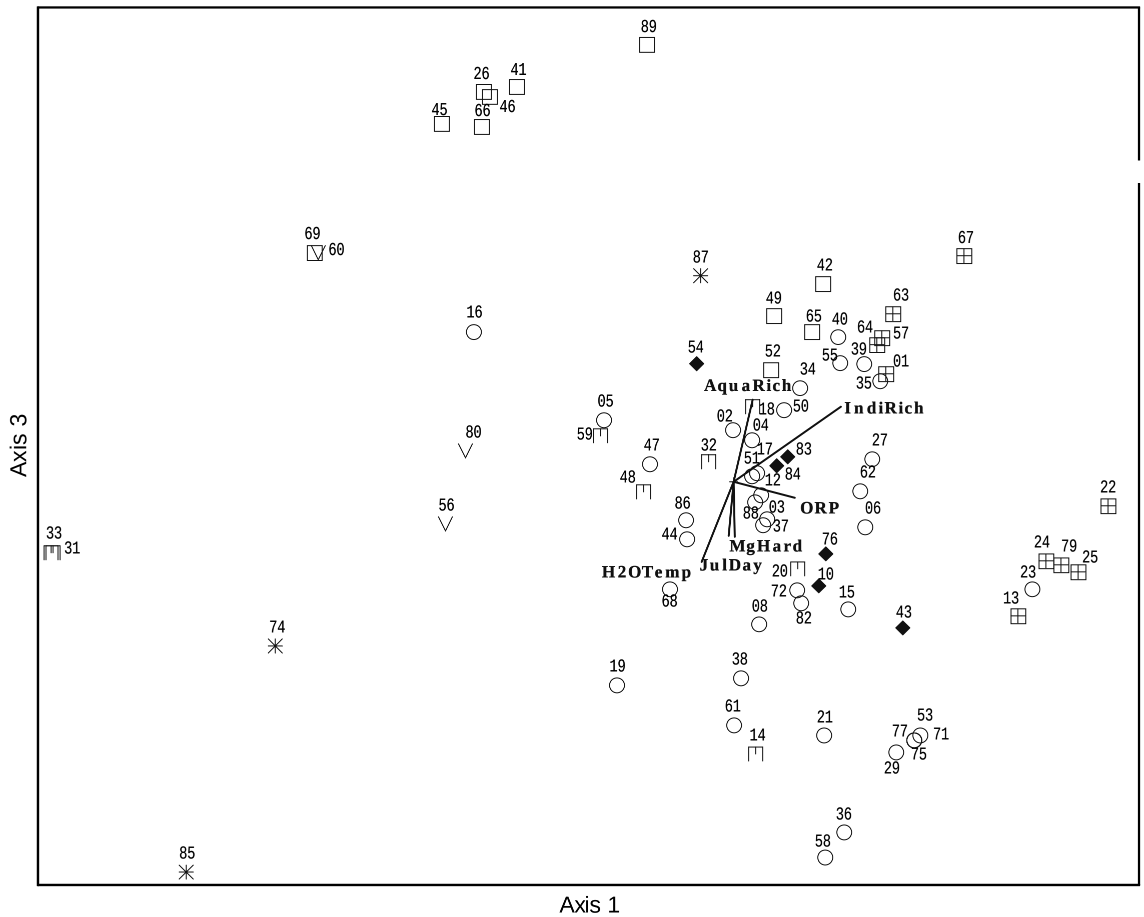


Figure 24. Axes 1 and 3 of and NMS ordination of eighty pools based on aquatic amphibian abundance.

Axis 1 is positively correlated with indicator species richness (r^2 = 0.202) and oxidation-reduction potential (r^2 = 0.115). Axis three is positively correlated with aquatic herptile richness r^2 = 0.155), indicator species richness (r^2 = 0.142), water temperature (r^2 = 0.151), magnesium hardness (r^2 = 0.104) and Julian day (r^2 = 0.102). Definitions of analysis codes are listed in Appendix 2.

Cluster group # and indicator species

○ 20 wood frog, spotted salamander
□ 21 spotted salamander
⊞ 22 Jefferson salamander
⋇ 23 marbled salamander
ℿ 24 red-spotted newt
◆ 25 spring peeper
∨ 26 green frog

Ordination of environmental variables and herptile and invertebrate richness and density:

An NMS was run on the environmental variables plus invertebrate and herptile richness and density values for eighty-eight seasonal pools. The NMS analysis recommended a three-dimensional ordination. The stress reduction for this dataset is shown in Table 24, with most of the stress reduction occurred in the first three dimensions. In each case the addition of dimensions four through six yield increasingly smaller reductions in stress. Therefore three dimensions were chosen as the final solution (final stress of 14.93). As a rule of thumb, a stress value between 5 and 10 indicates a good ordination that can be interpreted with confidence, although higher values are commonly obtained with community data. Values between 10 and 20 can still illustrate useful trends and groupings, although details of the plot should not be over-interpreted (Kruskal 1964a and Clarke 1993). Monte Carlo tests using 250 randomized runs were used to evaluate whether a similar final stress could be obtained randomly. Significant p values for three dimensions (p = 0.008) indicates that the final stress for three dimensions could not have been obtained by chance. The cumulative r^2 for all three axes equaled 0.838 (axis 1 r^2 = 0.259, axis 2 r^2 = 0.493, axis 3 r^2 = 0.838).

Table 24. Environmental and faunal richness/density NMS showing stress in relation to dimensionality (number of axes).

	Stress in real data 250 runs			Stress in randomized data Monte Carlo test, 250 runs			
Axes	Minimum	Mean	Maximim	Minimum	Mean	Maximum	p
1	37.272	48.979	57.075	39.196	48.833	57.075	0.0040
2	21.832	22.471	41.067	21.144	24.282	27.64	0.0159
3	14.929	15.22	16.016	14.804	16.424	17.979	0.0080

p = proportion of randomized runs with stress < or = observed stress
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)

Figure 25 shows two dimensions of the ordination based on environmental and faunal richness and density variables. An overlay of environmental and taxonomic richness and density variables shows correlations with each axis. Axis one is strongly positively correlated with area and to a lesser extent with depth of organic layer, richness of the shredder invertebrate trophic group. Axis one is negatively correlated with pH, distance to the nearest wetland, minimum canopy cover, and magnesium hardness. Axis three is strongly negatively correlated with distance to nearest road or stream and to a lesser extent distance to nearest disturbance, water temperature, minimum canopy cover, and percent forest within 300 meters of the vernal pool. Axis three is positively correlated with indicator species richness and width.

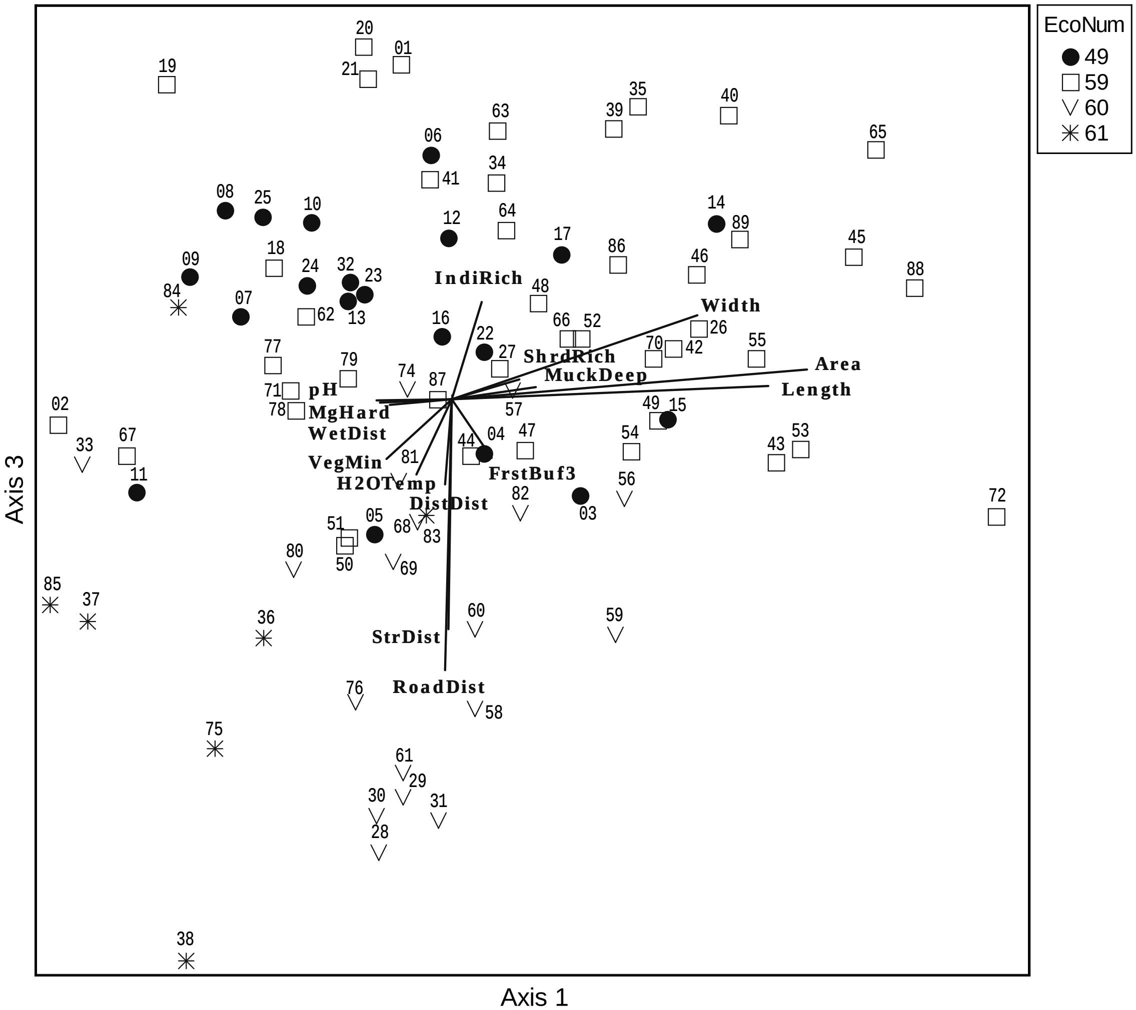


Figure 25. Two dimensions of an NMS ordination based on environmental and faunal richness and density variables.

An overlay of environmental and taxonomic richness and density variables shows correlations with each axis. Axis one is strongly positively correlated with area (r^2 = 0.753) and to a lesser extent with depth of organic layer (r^2 = 0.179), richness of the shredder invertebrate trophic group (r^2 = 0.142). Axis one is negatively correlated with pH (r^2 = 0.159), distance to the nearest wetland (r^2 = 0.152), minimum canopy cover (r^2 = 0.137), and magnesium hardness (r^2 = 0.131). Axis three is strongly negatively correlated with distance to nearest road (r^2 = 0.572) or stream (r^2 = 0.486) and to a lesser extent distance to nearest disturbance (r^2 = 0.179), water temperature (r^2 = 0.158), minimum canopy cover (r^2 = 0.126), and percent forest within 300 meters of the vernal pool (r^2 = 0.125). Axis three is positively correlated with indicator species richness (r^2 = 0.206) and width (r^2 = 0.178).

Symbol	Ecoregion name	Symbol	Ecoregion name
●	Western Allegheny Plateau	∨	High Allegheny Plateau
□	Central Appalachian Forest	✳	Lower New England / Northern Piedmont

One-way Analysis of Variance (Anova): Anovas and Tukey-Kramer post-hoc comparison of means were used to test if two or more sample means belong to a population with the same parametric mean to assist with interpretation of the multivariate analyses. Significant differences ($p < 0.05$) among group means were sought for taxon density and richness in a variety of pool classes (amphibian, invertebrate, and vegetation classification types, county, ecoregion and physiographic sections and subsections, surficial geology, glacial history, largest disturbance type within 600 m buffer, nearest road, stream, and wetland type, and vegetation structure). Anovas identified significant difference in means in invertebrate and amphibian richness and density among environmental groupings (Appendix 15), and among the plant and animal community groupings identified in cluster analysis (Appendix 16).

Anovas indicated that among the invertebrate groups, the fishfly group (Corydalidae: *Chauliodes*) had significantly lower invertebrate taxonomic richness than many other invertebrate community types. The *Chauliodes* and two other low diversity groups indicated by aquatic worms (Oligochaeta, group 3) and a diving beetle (Dytiscidae: *Copelatus*, group 61) trended on NMS axes towards higher dissolved oxygen levels, higher pH, and lower predator richness and density. These groups also trended towards low-moderate elevations and less forest cover in the surrounding 300 meters characteristic of study pools in the WAP and LNE/NP ecoregions. Two other lower diversity groups were the *Limnephilus* (44) and *Eubranchipus vernalis* (2) groups which trended towards higher dissolved oxygen, lower pH, and lower predator richness and diversity. These pools also trended towards higher percent forest in the surrounding 300 meters and higher elevations characteristic of pools in the CAP ecoregion. The *Aedes vexans* mosquito group (54) was more intermediate in placement along the NMS axes but trended towards greater predator richness and density and lower dissolved oxygen.

Anovas indicated several invertebrate community group types with significantly richer invertebrate communities. Groups 56 and 57 clustered in the same region of the NMS graph. Group 56 had the highest observed invertebrate richness with 28 taxa was characterized by pond snails (Physidae: *Physa*), fingernail clams (Sphaeridae, *Sphaerium*), and a diving beetle (Dytiscidae, *Hydroporus*). Group 57 was characterized by pond snails (Planorbidae) and a caddisfly (Limnephilidae: *Hesperophylax*). These groups trended along NMS axes towards high predator richness and density (strongly so in the *Physa* group) and towards higher pH (strongly so in the Planorbidae group). They were placed on NMS axes negatively correlated with dissolved oxygen levels (strongly so in the Physa group). Finally they occurred at moderate to low elevations with lower percent forest in the surrounding 300 meter upland which are characteristics of study pools in the WAP and LNE/NP ecoregions.

Invertebrate groups 43 and 53 were also significantly richer than many other invertebrate types. Group 43 was composed of diving beetles (Dytiscidae: *Liodessus*, *Agabus*) and mosquitoes (Culicidae: *Ochlerotatus excrucians*) and was positioned along NMS axes in directions correlated with higher elevations, highly forested buffers in the surrounding 300 meters around each pool, and lower pH levels. These are characteristic qualities of study pools in the CAP and HAL ecoregions. Group 53 was composed of a water scavenger beetle (Hydrophilidae: *Hydrochus*) and skimmer dragonflies (Libellulidae) was associated with NMS axes in the direction of greater predator richness and density, lower oxygen levels, higher elevations, and greater forest cover in the surrounding 300 meters of each pool.

Anovas comparing the mean richness of the amphibian community groups found significant a difference only between those pools with and without aquatic amphibians. An NMS ordination showed that the pools characterized by wood frog / spotted salamanders only were widely distributed throughout the ordination space but many trended along an axis positively correlated with oxidation-reduction potential (ORP). The spotted salamander (*Ambystoma maculatum*) group had two clusters in ordination space, both placed along axes positively correlated with aquatic amphibian and seasonal pool indicator richness, and negatively correlated with water temperature and magnesium hardness. The Jefferson salamander (*Ambystoma jeffersonianum*) group also had two clusters in ordination space, both along axes positively correlated with aquatic amphibian and indicator species richness and ORP, and negatively associated with water temperature. The spring peeper (*Pseudacris crucifer*) group was clustered in the center of the ordination, with most of the pools trending along axes positively correlated ORP. Several groups did not cluster well among themselves or with other amphibian groups. The green frog (*Rana clamitans*) and marbled salamander (*Ambystoma opacum*) groups were only composed of three pools each and were widely dispersed in ordination space along an axis positively correlated with water temperature. The red-spotted newt (*Notophthalmus viridescens*) pools were also fairly dispersed throughout the ordination space and to a lesser extent were distributed along the axis positively correlated with water temperature.

Table 25. Distribution of aquatic amphibian community types by ecoregion.

Amph Sub	***Amphibian classification group name***	***Distribution by ecoregion***	***Distribution comment***
0	No herptiles	W C H	Occured in CAP and HAL only in eastern PA along the boundary between them.
30	Terrestrial herptiles only	W C H	Occured in CAP only in eastern PA along its boundary with HAL
22	*Ambystoma jeffersonianum*	W C H	
21	*Ambystoma maculatum*	C H	Occured in HAL only in eastern PA along its boundary with CAP
23	*Ambystoma opacum*	C H L	
20	*Lithobates sylvaticus* / *Ambystoma maculatum*	W C H L	
24	*Notophthalmus viridescens*	W C H	Occured only in the north-western quadrat of state
25	*Pseudacris crucifer*	W C H L	
26	*Rana clamitans*	H	

Table 26. Distribution of invertebrate community types by ecoregion.

Invt Sub	Invertebrate classification group name	Distribution by ecoregion	Distribution comment
54	*Aedes vexans*	C	
1	*Chauliodes*	H L	
51	Cladocera	C H L	
61	*Copelatus*	W C H L	Occurred in HAL in eastern PA only along its boundary with LNE/NP.
62	*Dineutus*, Gerridae, Corixidae	W C H	Occurred in CAP and HAL only in eastern PA along the boundary between them.
58	*Dytiscus, Banksiola, Aeshna verticalis*, Coenagrionidae, *Desmopachria*	H	
2	*Eubranchipus vernalis*	C	
53	*Hydrochus*, Libellulidae	W C H	
55	Isotomidae, Sminthuridae	H L	Occurred in HAL and LNE/NP only in eastern PA along boundary between them.
44	*Limnephilus*	C	
43	*Liodessus, Agabus, Ochlerotatus excrucians*	C H	
41	*Ochlerotatus abserratus*	C	
3	Oligochaeta	W H L	
52	Ostracoda	W C	
56	*Physa, Sphaerium, Hydroporus*	W L	Occurred in WAP in the glaciated northwest
57	Planorbidae, *Hesperophylax*, Hirudinea, *Ochlerotatus canadensis*, Copepoda	W	Occurred in WAP in the glaciated northwest

Code	Ecoregion name
W	Western Allegheny Plateau (WAP)
C	Central Appalachian Forest (CAP)
H	High Allegheny Plateau (HAL)
L	Lower New England / Northern Piedmont (LNE/NP)

Table 27. Distribution of amphibian communities by vegetation structure and type.

Amph Sub	Amphibian community name (AmphSub)	# Pools in AmphSub by vegetation structure type	# Vegetation types in AmphSub: vegetation type name (# of pools in AmphSub in each vegetation type)	Total # of pools
0	No herptiles	2 black leaf, 1 marsh	3 types: dry oak - pitch pine forest (1), pin oak - mixed hardwood swamp forest (1), white oak upland depression (1)	3
30	Terrestrial herptiles only	5 black leaf, 1 marsh	3 types: red maple - northern hardwood (4), swamp white oak swamp forest (1), wool-grass – mannagrass mixed shrub marsh (1)	6
20	*Lithobates sylvaticus / Ambystoma maculatum*	17 marsh, 16 black leaf, 6 shrub	10 types: red maple - northern hardwood (10), pin oak - mixed hardwood swamp forest (7), ricecut grass – bulrush marsh (5), wool-grass - mannagrass mixed shrub marsh (5), remaining 12 pools in 6 vegetation types	39
21	*Ambystoma maculatum*	4 blackleaf, 4 marsh, 3 shrub	4 types: red maple - northern hardwood (5), sourgum - red maple woodland (4); ricecut grass – bulrush marsh (1), wool-grass - mannagrass mixed shrub marsh (1)	11
22	*Ambystoma jeffersonianum*	10 marsh, 1 black leaf	5 types: sourgum - red maple woodland (4), wet-mesic forested calcareous seep-fed (3), remaining 3 pools in 3 vegetation types	10
23	*Ambystoma opacum*	2 black leaf, 1 shrub	3 types: sourgum - red maple woodland (1), wet-mesic forested calcareous seep-fed (1), wool-grass - mannagrass mixed shrub marsh (1)	3
24	*Notophthalmus viridescens*	5 marsh, 3 black leaf	4 types: red maple - northern hardwood (3), ricecut grass - bulrush marsh (3), pin oak - mixed hardwood swamp forest (1), wool-grass - mannagrass mixed shrub marsh (1)	8
25	*Pseudacris crucifer*	5 marsh, 1 black leaf	5 types: wool-grass – mannagrass mixed shrub marsh (2), remaining 3 pools in 3 vegetation types	6
26	*Rana clamitans*	2 black leaf, 1 marsh	2 types: ricecut grass – bulrush marsh (1), sourgum - red maple woodland (2)	3

Table 28. Distribution of invertebrate communities by vegetation structure and type

Invt Sub	Invertebrate community name (InvtSub)	# Pools in InvtSub by vegetation structure type	# Vegetation types in InvtSub: vegetation type name (# of pools in InvtSub in each vegetation type)	Total # of pools
54	*Aedes vexans*	3 marsh	2 types: ricecut grass - bulrush marsh (2), unclassified (1)	3
1	*Chauliodes*	4 black leaf	2 types: red maple - northern hardwood (3), white oak upland depression (1)	4
51	Cladocera	4 black leaf, 2 marsh, 2 shrub	4 types: red maple - northern hardwood (3), wool-grass - mannagrass mixed shrub marsh (3), sourgum - red maple woodland (1), unclassified (1)	8
61	*Copelatus*	4 black leaf, 3 marsh	5 types: sourgum - red maple woodland (3), 4 remaining pools in 4 vegetation types	7
62	*Dineutus*, Gerridae, Corixidae	3 marsh	3 types: ricecut grass – bulrush marsh (1), wool-grass - mannagrass mixed shrub marsh (1), wet-mesic forested calcareous seep-fed (1)	3
58	*Dytiscus, Banksiola, Aeshna verticalis,* Coenagrionidae, *Desmopachria*	2 marsh	1 type: ricecut grass – bulrush marsh (2)	2
2	*Eubranchipus vernalis*	3 black leaf, 2 shrub, 1 marsh	2 types: red maple - northern hardwood (4), sourgum - red maple woodland (2)	6
53	*Hydrochus*, Libellulidae	6 marsh, 5 black leaf, 1 shrub	7 types: red maple - northern hardwood (3), wool-grass - mannagrass mixed shrub marsh (2), dry oak pitch pine forest (2), sourgum - red maple woodland (2), 3 remaining pools in 3 vegetation types.	12
55	Isotomidae, Sminthuridae	1 black leaf, 1 marsh, 1 shrub	2 types: red maple - northern hardwood (2), wool-grass - mannagrass mixed shrub marsh (1)	3
44	*Limnephilus*	5 marsh, 2 shrub	3 types: pin oak - mixed hardwood swamp forest (3), ricecut grass - bulrush marsh (2), sourgum - red maple woodland (2)	7
43	*Liodessus, Agabus, Ochlerotatus excrucians*	2 marsh, 1 shrub	3 types: pin oak - mixed hardwood swamp forest (1), ricecut grass – bulrush marsh (1), wool-grass - mannagrass mixed shrub marsh (1)	3
42	No indicator species	2 black leaf	2 types: sourgum - red maple woodland (1), pin oak - mixed hardwood swamp forest (1)	2
41	*Ochlerotatus abserratus*	2 black leaf	1 type: red maple - northern hardwood (2)	2
3	Oligochaeta	1 black leaf, 2 marsh	3 types: red maple - northern hardwood (1), sourgum - red maple woodland (1), wet-mesic forested calcareous seep-fed (1)	3
52	Ostracoda	8 marsh, 6 black leaf, 1 shrub	6 types: red maple - northern hardwood (4), wool-grass – mannagrass mixed shrub marsh (3), pin oak - mixed hardwood swamp forest (3), sourgum - red maple woodland (3), 2 remaining pools in 2 vegetation types	15
56	*Physa, Sphaerium, Hydroporus*	3 marsh	3 types: wet-mesic forested seep calcareous seep-fed (1), wool-grass - mannagrass mixed shrub marsh (1), unclassified (1)	3
57	Planorbidae, *Hesperophylax*, Hirudinea, *Ochlerotatus canadensis*, Copepoda	3 black leaf	3 types: pin oak - mixed hardwood swamp forest (1), red maple - northern hardwood (1), swamp white oak swamp forest (1)	3
7, 8	unclassified	1 black leaf, 1 marsh	1 type: white oak upland depression (2)	2
0	no invertebrates	1 marsh	1 type: white oak upland depression (1)	1

Vegetation Sampling

A total of 180 vascular plants (Appendix 9) and 57 bryophytes (Appendix 10), identified to species, were recorded growing within the high water marks of pools. Plant taxonomy and common names follow Rhoads and Block (2007).

While not always rooted in the pool basin, the species that occurred with greatest frequency in the overstory of 89 pools were red maple (*Acer rubrum*) (50 pools), sourgum (*Nyssa sylvatica*) (24 pools), white oak (*Quercus alba*) (17 pools), and pin oak (*Q. palustris*) (13 pools).

The most frequently occurring species in the tall shrub layer, which included species rooted in the pools and overhanging the water, were red maple (35 pools), buttonbush (*Cephalanthus occidentalis*) (15 pools), winterberry (*Ilex verticillata*) (6 pools), black birch (*Betula lenta*) (5 pools).

The most frequently occurring short shrub was winterberry (10 pools), swamp dewberry (*Rubus hispidus*) (7 pools), and highbush blueberry (*Vaccinium corymbosum*) (6 pools).

The most frequently observed herbaceous species were rice cutgrass (*Leersia oryzoides*) (24 pools), wool-grass (*Scirpus cyperinus*) (22 pools), bugleweed (*Lycopus uniflorus*), pale meadowgrass (*Torreyochloa pallida*) (16 pools), false nettle (*Boehmeria cylindrica*) (13 pools), marsh St. John's-wort (Triadenum virginicum) (13 pools), marsh-purslane (*Ludwigia palustris*) (12 pools), and dotted smartweed (*Persicaria punctata*) (12 pools).

Rare species
There was only one rare vascular plant species, tracked by the PNHP, recorded within the 89 pools, the federally listed northeastern bulrush (*Scirpus ancistrochaetus*). This species grows in open-canopied, herbaceous-dominated seasonal pools predominantly in the ridge and valley region (Central Appalachian Plateau Forest Ecoregion) of Pennsylvania, it is also known from sink-holes and beaver ponds in the northeastern United States.

Invasive species
Of the 179 species of vascular plants identified to species in this study, six are considered non-native. Reed canary-grass (*Phalaris arundinacea* at 2 pools), several species of non-native smartweeds (*Persicaria hydropiper* at 11 pools, *P. lapathifolia* at 1 pool, *P. longiseta* at 5 pools), and common dandelion (*Taraxacum officinale*) were observed in this study. Climbing nightshade (*Solanum dulcamara var. dulcamara*) occurred in 2 pools. Stiltgrass (*Microstegium vimineum*), was observed growing on the edges of several pools, but was not recorded as being rooted in the pool itself. While not impacting the vegetation of the pool, the above species can alter and degrade the surrounding landscape.

Vernal pool bryophytes
Ecologists documented 57 bryophyte species occurring in seasonal pools in Pennsylvania (nomenclature follows Anderson et al. 1990 for mosses and Anderson, 1990 for peat mosses). Five unnamed liverwort species were also collected but not identified. These species, identified by John Atwood at the Missouri Botanical Garden, were added to the bryophyte checklist of

Pennsylvania. Many of the specimens collected in this study, 31 in all, while not exceedingly rare in Pennsylvania, represent newly documented occurrences within Pennsylvania Counties. For example, new records for Potter County include *Warnstorfia fluitans* and three of the peat moss (*Sphagnum*) species collected near Ellisburg, Pennsylvania (EPASP.28, 29, 30, 31). While the number of new county records is more indicative of limited inventory of non-vascular plants in general, this result indicates the importance of this type of comprehensive survey.

Vegetation Community Classification

Several multivariate statistical techniques were employed to classify the data from 89 pools, representing a variety of forested and non-forested seasonal wetlands, into vegetation communities. Species occurring in both the canopy and subcanopy layers (T2 and T3) were combined prior to the analyses (species occurrences in multiple understory strata were treated as distinct species for analysis). To better understand the vegetation zones, the size of the database was reduced from 246 to 135 species by eliminating those with a frequency of 2 or less (i.e. occurred in less than 5% of the plots). The removal of infrequent species limited the potential for rare species to skew ordination and classification results; however, it opened up the possibility for misclassification.

<u>Cluster analysis</u>: Initial breaks in the cluster dendrogram showed two main types of pools: forested or woodland pools, and open herbaceous. Seven distinct vegetation types were initially identified with a 0.7% chaining (Figure 26). Indicator species analysis (ISA) shows that these groups were heavily influenced by the characteristics of the tree canopy, or in the absence of tree canopy, by the herbaceous species present within the pool (Table 29). A multi-response permutation procedure (MRPP) indicated that the groups indicated in the cluster analysis were significantly different from one another ($T = -25.5$, $A = 0.11$, $p = 0.00000$). While red maple, pin oak, and other hardwood species like swamp white oak (*Quercus bicolor*) were rooted in the pools, many of the trees contributing to the canopy cover were rooted outside of the pool area, such as white oak. Recognizable forested pools from the initial cluster analysis included **Sourgum – red maple woodland**, **Red maple – northern hardwood woodland**, and **Pin oak – mixed hardwood swamp** pools. Herbaceous pools included three recognizable types: **Rice cutgrass – bulrush marsh**, **Wool-grass – mannagrass mixed shrub marsh**, and **White oak upland depression forest** pools.

In addition to the six recognizable forested and non-forested types above, a seventh group contained 28 pools with a diverse mix of overstory, shrub, and herbaceous species in which no distinct pattern was discernable, nor were there any species with significant Monte Carlo p values in the ISA. The heterogeneity is most likely due to differences in the composition of herbaceous species among similar types that occurred in different regions, differences in the pools hydroperiod, differences in density of the canopy, or a combination of these factors. It may also be the case that herbaceous plant species found in seasonal pool ecosystems are simply opportunistic and are therefore difficult to classify based on the composition of the understory. Therefore, the 28 pools were further analyzed in an NMS ordination to re-evaluate this group containing a diverse mix of plant species in relation to the other groups.

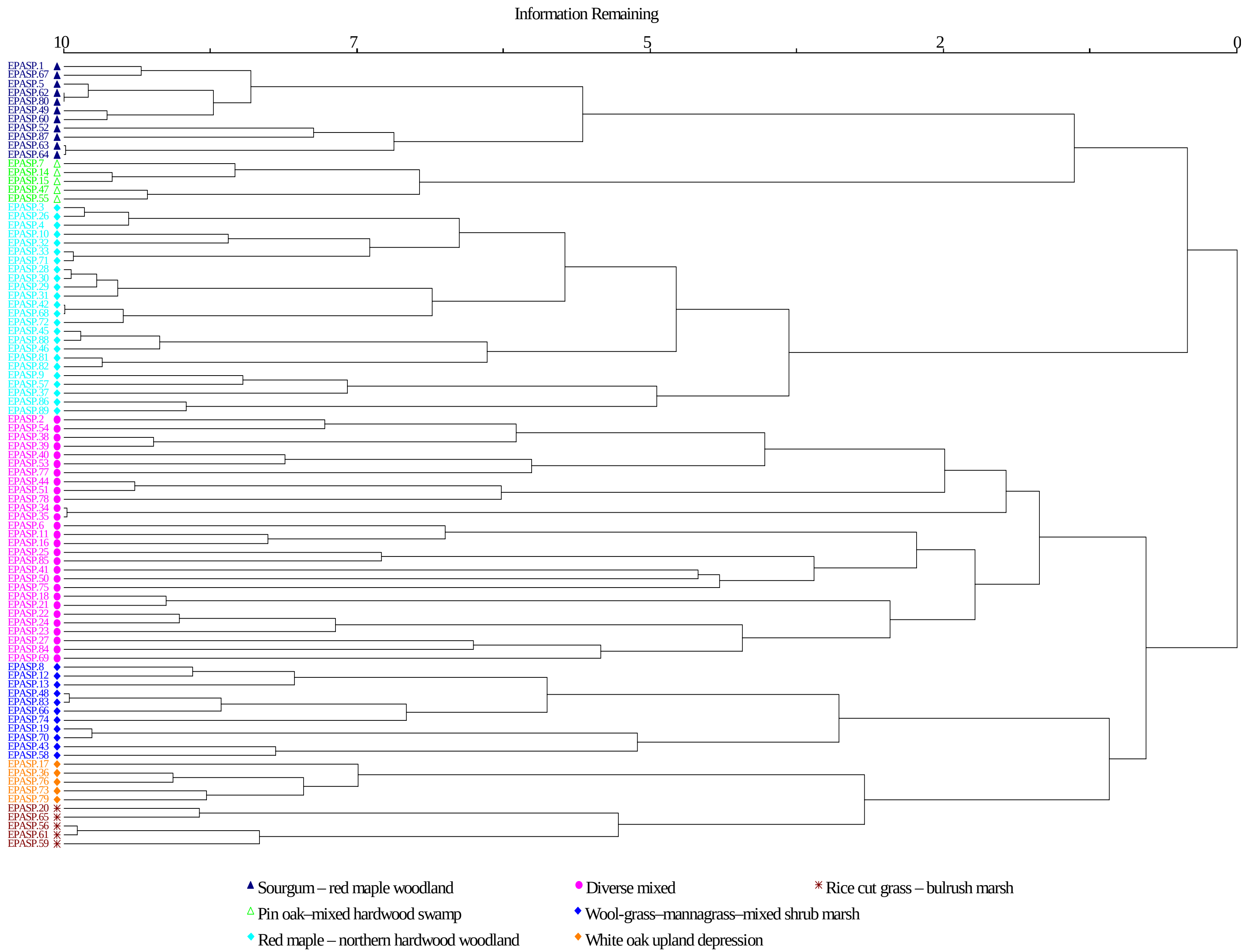


Figure 26. Initial cluster analysis of the vegetation data showing seven distinct groups.

Table 29. Average of all significant indicator species identified by Indicator Species Analysis for each seasonal pool vegetation community type identified in Pennsylvania.

Seasonal Pool Community Type	**Mean Indicator Value**	**Mean ISA p-value**
Sourgum – red maple woodland pool	63.0	0.0002
Pin oak – mixed hardwood swamp pool	45.7	0.0200
Red maple – northern hardwood woodland pool	33.7	0.0002
White oak upland depression pool	68.6	0.0002
Wet-mesic forested calcareous seep-fed pool	53.3	0.0104
Dry oak – pitch pine forest pool	59.4	0.0012
Rice cutgrass – bulrush marsh pool	47.2	0.0234
Wool-grass – mannagrass mixed shrub marsh pool	70.6	0.0002
Swamp white oak swamp forest pool	50.5	0.0171

Ordination of vegetation data: A non-metric multidimensional scaling (NMS) ordination was performed on vegetation plot data from the 89 seasonal pools yielded a three dimensional ordination in which all axes were significant. The stress reduction for each dataset is shown in Table 30, with most of the stress reduction occurring in the first three dimensions. The cumulative r^2 for all three axes equaled .562 (axis 1, r^2 = 0.170, axis 2 r^2 = 0.158, axis 3 r^2 = 0.234). Graphs of the main axes of the NMS ordination of pools based on vegetation data with the cluster analysis results as the grouping variable are presented in Figures 27 and 28.

Table 30. Vegetation NMS showing stress in relation to dimensionality (number of axes). An optimal configuration of three axes was selected for the final ordination.

	Stress in real data 250 runs			Stress in randomized data Monte Carlo test, 250 runs			
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	45.624	51.998	57.088	47.270	52.944	57.083	0.0040
2	29.788	31.497	41.108	29.565	32.622	43.612	0.0080
3	21.839	22.389	31.994	22.154	24.257	36.703	0.0040

p = proportion of randomized runs with stress < or = observed stress
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)

Pearson and Kendall correlations with the ordination axes are presented in Table 31. Axis 1 tended to be positively correlated with water pH, total hardness, and available calcium, suggesting that types falling along this axis contain plant species that favor rich site conditions. Axis 2 tended to show little correlation with environmental variables; however, it was somewhat positively correlated with mean canopy cover and somewhat negatively correlated with distance to nearest disturbance, suggesting that pools falling along this axis were those situated in slightly more open, more disturbed areas. Axis 3 was positively correlated with average canopy cover, minimum canopy cover, and water pH, thus pools falling along this axis exhibited a tendency to associate with open, rich sites.

Plots described as **Sourgum – red maple woodland**, **Red maple – northern hardwood woodland**, and **Pin oak – mixed hardwood swamp** pools grouped with like pools towards the higher ends of Axes 1 and 3, corresponding with closed canopy forests, whereas the open types, described as the **Rice cutgrass – bulrush marsh**, **Wool-grass – mannagrass mixed shrub marsh**, and **White oak upland depression** pools tended to cluster along the lower end of the two Axes.

Table 31. Pearson and Kendall Correlations with Ordination Axes; N= 89

Axis:	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
Elevation	-0.078	0.006	-0.032	-0.017	0.000	-0.034	-0.146	0.021	-0.117
Air temperature	-0.102	0.010	-0.113	-0.071	0.005	-0.048	0.076	0.006	0.058
Water temperature	0.019	0.000	-0.064	-0.082	0.007	-0.048	0.115	0.013	0.083
Conductivity	0.232	0.054	0.274	0.132	0.017	0.058	0.032	0.001	0.018
Oxygen	0.248	0.061	0.186	0.158	0.025	0.119	0.008	0.000	0.017
pH	0.463	0.214	0.272	-0.074	0.005	-0.054	0.348	0.121	0.278
ORP	0.344	0.119	0.296	0.061	0.004	0.008	0.014	0.000	0.010
Total hardness	0.525	0.276	0.329	0.065	0.004	0.063	0.233	0.054	0.233
Calcium hardness	0.494	0.244	0.365	0.101	0.010	0.145	0.131	0.017	0.163
Magnesium hardness	0.333	0.111	0.240	-0.025	0.001	0.022	0.288	0.083	0.231
Total alkalinity	0.423	0.179	0.109	-0.027	0.001	-0.009	0.068	0.005	0.093
Length	-0.028	0.001	-0.005	0.096	0.009	0.029	-0.077	0.006	-0.098
Width	0.148	0.022	0.129	-0.018	0.000	-0.021	-0.214	0.046	-0.172
Area	0.013	0.000	0.049	0.071	0.005	0.021	-0.120	0.014	-0.145
Depth	0.322	0.104	0.193	0.008	0.000	0.053	0.264	0.070	0.250
Depth to clay	0.198	0.039	0.138	0.168	0.028	0.128	-0.018	0.000	-0.007
Depth of organic matter	0.086	0.007	-0.001	0.116	0.013	0.065	-0.019	0.000	-0.016
Forest buffer 1	-0.039	0.002	0.003	0.095	0.009	-0.005	-0.013	0.000	0.022
Forest buffer 2	-0.065	0.004	-0.055	0.079	0.006	-0.078	-0.025	0.001	0.064
Forest buffer 3	-0.343	0.118	-0.363	0.086	0.007	-0.038	-0.108	0.012	-0.143
Distance to disturbance	-0.174	0.030	-0.041	-0.220	0.049	-0.119	-0.175	0.031	-0.024
Distance to stream	-0.087	0.008	-0.026	-0.003	0.000	-0.015	-0.015	0.000	0.011
Distance to wetland	0.197	0.039	0.285	0.087	0.008	-0.089	-0.182	0.033	-0.005
Distance to road	-0.108	0.012	0.024	-0.176	0.031	-0.136	0.184	0.034	0.155
Avg. canopy cover (%)	-0.118	0.014	-0.095	0.233	0.054	0.158	0.411	0.169	0.291
Min. canopy cover (%)	-0.116	0.013	-0.044	0.195	0.038	0.153	0.310	0.096	0.306

Clear differences in species composition and environmental variables were apparent within the group of 28 unassigned pools in the NMS ordination. Some pools from this group were assigned to previously identified community types based on their similarity to other pools within those community types.

An additional three plant community types were also identified within the group of 28 unassigned pools. The types were **Swamp white oak swamp forest**, **Wet-mesic forested seep-fed**, and **Dry oak – pitch pine forest** pools. There were relatively small separation distances among groups of plots, indicating there was a high degree of homogeneity in plant composition within the three groups. All contained significant overstory cover. **Swamp white oak swamp forest** and **Wet-mesic forested calcareous seep-fed** pools were associated with the far ends of Axis 1 and 3 suggesting that these types are associated with calcium rich sites and contain a relatively intact canopy. The **Swamp white oak swamp forest** type included a higher average canopy closure than the **Wet-mesic forested calcareous seep-fed** pools, as indicated by the location of the pools at the far end of Axis 1 and 3, which is consistent with the ecology of swamp white oak, which can tolerate significant inundation. Both types, however, are found where soils are higher in calcium, such as the glaciated portion of northwestern Pennsylvania or on diabase-derived soils of southeastern Pennsylvania. While site hydrology was not determined, it is thought that all sites within these two types are influenced by groundwater. In contrast to the **Swamp white oak swamp forest** and **Wet-mesic forested seep-fed** pools, three pools were described completely, or nearly so by upland, dry-site species found often growing on acidic soils. These pools, described as **Dry oak – pitch pine forest** pools, fall toward the lower end of Axis 1, are described by their overstory species and sparse cover of plants in the understory and groundcover layer. The negative relationship with calcium and pH are consistent with pitch pine (*Pinus rigida*) – dry oak forests (**Pitch pine – mixed oak forest community** (Fike (1999)) surrounding this type, which are typically associated with acidic, calcium-poor sites.

The NMS failed to elucidate additional patterns in three remaining pools, due to variation in species composition, possibly due to differences in hydrology, region, and other site characteristics. Three pools (EPASP.75, EPASP.77, EPASP.84) remained unclassified following the additional analyses. After further review of the characteristics of these pools, they were determined to be examples of plant community types represented by only one pool in the study. EPASP.75 was dominated by sweetgum (*Liquidambar styraciflua*), which occurred in no other plot. EPASP.77 was dominated by Virginia chain fern (*Woodwardia virginica*), which was rare in other community types. EPASP.84, occurring at Gifford Pinchot State Park, in York County, was heavily invaded by a non-native species, moneywort, and contained a diversity of overstory species including those that are both dry and wet site indicators. Of the three, pool EPASP.75 was most recognizable, appearing similar to sweetgum swamp forests found on the Coastal Plain of New Jersey, Maryland and is represented in NatureServe's National Vegetation Classification as the **Red maple – sweetgum swamp** (Sweetgum - Red Maple - Willow Oak / Swamp Doghobble Forest CEGL006110). This association is a seasonally flooded forest of shallow basins and other depressions of the Coastal Plain of the Chesapeake Bay region, identified in regional analyses of Maryland and Virginia conducted by Virginia Department of National Heritage for a mapping project in the National Capitol Region. However our data were insufficient to accurately describe its species composition, environmental settings, and distribution as a distinct plant community within this study.

Once group membership had been assigned to all 89 plots using ISA and NMS, an MRPP indicated that these groups were significantly different from one another ($T = -21.6$, $A = 0.11$, $p = 0.00000$).

Once the plant community types were primarily categorized by dominant vegetation, subtypes were defined based on the structure of the community. Structure often plays a large role in determining the faunal composition of the seasonal pool ecosystem. Within types, sub-categories are typically based on the percent cover shrubs and herbs, or in the case of unvegetated pools, the lack of live plant material. The vegetation community subtypes used in this study to refine the seasonal pool plant community type are shown in Table 32. A table showing a breakdown of the dominant structure of pools within in each vegetation type is presented in Table 33.

Table 32. Definition of plant community subtypes based on in-pool vegetation structure.

In-pool vegetation structure	Definition	Subtype
Herbaceous	>50% of the pool basin with herbaceous cover	1
Black leaf (unvegetated)	<50% of the pool basin with herbaceous or shrub cover	2
Shrub	>50% of the pool basin with shrub cover	3

Table 33. Distribution of plant communities by vegetation structure

Vegetation classification type	# Pools in type by dominant structure	Total # pools
Diverse mixed unclassified	1 black leaf, 2 marsh	3
Dry oak - pitch pine forest pool	2 black leaf, 1 marsh	3
Pin oak - mixed hardwood swamp forest pool	5 black leaf, 2 marsh, 2 shrub	9
Red maple - northern hardwood woodland pool	14 black leaf, 6 marsh, 4 shrub	24
Ricecut grass - bulrush marsh pool	10 marsh	10
Sourgum - red maple woodland pool	9 black leaf, 5 marsh, 1 shrub	15
Swamp white oak swamp forest pool	2 black leaf, 1 shrub	3
Wet-mesic forested calcareous seep-feed pool	4 marsh, 1 black leaf	5
White oak upland depression pool	3 marsh, 2 black leaf	5
Wool-grass - mannagrass mixed shrub marsh pool	10 marsh, 2 shrub	12

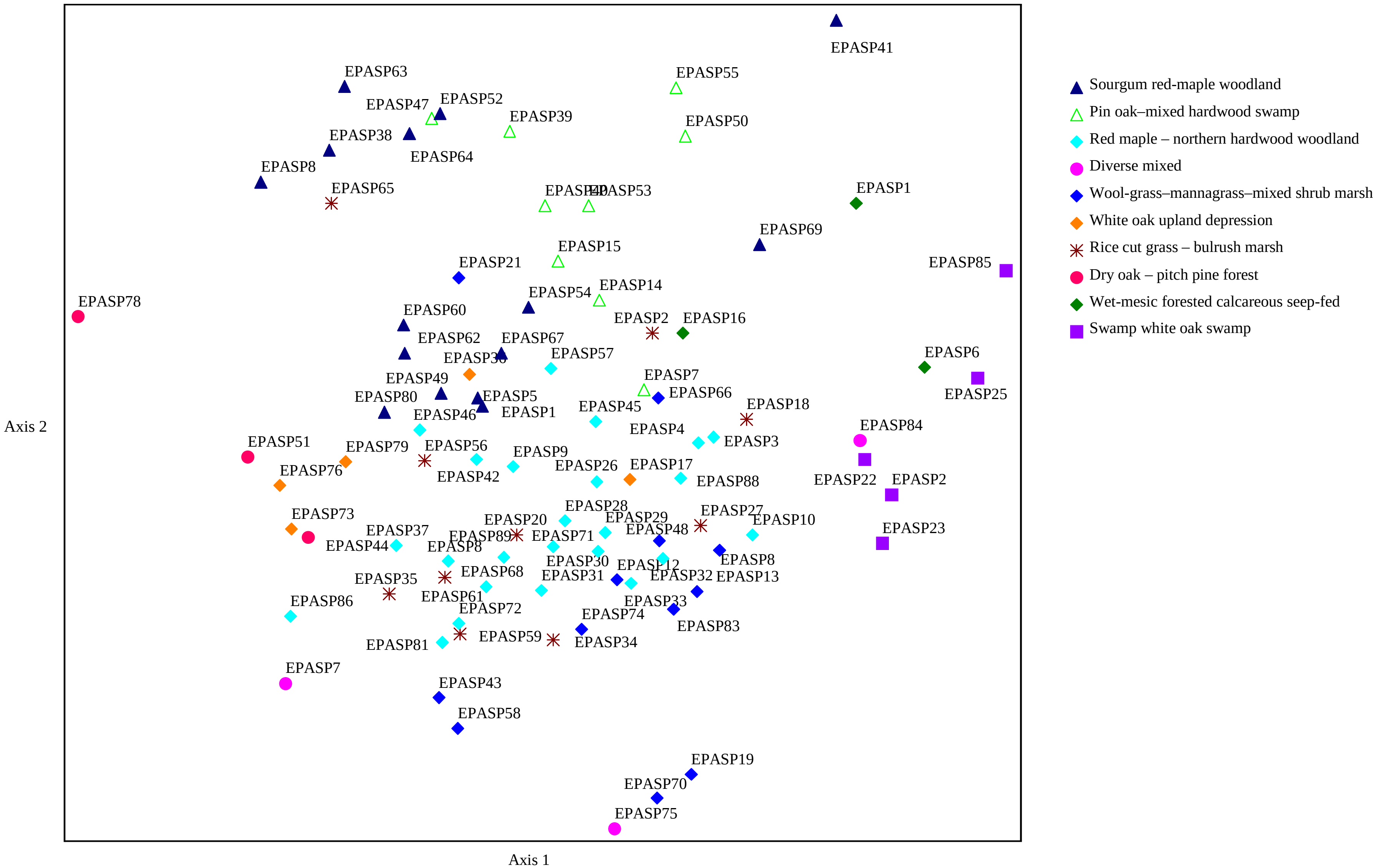


Figure 27. Axes 1 and 2 of an NMS ordination of pools based on vegetation data; cluster analysis groupings are used as the grouping variable.

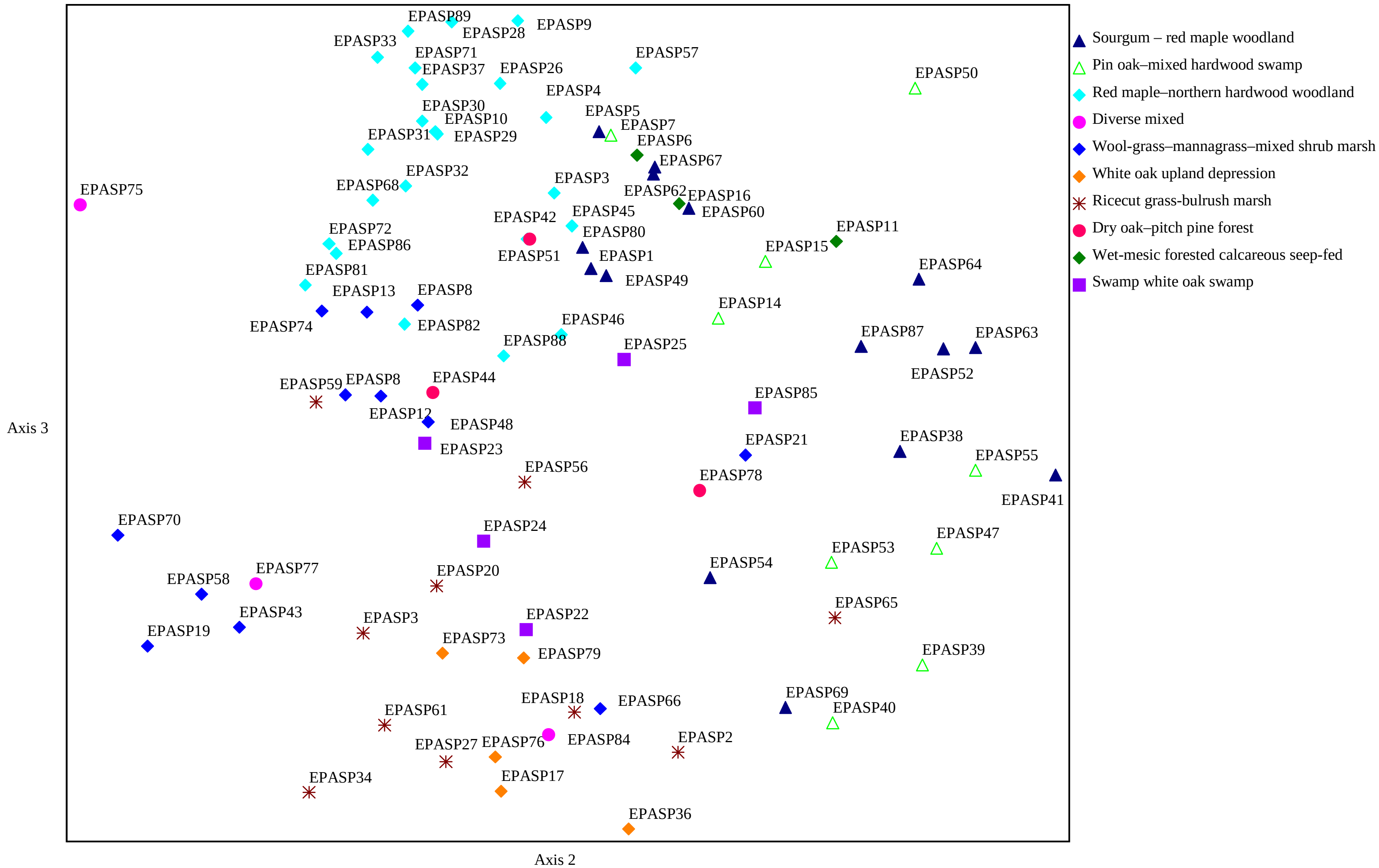


Figure 28. Axes 2 and 3 of an NMS ordination of pools based on vegetation data; cluster analysis groupings are used as the grouping variable.

IV. PLANT COMMUNITIES OF SEASONAL POOLS IN PENNSYLVANIA

Dichotomous Key

How to use the key

This is a key to the plant community types occurring in seasonal pool ecosystems in Pennsylvania. These types are described in full within the report. The key follows several keys developed by NatureServe and the Pennsylvania Natural Heritage Program to identify plant associations occurring in National Parks, which were intended to assist park managers in recognizing plant communities (e.g. Perles et al. 2004, Faber-Langendoen et al. 2007). Such keys assist in subsequent inventory, monitoring, and management activities by providing a community classification framework.

The following types are differentiated from each other by species composition, structure, and region. It is important to understand the landscape context in which the pool sits, as the surrounding plant communities, landform, soils, and other physical ecosystem factors greatly influence the plant composition of the pool.

Within the key, there may be multiple places in which a community keys out, and it is important to reference the information in the report in order to understand the plant composition and structure of the community and correctly identify it.

Season of use

This classification is primarily intended to be used during the growing season, which is usually from June to September, when dominant plants reach their full potential. However, much of the biological activity within seasonal pools takes place in the spring and familiarity with the woody species, primarily overstory and understory trees should allow the user to key out most, if not all of the types during the spring months.

Survey area

The entire pool is evaluated as a unit for this key. There are often many zones within each seasonal pool basin, and even more in the surrounding upland area. The plant community types and accompanying key are intended to be used to identify and describe the whole pool, and the many zones within each pool. Often the pool types, and key, are based on the dominant canopy cover. Dominance, in the context of forest, shrub, and herbaceous communities means >60% cover. In the context of woodland communities, dominance means >25% cover.

Terminology

***Canopy* –** Also called overstory; defined as the highest stratum of the forest that often provides the majority of the shade to a seasonal pool; can be measured from the center of the pool quantitatively with a densitometer or visually estimated.

***Herbs* –** Plants without perennial above-ground woody stems, including graminoids, forbs, and ferns.

***Hydrologic regime* –** Describes the frequency and duration of inundation and is an important influence on wetland communities.

***Non-vascular plants* –** Includes mosses, lichens, and liverworts.

Poorly drained soil – Most seasonal pools are described as containing poorly-drained soils, where soil moisture is high and/or saturated.

***Saturated* –** Surface water is seldom present, but the substrate is saturated to the surface.

***Seasonally flooded* –** Surface water is present in the early or late season of the year and is usually absent for some period during the year.

***Shrubs* –** Smaller woody plants, often multi-stemmed and mostly between 0.5 and 5 m tall. The shrub proportion of the community includes both shrub and tree species under 5 m tall.

***Trees* –** Large woody plants, often single-stemmed above 5 m tall.

Vegetation structure

While the following plant community types are primarily categorized by dominant vegetation, subtypes can be defined based on the structure of the community. Structure often plays a large role in determining the faunal composition of the seasonal pool ecosystem. Within types, sub-categories are typically based on the percent cover shrubs and herbs, or in the case of unvegetated pools, the lack of live plant material. The following subtypes can be added to further refine the seasonal pool plant community type.

Unvegetated: <25% of the pool basin with herbaceous or shrub cover
Herbaceous: >50% of the pool basin with herbaceous cover
Shrub: >50% of the pool basin with shrub cover
Mixed herbaceous/shrub: >25% of the pool basin with herbaceous cover and >25% of the pool basin with shrub cover)

Key to the Plant Communities

(scientific names from Rhoads and Block 2007)

1. Plant cover within the pool basin is dense (>75%) and dominated by graminoid species (grasses, sedges, rushes); total tree canopy over the pool < 25% with canopy trees limited to the pool margins and providing only limited shade to the pool basin; the federally endangered species, northeastern bulrush (*Scirpus ancistrochaetus*), is often found in these types and can sometimes comprise significant areas within the pool…..……….………..……….….…….…… 2

1' Plant cover within the pool basin is variable; pools range from sparsely vegetated (black-leaf) to vegetated pools. Herbaceous species are present and sometimes make up a large proportion of the pool basin; however pools are typically small; canopy trees often provide the primary plant cover; pool is primarily described by overstory vegetation…………………………..…..…… 3

2(1). Pool is shallow and seasonally flooded; dries nearly completely on an annual basis; vegetation within the pool basin vegetation with > 60% cover by herbaceous plants, usually graminoids; typically dominated by rice cutgrass (*Leersia oryzoides*); shrub species are nearly absent, making up < 10% of the vegetation cover in the pool basin………………………………. ………………………..……………………………..……… **Rice cutgrass – bulrush marsh pool**

2' Pool is somewhat deeper, seasonally to permanently flooded; vegetation within the pool basin dominated by wool-grass (*Scirpus cyperinus*); shrub cover is present, but variable…………..… ……………………….…...…………… **Wool-grass – mannagrass mixed shrub marsh pool**

3(1). Tree canopy cover is dominated by oak (*Quercus*) species; pool is situated in an upland setting…..…………..…………..…………..…………..…………..…………...…………..…… 4

3' Tree canopy not dominated by oak species.….………..…….………..…….………..… 7

4(3). Pool is situated in a lowland setting (bottomland, high terrace floodplain); tree canopy cover is relatively dense (>60%) and is comprised of swamp white oak (*Quercus bicolor*); depression inundated from overland flow, groundwater, floodwaters or a combination of all three; trees are usually rooted in the pool basin; pool type is limited to the Ohio River Basin……. .…………..…………..………………………..….….…… **Swamp white oak swamp forest pool**

4' Pool is situated in upland setting; tree canopy cover is variable; canopy not dominated by swamp white oak (*Quercus bicolor*).….………….……….………..……….……….……….…… 5

5(4). Tree canopy cover is relatively dense (> 60%) and is comprised of pin oak (*Quercus palustris*), red maple (*Acer rubrum*), and sourgum (*Nyssa sylvatica*); shrub and herbaceous layers vary; buttonbush (*Cephalanthus occidentalis*) often present..………….……….…………………….……….……….………..……….……….……….…… **Pin oak – mixed hardwood swamp pool**

5' Tree canopy cover is relatively sparse (60%) and is comprised by upland oak species (*Quercus alba, Q. velutina, Q montana, Q. rubra)*; pool is shallow and dries completely in most years; herbaceous vegetation is sparse; pools may be black-leaf or contain a significant peat moss (*Sphagnum* spp.) layer…………..……….………………….……….…………………..……….…… 6

6(5). Tree canopy over the pool and in the surrounding forest contains oaks (*Quercus* spp.) and pitch pine (*Pinus rigida*); adjacent upland understory contains substantial cover of blueberries and other heaths (*Vaccinium* spp.…………………………….…. **Dry oak – pitch pine forest pool**

6' Canopy of the pool and surrounding forest contains white oak (*Quercus alba*), but lacks pitch pine (*Pinus rigida*); adjacent upland understory contains substantial cover of blueberries and other heaths (*Vaccinium* spp.)..…..……….…………..……. **White oak upland depression pool**

7(3). Pool is situated in upland, dry oak – mixed hardwood forest matrix; pool is characterized by a closed tree canopy dominated by sourgum (*Nyssa sylvatica*) and red maple (*Acer rubrum*) ………...……………….…………………….………….…… **Sourgum – Red maple woodland pool**

7' Pool is situated in a northern hardwood forest matrix..………...………..……….…..………. 8

8(7). Pool is situated within an upland, mesic northern hardwoods forest and is characterized by a closed tree canopy dominated by red maple (*Acer rubrum*); the herbaceous composition of the pool is sparse and often reflects the composition of the surrounding upland……….………….... ………...…………………….……...……..…… **Red maple – northern hardwood woodland pool**

8' Pool basins are seasonally to permanently flooded and situated within kettle-depressions within the glaciated northwestern portion of Pennsylvania (ice-contact terrain) or in depressional wetlands in the southeastern portion of the state (Bucks County); pools are primarily groundwater-fed; water pH values > 6.0 typical of this type; pool is typically vegetated except for the area that remains underwater throughout the year… **Wet-mesic calcareous seep-fed pool**

Seasonal Pool Plant Community Descriptions

Vegetation data analyses identified nine plant communities found within seasonal pool ecosystems in Pennsylvania. The environmental setting, characteristic vegetation, distribution, and reference locations of each community are discussed in this section. Each community was also assigned a state rank (see Appendix 17 for conservation rank definitions). Locations of high quality examples and a crosswalk to a National Vegetation Classification Association are provided. The **Red maple – sweetgum swamp** and two other unclassified types are not described due to insufficient data or dominance by an invasive plant species.

SOURGUM – RED MAPLE WOODLAND POOL

General Description / Ecological Processes: The Sourgum – red maple woodland pool community occurs in seasonally inundated depressions in dry to mesic uplands, most often dry oak-dominated forests (Dry oak-mixed hardwood forest, Red oak – mixed hardwood forest, and Dry oak – pitch pine forest (Fike 1999)) throughout Pennsylvania.

Characteristic Vegetation: This community is characterized by the closed canopy forest, dominated by sourgum (*Nyssa sylvatica*) and red maple (*Acer rubrum*). Associate canopy species are primarily upland species with limbs overhanging the pools and include white oak (*Quercus alba*), black oak (*Q. velutina*), Canada hemlock (*Tsuga canadensis*) and other species common to upland oak-dominated forests. Beneath the canopy, the understory vegetation varies considerably, and is influenced heavily by site hydrology and light availability. Under more open canopies, the shrub layer contains buttonbush (*Cephalanthus occidentalis*), winterberry (*Ilex verticillata*), and highbush blueberry (*Vaccinium corymbosum*). Herbaceous species include sedges (*Carex vesicaria, C. folliculata, C. crinita*), floating mannagrass (*Glyceria septentrionalis*), pale meadowgrass (*Torreyochloa pallida*), wool-grass (*Scirpus cyperinus*), and other graminoids. Under closed canopies, species in the pool basin may be limited to bugleweed (*Lycopus uniflorus*), clearweed (*Pilea pumila*), and other species tolerant of lower light conditions. Pools beneath closed canopies may also contain a substantial bryophyte layer that includes several peat moss (*Sphagnum*) species or may be completely devoid of vegetation altogether.

Distribution: Entire State

State Rank: S3

High Quality Examples / Reference Locations: EPASP.1, EPASP.5, EPASP.38, EPASP.41, EPASP.49, EPASP.52, EPASP.54, EPASP.60, EPASP.62, EPASP.63, EPASP.64, EPASP.67, EPASP.69, EPASP.80, EPASP.87.

National Vegetation Classification Association: *Acer rubrum - Nyssa sylvatica - Betula alleghaniensis / Sphagnum* spp. forest CEGL006014

Sources: PNHP Field Surveys.

PIN OAK – MIXED HARDWOOD SWAMP FOREST POOL

General Description / Ecological Processes: The Pin oak – mixed hardwood swamp forest pool community occurs in seasonally inundated depressions in dry to mesic uplands, most often occurring in dry oak-dominated forests (Dry oak mixed hardwood forest, Red oak – mixed hardwood forest (Fike 1999)) throughout Pennsylvania.

Characteristic Vegetation: This community is characterized by the closed canopy forest, dominated by pin oak (*Quercus palustris*). Associate canopy species include red maple (*Acer rubrum*) and sourgum (*Nyssa sylvatica*). Upland species, with limbs overhanging the pools include northern red oak (*Q. rubra*), white oak (*Q. alba*), and tuliptree (*Liriodendron tulipifera*) that are common in the canopy, but are not rooted in the pool. The understory vegetation is generally sparse, but varies considerably depending on site hydrology and light availability. Under more open canopies, the shrub layer contains buttonbush (*Cephalanthus occidentalis*), winterberry (*Ilex verticillata*), northern arrow-wood (*Viburnum recognitum*), and highbush blueberry (*Vaccinium corymbosum*). The sparse herbaceous layer includes sedges (*Carex intumescens, C. lurida, C. crinita*), marsh fern (*Thelypteris palustris*), beggar-ticks (*Bidens frondosa*), dotted smartweed (*Persicaria punctata*), and floating mannagrass (*Glyceria septentrionalis*). Under closed canopies, species in the pool basin may be limited to bugleweed (*Lycopus uniflorus*), clearweed (*Pilea pumila*), false nettle (*Boehmeria cylindrica* var. *cylindrica*), and other species tolerant of lower light conditions. Pools beneath closed canopies may also contain a substantial bryophyte layer that includes several peat moss (*Sphagnum*) species or may be completely devoid of vegetation altogether.

Distribution: Entire State

State Rank: S3

High Quality Examples / Reference Locations: EPASP.7, EPASP.14, EPASP.15, EPASP.39, EPASP.40, EPASP.47, EPASP.50, EPASP.53, EPASP.55.

National Vegetation Classification Association: Que*rcus palustris - (Quercus bicolor) - Acer rubrum / Vaccinium corymbosum / Osmunda cinnamomea* Forest CEGL006240

Possibly: *Quercus palustris - Quercus bicolor / Viburnum prunifolium / Leersia virginica - Impatiens capensis* Forest CEGL004643

Sources: PNHP Field Surveys.

RED MAPLE – NORTHERN HARDWOOD WOODLAND POOL

General Description / Ecological Processes: The Red maple – northern hardwood woodland pool community occurs in seasonally inundated depressions in mesic uplands, most often occurring in Northern hardwood forests (Fike 1999) throughout Pennsylvania.

Characteristic Vegetation: This community is characterized by the closed canopy forest, dominated by red maple (*Acer rubrum*). Associate canopy species include and sourgum (*Nyssa sylvatica*) and pin oak (*Quercus palustris*). Upland species, with limbs overhanging the pools include northern red oak (*Q. rubra*), shagbark hickory (*Carya ovata*), white ash (*Fraxinus americana*), American beech (*Fagus grandifolia*), American elm (*Ulmus americana*), and wild black cherry (*Prunus serotina*) that are common in the canopy, but are not rooted in the pool.

The understory vegetation is generally sparse, but can occur at a greater cover under an open canopy. Under more open canopies, the shrub layer contains buttonbush (*Cephalanthus occidentalis*), winterberry (*Ilex verticillata*), swamp azalea (*Rhododendron viscosum*), and highbush blueberry (*Vaccinium corymbosum*). The sparse herbaceous layer includes sedges (*Carex baileyi, C. brunnescens, C. deweyana, C. folliculata*), marsh fern (*Thelypteris palustris*), beggar-ticks (*Bidens frondosa*), mild water-pepper (*Persicaria hydropiperoides*), and floating mannagrass (*Glyceria septentrionalis*). Under closed canopies, species in the pool basin may be limited to bugleweed (*Lycopus uniflorus*), beggar-ticks (*Bidens* spp.), clearweed (*Pilea pumila*), false nettle (*Boehmeria cylindrica* var. *cylindrica*) and other species tolerant of lower light conditions. Pools beneath closed canopies may also contain a substantial bryophyte layer that includes several peat moss (*Sphagnum*) species or maybe completely devoid of vegetation altogether.

Distribution: Entire State

State Rank: S3

High Quality Examples / Reference Locations: EPASP.10, EPASP.31, EPASP.37, EPASP.46, EPASP.72, EPASP.86, EPASP.88, EPASP.89, EPASP.3, EPASP.9, EPASP.28, EPASP.29, EPASP.30, EPASP.32, EPASP.33, EPASP.42, EPASP.57, EPASP.68, EPASP.71, EPASP.81, EPASP.4, EPASP.26, EPASP.45, EPASP.82.

National Vegetation Classification Association: *Acer rubrum - Nyssa sylvatica - Betula alleghaniensis / Sphagnum* spp. forest CEGL006014

Sources: PNHP Field Surveys.

WHITE OAK UPLAND DEPRESSION POOL

General Description / Ecological Processes: The White oak upland depression pool community represents seasonally flooded depressions with little or no overstory occurring within Dry oak – mixed hardwood forests (Fike 1999) throughout Pennsylvania.

Characteristic Vegetation: This community is characterized by a sparsely vegetated wetland depression exhibiting a diverse mix of herbaceous and non-vascular plant species. The unifying characteristic of these pools is that they all exhibit a partially open canopy (~ 40%), which is dominated by white oak (*Quercus alba*). Species composition varies with hydroperiod (duration of inundation) and regional distribution of plant species. Various dominants include marsh-purslane (*Ludwigia palustris*), smartweeds (*Persicaria* spp.), panic grass (*Dichanthelium acuminatum*), and rice cutgrass (*Leersia oryzoides*). Shrub species include highbush blueberry (*Vaccinium corymbosum*). The pools beneath may also contain a substantial bryophyte layer that includes several peat moss (*Sphagnum*) species or may be completely devoid of vegetation altogether.

Distribution: Entire State

State Rank: S3

High Quality Examples / Reference Locations: EPASP.17, EPASP.31, EPASP.73, EPASP.76, EPASP.79.

National Vegetation Classification Association: *NA*

Sources: PNHP Field Surveys.

WET-MESIC FORESTED CALCAREOUS SEEP-FEED POOL

General Description / Ecological Processes: The wet-mesic forested calcareous seep-fed pool community represents seasonally to permanently flooded depressions occurring in kettle-depressions within the glaciated northwestern portion of Pennsylvania and in depressional wetlands in the southeastern portion of the state (Bucks County) where groundwater discharge may be the primary source of water. In both cases, the water inputs may flow over or through calcareous geologic parent material (glacially derived tills or diabase) resulting in high pH and hardness of the water within the pool basin. The surrounding forest is typically mesic and composed of species typical of Northern hardwood forests (Fike 1999).

Characteristic Vegetation:

This community is characterized by a closed canopy forest and assortment of shrub and herbaceous species growing in somewhat permanently saturated substrates.

Overstory species, usually rooted outside the pool basin include yellow birch (*Betula allegheniensis*), wild black cherry (*Prunus serotina*), and American beech (*Fagus grandifolia*). Various species found in these seasonally flooded depressions include false nettle (*Boehmeria cylindrica*), rice cutgrass (*Leersia oryzoides*), jewel weed (*Impatiens capensis*), bugleweed (*Lycopus uniflorus*), clearweed (*Pilea pumila*), sedges (*Carex crinita*, and others), and three-way sedge (*Dulichium arundinaceum*). These pools are characteristically bare, containing large areas that remain flooded or saturated in most years. There is often a deep peat moss layer. Shrub species include silky willow (*Salix sericea*), and winterberry (*Ilex verticillata*).

Distribution: Glaciated Northwest, Southeast Piedmont State Rank: S3

High Quality Examples / Reference Locations: EPASP.22, EPASP.23, EPASP.24, EPASP.25, EPASP.85.

National Vegetation Classification Association: *NA*

Sources: PNHP Field Surveys.

DRY OAK – PITCH PINE FOREST POOL

General Description / Ecological Processes:

The Dry oak – pitch pine forest pool community represents seasonally flooded depressions with little or no overstory occurring within Dry oak – heath forests and Pitch pine – mixed oak forests (Fike 1999) throughout Pennsylvania.

Characteristic Vegetation:

This community is characterized by a sparsely vegetated wetland depression exhibiting a diverse mix of herbaceous and non-vascular plant species. Species composition varies with hydroperiod (duration of inundation) and regional distribution of plant species.

Various species found in these seasonally flooded depressions include sedges (*Carex* spp.), three-way sedge (*Dulichium arundinaceum*), and rice cutgrass (*Leersia oryzoides*). However, these pools are characteristically bare, with peat moss providing much of the vegetative cover of the pool basin. Shrub species are absent within the pool basin and the edges surrounding the pools reflect the surrounding upland shrub species, such as witch-hazel (*Hamamelis virginiana*). The unifying characteristic of these pools is that they are located in dry uplands, dominated by chestnut oak (*Quercus montana*), northern red oak (*Q. rubra*), sourgum (*Nyssa sylvatica*), and pitch pine (*Pinus rigida*), which may be present in the overstory, hanging over the pool.

Distribution: Entire State

State Rank: S3

High Quality Examples / Reference Locations: EPASP.44, EPASP.51, EPASP.78

National Vegetation Classification Association: *NA*

Sources: PNHP Field Surveys.

RICE CUTGRASS – BULRUSH MARSH POOL

General Description / Ecological Processes: The Rice cutgrass – bulrush marsh pool occurs in seasonally inundated depressions most often on saddles between ridges and high plateaus within the Central Appalachian Forest Ecoregion in Pennsylvania. The type is described as a seasonally flooded, mixed-herbaceous wetland meadow with defined basin boundaries and usually occurs within dry, oak-dominated forests with open canopies (Dry oak – mixed hardwoods forest (Fike 1999)). The pools are generally shallow, composed of several herbaceous species, and usually dry completely over the summer months, allowing herbaceous species to establish throughout the pool. This type differs from the White oak upland depression pool by the absence of a canopy.

Characteristic Vegetation: This community is characterized as an open, seasonally flooded depression, dominated by herbaceous plants, usually graminoids. Common dominant species include pale meadowgrass (*Torreyochloa pallida*), mannagrass (*Glyceria acutiflora*), rattlesnake mannagrass (*Glyceria canadensis*), three-way sedge (*Dulichium arundinaceum*), Canada bluejoint (*Calamagrostis canadensis*), rice cutgrass (*Leersia oryzoides*), sedges (e.g. *Carex tribuloides*, *C. lurida*, *C. gynandra*, *C. vesicaria*, *C. folliculata*), dotted smartweed (*Persicaria punctata*), marsh St. Johns-wort (*Triadenum fraseri*), royal fern (*Osmunda regalis*), needle spike-rush (*Eleocharis acicularis*), and white beak-rush (*Rhynchospora alba*). The federally endangered species, northeastern bulrush (*Scirpus ancistrochaetus*), is also found in this type, and can sometimes comprise a significant area within the pool. The invasive low smartweed (*Persicaria longiseta*) was present within this type in some pools and stiltgrass (*Microstegium vimineum*), can form dense patches on the edges of the pools. Shrubs such as winterberry (*Ilex verticillata*) and swamp dewberry (*Rubus hispidus*) are present, but never dominant and canopy trees most often include white oak (*Quercus alba*), sourgum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). The pools may also contain a substantial bryophyte layer that includes several species of peat moss (*Sphagnum*); there is relatively little area not covered by vegetation.

Distribution: Central Appalachian Forest Ecoregion State Rank: S1

High Quality Examples / Reference Locations: EPASP.2, EPASP.18, EPASP.20, EPASP.27, EPASP.34, EPASP.35, EPASP.56, EPASP.59, EPASP.61, EPASP.65.

National Vegetation Classification Association: *Calamagrostis canadensis* - *Scirpus* spp. - *Dulichium arundinaceum* Herbaceous Vegetation CEGL006519

Sources: PNHP Field Surveys.

WOOL-GRASS – MANNAGRASS MIXED SHRUB MARSH POOL

General Description / Ecological Processes: The Wool-grass – mannagrass mixed shrub marsh pool occurs in seasonally to somewhat permanently inundated depressions throughout Pennsylvania. The type can be described as a seasonally flooded, herbaceous swamp with well defined boundaries; some pools of this type exhibit somewhat poorly defined boundaries. The surrounding plant community varies with region, soils, and geology. The pools are generally deeper than those of the Rice cutgrass – bulrush marsh pool and may not dry completely over the summer months.

Characteristic Vegetation: This community is characterized as an open, seasonally to permanently flooded depression, dominated by herbaceous and shrubby species; wool-grass (*Scirpus cyperinus*) is usually dominant. Common co-dominant and associate species include floating mannagrass (*Glyceria septentrionalis*), rattlesnake mannagrass (*Glyceria canadensis*), rice cutgrass (*Leersia oryzoides*), pale meadowgrass (*Torreyochloa pallida*), sedges (e.g. *Carex crinita*, *C. lurida*, *C. lupulina*, *C. vesicaria*, *C. folliculata*), three-way sedge (*Dulichium arundinaceum*), mild water-pepper (*Persicaria hydropiperoides*), marsh-purslane (*Ludwigia palustris*), marsh St. Johns-wort (*Triadenum fraseri*). The federally endangered species, northeastern bulrush (*Scirpus ancistrochaetus*), is also found in this type. Shrubs include hardhack (*Spiraea tomentosa*), meadow-sweet (*S. alba*), northern arrow-wood (*Viburnum recognitum*), highbush blueberry (*Vaccinium corymbosum*), and buttonbush (*Cephalanthus occidentalis*). Canopy trees, which are limited to the pool margins, most often include white oak (*Quercus alba*), sourgum (*Nyssa sylvatica*), and red maple (*Acer rubrum*).

Distribution: Entire State

State Rank: S3

High Quality Examples: EPASP.8, EPASP.12, EPASP.13, EPASP.43, EPASP.48, EPASP.58, EPASP.66, EPASP.70, EPASP.74.

Additional Reference Locations: EPASP.19, EPASP.21

National Vegetation Classification Association: *Scirpus cyperinus* Seasonally Flooded Herbaceous Vegetation CEGL006349

Sources: PNHP Field Surveys.

SWAMP WHITE OAK SWAMP FOREST POOL

General Description / Ecological Processes:

The Swamp white oak swamp forest pool occurs in seasonally inundated depressions within uplands and higher floodplain terraces of creeks and rivers in the western portion of Pennsylvania. This type is similar to the Bottomland oak – mixed hardwoods forest commonly associated with oxbows and backswamps on broad floodplains of larger tributaries to the Ohio River, described in Zimmerman and Podniesinski (2008). This pool type exhibits a closed canopy composed of swamp white oak and other tree species tolerant to extended periods of inundation.

Soils are typically fine-textured clay soils often beneath a substantial layer of muck composed of decomposed leaves. The pool basin of this community is poorly circumscribed with poor definition of pool edges and overstory trees rooted in standing water throughout much of the spring. There is often groundwater influence as soils remain saturated throughout much of the growing season.

Characteristic Vegetation: This community is characterized by the closed canopy forest, dominated by swamp white oak (*Quercus bicolor*) and red maple (*Acer rubrum*). Associate canopy species include red ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), sourgum (*Nyssa sylvatica*), and black ash (*Fraxinus nigra*). The shrub layer is fairly open, with scattered common elderberry (*Sambucus nigra var. canadensis*), buttonbush (*Cephalanthus occidentalis*), hornbeam (*Carpinus caroliniana*), and poison ivy (*Toxicodendron radicans*). Herbaceous plants and bryophytes are sparse under the closed canopy swamp white oak overstory. Skunk cabbage (*Symplocarpus foetidus*) may be prevalent, as well as other shade-tolerant facultative and obligate wetland species such as false nettle (*Boehmeria cylindrica*), clearweed (*Pilea pumila*), and numerous sedges (*Carex* spp.).

Distribution: Glaciated Northwest State Rank: S4

High Quality Examples / Reference Locations: EPASP.6, EPASP.11, EPASP.16

National Vegetation Classification Association: *Quercus bicolor* / *Vaccinium corymbosum* / *Carex stipata* Forest CEGL006241

Sources: PNHP Field Surveys

V. DISCUSSION

Vegetation community classification

The nine described pool types tended to reflect composition of the canopy overstory. When canopy overstory was absent, the community types were determined by shrub and herbaceous plant species within the pool.

Herbaceous plants were limited in seasonal pools by hydrology and canopy cover. Shallower pools that draw down early and those beneath an open canopy tend to contain a greater percent cover of herbaceous plants as indicated most noticeably by the open pool types (Rice cutgrass – bulrush marsh and Wool-grass – mannagrass mixed shrub marsh pools). These pools plotted towards the lower end of Axis 1 in the NMS analysis and were correlated with percent cover of the canopy. Rice cutgrass and northeastern bulrush were significant indicators in the Rice cutgrass – bulrush marsh pool and wool-grass had a high affinity for the Wool-grass – mannagrass mixed shrub marsh pool. In contrast, Swamp white oak swamp forest pools contained only scattered herbaceous cover at best. This is consistent with the ecology of the dominant canopy tree, swamp white oak, which tolerates significant inundation and forms a dense canopy, rooted in the standing water of the seasonal pool. In most other pool types, such as closed canopy Sourgum – red maple woodland pools, Red maple – northern hardwood woodland pools, presence and percent cover of herbaceous species were observed to occur beneath canopy openings and in areas that dried early enough during the growing season for herbaceous plants to become established.

Most seasonal pool types contained shrub species in at least one of the pools within the study; however, the presence of shrubs was not a major grouping factor in the analysis. The main shrub species (not including trees) appearing in seasonal pools in Pennsylvania are buttonbush, winterberry, and highbush blueberry. Typically, buttonbush and winterberry are found throughout the pools; high bush blueberry is more common on the pool edges, or on mounds within the pool. Several other shrub species are found within seasonal pool wetlands including hobblebush (*Viburnum lantanoides*), northern arrow-wood (*Viburnum recognitum*), and swamp azalea (*Rhododendron viscosum*).

The shrub species do not appear to be restricted to any one pool plant community type and no shrub was a significant indicator ($p<0.05$) in the ISA. In forested or woodland pools, shrub occurrence and percent cover within vegetation zones varied considerably most likely due to variation in canopy cover, hydrology, soils, and probably a combination of these factors. The species' range distribution further resulted in variation composition among pool types within the study. Rice cutgrass – bulrush marsh pools, Wet-mesic forested calcareous seep-fed pools, and Dry oak – pitch pine forest pools did not contain zones dominated by one or more of the shrub species mentioned above. These pools were primarily vegetated by herbaceous species and/or contained no shrub or groundcover vegetation at all (black leaf).

Sourgum – red maple woodland, Pin oak – mixed hardwood swamp , Red maple – northern hardwood woodland, and the White oak upland depression pools included subtypes that could be described as herbaceous pools, black leaf pools, or shrub pools. In all four types, the vegetation within the seasonal pool basin ranged from little or no plant cover, “black leaf” conditions, to shrub-dominated, to herbaceous dominated. The later two only occurring when canopy gaps were large enough to allow enough light to the forest understory. Shrub species that are more tolerant of inundation, such as buttonbush and winterberry, thrive beneath openings in the canopy, even in deeper water. The shrub zone was also a significant component of the Wool-grass – mannagrass mixed shrub marsh pools, particularly examples of this type in glaciated northwestern Pennsylvania, which contained hardhack (*Spiraea tomentosa*), a species commonly associated with shrub-wetlands and wet meadows, which was not found in any of the closed canopy pool types exhibiting limited light beneath the canopy.

Invertebrate and amphibian community classifications

The vernal pool animal communities in this study did not consistently cluster by any one variable such as site, ecoregion, surficial geology, vegetation community, or any other examined environmental variable. This is expected because many interrelated factors are at work shaping the environment of each seasonal pool. Differences in hydroperiod, size, vegetation cover, and water chemistry can occur within one seasonal pool cluster, and regional differences affect species distributions, landscape context, and climatic conditions. Combined with the opportunistic and often haphazard colonization of temporary aquatic environments by flora and fauna, it is not surprising that there is too much variation regionally or locally to make detailed predictions on what types of pools will support which species.

Many weak correlations were found between environmental variables and the axes of the invertebrate and amphibian ordinations of this study (typical r^2 values between 0.10 and 0.20). These correlations can be used to identify overall themes that were strong enough to shape plant and animal community types across a broad geographic landscape, but many exceptions can be expected to occur. The strongest correlations were found with pool dimensions, indicator species richness, and predator and shredder richness. This suggests that environmental conditions related to pool size and interactions of suites of species with the environment and one another are key factors that distinguish pool types.

The scale at which seasonal pools are studied will provide insight into different aspects of their ecology. Large studies on an ecoregional or statewide scale are difficult to conduct in a manner that allows for a balanced comparison of the fauna. Environmental conditions such as rainfall and temperature can vary greatly, affecting the timing of spring migration and breeding events and maturation and hatching of amphibian egg masses. The invertebrate community undergoes a seasonal progression of larval emergence and development and colonization by species from permanent habitats. Even if data on a large set of pools statewide could be conducted rapidly in a one or two week period of time, the progression of development in the animal communities will vary along gradients of latitude, elevation, temperature, and rainfall.

Site level studies eliminate some of the challenges inherent in large scale studies. A smaller unit of pools can be sampled in rapid progression in the spring, yielding more consistent species suites to compare. Local site environmental conditions such as rainfall and temperature will be essentially the same. Examining pools on a local scale can shed more light on the effects of site level environmental variation on pool communities. For example, a study of fifteen pools in the

Central Appalachian Forest (Leppo 2008) ranging from small unvegetated pools to large shrub dominated pools found stronger correlations between environmental variables and the axes of invertebrate community ordinations. Variables such as the depth of the organic layer (r^2 = 0.488), marsh (r^2 = 0.265), shrubs (r^2 = 0.288), algae (r^2 = 0.264), pool area (r^2 = 0.314), pool depth (r^2 = 0.391), dissolved oxygen (r^2 = 0.513) and pH (r^2 = 0.415) were found to be correlations

Summary of important factors shaping aquatic amphibian and invertebrate communities of vernal pools

Landscape context

The site selection criteria for this study targeted high quality pools to provide reference conditions across ecoregions in the state to aid with restoration and mitigation efforts. Therefore the *chosen* study pools occurred in forested settings. Percent forest cover within the seasonal pool envelope (0-100 ft / 0-30.5 m from the edge of the pool basin) and the buffer designated in Bureau of Forestry management protocols (100-200 ft / 30.5-61 m) was typically close to 100% forested. Land use in the seasonal pool terrestrial habitat (0-1000 m from the edge of the pool basin) was more variable, and was comprised mostly by forest, uncultivated clearings, agriculture, development, and roads and right-of-ways. Amphibians that breed in seasonal pools spend most of the year in the upland habitat surrounding seasonal pools where they seek food and shelter and hibernation sites for the winter. Within this zone they require deep, moist, uncompacted organic litter, coarse woody debris, and shade (DeMaynadier and Hunter 1995). The seasonal pool terrestrial habitat for pools in the Central Appalachian Forest (CAP) and High Allegheny Plateau (HAL) ecoregions was most intact (93% and 99% forested respectively); the terrestrial habitat in the Lower New England / Northern Piedmont (LNE/NP) was slightly less forested (89%). Western Allegheny Plateau (WAP) pools had 74% forest on average within the seasonal pool terrestrial habitat, meaning nearly a quarter was composed of open areas. Line fitting on bivariate scatterplots did not show any correlations between the amount of forest in the terrestrial upland habitat and measured environmental variables. Percent forest within 1000 m of the pool did correlate with axes in the NMS ordination of invertebrate species, helping to separate those communities in the WAP that occurred at higher pH and moderate elevations.

Elevation and Julian day

Elevation analysis illustrated the geographic variation of seasonal pools in PA and aided with field survey planning. Pools occurring at the highest elevations were in the CAP (ave. 479 m) and HAL (ave. 523 m) ecoregions. Pools within the WAP were typically at more moderate elevations (average 401 m), and the LNE/NP pools were at the lowest elevations averaging 164 m above sea level. High elevation pools in northern PA were expected to have delayed spring phenology compared to pools in southern PA at lower elevation. Ideally field surveys each year would have started in late March at the lowest elevation sites in southern PA and progressed northward to higher elevation sites later in the season. However site selection was an ongoing process the first year and a half of the study. Practical matters ultimately dictated survey order as site selection and arrangements for site access evolved.

Julian day was used to evaluate any potential effects of survey date. Julian day is a continuous count of days starting with 1 on January 1st and ending with 365 on December 30. Julian day was strongly positively correlated with air temperature, and less strongly so with water temperature, reflecting a warming climate through the spring months. Julian day was negatively correlated with dissolved oxygen levels, which reflects the negative relationship between water temperature and oxygen solubility. Two invertebrate taxa, the water fleas (Cladocera) and the skimmer dragonflies (Libellulidae, mostly *Sympetrum* species), showed positive relationships with Julian day. Both of these taxa have desiccant and drought resistant egg stages. This suggests a delayed emergence from egg stages in the spring or possibly a bias in our sampling methods that made it more difficult to capture early instars. Taxonomic resolution may also be a factor, particularly among cladocerans which are a diverse group composed of many species. A study of a cluster of fifteen pools in south-central Pennsylvania identified three families and five genera of Cladocera (Leppo 2008). Species such as *Daphnia ephemeralis* appear to be most common in cold water conditions in the fall and winter and are replaced by other cladocerans as waters warm during the spring (per literature review by Colburn 2004). The increasing trend among Cladocera may represent the addition of species as the season progresses. One ordination axis of invertebrate data showed a correlation with Julian day and predator richness. These results suggest that as the spring season progresses, the invertebrate community gains more species that have delayed emergence, and species that colonize from permanent aquatic habitats such as predatory beetles and true bugs (Batzer and Resh 1992, Svensson 1992). Pools sampled early or late in the season are more likely to be characterized by early or late season invertebrate assemblages.

Another important finding related to Julian day was its negative relationship with indicator species richness. This suggests that our sampling period extended long enough that we began to miss indicator species. One indicator species, the springtime fairy shrimp (*Eubranchipus vernalis*), has a late winter / early spring phenology that may help it avoid the flush of vertebrate and invertebrate predators that dominate the pool as the season progresses (Kenney and Burne 2001). Our surveys may also have been less effective in finding indicator amphibians as the season progressed. Egg mass surveys are undoubtedly the easiest and most consistent way to assess the presence and abundance of seasonal pool indicator amphibians. The peak window for observing egg masses is relatively short, spanning a few weeks to a month at a site. While our dip net surveys targeted amphibian larvae, they can be very difficult to capture. Ideally amphibian egg mass surveys should take place within a tight time frame that coincides with peak egg mass conditions at a site. Due to the number of pools surveyed and the amount of travel required, surveys took place over approximately one and a half months rather than 2-3 weeks. At the very beginning of the spring survey period (late March / early April) breeding activity was still in progress; by the end of the period (early-mid May) egg masses were disintegrating and disappearing. Egg masses of Jefferson salamanders (*Ambystoma jeffersonianum*) and wood frogs (*Lithobates sylvaticus*) were the first to disappear since they are the first to breed in the spring and their egg masses are relatively soft. Spotted salamander (*Ambystoma maculatum*) egg masses are very firm in texture and tended to persist the longest.

Proximity to streams and other wetlands

Proximity to streams and permanent wetlands may affect how quickly certain species will find and colonize seasonal pools in the spring. Species that utilize permanent aquatic habitats during the dry phase of a seasonal pool include red-spotted newts (*Notophthalmus viridescens*), certain aquatic beetles (Coleoptera), and true bugs (Hemiptera) (Kenney and Burne 2001, Batzer and Resh 1992, Svensson 1992). These species must travel between seasonal and permanent pool habitats each year. Distance to the nearest stream or wetland did not show a significant linear relationship with invertebrate or amphibian richness, and therefore most of the pools in this study appear to be within migration distance of seasonal pool colonizers. Pools in the HAL and especially the LNE/NP ecoregions were among the farthest from the nearest stream, averaging 551 and 750 m respectively. HAL pools were the closest to neighboring wetlands, averaging 161 m, and LNE/NP pools were the farthest, averaging 664 m. Pools in the WAP and CAP ecoregions were located various distances from streams and wetlands, but in comparison to the two other ecoregions they had many more pools that were proximate to streams (ave. 280/303 m).

Degree of isolation from other vernal pools has been shown to be a factor in determining species composition and persistence over time (see summary in Calhoun and deMaynadier 2008). Carl and Blumenshine (2005) found that pools closer together have more similar invertebrate assemblages than isolated pools. Pool proximity to other vernal pools is an important factor in vernal pool metapopulation dynamics. In a study of 65 seasonal pools in south central Pennsylvania, Pongpat (2002) found that spotted salamander presence and abundance increased when another pool was within 200 m.

Field visits are the best way to determine whether a wetland is a seasonal pool, but this is not always practical. Aerial photography is useful for finding adjacent wetlands, and National Wetland Inventory (NWI) wetland types can be used to rank habitats based on how likely they are to have seasonally fluctuating hydrologies. Calhoun et al. (2003) identified several NWI types that were most likely to provide breeding habitat for vernal pool indicators. The NWI types considered ‘highly likely’ to support seasonal pool species were hydrologically isolated wetlands with evidence of standing water such as PUB (palustrine, unconsolidated bottom) and POW (palustrine open water) wetlands. ‘Moderately likely’ wetlands included PFOE (palustrine forested, seasonally saturated) and forested headwater wetlands that may have intermittent outlet streams, but did not appear to have permanent surficial connections with other wetlands.

This study did not visit the nearest wetland to each pool to determine if it was vernal or not. However, Pennsylvania Seasonal Pool Registry data was used as a GIS overlay on the study site locations. If the nearest wetland was a confirmed seasonal pool, the wetland type assigned by the NWI (if any) was recorded. Nine palustrine emergent wetlands (PEM), nine palustrine scrub shrub (PSS), and eight palustrine forested wetlands (PFO) were documented as vernal pools. One palustrine open water (POW) wetland was a documented vernal pool. Twenty-eight of the nearest wetlands to study pools were registry-documented vernal pools that were not identified as wetlands in the NWI.

Proximity to roads and disturbances

The distance between pools and the nearest disturbance was measured in this study because it could be associated with degradation of aquatic habitats. Pools in HAL and LNE/NP were also farthest from roads and disturbances (666/318 and 360/269 m respectively). Pools in the WAP and CAP ecoregions were located various distances from roads. However in comparison to the two other ecoregions, WAP and CAP had many more pools that were proximate to roads (ave. 227/108 m). Distance to the nearest road or disturbance did not exhibit a linear relationship with any of the measured water chemistry variables. However a negative linear relationship between indicator species richness and distance from roads was found. This is probably not a biologically meaningful relationship but rather reflects ecoregional trends. The CAP ecoregion supports the highest indicator species richness, and they also have the closest average proximity to roads. Pools in the CAP are by and large located near dirt forestry roads that run along ridgetops. These dirt roads typically have tree canopy shading them, and because they traverse large tracts of state lands they are not heavily used on a regular basis.

Trombulak and Frissell (2000) provide a comprehensive summary of the ecological effects of roads on aquatic communities. Primary concerns for vernal pools are altered hydrology and water chemistry from road run-off, introduction of invasive species, and fragmentation of the upland habitat. Fragmentation by roads and other features presents a multifaceted threat. Research has shown that persistence of characteristic vernal pool species such as the spotted salamander and wood frog depend on metapopulation dynamics, which in turn depend on the ability of species to move freely between pool habitats (Skelly et al. 1999, Harper et al. 2008). Roads and other disturbances such as clearings may serve as a barrier to movement, particularly to ambystomatid salamanders (deMaynadier and Hunter 2000, Calhoun and deMaynadier 2008). When roads separate uplands from breeding pool habitats, large numbers of road-kills may result during spring migrations (Colburn 2004).

Several studies on seasonal pools amphibians in Pennsylvania have examined the relationships between disturbances and vernal pools. Pongpat (2002) looked at landscape and local scale pool variables and their effects on amphibian assemblages in 65 pools in south-central Pennsylvania. Results showed that forest roads were correlated with higher pool pH, apparently due to runoff from limestone-maintained gravel roads. Pools that were surrounded by clearcuts had the highest average temperatures and were 30% smaller in average area than those surrounded by mature forest. Mixed findings were reported regarding species occurrence in clearcuts. Mobile habitat generalists such as green frogs (*Lithobates clamitans*), pickerel frogs (*Lithobates palustris*), American toads (*Anaxyrus americanus*), and spring peepers (*Pseudacris crucifer*) were more likely to occur in open pools, but mole salamanders (*Ambystoma* spp.) were present as well.

Pool size, depth, hydroperiod, and vegetation

Pool size, depth, and hydroperiod are all interrelated variables, but the degree to which they are correlated is variable. A study of 304 seasonal pools in Maine found neither size nor depth were consistently correlated with hydroperiod (Calhoun et al. 2003). A study of 42 wetlands in New Hampshire that included short, intermediate, and permanent wetlands found that longer hydroperiods were characteristic of larger wetlands (Tarr et al. 2005). A study of fifteen seasonal pools in the CAP ecoregion did not find correlations between pool depth and area (Leppo 2008). Another study of 37 pools in the same complex found that hydroperiod was directly related to pond maximum area (Wilson 2000). In the present study, pool area and depth were not correlated. Hydroperiod was not evaluated quantitatively and could not be evaluated against pool size.

Pool dimensions also have implications with presence of vegetation and water chemistry variables. Tarr et al. 2005 found that larger wetlands tended to have higher temperatures, pH, and dissolved oxygen resulting from plant and algal oxygen production. Short hydroperiod pools had lower mean temperatures and dissolved oxygen, and tended to be more heavily shaded with less vegetation and algae. Leppo (2008) found that canopy cover was negatively correlated with temperature at the substrate, grassy detritus, algae, marsh vegetation, and dissolved oxygen at 5 cm, and positively correlated with leaf litter. This indicates that heavily shaded pools were cooler than open canopy pools, had greater input of leaf detritus, and supported less marsh vegetation and algae due to the reduced availability of sunlight. Conversely, open canopy pools had more algae and vegetation which enrich the water with oxygen produced during photosynthesis.

Pool dimensions, vegetation characteristics, and water chemistry variables are often related to taxonomic composition and richness. Brooks (2000) found that among five seasonal forest pools, benthic macroinvertebrate richness and diversity increased with increasing hydroperiod. Wilson (2000) found that ponds with longer hydroperiods favored species with longer larval development period, while species with rapid development reached higher abundances in smaller, shorter hydroperiod pools with less emergent vegetation where perhaps their survivorship improved with less competition and predation. In this study, pool area exhibited a unimodal relationship with overall invertebrate and amphibian community richness, with the inflection point at 1250 m^2. This indicates an optimum pool size for invertebrate (particularly shredders and predators) and amphibian species richness. Invertebrate shredder richness was positively correlated with depth of the organic layer and negatively correlated with minimum canopy cover, indicating a preference for pools with open canopies and a more well-developed organic substrate.

The largest pools in the study were found in the Western Allegheny Plateau (WAP) and Central Appalachian Forest (CAP) ecoregions, though many small pools were found in both ecoregions. These ecoregions also had more open canopy pools and pools with a deeper organic layer and depth to clay. Pools smallest in area and with a less developed organic layer were found in the High Allegheny Plateau (HAL) and Lower New England / Northern Piedmont (LNE/NP) ecoregions with a few exceptions. The WAP was unique in the number of deep pools it supported. WAP pools were one meter deep on average, which was twice as deep as pools in the HAL and CAP. Pools in the LNE/NP were the shallowest, averaging under 0.4 m in depth, and had the least development of an organic layer on average. HAL and LNE/NP pools tended to have more closed canopy pools while pools in the WAP/CAP tended to have pools with open canopies.

Vegetation structure

Pools in this study were assigned a primary vegetation classification type based on the vegetation composition, and a subtype based on vegetation structure within the pools basin to group unvegetated, marsh, and shrub pools. A combination of plant structure and composition seems to be most useful for discerning important habitat types for amphibians and invertebrates (Colburn 2004).

At the pool level, vegetation type and structure (black leaf, marsh, or shrub) corresponded to the richness of the amphibian and invertebrate fauna. ANOVAs found that the open canopy ricecut grass – bulrush shrub marsh pools supported a significantly higher richness of invertebrate predators than five other vegetation types. Overall invertebrate richness was highest in the open canopy wool-grass – mannagrass mixed shrub marsh pool and lowest in white oak upland depression pools. Aquatic herptile richness was highest in the sourgum woodland and ricecut grass – bulrush marsh pool types and lowest in the red maple northern hardwood swamp forest pool types. Seasonal pool indicator species richness was highest in the sourgum woodland pools (especially those with marsh vegetation) and lowest in the red maple – northern hardwood pools (especially black leaf examples). Wilson (2000) similarly found that amphibian assemblages were structured around a percent emergent aquatic vegetation gradient. Vegetation structure alone was an important factor in taxonomic richness of several invertebrate groups. Shredders had significantly greater richness in shrub pools than in black leaf pools, while marsh pools supported higher richness of invertebrate predators and seasonal pool indicators than did black leaf pools.

Water chemistry

Freda and Dunson (1986) examined water chemistry variables in eleven pools in the Ridge and Valley Province of the CAP ecoregion, and sixteen permanent sphagnum bogs, seeps, and small ponds in the New Jersey Pine Barrens. They found that vernal pool water is generally very dilute, but contains various organic compounds such as organic acids and carbon, and ions such as sodium, potassium, magnesium, calcium, and aluminum, and chloride. pH was lowest immediately after ice melt and increased during the spring as temperatures and biological activity also increased. Tannic acid increased over time and ions fluctuated, probably in response to filling/drying episodes. Sphagnum was found to lower pH by exchanging hydrogen cations for calcium and magnesium cations. Runoff was discussed as a possible cause of elevated levels of calcium and pH in pools located near gravel roads.

This study found that total hardness, calcium hardness, and magnesium hardness levels in the study pools were all correlated, with amounts of calcium and magnesium varying slightly due to composition of parent rock underlying the pools. WAP and LNE/NP pools had higher total hardness related to the calcareous geologic parent material below the pools (such as glacial tills in the northwest portion of WAP and diabase intrusions the LNE/NP) which corresponded to higher pH values on average (6.18 and 5.72 respectively). HAL and CAP pools tended to be more acidic on average (pH of 4.94 and 4.50 respectively), however a number of pools within these ecoregions had high pH levels including pools positioned over sand, shale, and siltstone. Higher pH values may often reflect greater connectivity to ground water sources that flow through calcareous materials, even if the calcareous rock is not directly underlying the pools. Another source of calcium in seasonal pool waters may arrive from surface water flowing over limestone gravel used on dirt roads (Freda and Dunson 1986). Roads were found to be correlated with water chemistry of two pools clusters in the CAP that were located near limestone gravel maintained forestry roads (Pongpat 2002). An analysis of pH and road distance for 43 pools in the CAP ecoregion did not find a correlation between distance to roads and pH, but not all dirt roads are maintained with limestone-based gravel. One of the pool clusters from the Pongpat study was also included in this one. In this study, the pool located nearest a limestone coated road (31 m) did have a much higher pH (6.2) than three other pools sampled in that cluster (4.62 pH at 73 m from road, 4.50 pH at 79 m from road, and 4.03 pH at 129 m from road).

Average air and water temperatures were lowest and dissolved oxygen and oxidation-reduction potential (ORP) levels the highest in the WAP and CAP ecoregions. Consistently cooler average temperatures are expected in heavily shaded pools and pools receiving ground-water input. ORP is negatively correlated with water temperature and positively correlated with dissolved oxygen. ORP measures the oxidative state of a given environment and dictates what biogeochemical reactions can occur. ORP provides information on the chemical species likely to be present and the dominant form of microbial respiration (e.g. aerobic versus anaerobic, or sulfate-reducing microbes versus iron-reducing microbes). High values indicate that oxygen is the primary substrate for respiration, decreasing values indicate changes to moderate and then strongly anaerobic respiration, with carbon dioxide reduced to methane at the strongly negative ORP values. Oxidation-reduction potential exhibited a convex unimodal relationship with shredder density and predator richness, with inflection points of approximately 150 and 225, respectively. This indicates that optimal environmental conditions for the greatest number of taxon within these groups is at lower and higher ORP values and somewhat depressed at middle values.

Conductivity measures the levels of dissolved ions in the water. Seasonal pools are freshwater habitats fed primarily by rainwater and tend to have very low conductivity. Differences were apparent in average conductivity of pools among ecoregions, with highest average values in the CAP (71 mS/cm) and LNE/NP (90 mS/cm), and lowest in the WAP (52 mS/cm) and HAL (30 mS/cm).

Individual taxon response to biotic and abiotic variables

A number of significant biotic and abiotic variables were identified by linear regressions, correlations, Anovas, and the NMS ordination to be important to plant and animal richness, abundance, and distribution on regional and local scales. Most plants, amphibians, and invertebrates of seasonal pools have a fairly broad tolerance for environmental conditions, which allows them to use an environment that changes dramatically throughout the year. However individual taxon responses to environmental gradients were varied (see Tables 12-13 in Results). All of the studied environmental variables were found to have a significant relationship with the abundance or distribution of some taxon or taxa at the pool or community level. Environmental variables related to invertebrate and amphibian taxa included pool dimensions (length, width, area and depth), fullness of the pool, Julian day, water temperature, oxidation-reduction potential, pH, calcium and magnesium hardness, total alkalinity, and conductivity.

Other studies have documented species-specific relationships to environmental variables. Brooks (2000) and Leppo (2008) found that non-biting midge (Chironomidae) dominance was greatest in short hydroperiod pools. Brooks (2000) found that mollusks and leeches were only found in a semipermanent pond, and amphipods reached highest abundances there. Wilson (2000) found that the abundance of individual amphibian species varied based on pool hydroperiod and vegetation. This study found that fairy shrimp (Anostraca) were negatively correlated with pH, perhaps reflecting their primary distribution in the CAP ecoregion which has more acidic pools on average than the other ecoregions studied. Snails (Gastropoda) were strongly positively correlated with pH, which indicates their use of habitats with sufficient calcium available for shell building. Spreadwing damselflies (Lestidae) were found to be characteristic of pools with open canopies. Amphipods and isopods (Malacostraca) were positively correlated with magnesium hardness. These taxa have no drought resistant life stage, and so must have connections to perennially moist or wet soils characteristic of pools with some groundwater connection that is likely also the source of magnesium in the pools.

A notable finding in this study was that Jefferson salamanders had an overall positive linear relationship with pH. Fitting a unimodal curve showed a stronger convex relationship, with an inflection point at pH of 6.1 This confirms results of other studies that found that Jefferson salamanders prefer slightly less acidic habitats than other seasonal pools amphibians. Pongpat (2002) found low abundance of Jefferson salamanders at pH values below 4.7. Freda and Dunson (1986) found that the median pH of pools with Jefferson salamander embryos was pH 5.19; they were not found in pools with a mean pH below 4.62. In this study Jefferson's were found at pH values as low as 3.7 and as high as 7.53. Ultimately a combination of environmental factors can influence amphibian success in a pool including pool chemistry, microhabitat placement of eggs, and genetic variation in subpopulations (Freda and Dunson 1986).

Animal interactions

Individual taxa were found to be correlated positively or negatively with other taxa, perhaps due to predator/prey or competitive interactions or due to similar or contrasting responses to environmental variables. For example, the abundance of red-spotted newts was negatively correlated with wood frog presence and abundance. Newts prey heavily upon amphibian eggs and larvae (Hulse et al. 2001, Colburn 2004), and wood larvae appear to be particularly vulnerable due to their conspicuous behavior in a pool (personal observation). Pongpat (2002) found that wood frog abundance increased with elevation, while newt abundance decreased. Wood frog presence was not predicted by pH, but more abundant at lower pH while newts were more abundant at higher pH. Freda and Dunson (1986) also found that wood frog distribution was not limited by pH.

Invasive species

No invasive invertebrate species or amphibian species were documented in the seasonal pools during this study. However many taxon were not identified past higher taxonomic levels such as order and family. Identification of invertebrate species not native to these systems will be difficult barring better identification and life history resources. Most likely invasive species are fish and herptiles that arrive via human introduction. Local fisherman have stocked one large semipermanent seasonal pool in Centre County repeatedly (personal communication C. Shiffer). Some semipermanent pools are able to support fish populations for several years, during which time they can greatly alter the seasonal pool animal community which is not adapted to fish predation. Non-natives herptiles may be released into seasonal pool natural areas when pet owners no longer wish to take care of them. Non-natives can displace native species, but even capture and eventual release of native species can be disruptive to the natural ecosystems. While in captivity herptiles can contract diseases and then spread them into healthy wild populations upon their release. Taking animals into captivity, even temporarily, and especially releasing them into a site outside of their home range is highly stressful and disruptive to the individual animal.

Ecoregional overview of the plant, amphibian, and invertebrate communities of Pennsylvania

Ecoregional distribution of plant, amphibian, and invertebrate community types

The distribution of the plant and animal communities of seasonal pools by ecoregion yields useful information on the physical and biogeographic variation within the state. Pennsylvania is a diverse state, encompassing six ecoregions ranging from low coastal and lake plains, to ridges and valleys, to high and low plateaus.

Ecoregional differences were apparent in the distribution of vegetation, amphibian, and invertebrate community types (Tables 25-26 in Results). A review of classification studies of vernal pool plant communities in Calhoun and deMaynadier (2008) concluded that a common theme is variation across climatic and physiographic regions. The underlying geology of a seasonal pool is of particular importance, influencing key physical and chemical characteristics such as pool dimensions, hydroperiod, and pH. This study found several plant and animal types were restricted to certain regions of the state. The swamp white oak swamp forest pools and the Planorbidae snail invertebrate group were limited to the glaciated northwest portion of the Western Allegheny Plateau (WAP). The wet-mesic forested calcareous seep-fed pools and *Physa* snail invertebrate group were documented in the glaciated northwest plus the Lower New England / Northern Piedmont (LNE/NP). The amphibian groups indicated by the red-spotted newt (*Notophthalmus viridescens*) and the marbled salamander (*Ambystoma opacum*) were found in three ecoregions each, but all localities for the red-spotted newt group were within the north-western quadrant of the state, while all occurrences for the marbled salamander were in the eastern half of the state. Rice cutgrass – bulrush marsh pools, springtime fairy shrimp (*Eubranchipus vernalis*), log-cabin caddisfly (*Limnephilus*), and two mosquito indicated groups (*Ochlerotatus abserratus* and *Aedes vexans*) were limited to the Central Appalachian Forest (CAP). The spotted salamander (*Ambystoma maculatum*) group also reached its greatest frequency in the CAP. The *Dytiscus* diving beetle and green frog (*Rana clamitans*) indicated groups were only identified in the HAL ecoregion, while the springtail group (Isotomidae and Sminthuridae) was only found at the boundary between the High Allegheny Plateau (HAL) and the LNE/NP in eastern Pennsylvania. See Tables 27-28 in the Results for the distribution of amphibian and invertebrate communities by vegetation structure and community type. Note that while certain share groups ecoregional distribution, they do not necessarily co-occur in pools within that landscape.

With additional sampling the regional distribution and prevalence of the identified pools types will be refined, and additional pools types are expected to appear. For example one pool in this study was located at the boundary between the LNE/NP and North Atlantic Coast ecoregions suggested a red maple – sweetgum swamp pool type. This study also focused on upland isolated seasonal pools, but other types of ephemeral wetlands are utilized by seasonal pool species. For example, pools can form as part of wetland complexes, which commonly occur in the Great Lakes ecoregion in the very north-west corner of the state. Temporary pools can also form on the floodplains of streams and rivers, which is the main context of pools in south-western Pennsylvania. These pool types are expected to have even greater variation in their floral and faunal communities due to their ephemeral connections and close proximity to permanent wetlands and streams. These pool types may not fit classic definitions of vernal pool habitats, but they are important to breeding populations of seasonal pool species living in those regions.

Ecoregional differences in invertebrate and amphibian community richness

Ecoregional differences were also found in the richness of aquatic invertebrate and amphibian communities. Physiochemical characteristics combined with faunal richness and density and landscape context separated many pools by the ecoregion in which they were found. Pools in the LNE/NP and HAL tended to be smaller in size with closed canopies and were located farther from streams. The WAP and CAP pools had more overlap in characteristics, but separated somewhat along pool size and water chemistry variables. Larger, acidic pools characterized the CAP and moderately-sized, deep, less acidic pools characterized the WAP.

Anovas showed that the CAP ecoregion supported significantly higher richness of seasonal pool indicator species than pools in the HAL. Aquatic invertebrate richness however, was highest in the WAP ecoregion and was significantly higher than in the CAP and LNE/NP ecoregions, particularly in the collector-gatherer and shredder trophic groups. Looking at invertebrate richness by most recent glacial history, glaciated sites were significantly richer. An NMS ordination (Figure 25 in Results) of environmental and faunal richness and density variables illustrated additional ecoregional trends. Correlated variables with the NMS axes included pool dimensions and substrate, amount of canopy cover, and pH. Correlated landscape context variables included proximity to roads, wetlands and streams, and amount of forest in the surrounding 300 meters of upland habitat around each pool.

Ecoregional distribution of individual taxon

Ecoregional differences were reflected in the distributions of vertebrate and invertebrate species with some taxa commonly occurring throughout the state such as the wood frog (*Lithobates sylvaticus*) and the early spring mosquito *Ochlerotatus canadensis canadensis*. Other taxa reached greatest prevalence or were restricted to a single ecoregion. For example the Jefferson salamander (*Ambystoma jeffersonianum*) and the log-cabin caddisfly (*Limnephilus*) were most prevalent in the CAP and WAP ecoregions. The springtime fairy shrimp (*Eubranchipus* *vernalis*) was most prevalent in the CAP ecoregion. Dragonflies and damselflies were most commonly encountered in the CAP and HAL ecoregions, with one seasonal pool damselfly (*Lestes*) showing statewide distribution but with affinities for pools in the WAP and CAP. The three families of isopods and amphipods documented in this study were only found in the WAP and HAL ecoregions. All six documented snail and fingernail clam taxa were prevalent in the WAP. See Appendices 11 and 12 for lists of amphibian and invertebrate taxa encountered in this study and their distribution by ecoregion in the state.

VI. SEASONAL POOL CONSERVATION

Threats to seasonal pool ecosystems

The primary threat for seasonal pools and the supporting upland habitat in the Mid-Atlantic region is complete or partial habitat loss (EPA 2005). Development can outright destroy vernal pools through filling or through excavation to convert them into permanent ponds. Indirect effects of development include alteration of pool hydrology when excessive water is diverted from the groundwater supply to supply wells and to irrigate lawns and golf courses. Other conflicts occur when human developments encroach on wetland habitats. For example mosquitoes are an integral part of the seasonal pool food chain, but are a general nuisance and can transmit diseases such as the West Nile Virus. When vernal pools are treated to eradicate mosquitoes, other aquatic animals may be harmed directly or indirectly. Development can also impact the upland habitat needed by vernal pool species. Fragmentation of pool habitats by roads can lead to heavy road-kills during breeding migration nights. Forestry and agricultural practices may have profound effects on vernal pools as well. Timber extraction alters pool and upland habitat by opening the tree canopy, compacting soils, increasing sedimentation, and creating ruts and ditches that can fill with water in the spring and divert breeding activity from higher quality habitats nearby. Intensive agriculture practices can create sediment laden runoff carrying nutrients, pesticides, and herbicides into pools.

Regulations

Vernal pools are provided protection in Pennsylvania under 25 PA Code Chapter 105, the Dam Safety and Waterway Management, which can be accessed at http://pacode.com/secure/data/025/chapter105/chap105toc.html. Vernal pool habitats are not specifically identified in the code, but the Department of Environmental Protection (DEP) include them in the "body of water" category as defined in section 105.1. Chapter 105 protects Pennsylvania's waters from encroachments including any structure or activity which changes the course, current, or cross section of a body of water. Permits are necessary to directly impact vernal pools by fill or excavation. Section 105.20a sets wetland replacement criteria for wetland losses. When a permit is granted for destruction of a vernal pool over 0.05 acres, it must be mitigated at a minimum 1:1 ratio. If a permit is granted for vernal pool losses after-the fact, a minimum 2:1 mitigation ratio is required. The DEP designates pools under 0.05 acres (area of approximately 2,100 ft^2 or 202 m^2) as de minimus. Permittees are not required to mitigate the loss of very small pools in part because it is difficult to recreate small functioning wetlands.

Vernal pools can receive protection under section 404 of the Federal Clean Water Act, administered by the U.S. Army Corps of Engineers (ACOE). Section 404 can be viewed at http://www.wetlands.com/regs/sec404fc.htm). The ACOE cannot regulate "isolated wetlands" that lack a connection to a stream or waterway. However, the ACOE has some flexibility if an indirect connection can be demonstrated. For example a vernal pool may be considered connected to a waterway if it is connected to another wetland which drains into a stream, or if it is located in the floodplain of a stream, even if it does not usually have a direct surface connection to that stream.

The U.S. Environmental Protection Agency provides protection to threatened and endangered species through the Endangered Species Act (http://www.epa.gov/lawsregs/laws/esa.html). The law prohibits the "taking" or the importation/exportation of any listed species. The Northeastern Bulrush (*Scirpus ancistrochaetus*) is a wetland plant that frequently occurs in seasonal pools. Proposed filling of a *Scirpus ancistrochaetus* wetland that falls under the jurisdiction of the U.S. Army Corps of engineers would require a Section 7 review of "Interrelated/Interdependent Activities".

The Pennsylvania Fish and Boat Commission (http://www.fish.state.pa.us/) is responsible for regulations concerning game and non-game fish, reptiles, amphibians, and aquatic invertebrates. Current regulations prohibit the collection or possession of the following species associated with seasonal pools: Four-toed salamanders (*Hemidactylium scutatum)*, Jefferson salamanders (*Ambystoma jeffersonianum*), Marbled salamanders (*Ambystoma opacum*), and Spotted turtles (*Clemmys guttata*).

The Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, developed a State Forest Resource Management Plan that recognizes that more than the pool basin is critical to seasonal pool conservation (DCNR-BOF 2004). The management plan designates specific management guidelines for seasonal pools and their upland habitats and is viewable at http://www.dcnr.state.pa.us/forestry/sfrmp/fauna.htm#wetland. This plan designates a 200 foot buffer zone around each pool to maintain forest-cover shade and minimize soil and leaf litter disturbance. The buffer is subdivided into two 100 foot (30.5 m) buffers. The 100 feet of upland immediately surrounding a pool is designated as "no disturbance." Timber removal or fuel-wood harvest activities are prohibited within 0-100 feet of a seasonal pool. Logging is permitted within the second 100 foot buffer, however the buffer must retain at least a 50% tree canopy closure, or a minimum basal area of 60 square feet of live trees. Furthermore, cutting operations within the second 100 foot buffer are restricted to winter months (November through January). Any ruts that are created within the buffer must be graded or raked to the original contour. Recreational trails are permitted within the buffer zones so long as they do not contribute sediment to the pool.

While some regulatory tools are in place for the protection of seasonal pools, a key gap in protection concerns the seasonal pool terrestrial habitat. Only the DCNR Bureau of Forestry attempts to address this critical habitat within its management plan. Continued efforts to educate land managers and regulators at all levels of government is critical to garner adequate protection of seasonal pools and their supporting upland habitats.

Seasonal pool protection strategies – local

Many vernal pool conservation tools are best applied at the site level, such as establishing protective buffers. A slightly larger scale is also necessary to assess regional landscape changes that can influence seasonal pool sites, such as heavy development within a small watershed supporting seasonal pools. A variety of strategies are needed to help protect and conserve vernal pools and they should be tailored based on the unique conditions found at each site and the surrounding local landscape. These include:

- Inventory and monitor vernal pool sites to establish baseline data, track plant and animal community health, document the range of environmental conditions experienced on an annual basis, identify management needs and threats.
- Monitor changes in land use in the surrounding local landscape (small watersheds or townships).
- Prioritize vernal pool sites for protection and identifying the most efficient means of protection for individual pools and pools clusters, from voluntary landowner agreements to conservation easements to outright purchase of critical habitat for conservation.
- Implement best management practices (BMPs) when managing a vernal pool site for conservation purposes or when altering the landscape in proximity to vernal pool via timber extraction, development, agriculture, energy development, etc. (see the references on seasonal pool ecology and best management practices in this section).
- Examine the landscape context around pools to assess threats, identify corridors to connect isolated pools to nearest streams and wetlands, and to maintain integrity of seasonal pool complexes.
- Identify hot spots where roads separate vernal pools from upland adult habitats. This information can be used to plan road closures or establish volunteer programs to help animals safely cross the roads and prevent high numbers of road kills on spring migration nights.

Seasonal pool protection strategies – statewide and across state boundaries

Several conservation needs are best addressed at the state level and may cross state lines.

- Landscape analyses: create vernal pool reserves and corridors between high quality pool habitats to help ensure the long term health and stability of vernal pool plant and animal populations. Climate change is expected to impact vernal pool habitats through a variety of mechanisms including gradual increases in average temperatures, changes in patterns of seasonal rainfall, and more extreme weather events. Having many protected vernal pool reserves throughout Pennsylvania and with neighboring states with connecting corridors will help the plants and animals adapt to local and global changes that may alter and destabilize the dynamics of an already highly stochastic wetland habitat.
- Statewide inventory efforts: Continue the Pennsylvania Seasonal Pools Registry (http://www.waterlandlife.org/54/seasonal-pools) and the Pennsylvania Herptile Atlas (http://www.paherpatlas.org/) . A key element to providing protection to vernal pools is knowing where they are located and what species they support.

Establishing conservation priorities

Economic and political realities dictate that some method of prioritizing seasonal pools by the quality of their habitat or presence of target species is necessary. Limited resources can then be focused where they will most effectively conserve seasonal pools and their habitats. Several considerations for prioritizing are listed below.

Species of conservation concern

One method of prioritizing seasonal pools for conservation is based on presence of species of conservation concern based on rarity or evidence of decline. Four species were found in seasonal pools in this study that are identified as priority species in Pennsylvania's Wildlife Action Plan (http://www.pgc.state.pa.us/pgc/cwp/view.asp?a=496&q=162067). Priority species are placed in one of five levels or tiers.

- Conservation Tier 1: Immediate Concern - those species most at risk across their range.
- Conservation Tier 2: High-level Concern – nationally or regionally significant species that are vulnerable in Pennsylvania
- Conservation Tier 3: Responsibility Species – core populations or a significant proportion of the regional population occurs in PA
- Conservation Tier 4: Pennsylvania Vulnerable – species most at risk or experiencing dramatic declines in PA but not at risk elsewhere
- Conservation Tier 5: Maintenance Concern – species that are fairly secure in PA but warrant some level of management attention

The Jefferson salamander, *Ambystoma jeffersonianum*, is considered a vernal pool obligate species and is ranked as a Responsibility Species. Hybrids of this species exist in parts of its range; however, southern Pennsylvania is one area that has non-hybrid populations. These populations are thus ones with high conservation value. The known distribution of the Jefferson salamander is statewide but limited to areas with proper habitat. Its status is poorly understood.

The marbled salamander, *A. opacum*, is another vernal pool obligate species and is listed under Tier 5 as a Maintenance Concern. It is reported present from the northeastern to the southwestern part of the state. Its status is poorly understood with evidence of decline.

The four-toed salamander, *Hemidactylium scutatum*, is listed under Tier 5 – Maintenance Concern. This salamander is a habitat specialist requiring wet areas with sphagnum. Its distribution is statewide in Pennsylvania but quite spotty due to its specific habitat requirements. Its status is unknown.

The spotted turtle, *Clemmys guttata*, is a vernal pool facultative species and has been placed in Tier 1 as a species of Immediate Concern. The turtle is at high risk and numbers are declining due to habitat destruction, illegal collection, and road kill. In Pennsylvania the spotted turtle has a patchy distribution across the state. It is limited to areas with suitable habitat and is absent across most of the northern tier of counties and the Ridge and Valley Provinces.

Three dragonfly species of special concern were identified in this study based on larval specimens: the Green-striped Darner (*Aeshna verticalis*), the American Emerald (*Cordulia shurtleffii*), and the Taiga Bluet (*Chromagrion resolutum*). Surveys for adults at the localities where the nymphs were collected to confirm presence of these species are recommended.

One species of fairy shrimp, *Eubranchipus vernalis*, was found in only ten out of eighty-nine seasonal pools surveyed in this study. A second species of fairy shrimp, *Eubranchipus holmani*, appears to be even less common in seasonal pools Pennsylvania. In recent years this species has been documented at one locality each in Centre County and Franklin County (Leppo and Evans 2004 and this study). Fairy shrimp are difficult to inventory due to their unreliable emergence and ephemeral presence in a pool in a given year. Continued surveys of fairy shrimp in seasonal pools in early spring are needed to asses which species are present and to document their distribution in the state.

Vernal pool indicators

Presence of breeding populations of two or more indicator species is suggested as another ranking criteria that would elevate the status of a seasonal pool for conservation (Calhoun et al. 2005). However, Calhoun et al. (2003) determined that ranking pools by the number of indicator species alone is not an ideal qualifying index based on a study of 304 seasonal pools throughout Maine. In one region, 75% of the pools only had 1 indicator species, therefore the majority of pools in that region would drop out of consideration for conservation if that ranking guideline was used.

Abundance of egg masses

Pools with over 25 egg masses, regardless of the species, suggests a pool with an active and likely persistent pool-breeding amphibian population. This is a general rule of thumb to try to eliminate habitats that are used incidentally such as roadside ditches and skidder ruts (Calhoun et al. 2005).

Pool size and hydroperiod

Implications for conservation regarding pool size and hydroperiod based on this study reflect findings by other authors studying vernal pool vertebrates and invertebrates (see Semlitsch and Bodie 1998, Semlitsch 2000, Pechmann et al. 2001, Skelly et al. 2002, Rubbo and Kiesecker 2005, Skelly et al. 2005, Skidds and Golet 2005, Tarr et al. 2005, Ryan 2007). Larger area vernal pools typically have more diverse animal communities. However not all species found in smaller pools are also found in larger pools. Ponds with shorter hydroperiods have fewer species, but more of them are vernal pool specialists. They have adaptations for dry periods such as dessication-resistant eggs, or the ability of larvae or adults to survive in moist pool substrates. Ponds with longer hydroperiods have more species, but fewer of the species are adapted for dry periods. Long hydroperiod pools provide more time for opportunistic habitat generalists to find and colonize them. Predators also have more time to immigrate from permanent aquatic habitats, leading to higher predation pressures. Open pools are more taxonomically diverse, but some species reach their highest abundance or have higher survivorship in shaded habitats. While wetland size is currently a common consideration in wetland regulations, hydroperiod is perhaps the more critical variable. Wetland size is an imperfect predictor of hydroperiod and species diversity and neglects species found only in smaller wetlands (Snodgrass et al. 2000). Protection of pools representing a continuum of hydroperiod, size, water chemistry, vegetation, substrate, and structure will lead to the greatest protection of all vernal pool organisms.

Condition of seasonal pool envelope and terrestrial upland

The quality of the surrounding upland around a seasonal pool is another key component in evaluating a site for potential conservation. Calhoun et al. (2005) suggest that at least 75% of the seasonal pool envelope (100 ft / 30.5 m from the pool edge) and at least 50% of the critical terrestrial habitat (100-750 ft / 30.5-229 m) should be undeveloped.

Connectivity to other pools

Pool clusters are a conservation priority wherever they occur on the landscape. Protection of clusters of pools allows species to select pools that meet their habitat preferences. An assortment of large and small, deep and shallow, vegetated and unvegetated, long and short hydroperiod pools will optimize recruitment for all species during the good years. In dry years when drought eliminates shorter hydroperiod pools, the larger and/or longer hydroperiod pools can maintain some level of continued productive breeding habitat and provide long term stability for populations.

Pool clusters are thought to have more viable animal populations, but isolated pools can serve as stepping stones allowing gene flow, or may be the only habitat available for vernal pool species at that locale. In areas with low density of pools, it becomes more critical to protect isolated pools and protect natural corridors such as riparian areas or ridgelines that connect pools.

Threat level

Threat level can be used to increase or decrease the priority of a pool for conservation. Isolated pools occurring in urbanizing landscapes may be highly threatened, and may also represent opportunities to preserve reservoirs of biodiversity that would otherwise be lost completely. Connecting pools such as these to other wetlands and riparian areas through greenways can help increase their viability in the long term. On the other hand, a seasonal pool under threat of destruction in a region where pools abound may become a lower priority because other suitable habitat exists to support local seasonal pool populations.

Determining buffer sizes for seasonal pool conservation

Protection of upland habitats is a key component to vernal pool conservation (Gibbons 2003, Leibowitz 2003, Semlitsch and Bodie 2003, Zedler 2003, Rubbo and Kiesecker 2005, Skidds et al. 2007). Naturally vegetated uplands provide necessary habitat for adult amphibian and insect life stages, maintain ecosystem processes such as hydrological regime, and serve as corridors for wildlife movement between pool clusters and isolated 'stepping stone' pools. Further research is needed to define critical upland habitats and management recommendations for a variety of vernal pool species.

Amphibian dispersal distances from the pools where they breed to the uplands where they spend the remainder of the year varies by populations and individuals. Several literature reviews (Jung and Brown 2005, Colburn 2004) found the following dispersal distances for characteristic seasonal pool amphibian species:

- Four-toed salamanders (*Hemidactylium scutatum*) move a maximum of 650 ft (198 m)
- Wood frogs (*Lithobates sylvaticus*) commonly move 1,200-1,600 ft (366-488 m)
- Spotted salamanders (*Ambystoma maculatum*) move on average over 500 ft (153 m) but will move 2700 ft (824 m)
- Jefferson salamanders (*Ambystoma jeffersonianum*) move on average approximately 820 ft (250 m) but will move up to 2050 feet (625 m).
- Marbled salamanders (*Ambystoma opacum*) move average about 635 ft (194 m) but travel up to 1475 ft (450 m).

Based on a review of the scientific literature, the Environmental Protection Agency delineated two critical buffers in relation to seasonal pool habitats. The 100 ft (30.5 m) of upland immediately surrounding the pool, called the seasonal pool envelope, is highly sensitive to disturbance throughout the year. This area is prime real estate for adult amphibians migrating to and from the pool during the breeding season, recently metamorphosed amphibians in the summer and fall, and overwintering amphibians through the coldest months. A larger 1000 ft (305 m) buffer provides the seasonal pool terrestrial habitat where over 95% of the populations of pool-breeding amphibians live outside of the breeding season. This buffer, when in a relatively unfragmented and vegetated state, helps maintain water quality of the pool and facilitate movement of animals between pools and between nearby streams and wetlands. A computer model developed by Harper et al. (2008) suggests that larger buffer sizes (e.g. 100-165 m buffer for spotted salamanders) may be needed to have a high probability (over 95%) of preserving amphibian populations over the long term (20+years).

Compensatory mitigation and value of created wetlands

While compensatory mitigation has a role in wetland regulations, it is best used as a last resort. Recreating forested wetland habitats with the desired fluctuating hydroperiod and vegetation is a difficult task (Pechmann et al. 2001). It is also not accomplished quickly. Balcombe et al. (2005) concluded that created wetlands need to mature 9-10 years before they can be initially assessed and compared with reference wetlands. The authors cite other researchers who suggest waiting 15-20 years before evaluating the success of a constructed freshwater wetland, and over 50 years for a forested wetland. Created wetlands can become overrun with invasive plants such as reed canarygrass (*Phalaris arundinacea*) or monocultures of natives such as cattails (*Typha* spp.) which prevent the establishment of a variety of desirable native species (Balcombe et al. 2005). Created seasonal pools can also fail to simulate the hydrology of natural pools, especially those with small basins (Ferren et al. 1998).

Loss of seasonal pools even during the dry part of the year will impact adult amphibians who exhibit great breeding habitat fidelity and will return year after year to same pool location (per literature review in Colburn 2004). Juvenile amphibians are more likely to travel long distances from breeding pools to seek territories where they will spend the remainder of the year (per literature reviews in Calhoun and deMaynadier 2008 and Colburn 2004). Once mature, these individuals seek breeding habitats and may colonize newly created pools or pools that experienced a natural extinction event due to drought. Prior to destruction of existing seasonal wetlands, functioning vernal pools habitats and connecting forested corridors should be identified or established within the dispersal distance of the least mobile species.

New wetland construction should first attempt to recreate the types of pools that were lost from a site or region. When funds are available for enhancement and restoration of seasonal pool habitats, addition of new types of pools that vary in size and depth, vegetation, amount of tree canopy cover over the basin, and length of hydroperiod can lead to greater diversity on the landscape.

Education and collaboration

Vernal pools provide an excellent outdoor classroom. Education of the public, landowners, and resource managers will help prevent introduction of undesirable biota to vernal pools such as fish, non-native species and captive raised reptiles and amphibians. Providing information on how chemicals commonly used for agriculture, road and lawn maintenance, and insect control can cause adverse effects to vernal pool plants and animals will encourage thoughtful use of these chemicals near vernal pool habitats. Uniting science and education is a key component to comprehensive management and protection of vernal pool ecosystems. Fostering collaboration among researchers is important to facilitate sharing of data and to establish research and protection priorities.

References for seasonal pool ecology and best management practices

A wealth of information now exists on vernal pool conservation thanks to the research and publications of vernal pool ecologists in the past ten years. Several excellent publications are suggested below that provide extensive background information on vernal pool ecology and/or detailed recommendations for vernal pool conservation.

Brown, L.J. and R.E. Jung. 2005. An Introduction to Mid-Atlantic Seasonal Pools, EPA/903/B-05/001. U.S. Environmental Protection Agency, Mid-Atlantic Integrated Assessment, Ft. Meade, Maryland. Available at <http://epa.gov/maia/html/SeasonalPools_PDF.html>.

This publication provides a good overall view of seasonal pools in the Mid-Atlantic States. Section 3 covers conservation challenges including the direct loss of pools, and loss and fragmentation of terrestrial habitat. Section 4 addresses amphibian diseases, the consequences of mosquito control, acid deposition and a short section on climate change as it relates to seasonal pools. Section 5 takes a look at conservation of pools on a broader scale including landscape level planning and management.

Calhoun, A.J.K. and M.W. Klemens. 2002. Best development practices: Conserving pool-breeding amphibians in residential and commercial developments in the northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation society, Bronx, New York.

Habitat management guidelines are provided for landowners and developers who want to find ways to protect the wildlife associated with vernal pools in areas where the landscape is being fragmented by residential and commercial development. Guidelines for developing conservation plans are given. These include specific recommendations for roads and driveways, site clearing, storm water management and lighting. Another section covers the legal aspects that govern vernal pools in the northeastern states.

Calhoun, A.J.K. and P. deMaynadier. 2004. Forestry habitat management guidelines for vernal pool wildlife. MCA Technical Paper No. 6, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

This publication is a companion guide to the publication by Calhoun and Klemens (2002) mentioned above. The guidelines apply not just to Maine but to all the northeastern states. The focus is on how to protect wildlife in managed forests. Why vernal pools and the upland habitat that surrounds them need protective measures is discussed. Detailed habitat management guidelines for vernal pools are provided with recommendations for both small woodlot and large forest landowners

Calhoun, A.J.K. and P.G. deMaynadier (eds). 2008. Science and conservation of vernal pools in Northeastern North America. CRC Press, Boca Raton, FL. xxvii+363 pp.

This book is a valuable addition to what we know about vernal pools and how best to protect them. The book is divided into three major sections. Section 1 provides background information on the physical aspects of vernal pools while Section 2 takes a detailed look at the plants and animals that inhabit them. Topics covered in Section 3 include a look at federal, provincial and local regulations as they apply to vernal pools. Guidelines for conserving pools in both urban landscapes and in managed forest are explored and a look is taken at conservation of amphibians at a landscape species level.

Colburn, E.A. 2004. Vernal Pools: Natural History and Conservation. The McDonald and Woodward Publishing Company, Blacksburg VA. xiii + 426 pp.

Colburn's book provides detailed coverage on the ecology and biology of vernal pool species. The extensive Bibliography is a valuable resource in itself. The final chapter in the book covers the conservation of vernal pools. Various threats to vernal pools are discussed such as the actual destruction of pools and changes to the landscape that affect pool hydrology. Other threats covered include the effects of forestry and agricultural practices on pools and issues such as mosquito control, and pollution issues. The chapter concludes with specific suggestions for conservation action.

Pennsylvania-specific seasonal pool references

A list of seasonal pool research conducted in Pennsylvania was compiled during the course of this study. While this is not an exhaustive list, it highlights research across a variety of topics relevant to seasonal pool ecology and conservation in Pennsylvania.

- Balcombe et al. 2005: A comparison of plant communities in mitigation and reference wetlands in the mid-Appalachians.
- Campell et al. 2002: A comparison of created and natural wetlands in Pennsylvania, USA.
- Davis 1993: Rare wetland plants and their habitats in Pennsylvania.
- Fairchild et al. 2000: Effects of habitat and site age on beetles assemblages.
- Fairchild et al. 2003: Microhabitat and landscape influences on aquatic beetle assemblages in a cluster of temporary and permanent pools.
- Freda and Dunson 1986: Effects of low pH and other chemical variables on the local distribution of amphibians.
- Julian et al. 2006: The use of artificial impoundments by two amphibian species in the Delaware Water Gap National Recreation Area.
- Klotz 1999: Vegetation of the northern part of the Mount Cydonia Ponds Natural Area and adjacent lands. Franklin County, Pennsylvania.
- Klotz and Falkenstein 2002: Vegetation of the southern part of the Mount Cydonia Ponds Natural Area, Michaux State Forest, Franklin County, Pennsylvania.
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- Klotz and Freese 1995: Vegetation in a group of natural seasonal ponds in southcentral Pennsylvania.
- Leppo and Evans 2004: Refining the natural communities in Pennsylvania through zoological studies on State Lands: a study of vernal pool invertebrates in the Central Appalachian Ecoregion.
- Leppo 2008: Environmental variables that shape the macroinvertebrate communities of vernal pools in the Central Appalachian Ecoregion.
- Maret and Cassell 2002: The effect of forest management practices on vernal woodland pond amphibians.
- McGonigle 1987: The natural history of Ptilostomis postica (Walker) (Trichoptera: Phryganeidae) in temporary pools in southcentral Pennsylvania.
- Morris and Maret 2007: Effects of timber management on pond-breeding salamanders.
- Pongpat 2002: The effects of landscape-scale and local breeding pond variables on amphibian assemblages in south-central Pennsylvania.
- Rowe and Dunson 1993: Relationships among abiotic parameters and breeding effort by three amphibians in temporary wetlands of central Pennsylvania.
- Rowe and Dunson 1995: Impacts of hydroperiod on growth and survival of larval amphibians in temporary ponds of central Pennsylvania, USA.
- Rubbo and Kiesecker 2005: Amphibian breeding distribution in an urbanized landscape.
- Rubbo et al. 2006: The influence of multi-stage predation on population growth and distribution of the pond-breeding salamander, *Ambystoma jeffersonianum*.
- Wilson 2000: Ecological correlates of wetland amphibian assemblages in south-central Pennsylvania.
- Wissinger and Gallagher 1999: Beaver pond wetlands in northwestern Pennsylvania: Modes of colonization and succession after drought.

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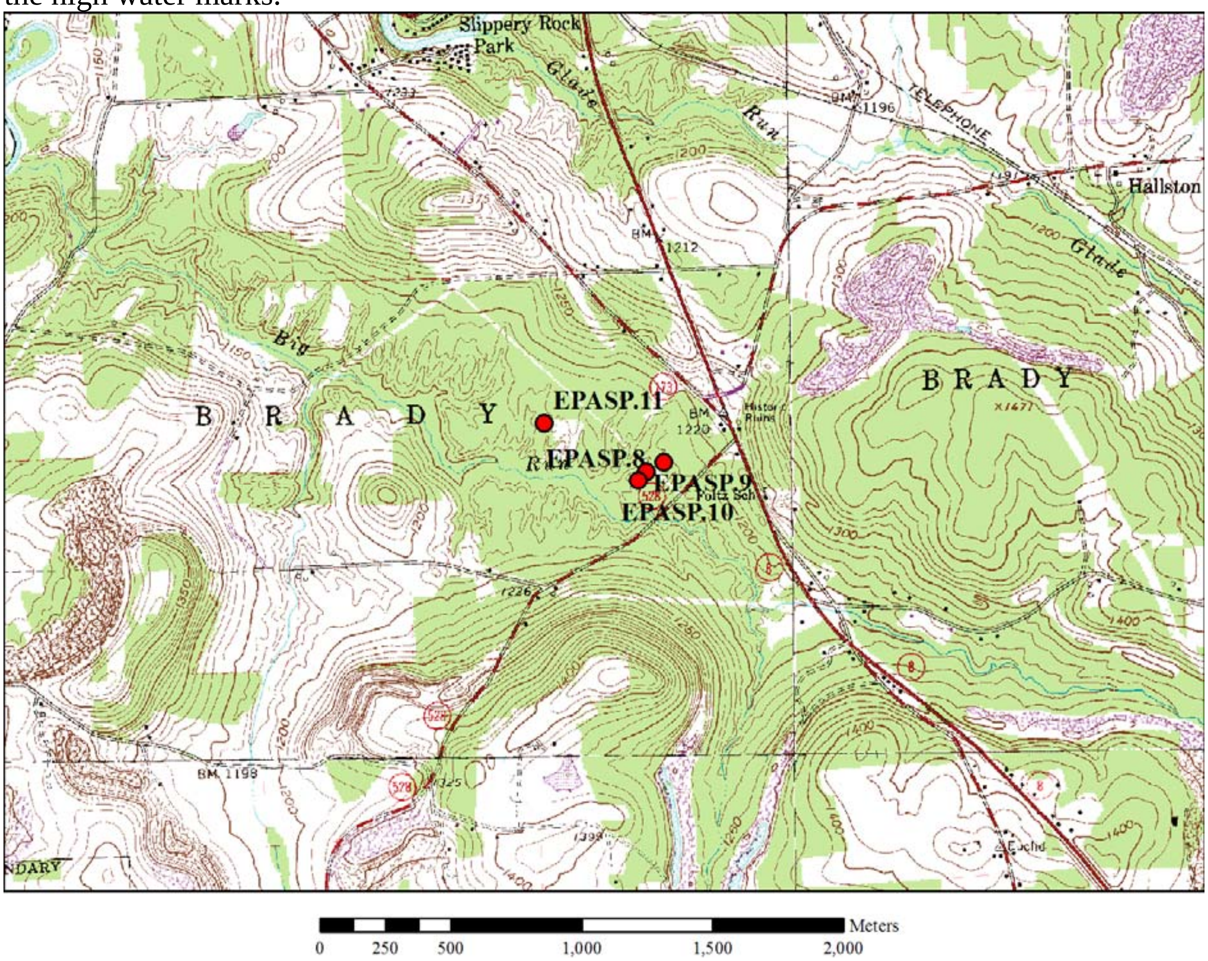
VIII. APPENDICES

Appendix 1. Seasonal pool site descriptions

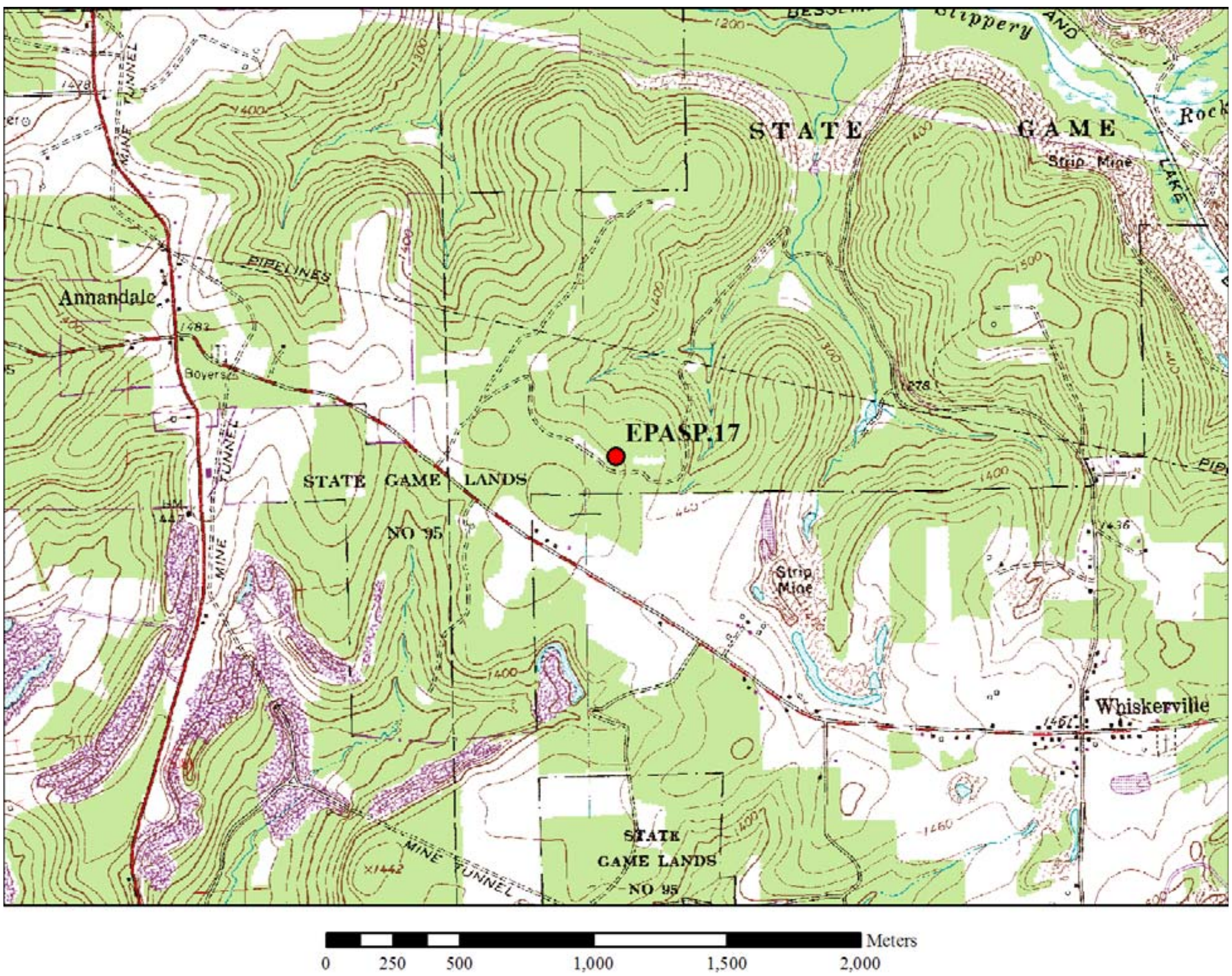
Site: EPASP.8, 9, 10, 11 Pool names: JEEC 1, 2, 3, and 4
USGS 7.5' Quadrangle: Slippery Rock, PA
Butler County, Brady Twp.
Location: West Liberty, PA, 4.0 km ENE.

EPASP.8, 9, 10, and 11are situated within the Pittsburgh Low Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Butler County, PA. The pools are situated within the forested area of Jennings Environmental Center, on the edge of Jennings Prairie, a remnant wet pocket- prairie thought to have been considerably larger historically. The pools are found within mixed oak and red maple-dominated forests, classified as Red maple forest and Dry oak – mixed hardwood forest communities. Pool 8 is an open-canopied pool, surrounded by second growth red maples possessing a high percent-cover of herbaceous species, which includes floating mannagrass. Pools 9, 10, and 11 occur within the Dry oak – mixed hardwoods forest and vary considerably in size and depth. Pool 9 is very shallow and nearly dry at the time of the spring sample. Few herbaceous species occurred in this pool. Pool 10 contained multiple herbaceous patches dominated primarily by manna grasses (Glyceria spp.) and ferns. Pool 11 was a large shallow pool and completely dry by August; however, several wetland plants occurred between the high water marks.



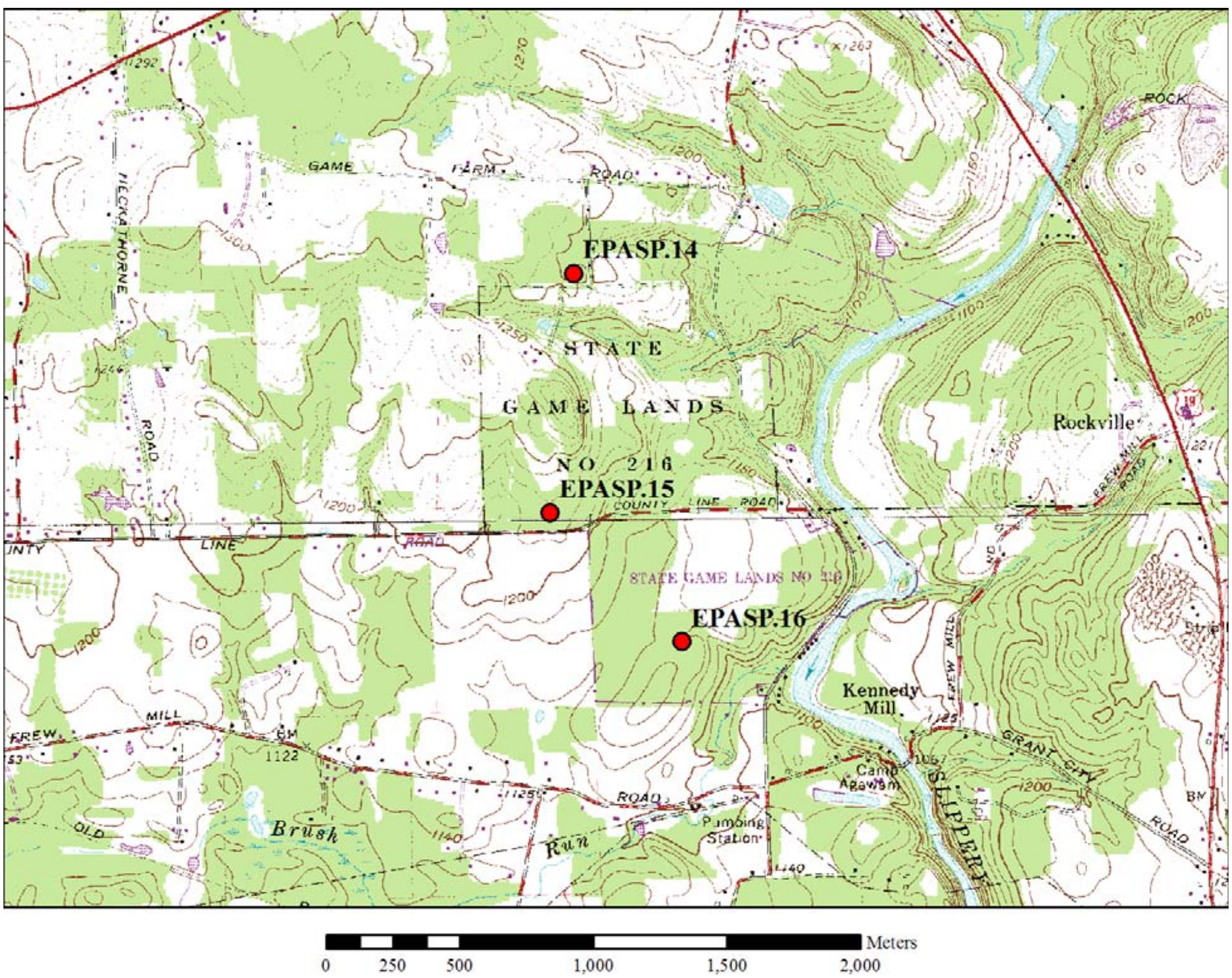
Site: EPASP.17 Pool name: SGL 95
USGS 7.5' Quadrangle: Hilliards, PA
Butler County, Washington Twp.
Location: Hilliards, PA, 4 km W.

EPASP.17 is situated within the Pittsburgh Low Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Butler County, PA. The pools are situated within a forested area of State Game Land 95, managed by the PGC. Pool 17 is nearly canopy-free surrounded by a young Dry oak – mixed hardwood forest patches with pine and spruce plantations intermixed. The PGC has installed wood duck boxes in the center of the pool; however, this pool dries completely leaving a zone of annual vegetation on saturated substrate in the center. There are three main zones to the pool, all dominated by herbaceous species: a sparsely vegetated annual zone, an open herbaceous zone dominated by rice cut grass (*Leersia oryzoides*) and a zone dominated almost exclusively by reed canarygrass (*Phalaris arundinacea*). This is the only pool studied with a significant infestation of reed canarygrass.



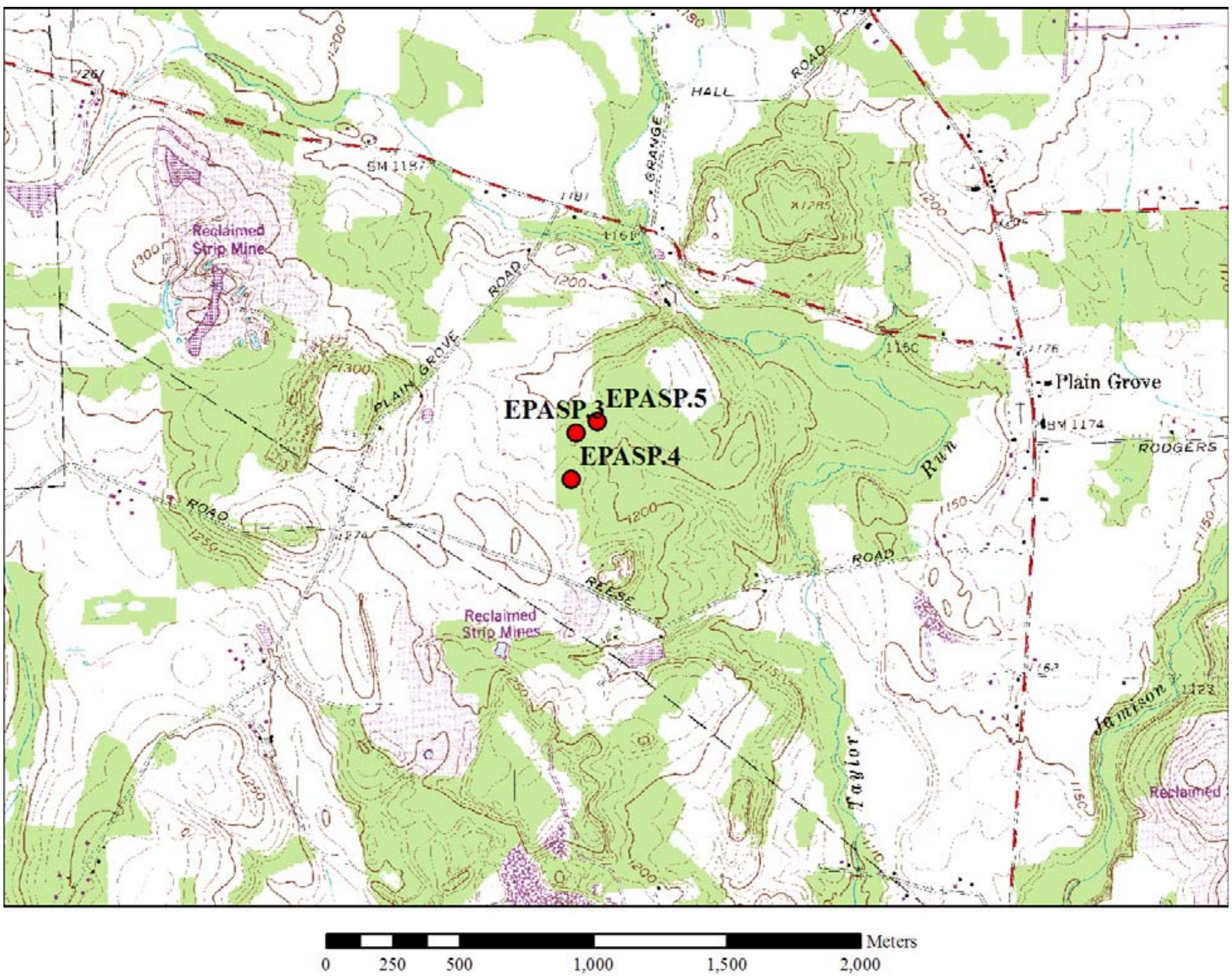
Site: EPASP.14, 15, 16 Pool names: SGL 216-1, 216-2, and 216-3
USGS 7.5’ Quadrangle: Harlansburg, Portersville, PA
Lawrence County, Slippery Rock, Scott Twps.
Location: New Castle, PA, 12.5 km E.

EPASP.14, 15, and 16 are situated within the Allegheny Plateau Subsection of TNC’s Western Allegheny Plateau Ecoregion in Lawrence County, PA. The pools are situated within a forested area of State Game Land 216, managed by the PGC. The pools are found within Red oak – mixed hardwood forest patches with red maple comprising the majority of the overstory immediately adjacent to the pools. The PGC has installed wood duck boxes in all three of the pools studied and all pools appear to hold water through much of the growing season. All three pools are closed canopy pools dominated by pin oak (Quercus palustris). While all have patches of sedges and rice cutgrass, most of the pool are is sparsely vegetated due to the overstory density and the length of inundation. Pool 16 has a significant shrub layer composed predominantly of button bush.



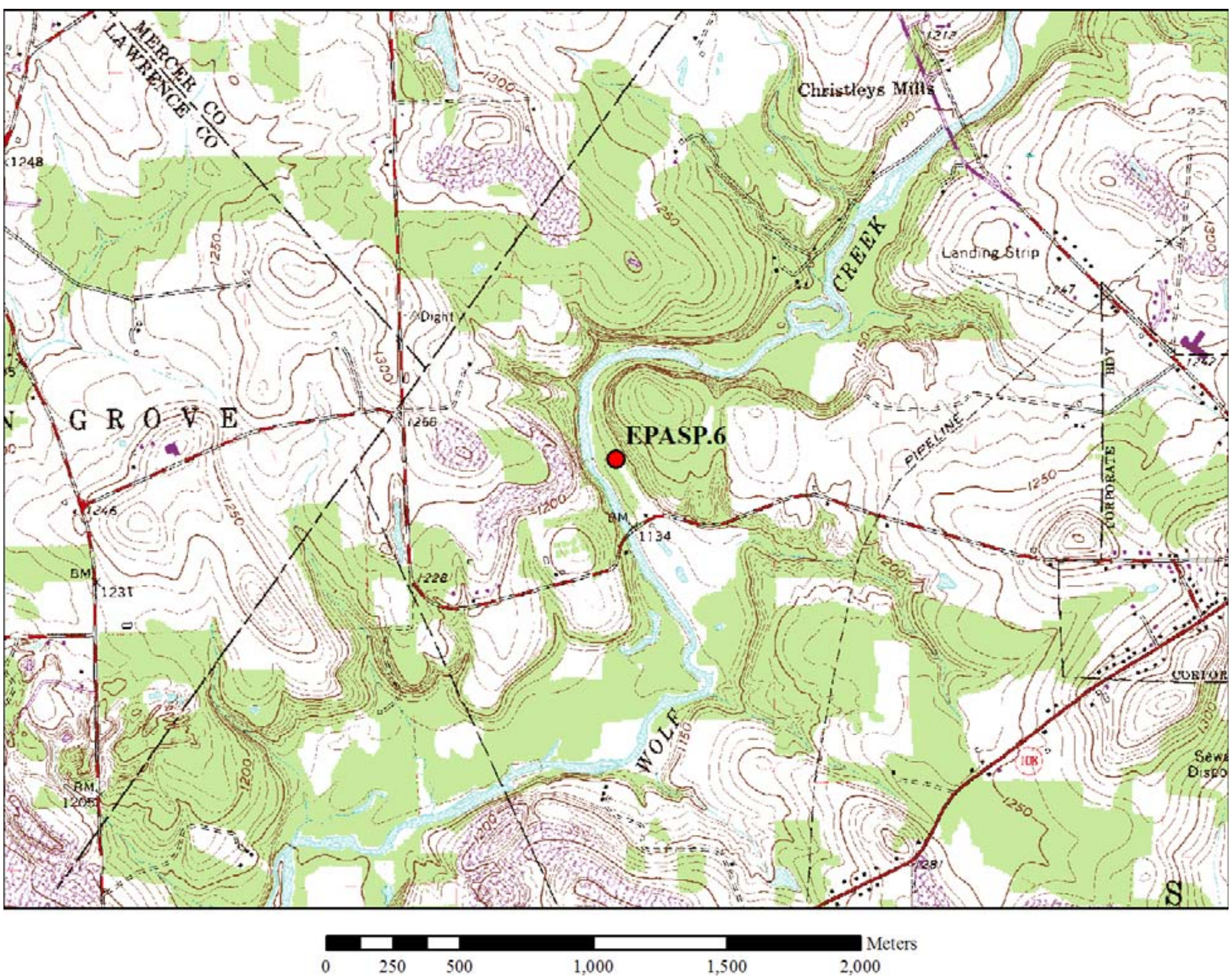
Site: EPASP.3, 4, 5 Pool names: Plain Grove 1, 2 and 3
USGS 7.5' Quadrangle: Harlansburg, PA
Lawrence County, Plaingrove Twp.
Location: Plaingrove PA,1.6 km W.

EPASP.2, 4, and 5 are situated within the Allegheny Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Lawrence County, PA. The three pools are found within Western Pennsylvania Conservancy's Plaingrove Fen Property, in a Northern hardwood forest. Red maple dominates the overstory of pools three and four. Black gum dominates the canopy of pool five. All three are sparsely vegetated with distinct shrub, annual, and black-leaf zones.



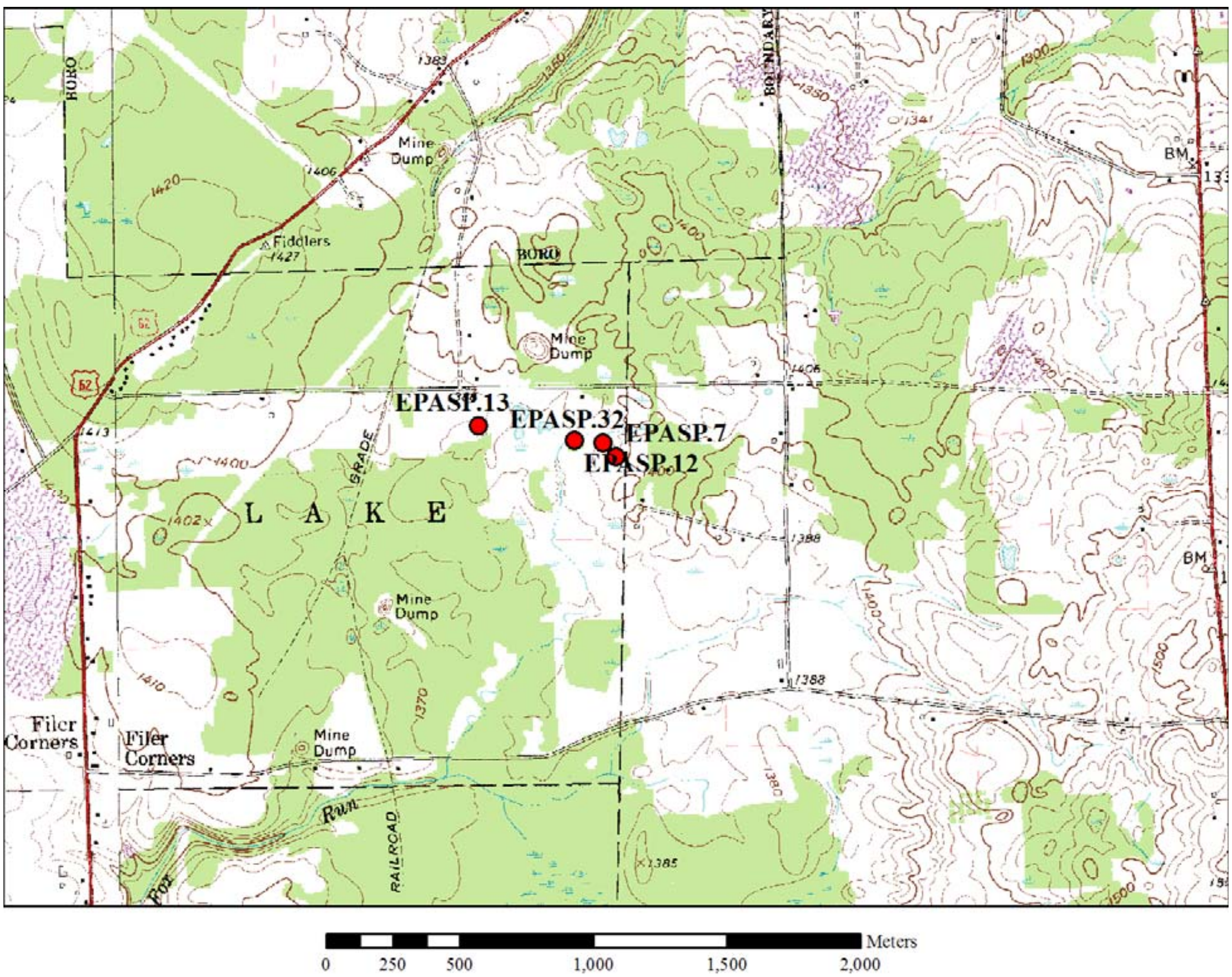
Site: EPASP.6 Pool name: Wolf Creek Narrows
USGS 7.5' Quadrangle: Slippery Rock, PA
Butler County, Slippery Rock Twp.
Location:, Slippery Rock PA, 2.5 km WNW.

EPASP.6 lies within the Allegheny Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Butler County, PA. The pool is situated on a high floodplain terrace within Western Pennsylvania Conservancy's Wolf Creek Narrows Property, within a Northern hardwood forest. The pool lies beneath a closed canopy dominated by swamp white oak and contains a sparsely vegetated black-leaf zone, an herbaceous margin, and a zone dominated by skunk cabbage. The skunk cabbage may suggest a permanent source of groundwater input in one area of the pool. The occurrence of several plant species, such as cardinal flower, more closely associated with moving water systems, is due to the close proximity to Wolf Creek. This site is believed to be outside of the floodplain; however it may be inundated periodically, during times of extreme flooding.



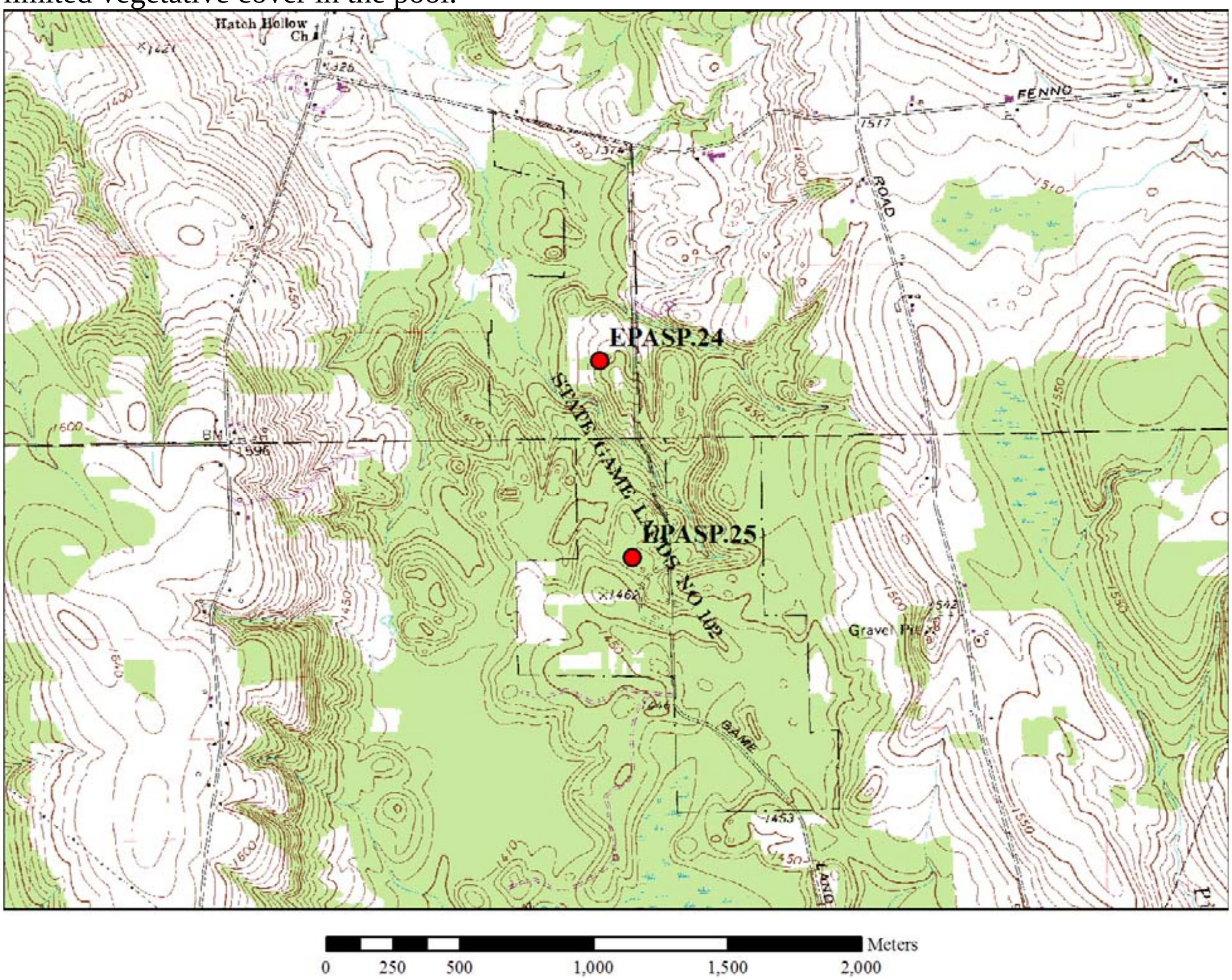
Site: EPASP.7, 12, 13, 32 Pool names: Lisica 1, 2, 3, and 4
USGS 7.5' Quadrangle: Sandy Lake, PA
Mercer County, Lake Twp.
Location: Stoneboro, PA, 2.5 km S.

EPASP.7, 12, 13, and 32 are situated within the Allegheny Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Mercer County, PA. The pool is situated on a broad and rolling ground moraine in a second growth forest dominated by red maple and pin oak. Two of the for pools (7 and 32) are small (XXX m2) and characterized as having closed canopies and sparse groundcover herbaceous layers. Plots 12 and 14 are larger, more open, and dominated by wool grass and other herbaceous wetland species.



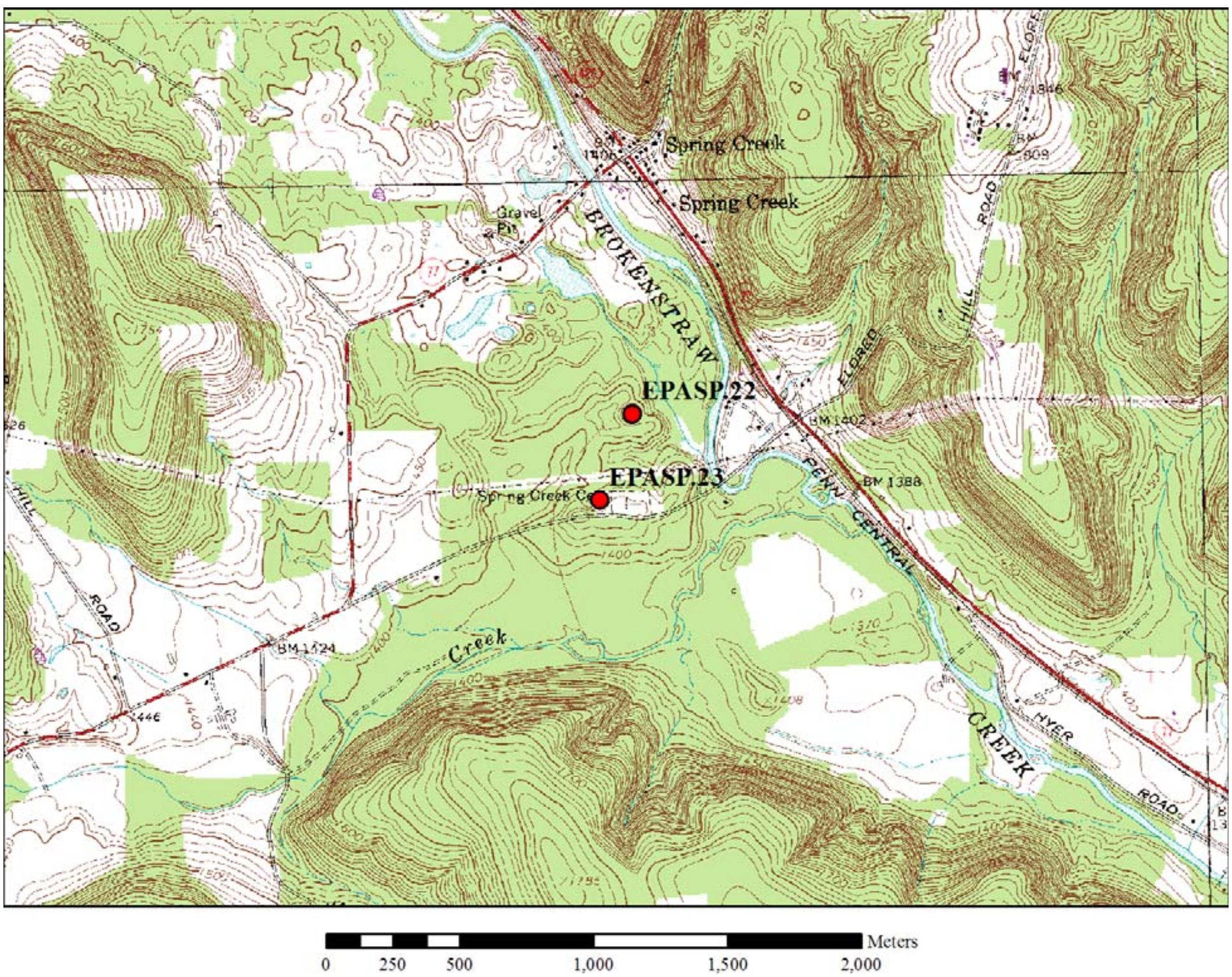
Site: EPASP.24, 25 Pool names: SGL 102-1, 102-2
USGS 7.5' Quadrangle: Unity, PA
Erie County, Amity, Union Twps.
Location: Union City, PA, 5 km NE.

EPASP.22 and 23 are situated within the Allegheny Plateau Subsection of TNC's Western Allegheny Plateau Ecoregion in Erie County, PA on State Game Land 102, near Union City, PA. Like EPA.21 and 22, the pools are situated within glacial kettle-hole features, ice-contact terrain and are defined by steeply sloping sides formed as large chunks of glacial ice melted in place. The two pools studied at this site occur within a Black cherry – northern hardwood forest containing black cherry, sugar maple, American beech, and red maple. Pool 24 contains three distinct zones: a central open graminoid-dominated zone, a sparsely vegetated area, and a meadowsweet (Spiraea alba) – shrub zone on the edge of the pool. Overstory trees, rooted in the steeply sloping kettle hole banks provide a nearly unbroken canopy over Pool 25 resulting in limited vegetative cover in the pool.



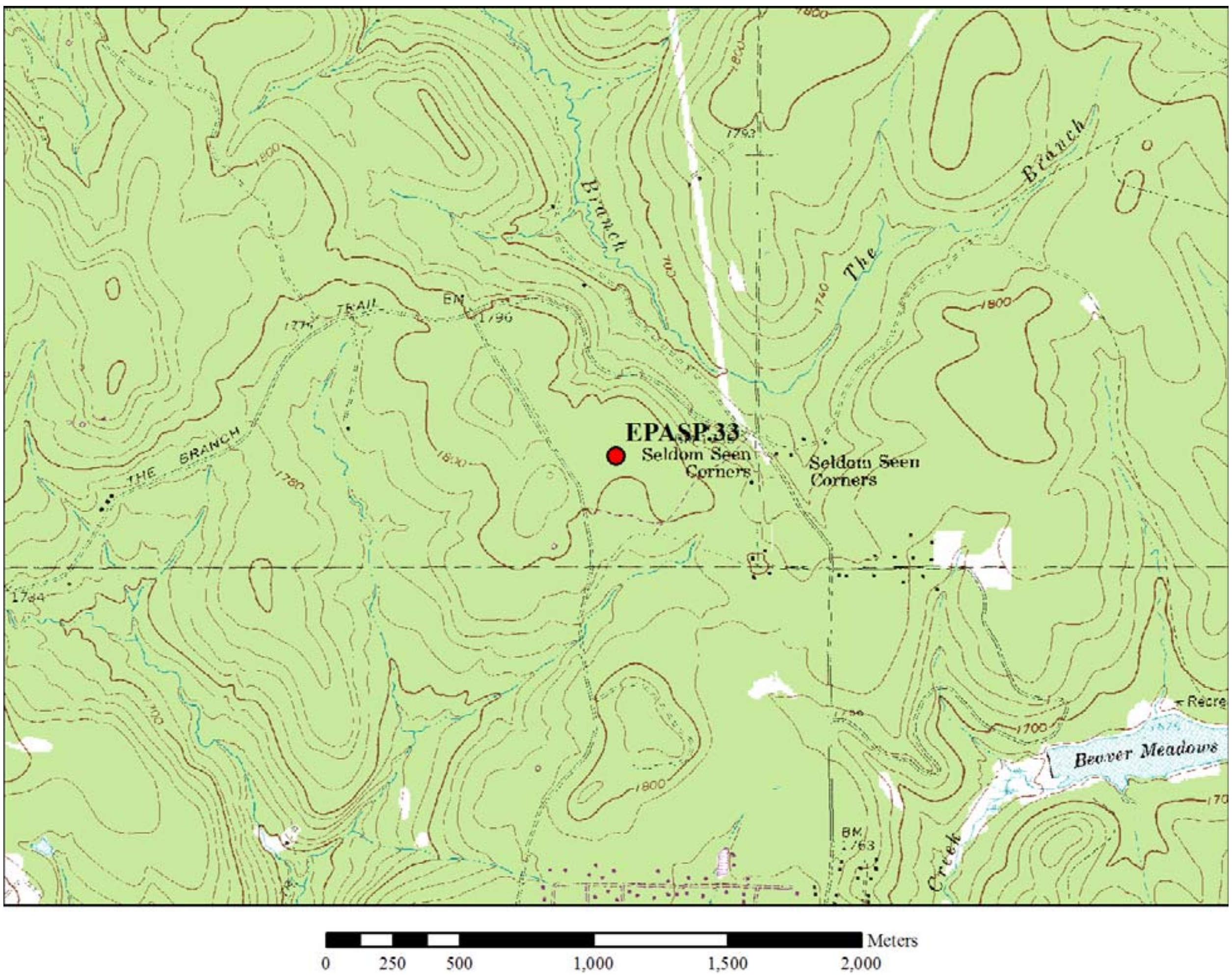
Site: EPASP.22, 23 Pool names: Spring Creek 1 and 2
USGS 7.5’ Quadrangle: Spring Creek, PA
Warren County, Spring Creek Twp.
Location: Corry, PA, 11.0 km SE.

EPASP.22 and 23 are situated within the Allegheny Plateau Subsection of TNC’s Western Allegheny Plateau Ecoregion in Warren County, PA. The pools are situated within glacial kettle-hole features, ice-contact terrain above the Spring Creek floodplain, which is a tributary to the Brokenstraw Creek. The pools occur within a Northern hardwood forest containing sugar maple, American beech, and red maple. Eastern hemlock is also present in the surrounding forest. These overstory trees, rooted in the steeply sloping kettle hole banks provide a nearly unbroken canopy over Pool 22. The vegetation of Pool 22 is sparse, containing a sparsely vegetated zone and open water zone supporting emergent bur reed (*Sparganium* sp.) and blue flag iris (*Iris versicolor*). The non-native (*Solanum dulcamara*) is also present in this pool. Pool 23, located nearby Pool 22, is larger, shallower and supports a much more open canopy. The pool supports an open sedge and grass zone. There is also a distinct zone dominated by silky willow (*Salix sericea*), and a sparsely vegetated zone beneath a canopy of red maple and yellow birch.



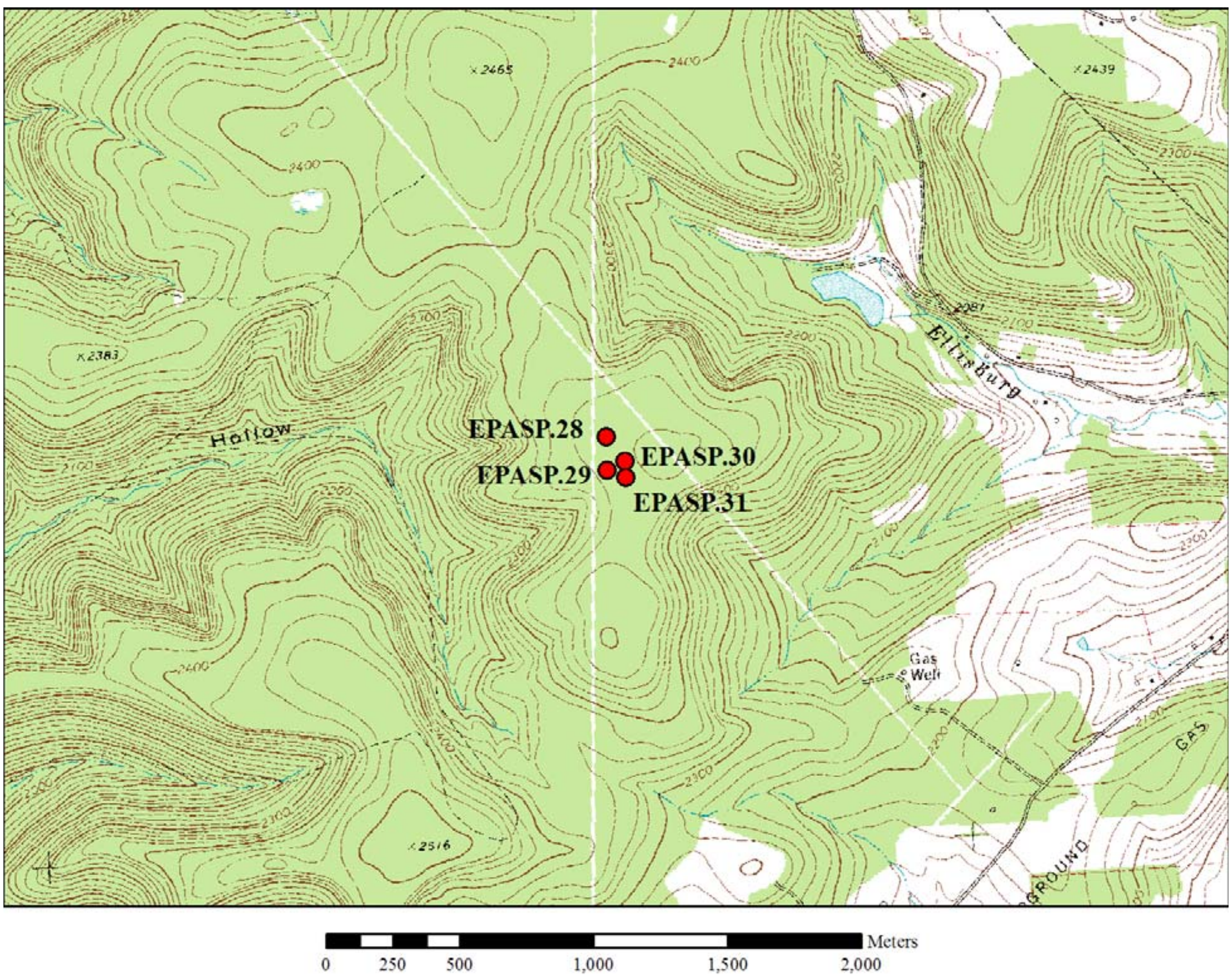
Site: EPA.33 Pool name: Allegheny National Forest
USGS 7.5' Quadrangle: Mayburg, PA
Forest County, Howe Twp.
Location: Marienville, PA, 6.8 km N.

EPA.33 is situated within the Allegheny High Plateau Subsection of TNC's High Allegheny Plateau Ecoregion in Forest County, near Marienville, PA. This pool, occurring in the Allegheny National Forest, is located on a high forested plateau supporting northern hardwood and Black cherry – northern hardwood forests. One pool was studied within this area and was the only pool holding water in the spring of 2008; however, several additional small depressions may represent seasonal pool habitats in wetter years. The pool is small and represents pools characteristic of tip up, pit and mound topography. Pool 33 was sparsely vegetated and contained only scattered seedlings of woody plants and upland herbaceous species, such as cucumber root (*Medeola virginica*).



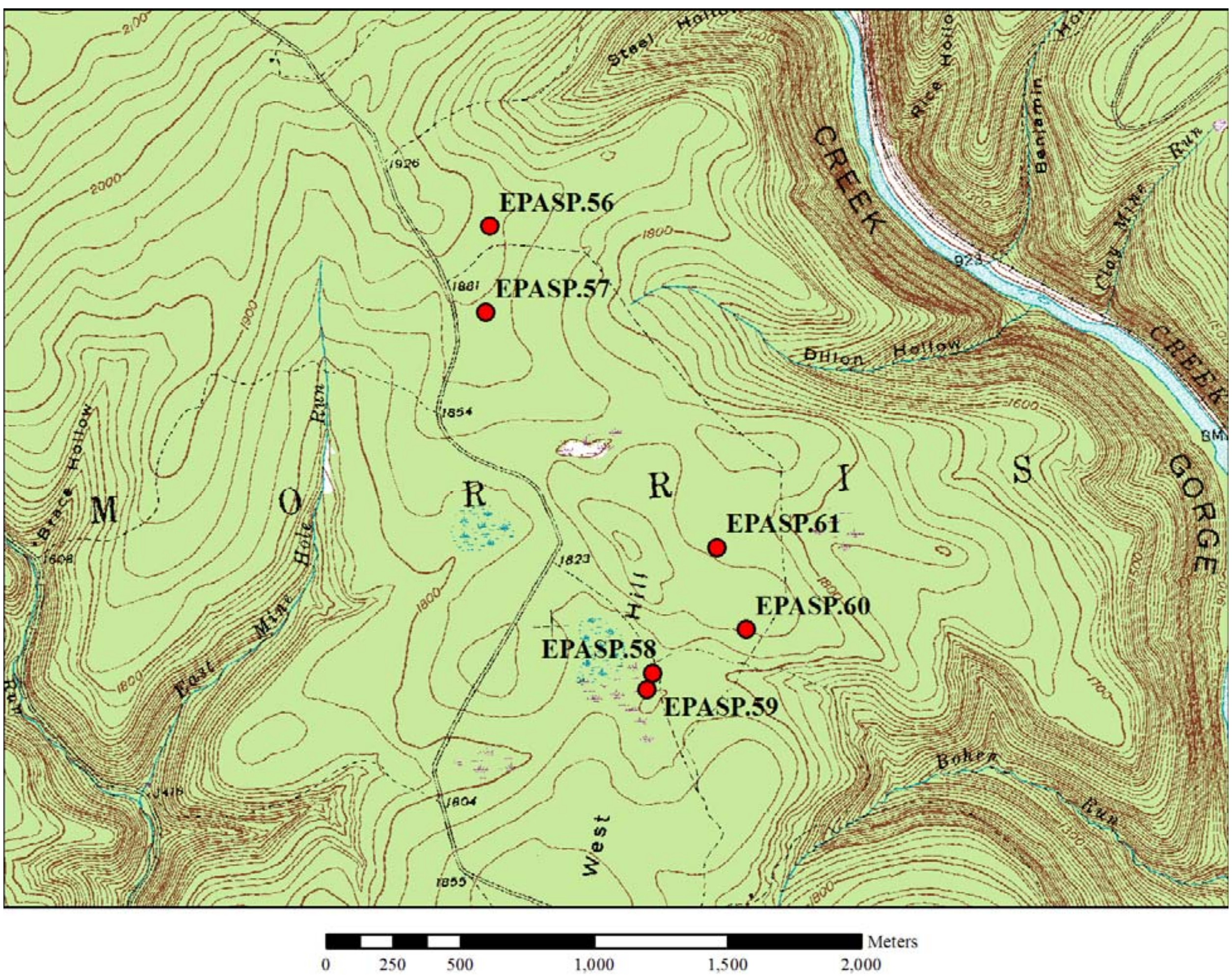
Site: EPA.28, 29, 30, 31 Pool names: Ellisburg 1, 2, 3, and 4
USGS 7.5' Quadrangle: Ellisburg, PA
Potter County, Genesee Twp.
Location: Ellisburg, PA, 3.0 km W.

EPA.28, 29, 30, and 31 are situated within the Cattaraugus Highlands Subsection of TNC's High Allegheny Plateau Ecoregion in Potter County, near Ellisburg, PA. The pools, identified in the Potter County Natural Heritage Inventory are located on a high forested plateau supporting northern hardwood and Black cherry – northern hardwood forests. The pools themselves are surrounded by a forest with an overstory predominantly composed of red maple. The four pools are small and represent pools characteristic of tip up, pit and mound topography. The pools range from unvegetated black leaf sites with scattered sedges (Pool 28) to pools with a high percent cover of graminoids (*Carex baileyi, C. brunnescens*) (pools 29, 30, 31).



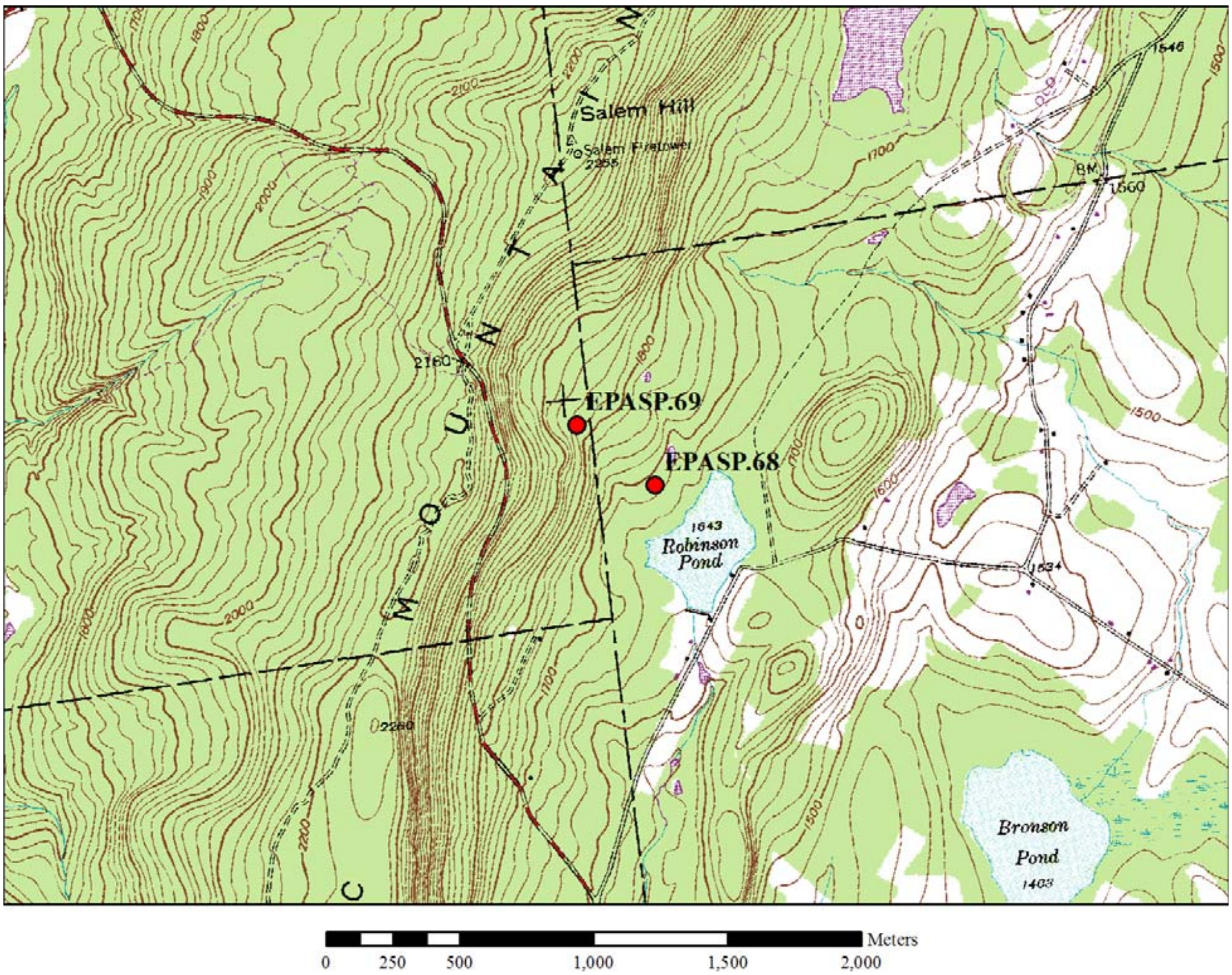
Site: EPASP.56, 57, 58, 59, 60, and 61   Pool names: West Rim N11, N2, S11, S2, S3, and S7
USGS 7.5' Quadrangle: Cedar Run, PA
Tioga County, Morris Twp.
Location: Blackwell, PA 4.5 km NNW

EPASP.56, 57, 58, 59, 60, and 61 fall within the Allegheny Deep Valleys Subsection of TNC's High Allegheny Plateau Ecoregion in Tioga County, PA. They are located within Tioga State Forest along the west rim of the Pine Creek Gorge. The forest canopy surrounding these pools includes red maple, black gum, white pine, birch, and oak. Pools 57 and 60 are mostly black-leaf pools. Pool 57 resembles an old winding streambed. Pool 58 is mostly surrounded by white pine. The pool has a partial open canopy with a black-leaf zone and some open areas that are covered with grasses, sedges and mosses. A portion of Pool 56 extends into an adjacent swamp forest. This pool is dominated by sedges with a mixed low herbaceous layer. Pools 59 and 61 are poorly drained and have partial open canopies. Sedges dominate these pools. Pools 56, 59 and 61 contain the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*).



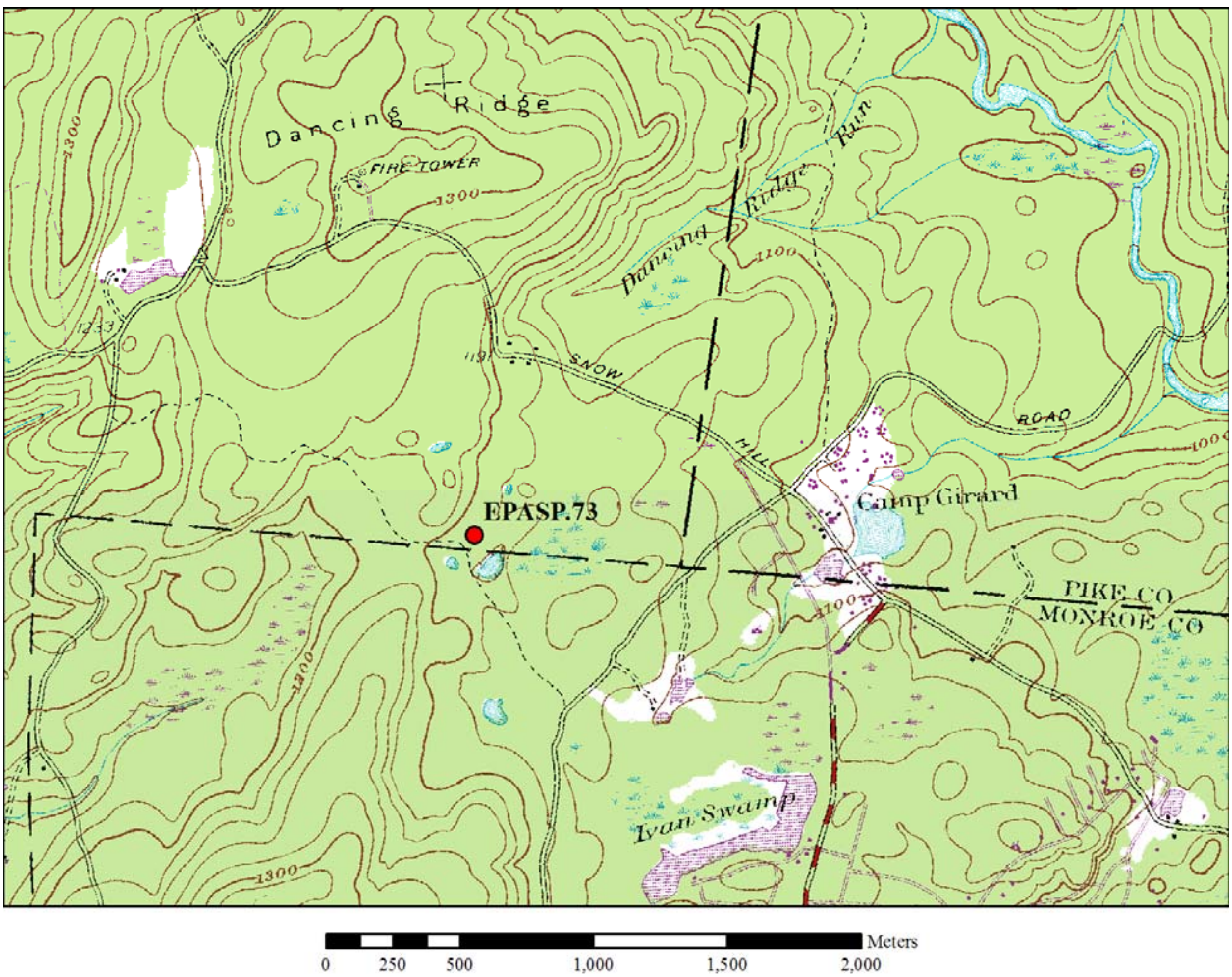
Site: EPASP.68 and 69 Pool name: SGL 300-1, 300-2
USGS 7.5 Quadrangle: Waymart, PA
Wayne County, South Canaan Twp and Lackawanna County, Carbondale Twp.
Location: Carbondale, PA, 5 km SE

EPASP.68 and 69 fall within the Eastern Allegheny Plateau Subsection of TNC's High Allegheny Plateau Ecoregion in Wayne County, PA and are part of State Game Land 40. Pool 68 is mostly black-leaf with scattered patches of sphagnum. Red maple, white oak and black birch make up the nearly closed canopy with trees growing on the edge and in the pool. Pool 69 is well circumscribed with a partially open canopy dominated by blackgum, red maple and black birch. At least 75% of the pool contained water in early August. The shallower waters have emergent vegetation.



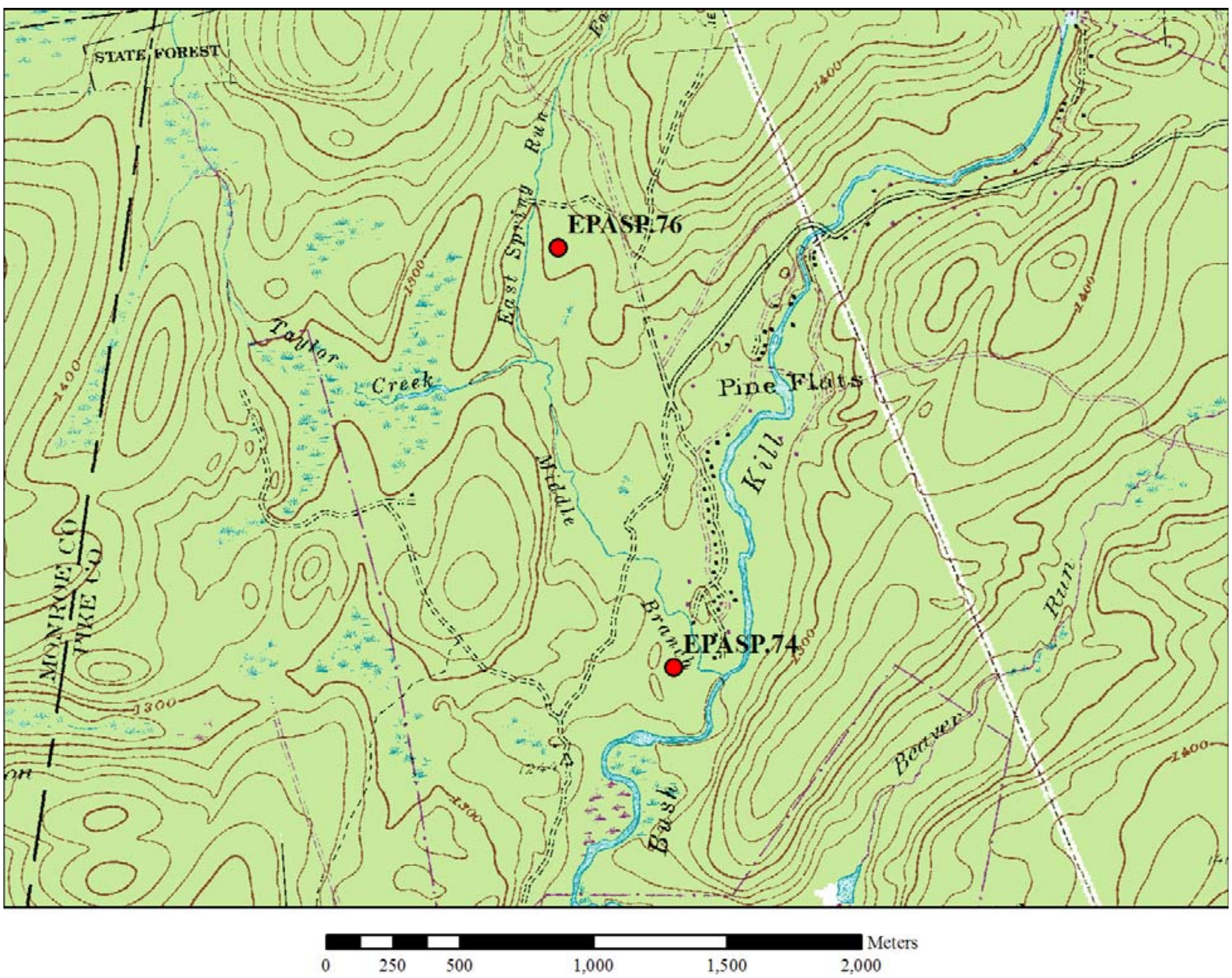
Site: EPASP.73 Pool name: Delaware State Forest – 14
USGS 7.5 Quadrangle: Skytop, PA
Monroe County, Middle Smithfield Twp.
Location: Henryville, PA 9 km NW

EPASP.73 is situated within the Eastern Allegheny Plateau Subsection of TNC's High Allegheny Plateau Ecoregion in Monroe County, PA and is a part of the Delaware State Forest. The pool sits in a basin and is under a partial canopy dominated by red oak, white oak and black birch. The understory is composed of witch-hazel, blueberries, dangleberries and winterberry. There is little species diversity within the pool. The soil surface is rocky but covered with moss/sphagnum and leaf litter. Only a few herbs are present.



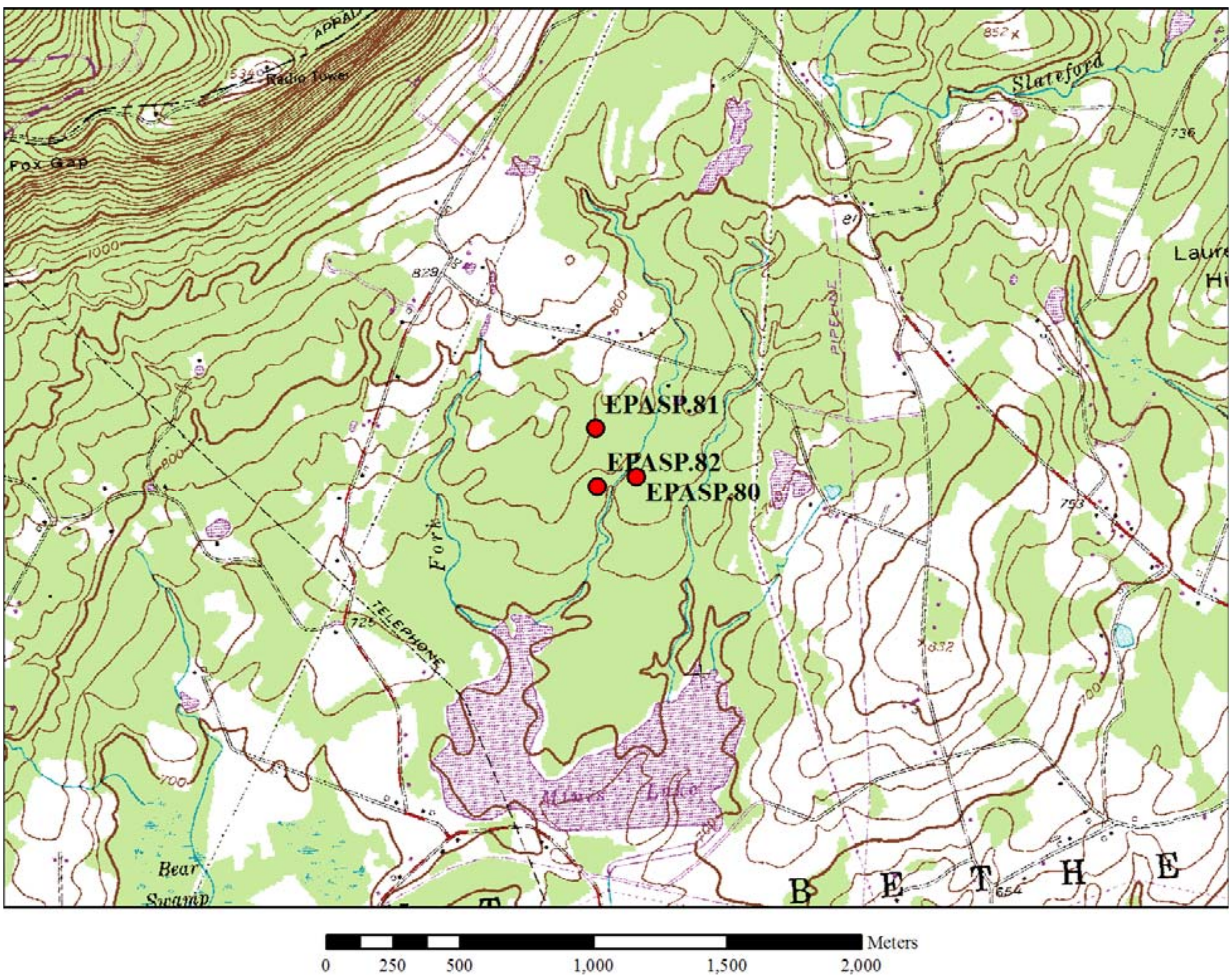
Site: EPASP.74 and 76   Pool names: Delaware State Forest – 32 and 46
USGS 7.5 Quadrangle: Twelvemile Pond, PA
Pike County, Porter Twp.
Location: Pine Flats, PA EPASP.74, 1 km S and EPASP.76, 1 km NW

EPASP.74 and 76 are situated within the Eastern Allegheny Plateau Subsection of TNC's High Allegheny Plateau Ecoregion in Pike County, PA and are a part of the Delaware State Forest. Pool 74 contained water in early August. The south side of the pool is under partial canopy while the rest is mostly open. Red oak, black ash and shagbark hickory make up the canopy surrounding the pool. The pool is vegetated with most species scattered throughout and not in clearly defined zones. Buttonbush, sedges, blueberries, cranberries, and spiraea are present. Pool 76 is sparsely vegetated. It would normally be under a closed canopy of red maple and white oak, but the overstory leaves appear damaged. Because the pool is nearly full in mid-summer suggests possible groundwater influence. The area surrounding the pool is very rocky.



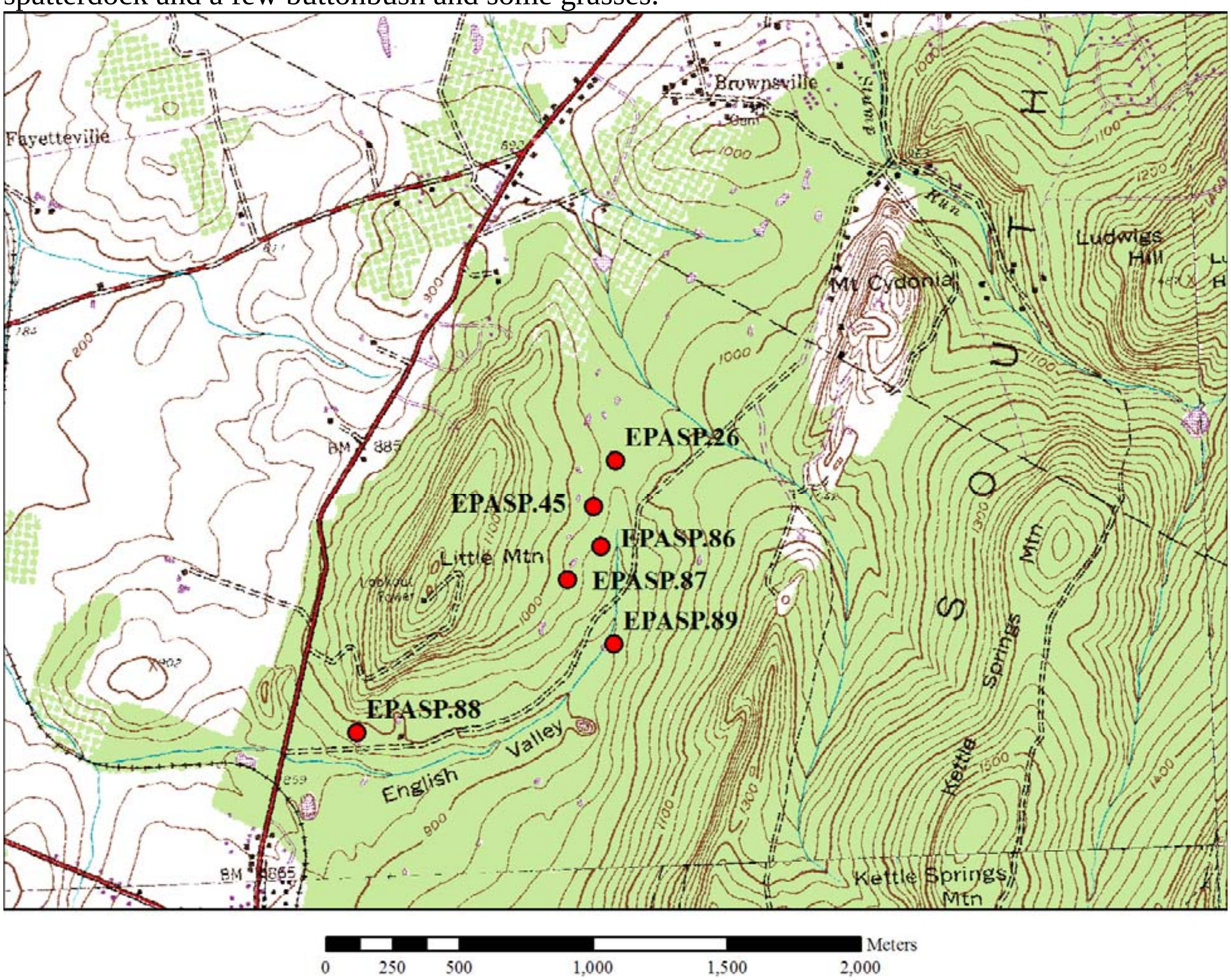
Site: EPASP.80, 81, 82 Pool names: Minsi 1, 9 and 14
USGS 7.5 Quadrangle: Stroudsburg, PA
Northampton County, Upper Mt. Bethel Twp.
Location: North Bangor, PA, 3 km NE

EPASP 80, 81, and 82 are situated within the Kittatinny-Shawangunk Ridge Subsection of TNC's High Allegheny Plateau Ecoregion in Northampton County, PA. The pools are within a forest dominated by red maple, blackgum, white oak, tuliptree and American beech. Pool 80 is in a very shallow depression with a mostly closed canopy. It is a black-leaf pool with sparse vegetation. Pool 81 is also black-leaf with a partially closed canopy and some sparse vegetation; highbush blueberry dominates the pool edge. Pool 82 is vegetated with buttonbush, royal fern and a few patches of iris under a partially closed canopy but is not very diverse in terms of vegetation.



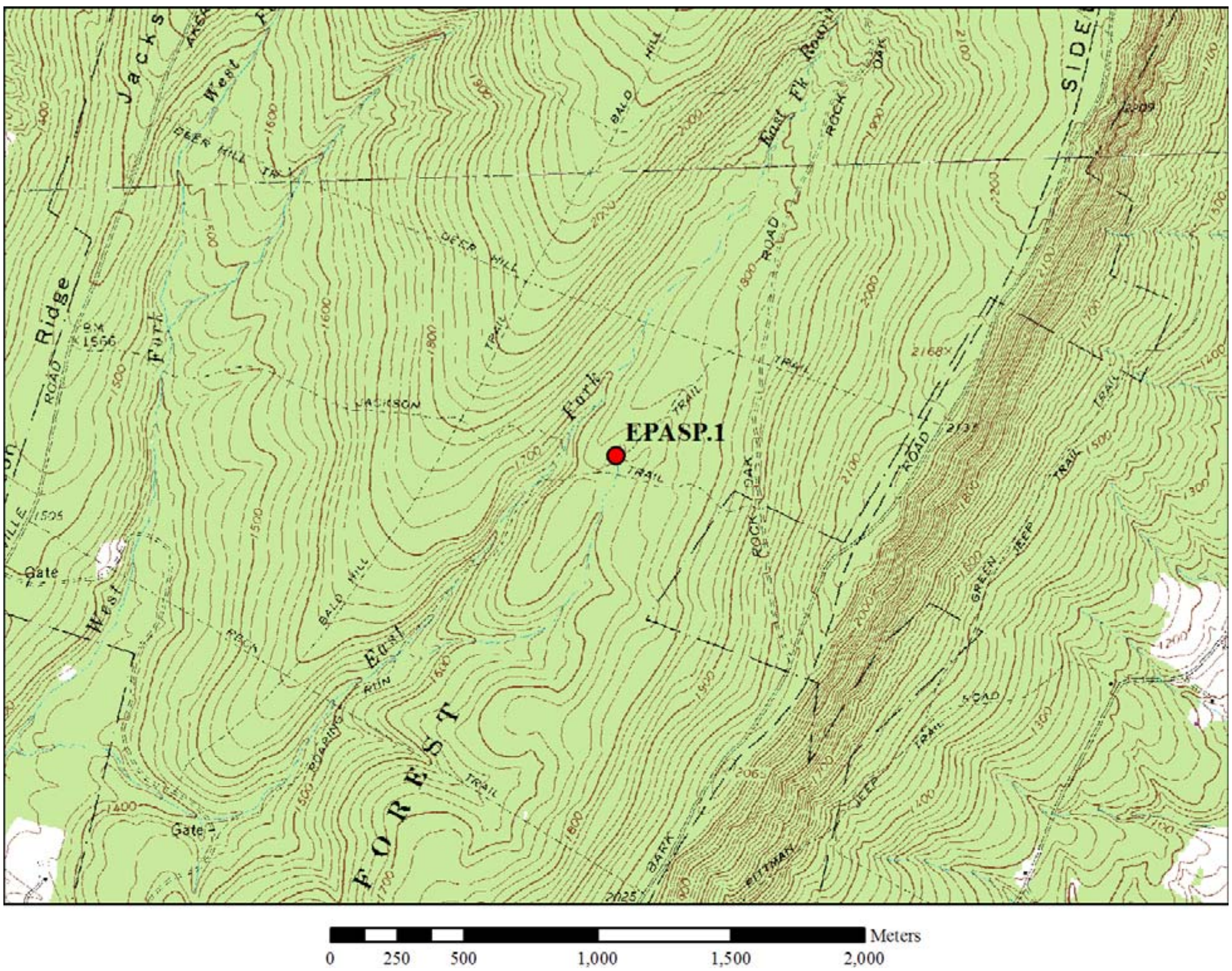
Site: EPASP.26, 45, 86, 87, 88, 89   Pool names: Mt. Cy: W3, W2, W1, W-16, S1, Lily
USGS 7.5' Quadrangle: Scotland, PA
Franklin County, Guildford Twp.
Location: Brownsville, PA, 2 km S

EPASP. 26, 45, 86, 87, 88, and 89 are within the Northern Great Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Franklin County, PA. They are a part of Michaux State Forest. Red maple dominates the canopy at all six pools along with black gum and various oak species. Pool 26 has a large overarch zone and a shrub layer along the pool edge with mostly leaf litter and woody debris. Buttonbush dominates the center of the pool. Pool 45 is a large open pool. Buttonbush and pale meadowgrass dominate the pool basin along with some three-way sedge. Pool 86 is defined by an overarch zone with much woody debris and a few sparse herbs and another area dominated by panic grass. Pool 87 is under closed canopy. At the northern end of the pool is a tangle of catbrier. The remainder of the pool is black-leaf and woody debris. The pool appears as a shallow basin and may be a rapidly drying pool.
Pool 88 is completely vegetated except for overhang areas where there is leaf litter and woody debris. Although there are discrete zones of sedges, grasses and buttonbush, most zones are a mix with little diversity. Pool 89 held a small pool of water at the end of July with a zone of spatterdock and a few buttonbush and some grasses.



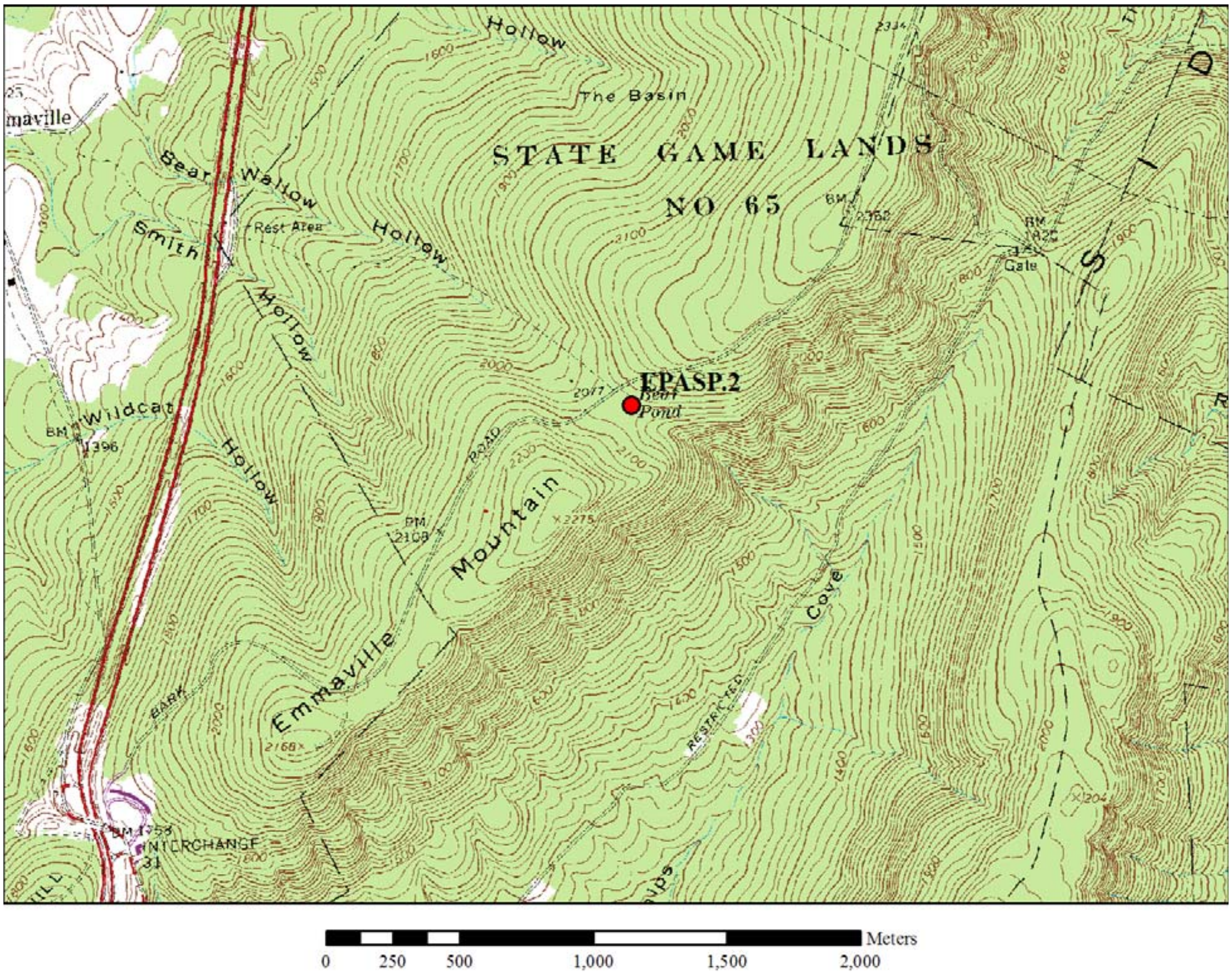
Site: EPASP.1 Pool name: Roaring Run 1
USGS 7.5' Quadrangle: Breezewood, PA
Fulton County, Brush Creek Twp.
Location: Green Hill PA, 5.5 km W

EPASP.1 is situated within the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion on Emmaville Mountain, within Buchannan State Forest, in Fulton County, PA. The pool lies along a broad forested step of the supporting a second growth-forest of white and chestnut oaks, black gum, and red maple. The understory is composed of sweet birch, red maple, witch-hazel and blueberries. The pool has two distinct zones that include a zone beneath a dense canopy of red maple and black gum, and an open sedge-graminoid zone, dominated by sedges (*Carex* spp.), creeping mannagrass (*Glyceria acutiflora*), and wool grass (*Scirpus cyperinus*).



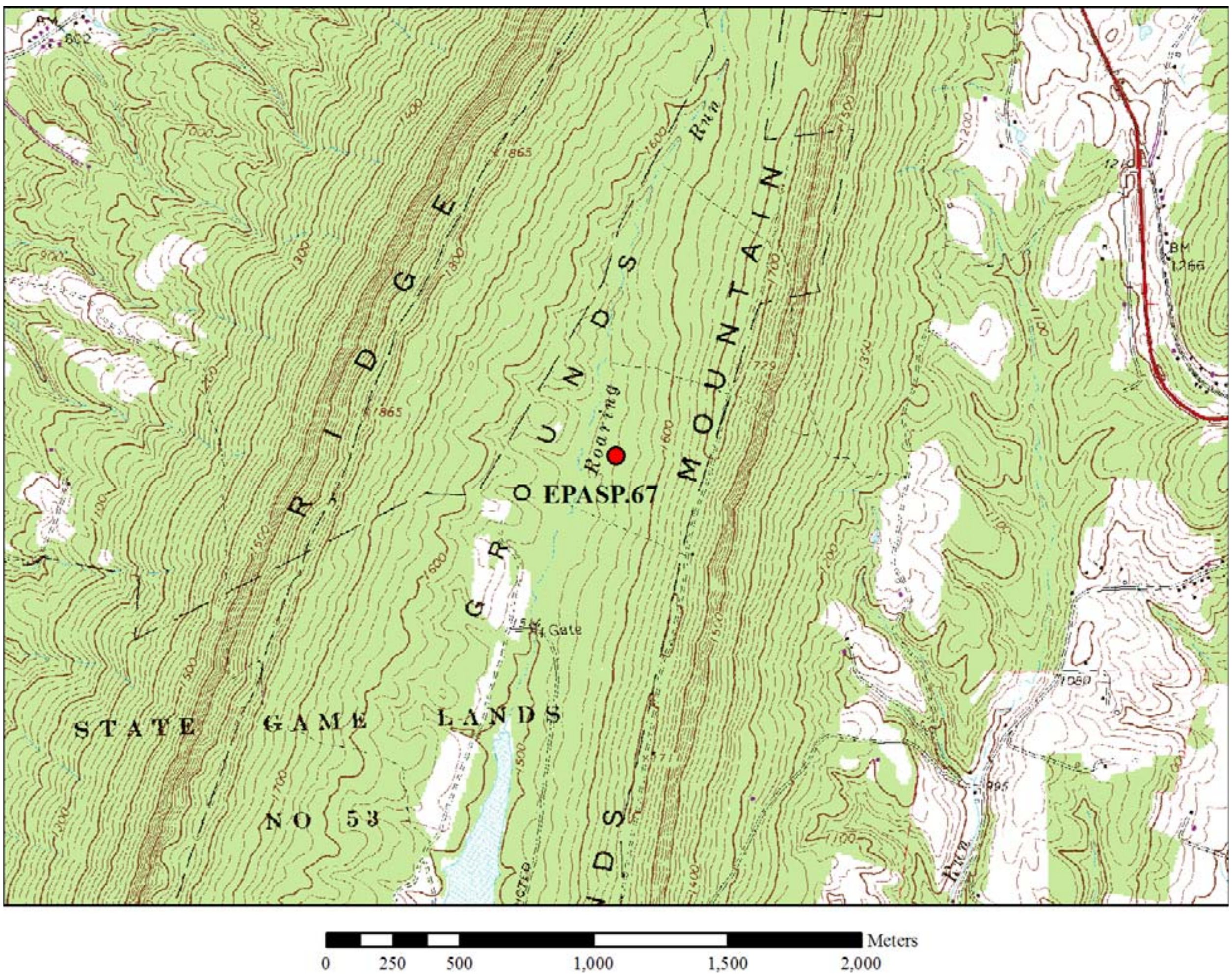
Site: EPASP.2 Pool name: Bear Wallow
USGS 7.5’ Quadrangle: Breezewood, PA
Fulton County, Brush Creek Twp.
Location: Needmore, PA, 8 km NW

EPASP.2 lies within the Northern Ridge and Valley Subsection of TNC’s Central Appalachian Forest Ecoregion on Emmaville Mountain, within State Game Lands 65, in Fulton County. The pool, identified as Bear Pond or Bear Wallow is found along a broad forested saddle supporting a second growth-forest of white and chestnut oaks, black gum, and red maple. The understory of the surrounding forest is composed of sweet birch, red maple, witch-hazel and blueberries. The only pool studied at this site is open and shallow and dominated by herbaceous species, predominantly rice cut grass (*Leersia oryzoides*). This pool contains the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*).



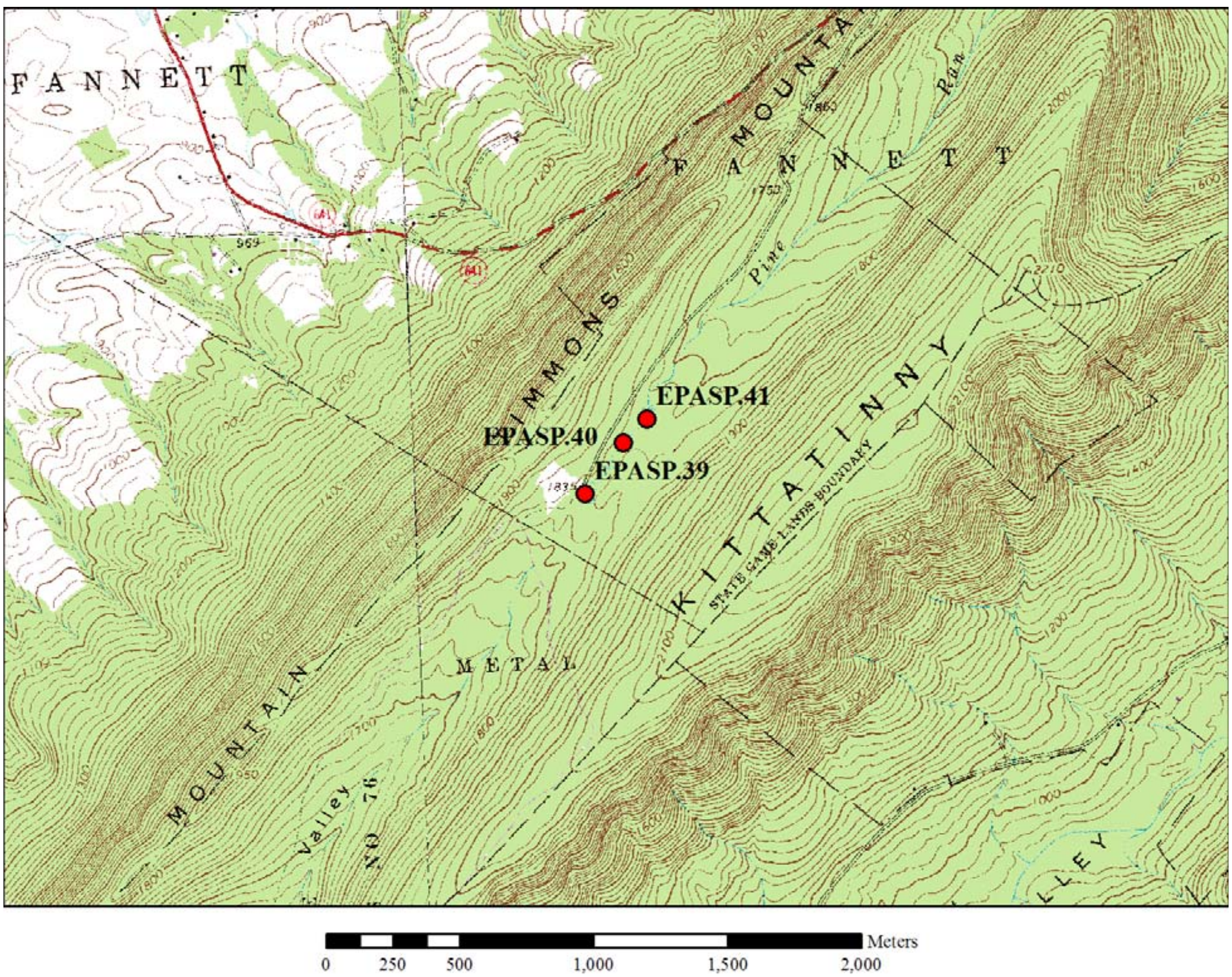
Site: EPASP.67 Pool name: Meadow Grounds 4
USGS 7.5' Quadrangle: Meadow Grounds, PA
Fulton County, Ayr Twp.
Location: McConnellsburg, PA, 4 km W

Site: EPASP.67 is situated in the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Fulton County, PA. The site is within State Game Land 53. The pool is dominated by ferns and low shrubs. Red maple makes up the dominant canopy surrounding the pool. The pool has a partly open canopy. Grasses, sedges and herbs dominate the pool basin.



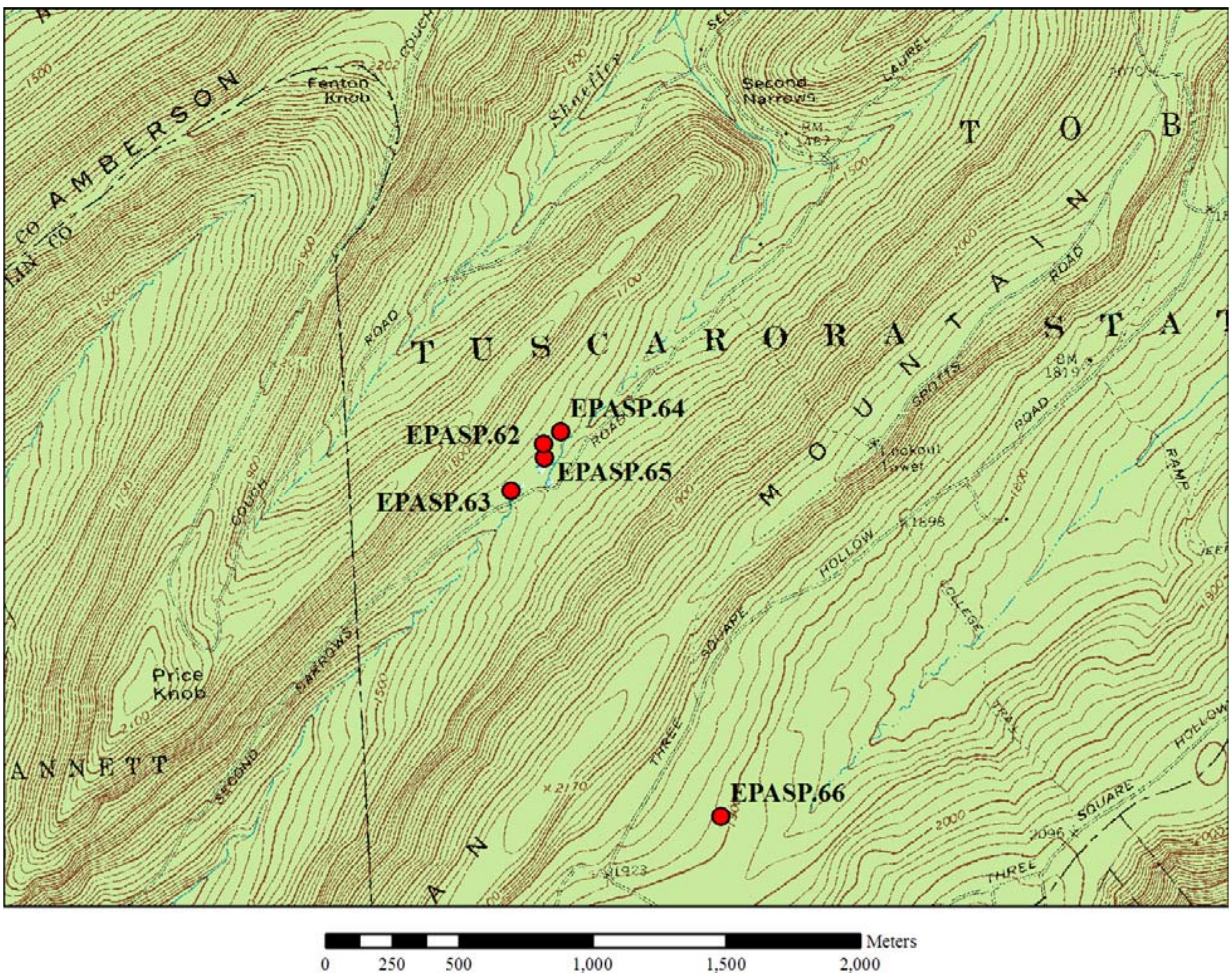
Site: EPASP.39, 40, and 41 Pool names: SGL 76 - 12b, 14, and 4
USGS 7.5' Quadrangle: Roxbury, PA
Franklin County, Fannett Twp.
Location: Roxbury, PA, 6.5 km W

EPASP 39, 40 and 41are situated in the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Franklin County, PA. They are a part of State Game Land 76. Red maple, black gum and black birch dominate the canopy surrounding these pools. Pools 39 and 40 are under mostly open canopy and are vegetated. Grasses and sedges dominate the in-pool vegetation. Ferns dominate over half of Pool 40 along with lesser amounts of grasses and sedges. Pool 41 is mostly unvegetated.



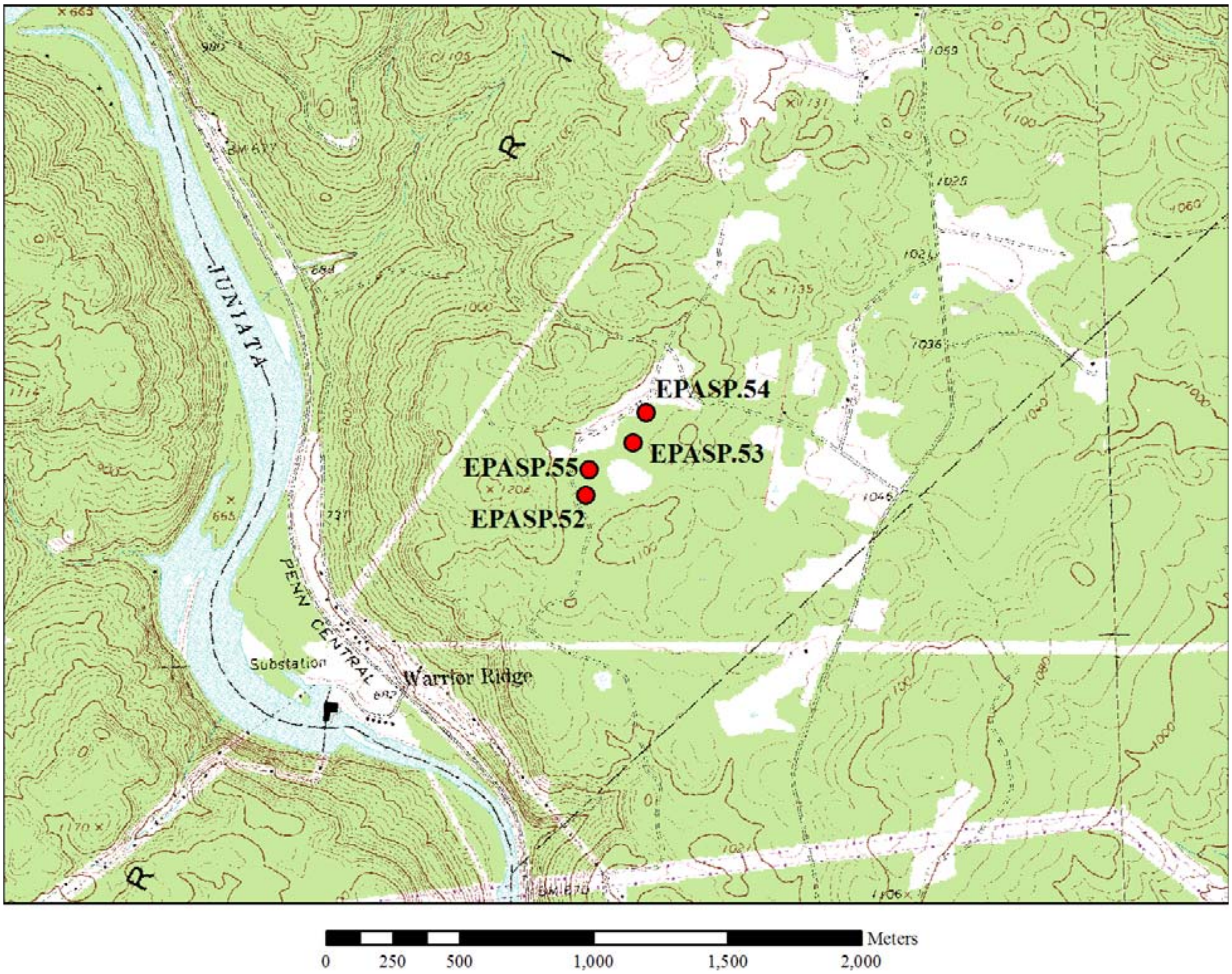
Site: EPASP.62, 63, 64, 65 and 66   Pool names: Second Narrows 1, 4, 5, and 6, Three-square
USGU 7.5' Quadrangle: Newburg, PA
Perry County, Toboyne Twp.
Location: McKinney, PA, 7.5 km N

EPASP.62, 63, 64, 65 and 66 are located within the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Perry County, PA and are within the Tuscarora State Forest. The pools are located in a basin floor with the exception of Pool 66 which sits in a depression along a midslope. Black gum, black birch, and red maple make up the dominate canopy surrounding these pools. Pool 62 is an unvegetated pool under a mostly closed canopy. Pools 63 and 64 have a partial open canopy with sparse vegetation. Pool 65 is a vegetated, open canopy pool dominated by three-way sedge. This pool contains the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*). Pool 66 is mostly closed canopy and is vegetated by grasses and sedges.



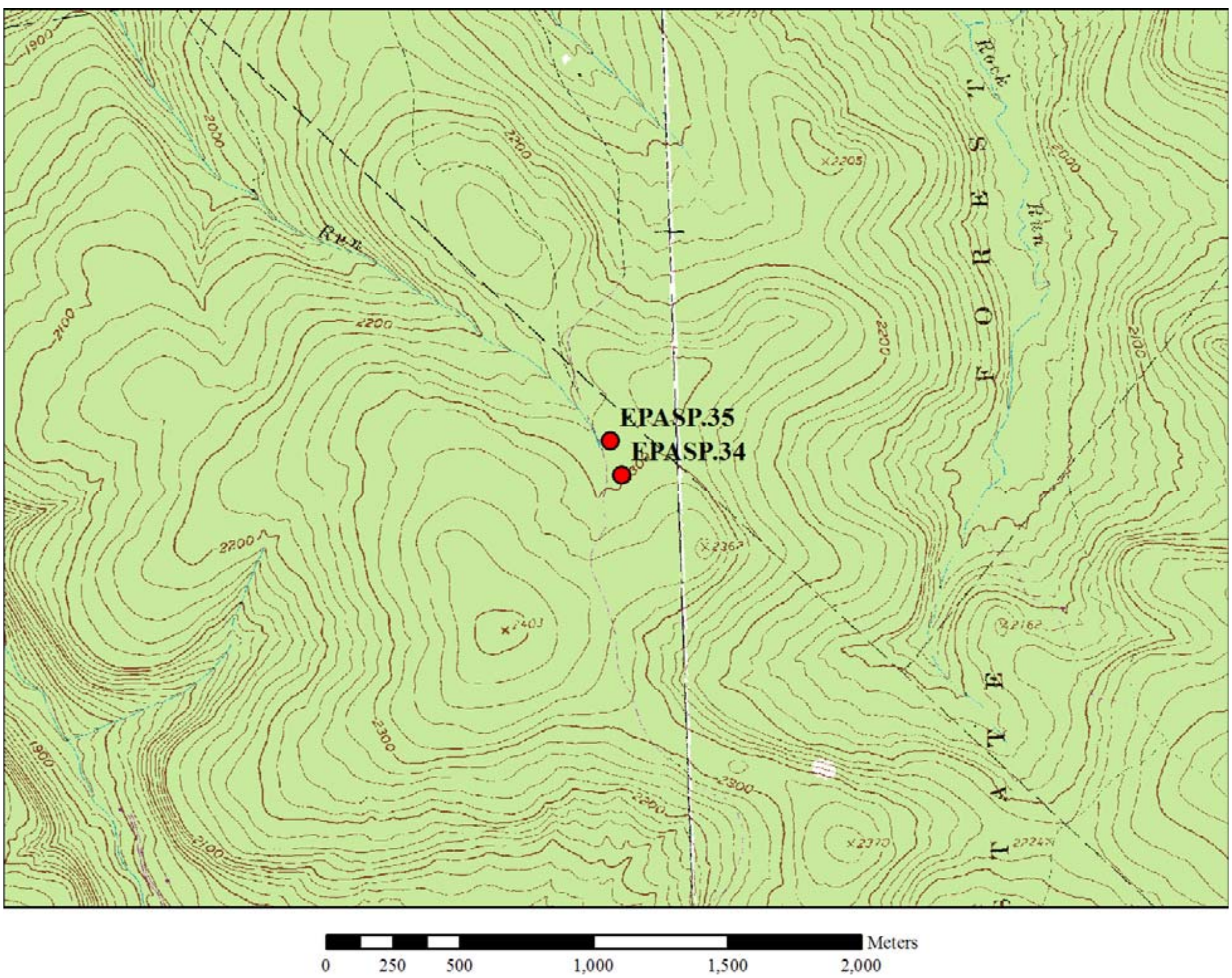
Site: EPASP.52, 53, 54, and 55 Pool names: SGL322 – 0, 5, 9, B
USGS 7.5’ Quadrangle: Alexandria, PA
Huntingdon County, Logan Twp.
Location: Warrior Ridge, PA 0.9 km NE

EPASP.52, 53, 54, and 55 are situated in the Northern Ridge and Valley Subsection of TNC’s Central Appalachian Forest Ecoregion in Huntingdon County, PA. The pools are within State Game Land 322 near Warrior Ridge in a red oak-mixed hardwood forest. All four pools are vegetated. Pool 55 has a mostly closed canopy with shrubs and an herb layer. Pool 54 is a shallow, partially open pool that is nearly completely vegetated by shrubs, grasses, sedges and ferns. Over half of Pool 53 is dominated by winterberry and Winterberry surrounds Pool 52; sedges grow in the center.



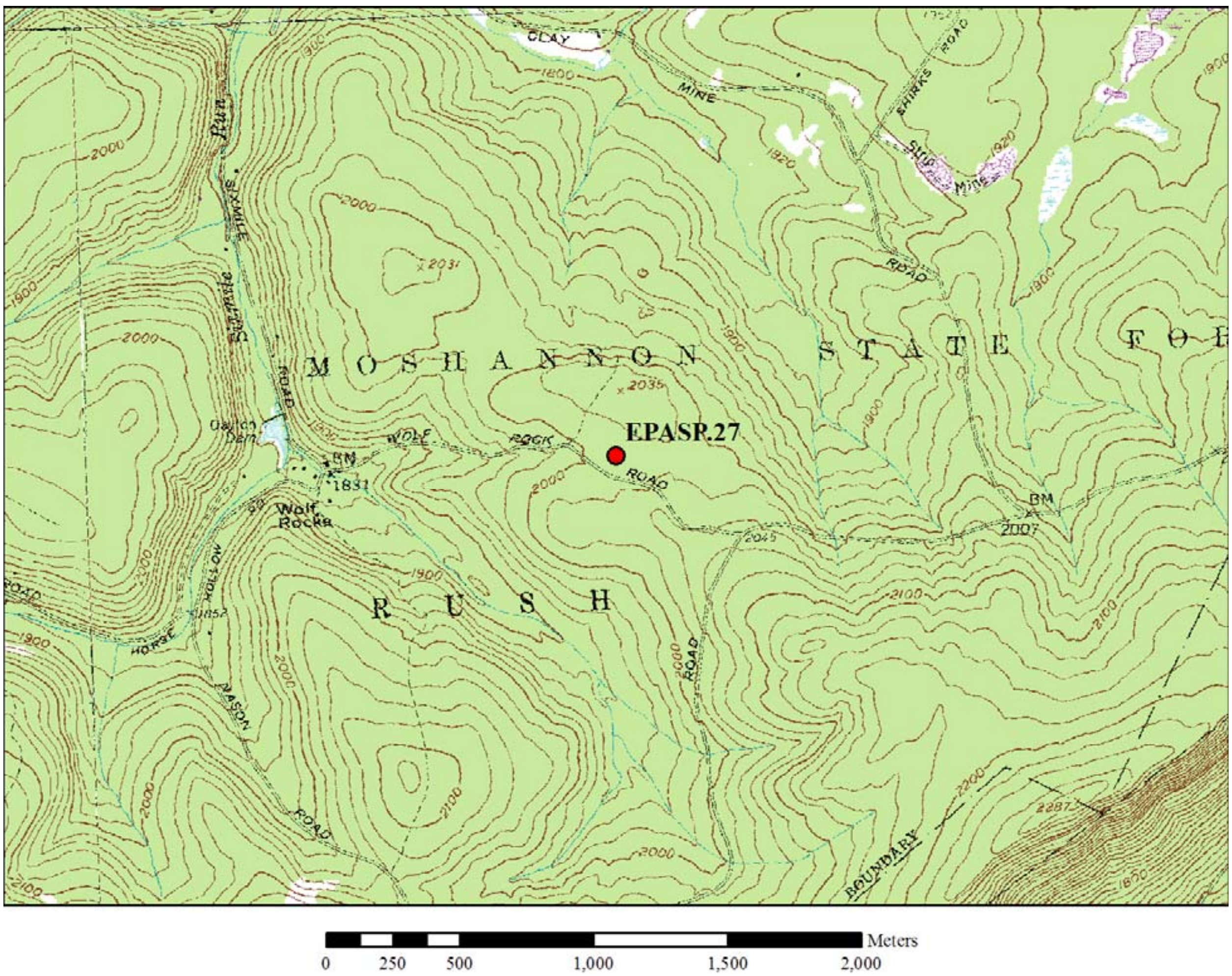
Site: EPASP.34 and 35 Pool names: Black Moshannon 5 and 6
USGS 7.5' Quadrangle: Black Moshannon, PA
Centre County, Rush Twp.
Location: Julian, PA, 11 km SE

EPASP. 34 and 35 are part of the Allegheny Mountain Plateau Subsection of TNC's Central Appalachian Forest Ecoregion in Centre County, PA. The pools are within Black Moshannon State Forest. Red maple and white oak dominate the area around the pools. Both pools are almost completely vegetated except for a few overarch zones. Pool 34 is filled with both grasses and sedges. Pool 35 is a large horseshoe shaped pool with two lobes and a narrow isthmus between them that is covered by a dense swath of royal fern. The pool is mostly open canopy. During the spring, the lobes are joined but later appear separated as the pool dries down. Both lobes are similar in species composition with zones of grasses and sedges.



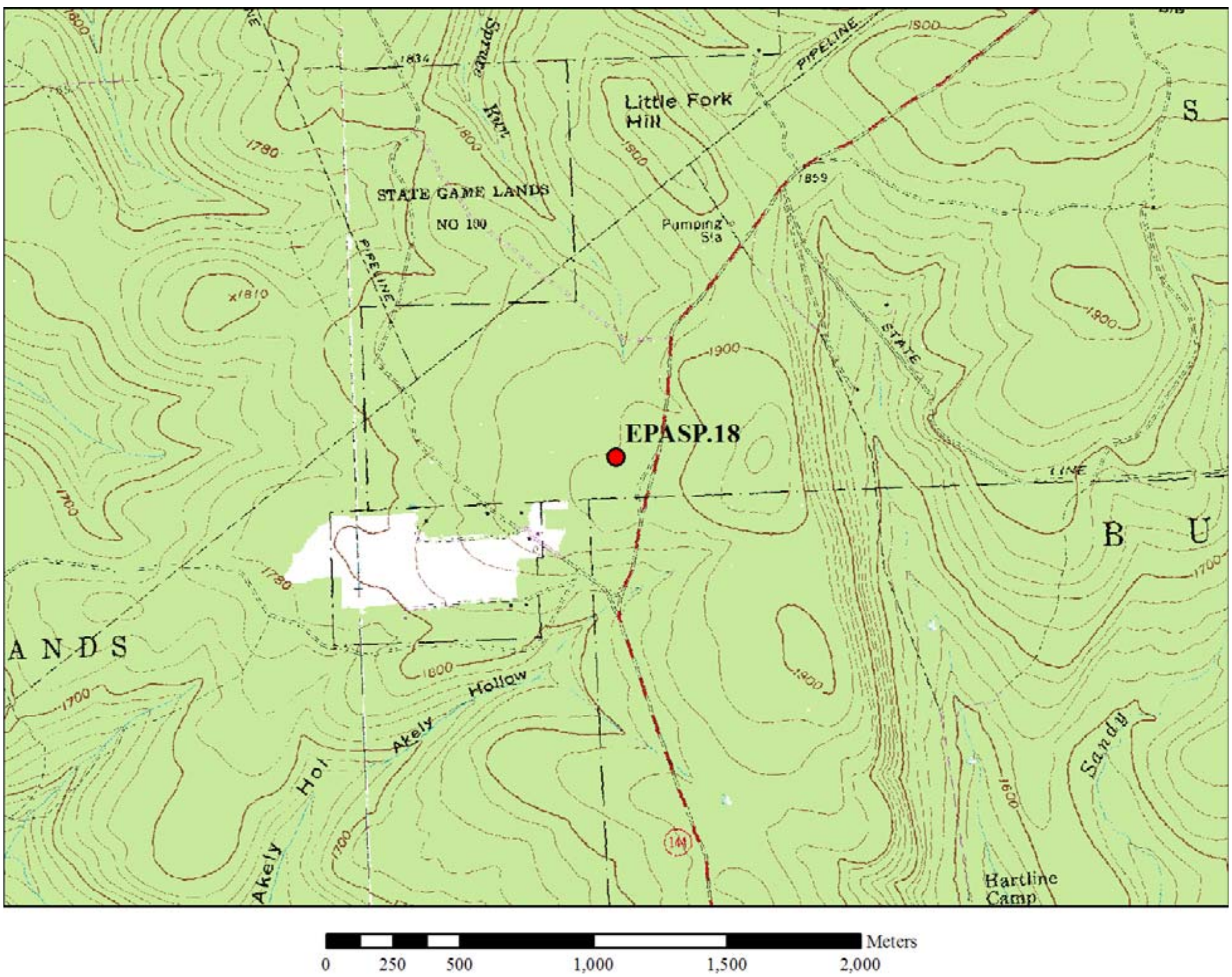
Site: EPA.27 Pool name: Wolf Rocks
USGS 7.5' Quadrangle: Port Matilda, PA
Centre County, Rush Twp.
Location: Port Matilda, PA, 7.8 km NNW .

EPASP.27 is situated within the Allegheny Mountain Plateau Subsection of TNC's Central Appalachian Forest Ecoregion in Centre County, on the Moshannon State Forest, near Port Matilda, PA. The pool, located on a broad forested ridgeline is surrounded by a Red oak – mixed hardwood forest. The canopy is open and the four zones are dominated by graminoids, royal fern (Osmunda regalis), and marsh St. Johnswort (Triadenum virginicum). This pool contains the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*) and is one of several sites on the Moshannon State Forest supporting this species.



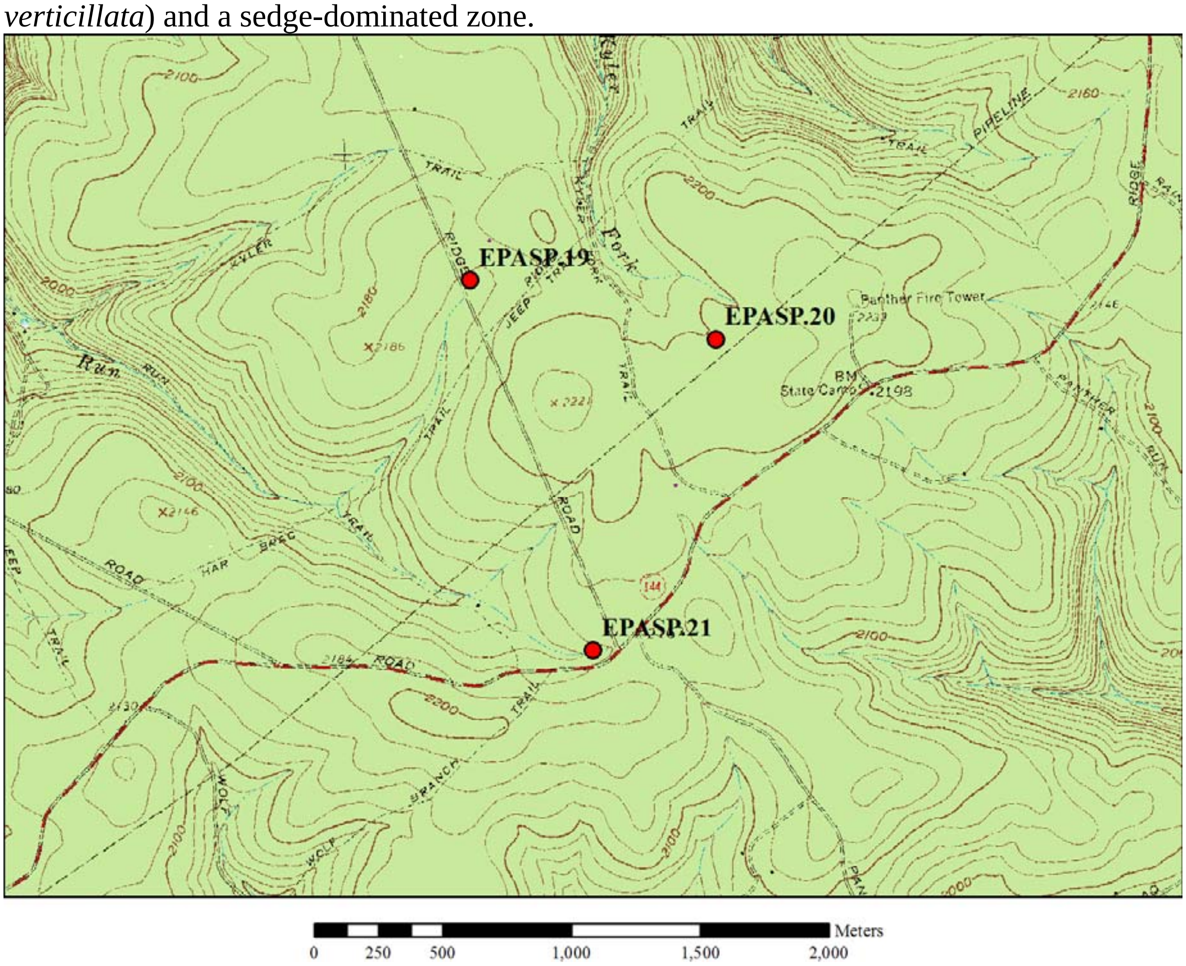
Site: EPASP.18 Pool name: Sproul 1
USGS 7.5' Quadrangle: Snowshoe, PA
Centre County, Burnside Twp.
Location: Karthaus PA, 10.7 km ESE.

EPASP.18 is situated within the Allegheny Mountain Plateau Subsection of TNC's Central Appalachian Forest Ecoregion in Centre County, PA. The pool is situated in an oak-dominated plateau located within the Sproul State Forest, managed by DCNR Bureau of Forestry. Pool 18 is nearly canopy-free surrounded by a Dry oak – mixed hardwood forest heavily logged following a gypsy moth outbreak in the 1980s. The white oaks left standing within the forested buffer (100ft from the pool edge) rebounded from the gypsy moth defoliation, most likely because of the higher soil water content of the area immediately adjacent to the pool. The pool is dominated by rice cut grass (Leersia oryzoides) and is surrounded by a open canopied white oak forest (Dry oak – mixed hardwood forest). This pool contains the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*) and is one of several sites on the Sproul State Forest supporting this species.



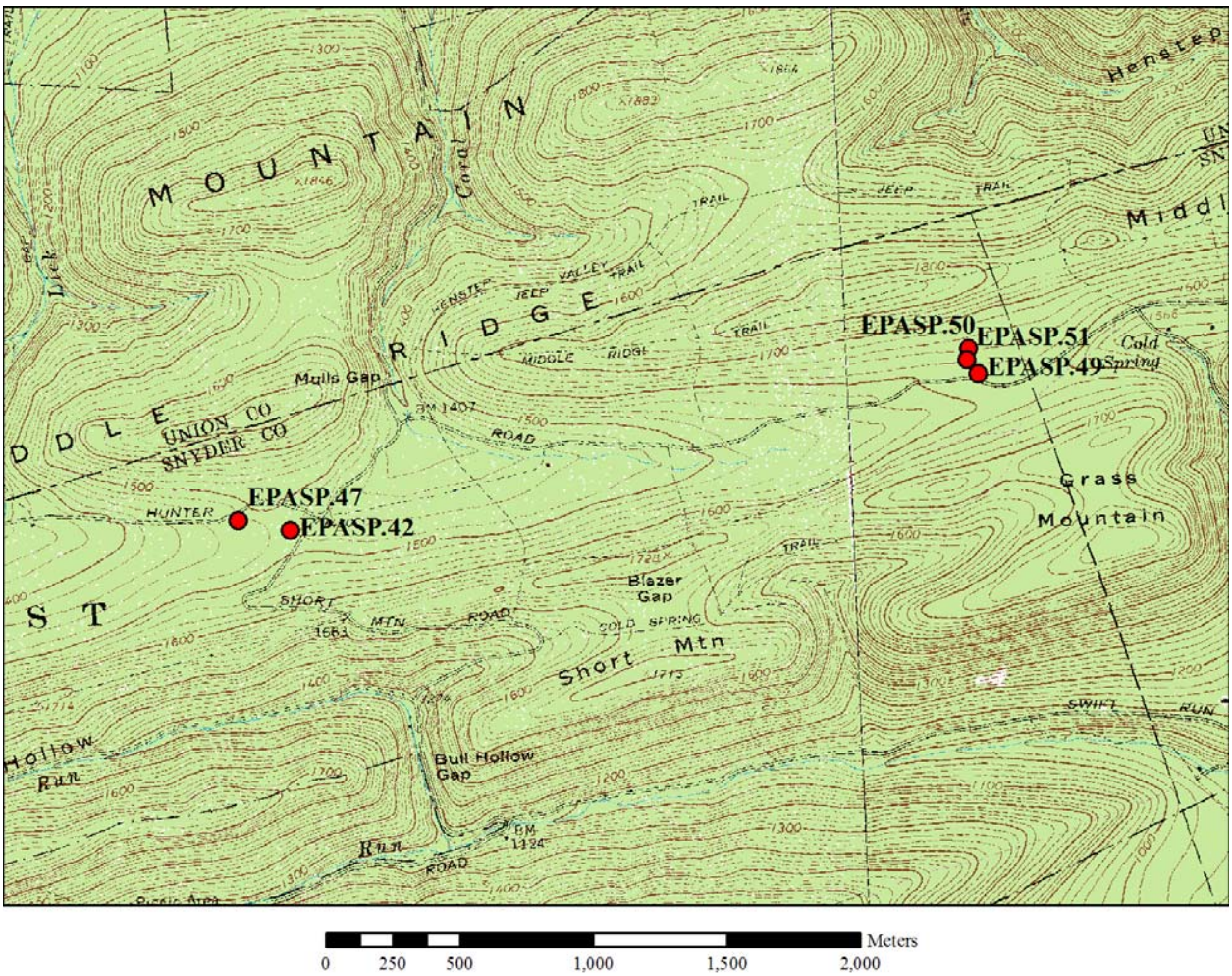
Site: EPASP.19, 20, 21 Pool names: Sproul 2, 3 (Yost Run BDA) and 4
USGS 7.5' Quadrangle: Snowshoe NW, PA
Centre County, Burnside Twp.
Location: Karthaus PA, 18 km NE.

EPASP.19, 20, 21 are situated within the Allegheny Mountain Plateau Subsection of TNC's Central Appalachian Forest Ecoregion in Centre County, PA. The pools are situated in an oak-dominated plateau located within the Sproul State Forest, managed by DCNR Bureau of Forestry. All three pools are nearly canopy-free within the surrounding Dry oak – mixed hardwood forest patches, which were heavily logged following a gypsy moth outbreak in the 1980s. The white oaks left standing within the forested buffer (roughly 100ft from the pool edge) rebounded from the gypsy moth defoliation, most likely because of the higher soil water content of the area immediately adjacent to the pool. Pool 19 was completely dry at the time vegetation was sampled and contained several species, such as poverty grass (*Danthonia compressa*) not generally associated with seasonal pools; wool grass (*Scirpus cyperinus*) was prevalent in the pool. Pool 20 was similar to pool 18, dominated by rice cut grass (*Leersia oryzoides*) and contained the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*); this pool is one of several sites on the Sproul State Forest supporting this species. Pool 21 was situated in a slightly denser forest patch than the three other pools on the Sproul State Forest and contained three zones, which included a central shrub zone, dominated by winterberry (*Ilex verticillata*) and a sedge-dominated zone.



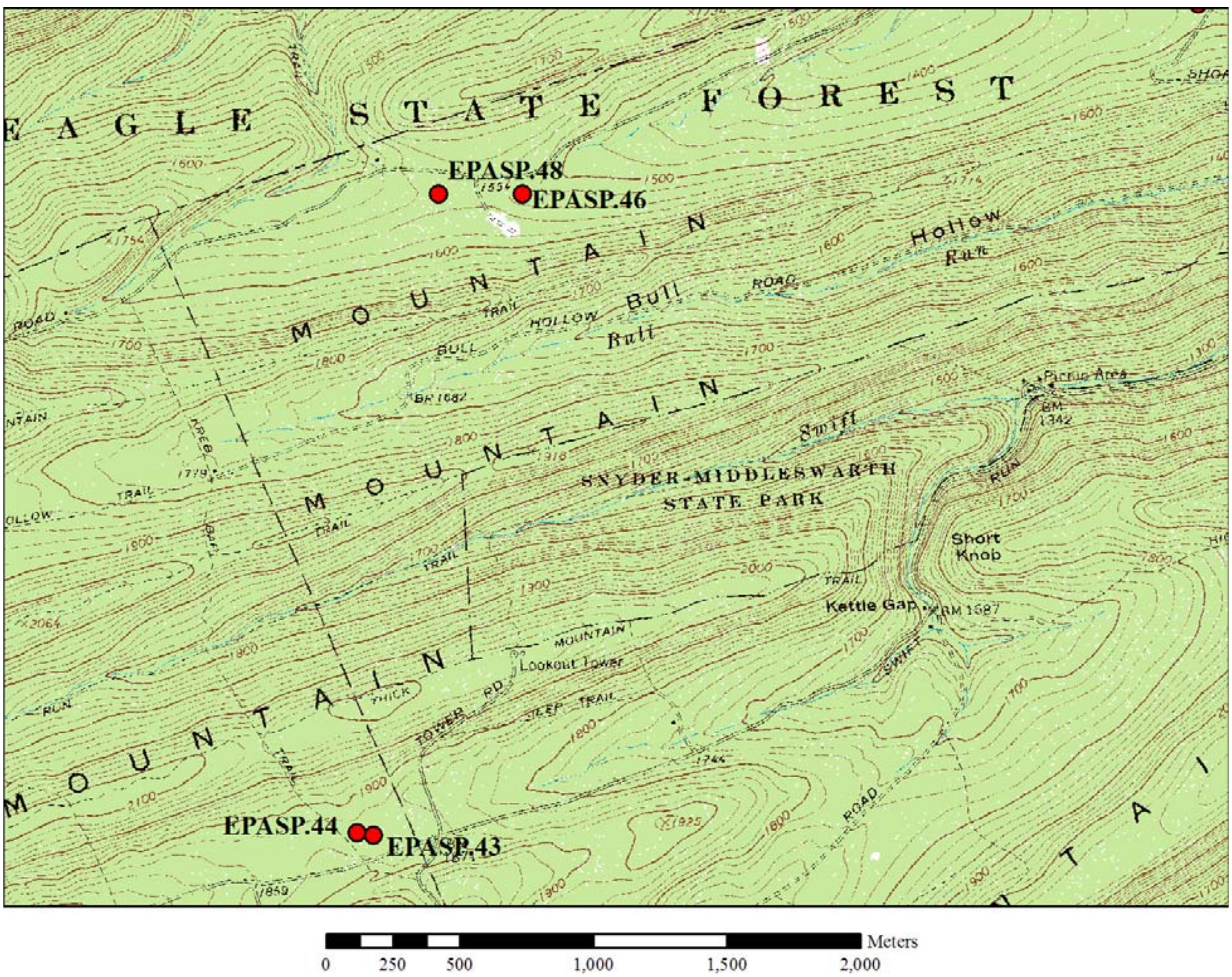
Site: EPASP.42, 47, 49. 50 and 51   Pool names: Mulls Gap 4 and 9, Grass Mt. 19, 5 and 6
USGS 7.5' Quadrangles: Weikert and Beavertown, PA
Snyder County, Spring Twp.
Location: Middle Creek, PA, 7.0 km N

These pools are situated in the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Snyder County, PA. The pools are within Bald Eagle State Forest. Pool 42 has a small amount of open canopy where some sparse short vegetation occurs. Pool 47 is an unvegetated pool under a closed canopy. Most of the pool is dominated by leaf litter, bare muck and moss covered woody debris. Red maple, black gum and white pine make up the overstory surrounding these pools. Pools 49, 50 and 51 are in a red oak-mixed hardwood forest within Bald Eagle State Forest and have a partially closed canopy. Pool 49 has two areas dominated by shrubs, but most of the pool is covered by leaf litter, woody debris and sparse vegetation.   Pools 50 and 51 are unvegetated except for some mosses.



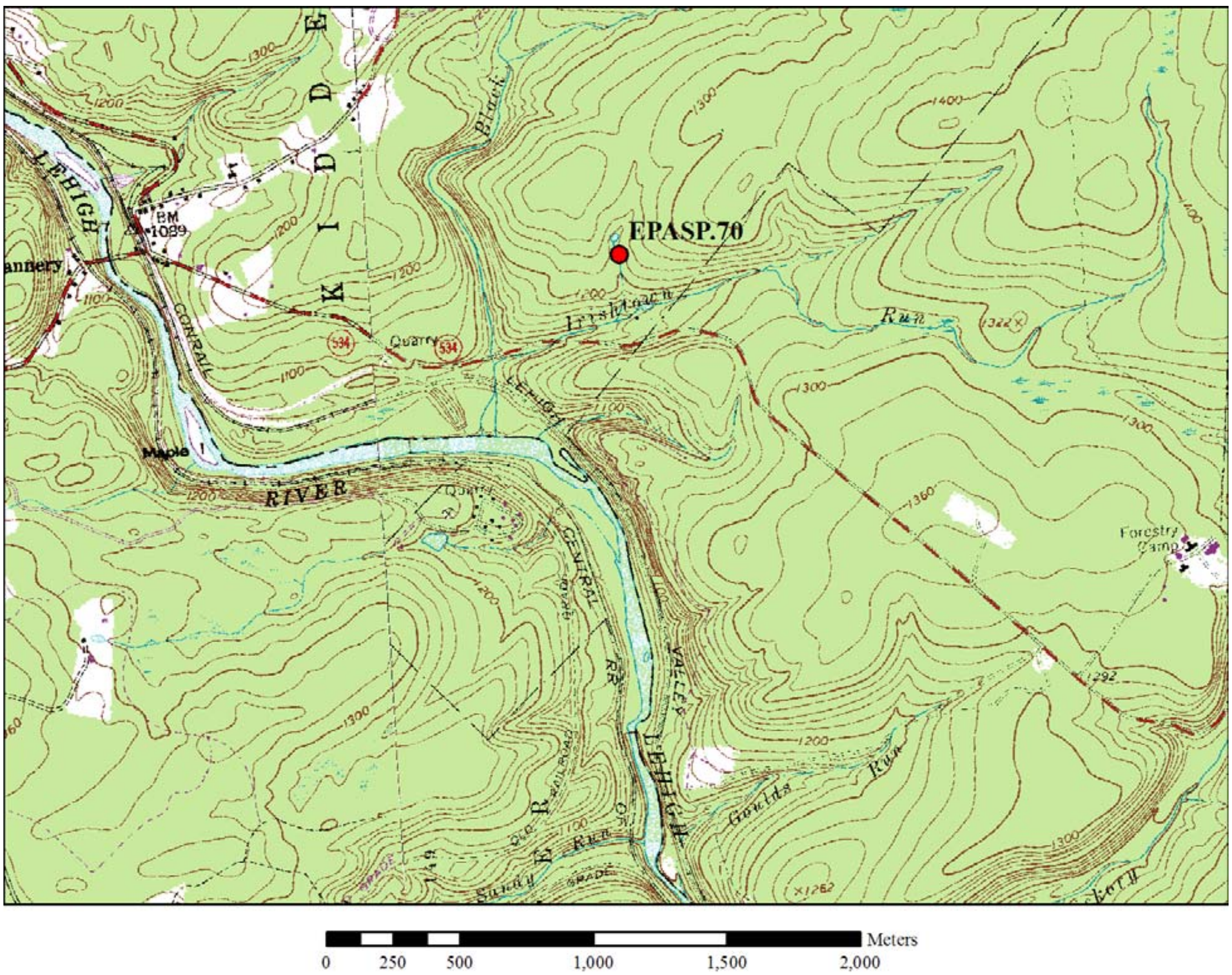
Site: EPASP.43, 44, 46 and 48 Pool names: Kreb Trail 5 and 6; Little Mt. 13 and 7
USGS 7.5' Quadrangle: Weikert, PA
Snyder County, West Beaver and Spring Twps.
Location: Middle Creek, PA, 6 - 7 km NW

EPASP.43, 44, 46 and 48 are situated in the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Snyder County, PA and are within Bald Eagle State Forest. Pools 43 and 44 are vegetated and have a mostly open canopy. Black gum, red oak and white pine surround these pools. Pool 43 has a dense shrub area along the perimeter and an open canopy that is dominated by three-way sedge and hummocks. Pool 44 is dominated by sphagnum and a short vegetated center. Red maple and black gum dominate the canopy surrounding pools 46 and 48. Pool 46 has a partial canopy and contained standing water in late August. Three-way sedge and royal fern dominate the pool basin. Pool 48 has a partial canopy and is mostly vegetated; wool-grass is the dominate plant. This pool also contains the federally listed Northeastern bulrush (*Scirpus ancistrochaetus*).



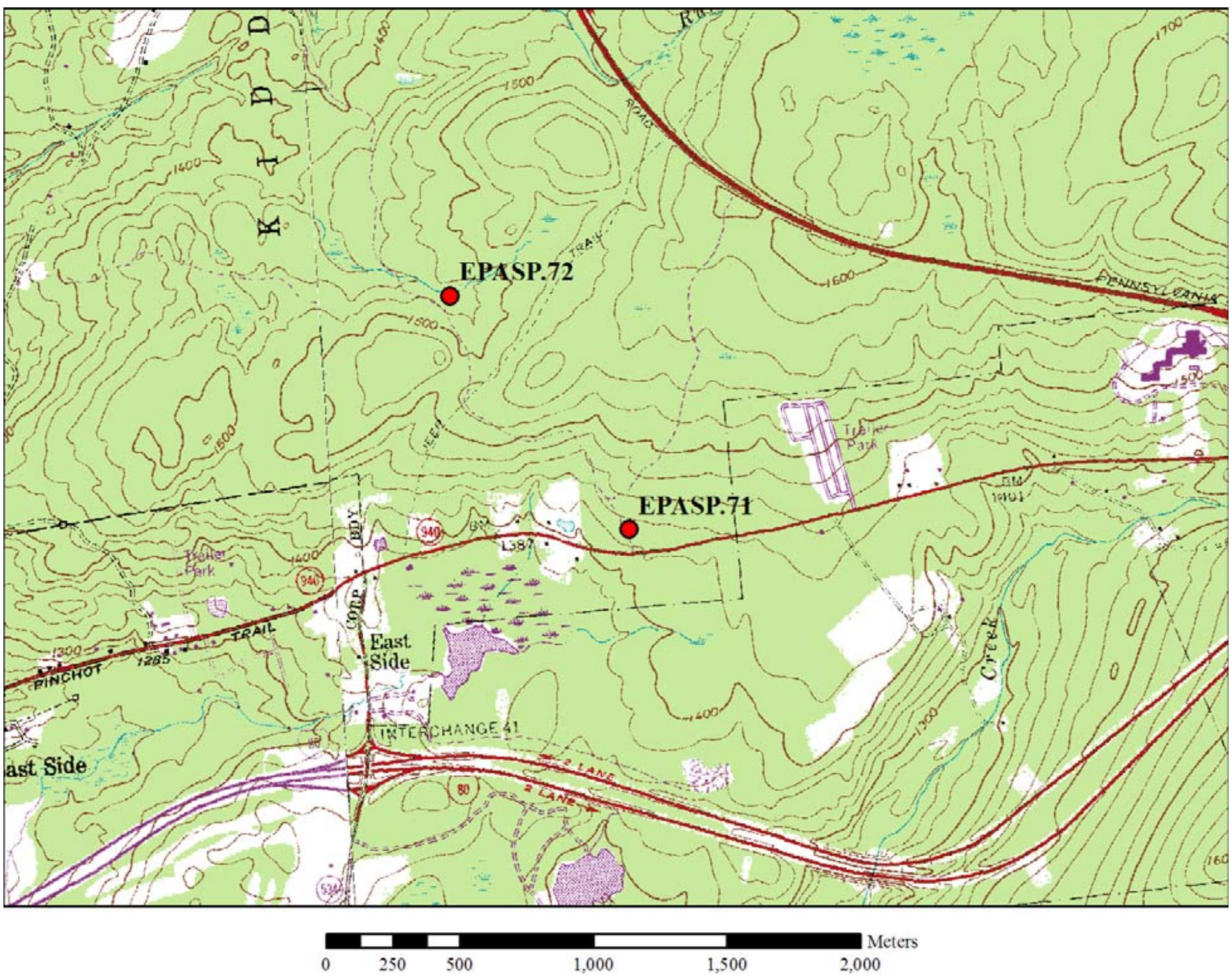
Site: EPASP.70 Pool name: Irishtown Run, PA
USGS 7.5 Quadrangle: Hickory Run
Carbon County, Kidder Twp.
Location: Tannery, PA 2 km W

EPASP.70 is within the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Carbon County, PA. Pool 70 is part of State Game Land 40. The pool is a deep boulder bottomed pool with a mostly open canopy. It is partially vegetated, but has little plant diversity within the pool. American beech and red maple make up the dominate canopy around the pool edge. Pool 70 sits in the basin of a valley.



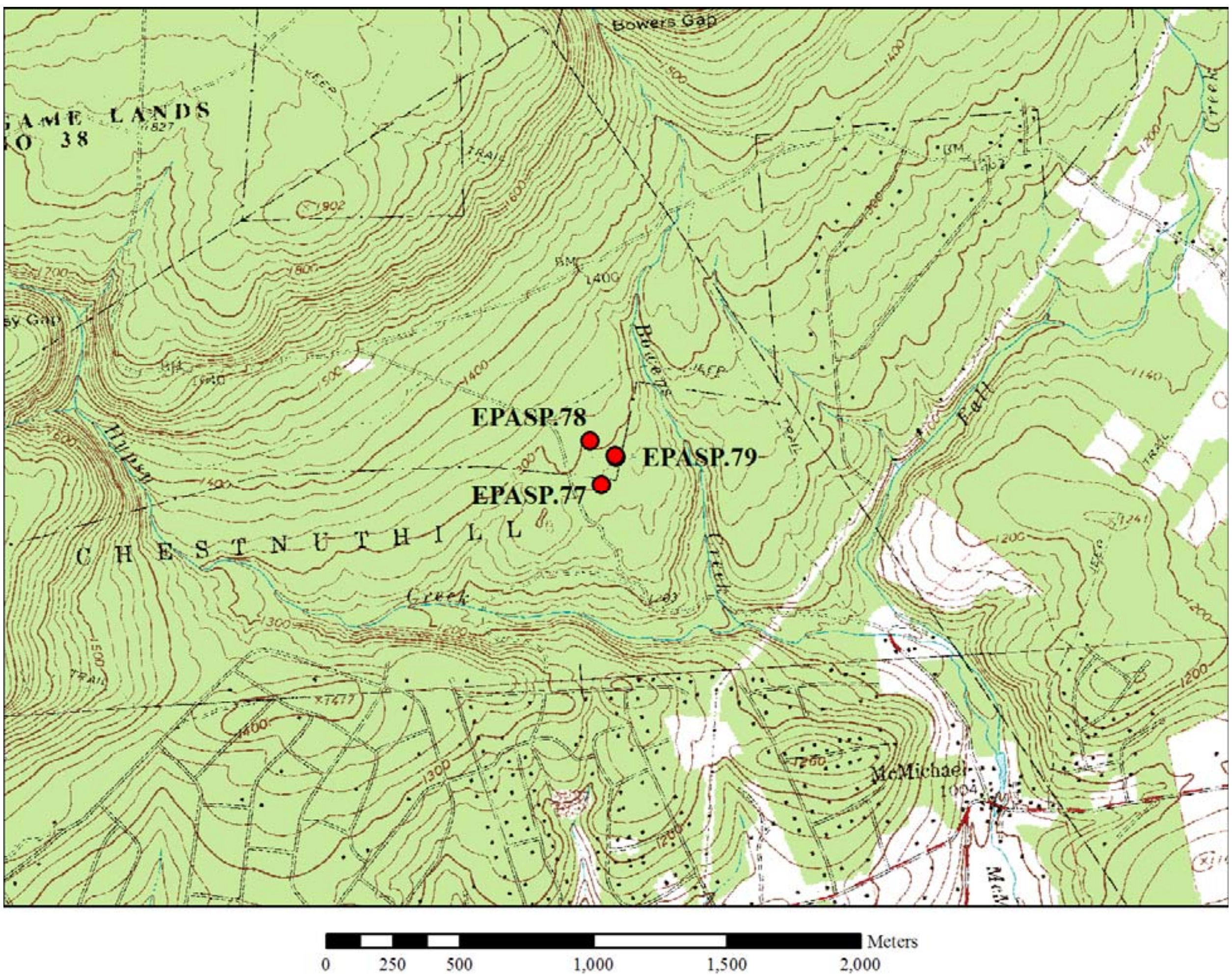
Site: EPASP.71 and 72 Pool names: Kidder 2 and 9
USGS 7.5 Quadrangle: Hickory Run
Carbon County, Kidder Twp.
Location: East Side, PA 1 km NE

EPASP.71 and 72 are within the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Carbon County, PA. The pools are located within a forested area of State Game Land 40. Pool 71 is under a closed canopy and is nearly unvegetated except for some mosses. The pool held water in mid-August. Pool 72 is a large pool with a partially open canopy. The pool edges are difficult to define and probably extend into the floodplain forest. The pool is densely vegetated with a large zone of grasses. Red maple, gray birch and American beech make up the dominant canopy surrounding both pools.



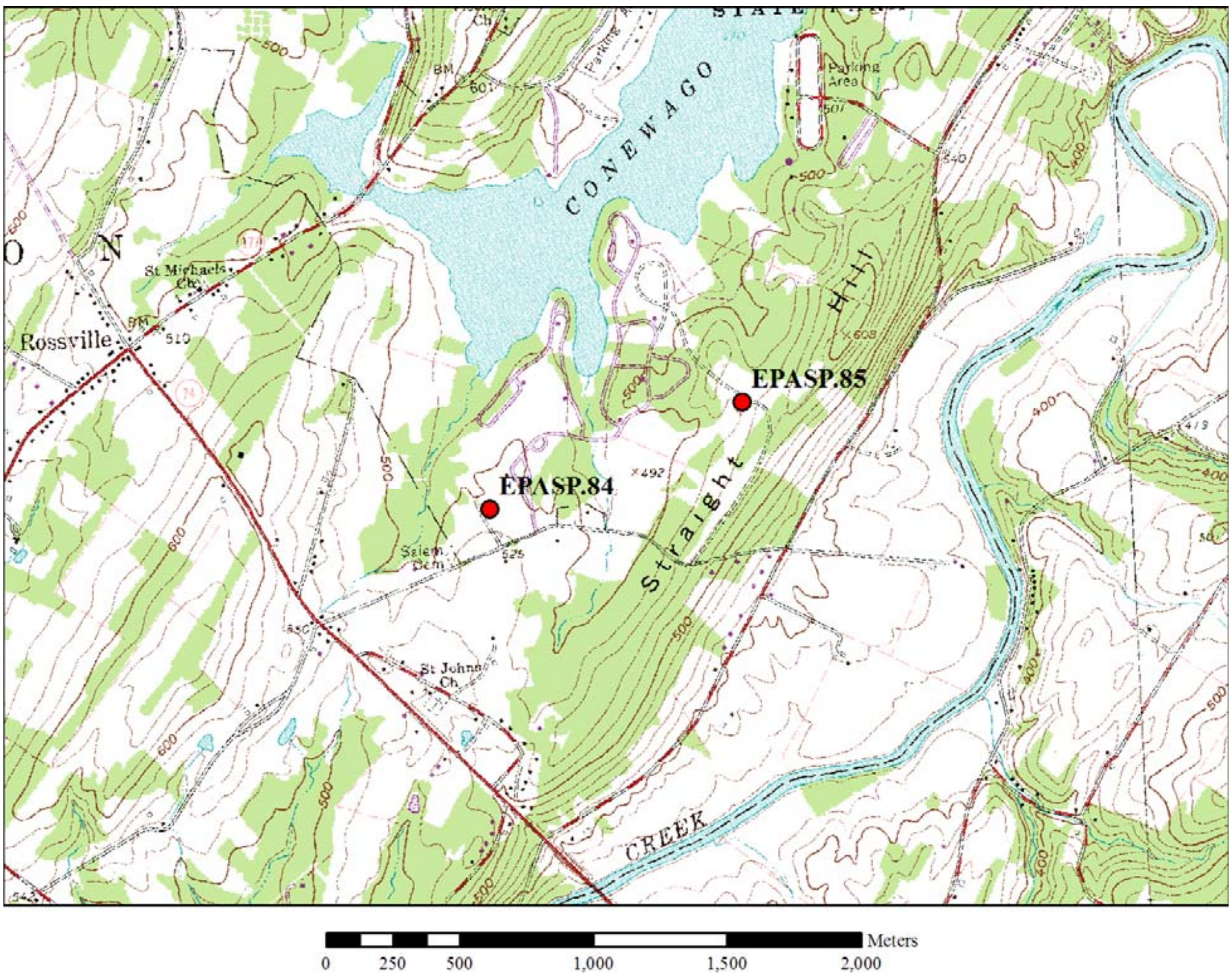
Site: EPASP.77, 78, 79 Pool names: Bowers Creek 1, 3, and 8
USGS 7.5 Quadrangle: Pocono Pines, PA
Monroe County, Chestnuthill Twp.
Location: McMichael, PA, 1.8 km NW

EPASP. 77, 78, and 79 are located in the Northern Ridge and Valley Subsection of TNC's Central Appalachian Forest Ecoregion in Monroe County, PA and are within State Game Lands 38. Chestnut oak, white oak, red maple and sassafras dominate the overstory surrounding pools 77 and 79. A dry oak/heath forest with pitch pine and chestnut oaks dominates the forest around pool 78. Pool 77 is under an open canopy with edges well defined by highbush blueberry; ferns dominate the pool. Pool 78 has a closed canopy and is almost entirely unvegetated with black-leaf, woody debris and rocks in the pool basin. Pool 79 is a well circumscribed depression that sits along a plateau. The pool is under a partially open canopy and is considered one large pool although when dry, a centrally raised cluster of highbush blueberry separates the pool into two distinct basins. The north end of the pool is mostly sphagnum and leaf litter with a closed canopy. The southern end is dominated by a mix of herbs and is under a mostly open canopy.



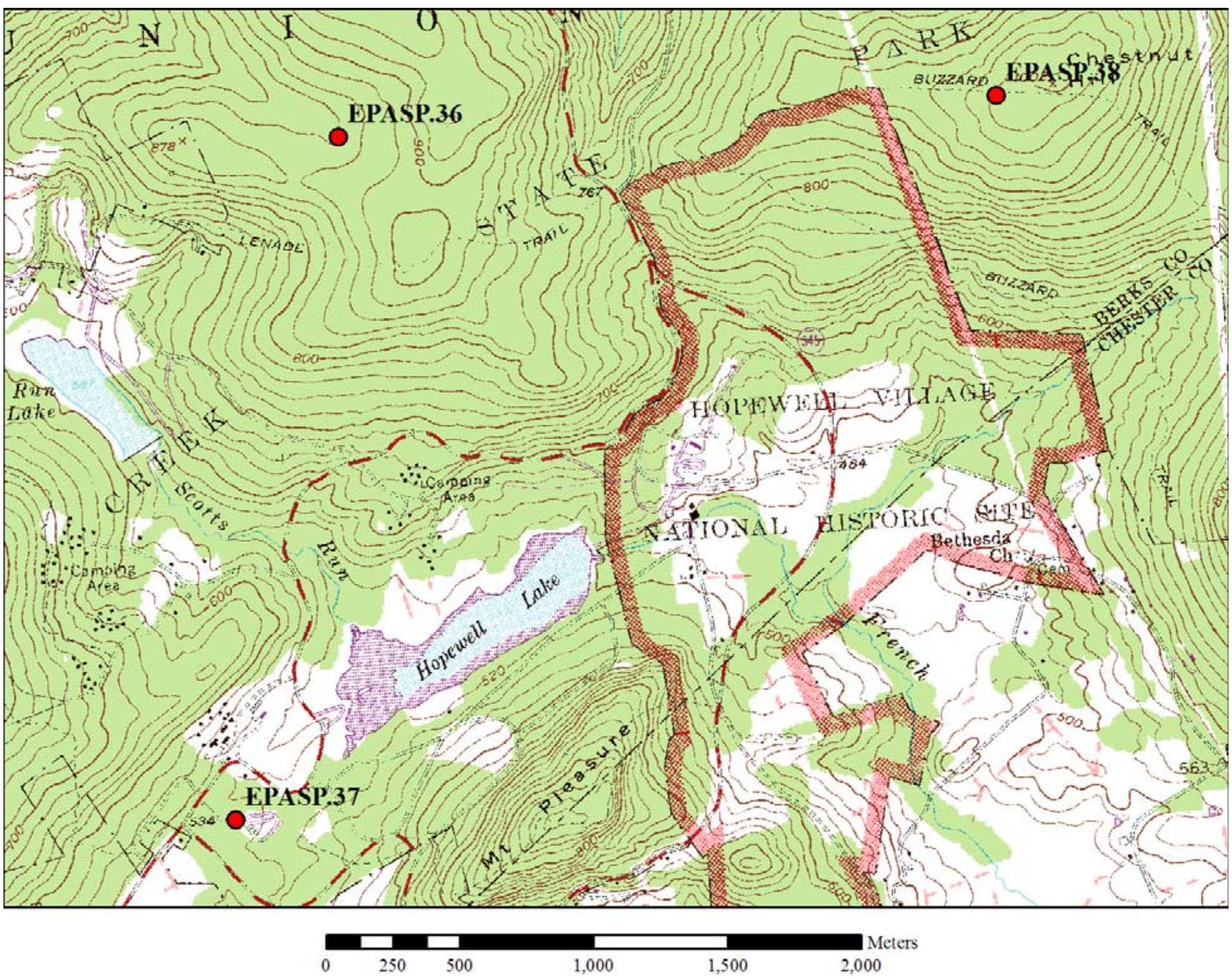
Site: EPASP.84, 85 Pool names: Gifford Pinchot State Park 1 and 2
USGS 7.5 Quadrangle: Wellsville, PA, PA
York County, Warrington Twp.
Location: Wellsville, PA 1.5 km SE

EPASP.84 and 85 are situated within the Gettysburg Piedmont Lowland Subsection of TNC's Lower New England/Northern Piedmont Ecoregion in York County, PA. These pools are situated within Gifford Pinchot State Park. Pool 1 is a large shallow basin. The area surrounding the pool is an old successional field. The open canopy area of the pool has zones with rushes, grasses, sedges and herbs. Pool 2 is in a woodlot that once surrounded a homestead 50 years ago. Three vernal pool indicator species use this pool, which was once an old barn foundation. False nettle dominates the pool with few other species present. Black walnut, red maple and chestnut oak make up the wooded area. Both pools have partially closed canopies. Invasives, especially multiflora rose, have infiltrated the perimeter of both pools.



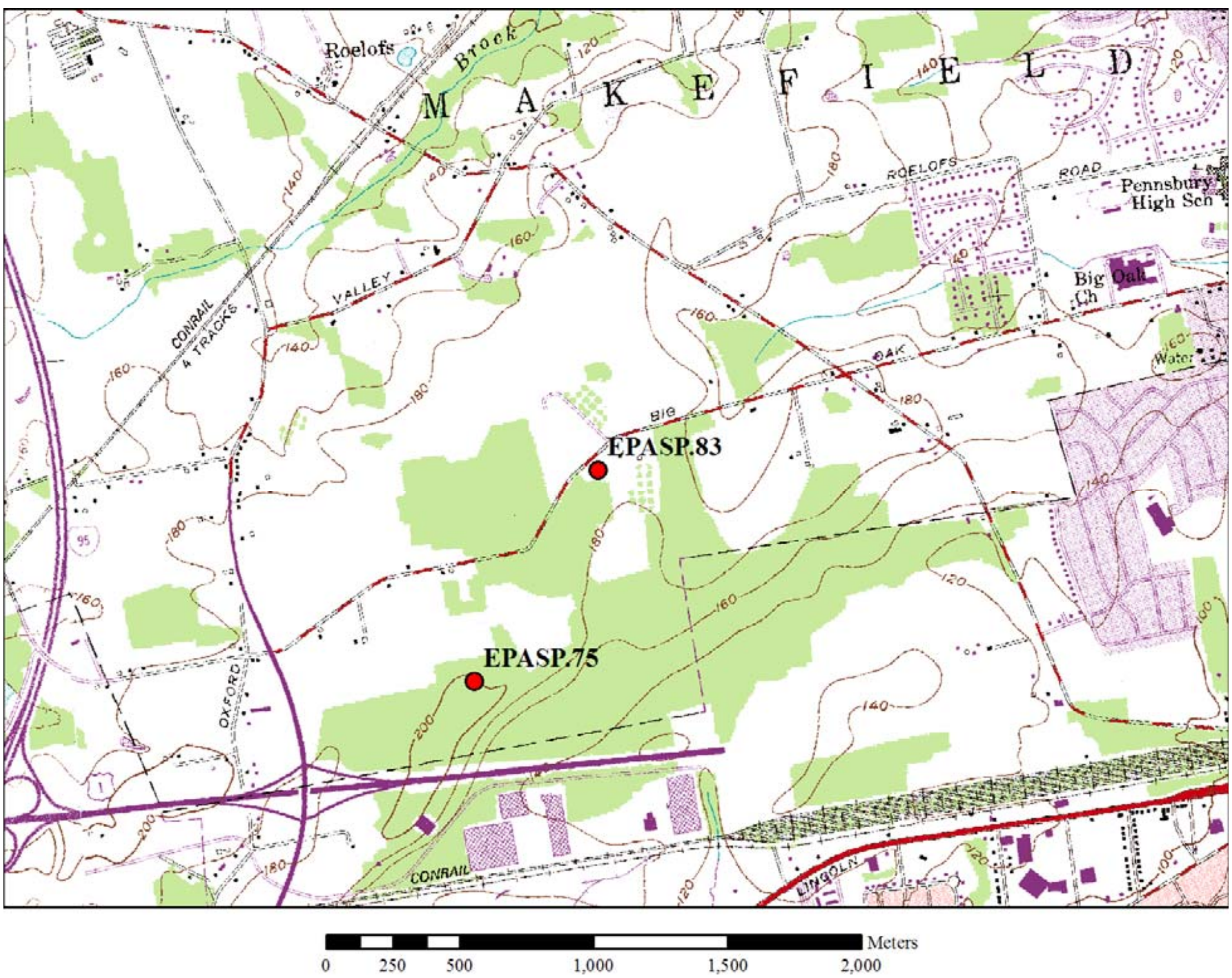
Site: EPASP.36, 37, and 38   Pool names: French Creek State Park 3, 5 and 6
USGS 7.5' Quadrangle: Elverson, PA
Berks County, Union Twp.
Location: Geigertown, PA, 5 km E

EPASP. 36, 37, and 38 are located in the Gettysburg Piedmont Lowland Subsection of TNC's Lower New England/Northern Piedmont Ecoregion in Berks County, PA. The pools are within French Creek State Park.   Pool 36 has a nearly closed canopy with white oak, black gum and red maple dominating the canopy. Over half the pool is leaf litter and bare soil. Grasses dominate the remainder. Chestnut oak and black birch dominate the closed canopy surrounding Pool 38. Leaf litter, muck, and woody debris are present under the overarch zone. A sedge area occurs between the pool and upland forest. Red maple, pin oak and white oak dominate the canopy around Pool 37. Water smartweed dominates the pool with few other species present.



Site: EPASP.75 and 83 Pool names: Five Mile Woods – Evergreen and Sphagnum
USGS 7.5 Quadrangle: Trenton West, PA
Bucks County, Lower Makefield Twp.
Location: Fairless Hills, PA, 1.8 km N

EPASP.75 and 83 are situated within the Piedmont Upland Subsection of TNC's Lower New England/Northern Piedmont Ecoregion in Bucks County, PA. The pools are within a township park that is an island of green in an otherwise highly developed area. The dominate canopy surrounding both pools is comprised of sweet gum, red maple and American beech. Pool 75 is a black-leaf pool and is part of a plateau that overlooks the fall line onto the Atlantic Coastal Plain. Pool 83 has a partial open canopy with areas of mixed herbs, shrubs and a black-leaf area under the closed canopy section.



Appendix 2. Master table of codes used in the seasonal pool study.
Includes codes for geographic information, physiochemical variables, landscape analysis, herptile density, richness, and abundance groupings, invertebrate abundance, density, and richness groupings, and classification groupings.

Codes	Geographic information
CntyNum	County
EcoNum	Ecoregion name used by The Nature Conservancy (TNC)
EcoSub	Ecoregion subsection
GeoNum	Surficial geology and primary lithosome
Glaciate	1 = unglaciated; 2 = glaciated
PhysProv	Physiographic province and section
PoolNum	Number assigned each study pool, no significance to numbering system.

Codes	Physiochemical variables
AirTemp	Air temperature in degrees Celsius
Area	Pool maximum potential area in square meters
CalcHard	Calcium hardness in ppm/$CaCO_3$
ClayDeep	Depth (cm) to clay, rock or hardpan based on soil core sample taken in the deepest region of the pool basin taken in centimeters.
Conduct	Conductivity in mS/cm
Elev_m	Elevation in meters
Fullness	Estimation of what percent of the pool basin was filled with water at the time of the spring faunal visit.
H_2OTemp	Water temperature in degrees Celsius
Length	Pool maximum potential length in meters.
MgHard	Magnesium hardness in ppm/$CaCO_3$
MuckDeep	Depth (cm) of layer of organic matter in the deepest region of the pool basin
ORP	Oxidation reduction potential in mV
Oxygen	Dissolved oxygen in mg/l
pH	pH values between 0 and 14
TotAlk	Total alkalinity in ppm/$CaCO_3$
TotHard	Total hardness in ppm/$CaCO_3$
VegAve	Average canopy cover over the pool basin
VegMin	Minimum canopy cover over the pool basin (the greater this number the greater the size of the canopy opening over the pool basin).
Water color	Relative amount of color of the water. 1 = clear or lightly stained, 2 = moderately stained, 3 = highly stained.
Width	Pool maximum potential width in meters

cont.

Codes	Landscape analysis
DistDist	Distance to disturbance: Distance to the most significant disturbance (largest and/or most likely to impact water quality) within a 0-610 m (0-2000 ft) radius around pool.
DistType	Disturbance type: Most significant disturbance type within a 0-610 m (0-2000 ft) radius around pool. 1 = Clearing (e.g. old field, pasture, food plot) 2 = Right of ways (e.g. powerline, forestry road not open to public) 3 = Dirt or paved road 4 = Logging 5 = Oil & gas development 6 = Abandoned mine lands 7 = Agriculture 8 = Residential / urban development 9 = Quarry / mining
DistAmt	Disturbance amount: Cumulative amount of disturbance within a 0-610 m (0-1000 ft) radius around pool: 0-33% low (1); 34-66% medium (2); 67-100% high (3).
FrstBuf1	Forest Buffer 1: Percent forest within a 0-30.5 m (0-100 ft) radius around pool. Based on the EPA defined vernal pool envelope & the PA Bureau of Forestry no cut zone (Brown and Jung 2005)
FrstBuf2	Forest Buffer 2: Percent forest within a 30.5-61 m (100-200 ft) radius around pool. Based on the PA Bureau of Forestry 50% cut zone (PA DCNR-BOF 2003).
FrstBuf3	Forest Buffer 3: Percent forest within a 0-305 m (0-1000 ft) radius around pool. Based on the EPA-defined terrestrial upland (Brown and Jung 2005)
RoadDist	Distance to nearest publicly accessible dirt or paved road (m)
RoadType	Nearest road type: dirt (1) or paved (2)
StrmDist	Distance to nearest stream (m)
StrmType	Stream type: Nearest stream type: intermittent (1) or permanent (2)
WetDist	Distance to nearest wetland (m)
WetType	Nearest wetland type (used National Wetland Service wetland types if identified). PEM = Palustrine Emergent Wetland PFO = Palustrine Forested Wetland POW = Palustrine Open Water PSS = Palustrine Scrub Shrub PUB = Palustrine Unconsolidated Bottom L = Lake vp = documented vernal pools (some not identified as wetlands in the NWI) Fldpln wtlnd = floodplain wetlands not identified in the NWI
WetCode	Grouping code for wetland types: known vernal pool (1); wetland (2); pond or lake (3)

cont.

Codes	Herptile abundance, density, and richness groupings
AquaRich	Aquatic reptile and amphibian richness: Tally of herptile taxa found in each pool that are aquatic or semiaquatic.
EggAbun	Egg abundance: Original count data of all indicator amphibian species egg masses. Includes egg masses of *Ambystoma jeffersonianum*, *A. maculatum*, *A. opacum*, and *Lithobates sylvaticus.*
EggDens	Egg density: Original count data of all indicator amphibian species egg masses (a total pool count was conducted) divided by pool area. Yields number of egg masses per 1 m^2. Includes egg masses of *Ambystoma jeffersonianum*, *A. maculatum*, *A. opacum*, and *Lithobates sylvaticus*.
HerpRich	Herptile richness: Tally of all herptiles found around each pool including aquatic and terrestrial species.
IndiRich	Indicator species richness: Tally of the amphibian and invertebrate species documented from each pool that are considered indicators of seasonal pools. In this study indicators were: *Ambystoma jeffersonianum*, *A. maculatum*, *A. opacum*, *Lithobates sylvaticus*, *Eubranchipus holmani*, and *E. vernalis*.
TerrRich	Terrestrial reptile and amphibian richness: Tally of herptile taxa found around the perimeter of each pool that are terrestrial (*Notophthalmus viridescens* subadults, *Thamnophis sirtalis, Plethodon cinereus* and *P. glutinosus*).

Codes	Invertebrate abundance, density and richness groupings
CGAbun	Collector-gatherer abundance: Original count of invertebrates in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
CGDens	Collector-gatherer density: Original count divided by sample effort per pool. Group includes invertebrate taxa in the collector-gatherer, detritivore, filterer, and scraper trophic groups. Yields number of collector-gatherers per d-frame net sample.
CGRich	Collector-gatherer richness: Tally of the invertebrate taxa collected from a pool in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
InvtAbun	Invertebrate taxon abundance: Original count data of all invertebrate taxon across all trophic groups.
InvtDens	Invertebrate density: Original count of all invertebrate taxon in all trophic groups divided by sample effort per pool. Yields number of invertebrates per d-frame net sample.
InvtRich	Invertebrate richness: Tally of all invertebrate taxa collected from a pool across all trophic groups.
PredAbun	Predator abundance: Original count of invertebrates in the predator trophic group.
PredDens	Predator density: Original count of invertebrates in the predator trophic group divided by sample effort per pool. Yields number of predators per d-frame net sample.
PredRich	Predator richness: Tally of the invertebrate taxa collected from a pool in the predator trophic groups.
ShrdAbun	Shredder taxon abundance: Original count of invertebrates in the shredder trophic group.
ShrdDens	Shredder density: Original count of invertebrates in the shredder trophic group divided by sample effort per pool. Yields number of shredders per d-frame net sample.
ShrdRich	Shredder richness: Tally of the invertebrate taxa collected from a pool in the shredder trophic group.

cont.

Codes	Classification groupings
AmphSub	Aquatic amphibian cluster analysis subgroupings
InvtFinal	Final invertebrate cluster analysis groupings
InvtSub	Invertebrate cluster analysis subgroupings (InvtClus4)
Structr	In-pool vegetation structure. Derived from second number in vegetation cluster analysis subgroup (VegSub). 1 = herbaceous; 2 = unvegetated; 3 = shrub
VegFinal	Final vegetation cluster analysis groupings
VegSub	Final vegetation cluster analysis subgroupings
VegTyp2	Initial vegetation cluster analysis groupings

Appendix 3. Pool site names and latitude / longitude coordinates.

Pool Num	Site name	Pool name	Nad 83 UTM Latitude (X)	Nad 83 UTM Longitude (Y)	UTM zone
ESP33	Allegheny National Forest	ANF Marienville	655863	4599464	17
ESP49	Bald Eagle State Forest	Grass Mountain 17	310790	4521988	18
ESP50	Bald Eagle State Forest	Grass Mountain 18	310758	4522084	18
ESP51	Bald Eagle State Forest	Grass Mountain 19	310749	4522042	18
ESP43	Bald Eagle State Forest	Kreb Trail 5 (D)	304890	4518685	18
ESP44	Bald Eagle State Forest	Kreb Trail 6 (C)	304831	4518698	18
ESP48	Bald Eagle State Forest	Little Mountain 13	305297	4521064	18
ESP46	Bald Eagle State Forest	Little Mountain 7	305610	4521043	18
ESP42	Bald Eagle State Forest	Mulls Gap 4	308182	4521576	18
ESP47	Bald Eagle State Forest	Mulls Gap 9	307991	4521626	18
ESP01	Buchanan State Forest	Roaring Run 1	743114	4430586	17
ESP02	Buchanan State Forest	Roaring Run 2 Bear Wallow	737639	4420245	17
ESP73	Delaware State Forest	DSF 14	486051	4555588	18
ESP74	Delaware State Forest	DSF 32	491058	4564232	18
ESP76	Delaware State Forest	DSF 46	490738	4565824	18
ESP28	Ellisburg Pools	Ellisburg 1	754355	4646618	17
ESP29	Ellisburg Pools	Ellisburg 2	754359	4646495	17
ESP30	Ellisburg Pools	Ellisburg 3	754427	4646528	17
ESP31	Ellisburg Pools	Ellisburg 4	754430	4646467	17
ESP83	Five Mile Woods	5MW1 Sphagnum pool	512688	4450356	18
ESP75	Five Mile Woods	5MW2 Evergreen pool	512173	4449601	18
ESP37	French Creek	French Creek 5	432397	4449845	18
ESP36	French Creek	French Creek 3	432952	4452365	18
ESP38	French Creek	French Creek 6	435411	4452354	18
ESP84	Gifford Pinchot SP	Pinchot 1 Gray Tree Frog	337710	4435925	18
ESP85	Gifford Pinchot SP	Pinchot 2 Barn	338677	4436264	18
ESP08	JEEC	Jennings 1	583623	4540363	17
ESP09	JEEC	Jennings 2	583556	4540325	17
ESP10	JEEC	Jennings 3	583525	4540292	17
ESP11	JEEC	Jennings 4	583165	4540513	17
ESP07	Lisica Property	Lisica 1	575129	4574047	17
ESP12	Lisica Property	Lisica 2	574973	4574108	17
ESP13	Lisica Property	Lisica 3	574614	4574162	17
ESP32	Lisica Property	Lisica 4	575079	4574099	17
ESP80	Minsi Lake	Minsi 1	485809	4530279	18
ESP81	Minsi Lake	Minsi 4	485670	4530470	18
ESP82	Minsi Lake	Minsi 9	485661	4530254	18
ESP34	Moshannon State Forest	Black Mo 5	752325	4537567	17
ESP35	Moshannon State Forest	Black Mo 6	752283	4537694	17
ESP89	Mount Cydonia	Lily Pond	284021	4417785	18
ESP88	Mount Cydonia	S1	283038	4417518	18
ESP86	Mount Cydonia	W1	283997	4418155	18
ESP87	Mount Cydonia	W16	283864	4418038	18
ESP45	Mount Cydonia	W2	283981	4418305	18
ESP26	Mount Cydonia	W3	284074	4418472	18
ESP03	Plain Grove	Plain Grove 1	570289	4545045	17
ESP04	Plain Grove	Plain Grove 2	570268	4544873	17
ESP05	Plain Grove	Plain Grove 3	570366	4545090	17

Pool Num	Site name	Pool name	Nad 83 UTM Latitude (X)	Nad 83 UTM Longitude (Y)	UTM zone
ESP24	SGL 102	SGL 102-1	598646	4643818	17
ESP25	SGL 102	SGL 102-2	598769	4643080	17
ESP14	SGL 216	SGL 216-1	567343	4539997	17
ESP15	SGL 216	SGL 216-2	567255	4539101	17
ESP16	SGL 216	SGL 216-3	567747	4538617	17
ESP68	SGL 300	SGL 300-1	462123	4598655	18
ESP69	SGL 300	SGL 300-2	461848	4598898	18
ESP54	SGL 322	Warrior Ridge 0	752328	4493046	17
ESP52	SGL 322	Warrior Ridge 5	752105	4492736	17
ESP53	SGL 322	Warrior Ridge 9	752281	4492935	17
ESP55	SGL 322	Warrior Ridge B	752115	4492833	17
ESP77	SGL 38	Bowers Creek 1	465086	4539737	18
ESP78	SGL 38	Bowers Creek 3	465174	4539676	18
ESP79	SGL 38	Bowers Creek 8	465116	4539571	18
ESP70	SGL 40	Irishtown 1	437933	4543207	18
ESP71	SGL 40	Kidder 2	438127	4546566	18
ESP72	SGL 40	Kidder 9	437518	4547483	18
ESP67	SGL 53	Meadow Grounds 4	752541	4424966	17
ESP40	SGL 76	Butler Knob 12b	266426	4443268	18
ESP41	SGL 76	Butler Knob 14	266519	4443350	18
ESP39	SGL 76	Butler Knob 4	266271	4443086	18
ESP17	SGL 95	SGL 95	594629	4548844	17
ESP22	Spring Creek	Spring Creek 1	622375	4636080	17
ESP23	Spring Creek	Spring Creek 2	622252	4635758	17
ESP19	Sproul State Forest	Sproul 2	759190	4561360	17
ESP20	Sproul State Forest	Sproul 3 Yost Run BDA	760147	4561129	17
ESP21	Sproul State Forest	Sproul 4	759669	4559913	17
ESP18	Sproul State Forest	Sproul1	752925	4554653	17
ESP57	Tioga State Forest	West Rim North 11	298410	4607535	18
ESP56	Tioga State Forest	West Rim North 2	298450	4607854	18
ESP61	Tioga State Forest	West Rim South 11	299214	4606594	18
ESP58	Tioga State Forest	West Rim South 2	298939	4606143	18
ESP59	Tioga State Forest	West Rim South 3	298916	4606083	18
ESP60	Tioga State Forest	West Rim South 7	299302	4606280	18
ESP63	Tuscarora State Forest	2nd Narrows 1	279179	4455845	18
ESP65	Tuscarora State Forest	2nd Narrows 4	279306	4455964	18
ESP62	Tuscarora State Forest	2nd Narrows 5	279305	4456017	18
ESP64	Tuscarora State Forest	2nd Narrows 6	279372	4456057	18
ESP66	Tuscarora State Forest	3 Square Hollow 3	279874	4454578	18
ESP06	Wolf Creek Narrows	Wolf Creek Narrows	576594	4546539	17
ESP27	Wolf Rocks	Wolf Rocks	744327	4527265	17

Appendix 4. Distribution of eighty nine EPA study seasonal pools calculated for TNC Ecoregion, Ecoregion Subsection, Physiographic Province, and Physiographic Province Section.

Pool num	Pool name	Ecoregion TNC name	Eco num	Ecoregion subsection	Eco sub	Physiographic province	Physiographic province section	Phys prov
ESP01	Roaring Run 1	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP02	Roaring Run 2 Bear Wallow	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP03	Plain Grove 1	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP04	Plain Grove 2	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP05	Plain Grove 3	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP06	Wolf Creek Narrows	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP07	Lisica 1	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP08	Jennings 1	Western Allegheny Plateau	49	Pittsburg Low Plateau	221.51	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP09	Jennings 2	Western Allegheny Plateau	49	Pittsburg Low Plateau	221.51	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP10	Jennings 3	Western Allegheny Plateau	49	Pittsburg Low Plateau	221.51	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP11	Jennings 4	Western Allegheny Plateau	49	Pittsburg Low Plateau	221.51	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP12	Lisica 2	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP13	Lisica 3	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP14	SGL 216-1	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP15	SGL 216-2	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP16	SGL 216-3	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP17	SGL 95	Western Allegheny Plateau	49	Pittsburg Low Plateau	221.51	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP18	Sproul 1	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Appalachian Plateaus	Pittsburgh Low Plateau	14
ESP19	Sproul 2	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Ridge and Valley	Deep Valleys	6
ESP20	Sproul 3 Yost Run BDA	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Ridge and Valley	Deep Valleys	6
ESP21	Sproul 4	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Ridge and Valley	Deep Valleys	6
ESP22	Spring Creek 1	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP23	Spring Creek 2	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP24	SGL 102-1	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP25	SGL 102-2	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP26	MC W3	Central Appalachian Forest	59	Northern Blue Ridge Mountains	221.44	Ridge and Valley	Great Valley	21
ESP27	Wolf Rocks	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Appalachian Plateaus	Allegheny Front	17
ESP28	Ellisburg 1	High Allegheny Plateau	60	Cattaraugus Highlands	212.61	Ridge and Valley	Deep Valleys	6
ESP29	Ellisburg 2	High Allegheny Plateau	60	Cattaraugus Highlands	212.61	Ridge and Valley	Deep Valleys	6
ESP30	Ellisburg 3	High Allegheny Plateau	60	Cattaraugus Highlands	212.61	Ridge and Valley	Deep Valleys	6
ESP31	Ellisburg 4	High Allegheny Plateau	60	Cattaraugus Highlands	212.61	Ridge and Valley	Deep Valleys	6
ESP32	Lisica 4	Western Allegheny Plateau	49	Allegheny Plateau	221.61	Appalachian Plateaus	Northwestern Glaciated Plateau	3
ESP33	ANF Marienville	High Allegheny Plateau	60	Allegheny High Plateau	212.71	Appalachian Plateaus	High Plateau	5
ESP34	Black Mo 5	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Appalachian Plateaus	Allegheny Front	17
ESP35	Black Mo 6	Central Appalachian Forest	59	Allegheny Mountain Plateau	221.26	Appalachian Plateaus	Allegheny Front	17

Pool num	Pool name	Ecoregion TNC name	Eco num	Ecoregion subsection	Eco sub	Physiographic province	Physiographic province section	Phys prov
ESP36	French Creek 3	Lower New England/Northern Piedmont	61	Gettysburg Piedmont Lowland	221.41	Piedmont	Gettysburg-Newark Lowland	29
ESP37	French Creek 5	Lower New England/Northern Piedmont	61	Gettysburg Piedmont Lowland	221.41	Piedmont	Gettysburg-Newark Lowland	29
ESP38	French Creek 6	Lower New England/Northern Piedmont	61	Gettysburg Piedmont Lowland	221.41	Piedmont	Gettysburg-Newark Lowland	29
ESP39	Butler Knob 4	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP40	Butler Knob 12b	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP41	Butler Knob 14	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP42	Mulls Gap 4	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP43	Kreb Trail 5 (D)	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP44	Kreb Trail 6 (C)	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP45	MC W2	Central Appalachian Forest	59	Northern Blue Ridge Mountains	221.44	Ridge and Valley	Great Valley	21
ESP46	Little Mountain 7	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP47	Mulls Gap 9	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP48	Little Mountain 13	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP49	Grass Mountain 17	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP50	Grass Mountain 18	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP51	Grass Mountain 19	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP52	Warrior Ridge 5	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP53	Warrior Ridge 9	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP54	Warrior Ridge 0	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP55	Warrior Ridge B	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP56	West Rim North 2	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP57	West Rim North 11	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP58	West Rim South 2	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP59	West Rim South 3	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP60	West Rim South 7	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP61	West Rim South 11	High Allegheny Plateau	60	Allegheny Deep Valleys	212.72	Ridge and Valley	Deep Valleys	6
ESP62	2nd Narrows 5	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP63	2nd Narrows 1	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP64	2nd Narrows 6	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP65	2nd Narrows 4	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP66	3 Square Hollow 3	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP67	Meadow Grounds 4	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Appalachian Mountain	18
ESP68	SGL 300-1	High Allegheny Plateau	60	Eastern Allegheny Plateau	212.63	Appalachian Plateaus	Glaciated Low Plateau	4
ESP69	SGL 300-2	High Allegheny Plateau	60	Eastern Allegheny Plateau	212.63	Ridge and Valley	Anthracite Valley	11
ESP70	Irishtown 1	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Anthracite Upland	19
ESP71	Kidder 2	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Anthracite Upland	19
ESP72	Kidder 9	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Anthracite Upland	19

Pool num	Pool name	Ecoregion TNC name	Eco num	Ecoregion subsection	Eco sub	Physiographic province	Physiographic province section	Phys prov
ESP73	DSF14	High Allegheny Plateau	60	Eastern Allegheny Plateau	212.63	Appalachian Plateaus	Glaciated Low Plateau	4
ESP74	DSF32	High Allegheny Plateau	60	Eastern Allegheny Plateau	212.63	Appalachian Plateaus	Glaciated Low Plateau	4
ESP75	5MW2 Evergreen	Lower New England/Northern Piedmont	61	Piedmont Upland	221.42	Piedmont	Piedmont Upland	38
ESP76	DSF46	High Allegheny Plateau	60	Eastern Allegheny Plateau	212.63	Appalachian Plateaus	Glaciated Low Plateau	4
ESP77	Bowers Creek 1	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Blue Mountain	20
ESP78	Bowers Creek 3	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Blue Mountain	20
ESP79	Bowers Creek 8	Central Appalachian Forest	59	Northern Ridge and Valley	221.13	Ridge and Valley	Blue Mountain	20
ESP80	Minsi 1	High Allegheny Plateau	60	Kittatinny-Shawangunk Ridges	221.24	Ridge and Valley	Great Valley	21
ESP81	Minsi 4	High Allegheny Plateau	60	Kittatinny-Shawangunk Ridges	221.24	Ridge and Valley	Great Valley	21
ESP82	Minsi 9	High Allegheny Plateau	60	Kittatinny-Shawangunk Ridges	221.24	Ridge and Valley	Great Valley	21
ESP83	5MW1 Sphagnum	Lower New England/Northern Piedmont	61	Piedmont Upland	221.42	Piedmont	Piedmont Upland	38
ESP84	Pinchot 1 Gray Tree Frog	Lower New England/Northern Piedmont	61	Gettysburg Piedmont Lowland	221.41	Piedmont	Gettysburg-Newark Lowland	29
ESP85	Pinchot 2 Barn	Lower New England/Northern Piedmont	61	Gettysburg Piedmont Lowland	221.41	Piedmont	Gettysburg-Newark Lowland	29
ESP86	MC W1	Central Appalachian Forest	59	Northern Blue Ridge Mountains	221.44	Ridge and Valley	Great Valley	21
ESP87	MC W16	Central Appalachian Forest	59	Northern Blue Ridge Mountains	221.44	Ridge and Valley	Great Valley	21
ESP88	MC S1	Central Appalachian Forest	59	Northern Great Valley	221.14	Ridge and Valley	Great Valley	21
ESP89	Lily Pond	Central Appalachian Forest	59	Northern Blue Ridge Mountains	221.44	Ridge and Valley	Great Valley	21

Appendix 5. Counties, surficial geology and primary lithosome listed for the eighty-nine EPA study seasonal pools.

Pool num	Pool name	Cnty num	County	Surficial geology name	Primary lithosome	Geo num
ESP01	Roaring Run 1	29	Fulton	Pocono Formation	Sandstone	37
ESP02	Roaring Run 2 Bear Wallow	29	Fulton	Rockwell Formation	Argillaceous sandstone	44
ESP03	Plain Grove 1	37	Lawrence	Allegheny Formation	Sandstone	31
ESP04	Plain Grove 2	37	Lawrence	Allegheny Formation	Sandstone	31
ESP05	Plain Grove 3	37	Lawrence	Allegheny Formation	Sandstone	31
ESP06	Wolf Creek Narrows	10	Butler	Pottsville Formation	Sandstone	33
ESP07	Lisica 1	43	Mercer	Allegheny Formation	Sandstone	31
ESP08	Jennings 1	10	Butler	Allegheny Formation	Sandstone	31
ESP09	Jennings 2	10	Butler	Allegheny Formation	Sandstone	31
ESP10	Jennings 3	10	Butler	Allegheny Formation	Sandstone	31
ESP11	Jennings 4	10	Butler	Allegheny Formation	Sandstone	31
ESP12	Lisica 2	43	Mercer	Allegheny Formation	Sandstone	31
ESP13	Lisica 3	43	Mercer	Allegheny Formation	Sandstone	31
ESP14	SGL 216-1	37	Lawrence	Allegheny Formation	Sandstone	31
ESP15	SGL 216-2	37	Lawrence	Allegheny Formation	Sandstone	31
ESP16	SGL 216-3	37	Lawrence	Allegheny Formation	Sandstone	31
ESP17	SGL 95	10	Butler	Allegheny Formation	Sandstone	31
ESP18	Sproul 1	14	Centre	Mauch Chunk Formation	Shale	34
ESP19	Sproul 2	14	Centre	Burgoon Sandstone	Sandstone	36
ESP20	Sproul 3 Yost Run BDA	14	Centre	Burgoon Sandstone	Sandstone	36
ESP21	Sproul 4	14	Centre	Burgoon Sandstone	Sandstone	36
ESP22	Spring Creek 1	61	Warren	Venango Formation	Siltstone	50
ESP23	Spring Creek 2	61	Warren	Venango Formation	Siltstone	50
ESP24	SGL 102-1	25	Erie	Venango Formation	Siltstone	50
ESP25	SGL 102-2	25	Erie	Venango Formation	Siltstone	50
ESP26	W3	28	Franklin	Tomstown Formation	Dolomite	154
ESP27	Wolf Rocks	14	Centre	Pottsville Formation	Sandstone	33

Pool num	Pool name	Cnty num	County	Surficial geology name	Primary lithosome	Geo num
ESP28	Ellisburg 1	52	Potter	Huntley Mountain Formation	Sandstone	45
ESP29	Ellisburg 2	52	Potter	Huntley Mountain Formation	Sandstone	45
ESP30	Ellisburg 3	52	Potter	Huntley Mountain Formation	Sandstone	45
ESP31	Ellisburg 4	52	Potter	Huntley Mountain Formation	Sandstone	45
ESP32	Lisica 4	43	Mercer	Allegheny Formation	Sandstone	31
ESP33	ANF Marienville	27	Forest	Pottsville Formation	Sandstone	33
ESP34	Black Mo 5	14	Centre	Mauch Chunk Formation	Shale	34
ESP35	Black Mo 6	14	Centre	Mauch Chunk Formation	Shale	34
ESP36	French Creek 3	6	Berks	Hammer Creek conglomerate	Quartz conglomerate	18
ESP37	French Creek 5	6	Berks	Stockton Formation	Arkosic sandstone	20
ESP38	French Creek 6	6	Berks	Hammer Creek conglomerate	Quartz conglomerate	18
ESP39	Butler Knob 4	28	Franklin	Clinton Group	Shale	94
ESP40	Butler Knob 12b	28	Franklin	Clinton Group	Shale	94
ESP41	Butler Knob 14	28	Franklin	Clinton Group	Shale	94
ESP42	Mulls Gap 4	54	Snyder	Reedsville Formation	Shale	99
ESP43	Kreb Trail 5 (D)	54	Snyder	Juniata Formation	Sandstone	97
ESP44	Kreb Trail 6 (C)	54	Snyder	Juniata Formation	Sandstone	97
ESP45	W2	28	Franklin	Tomstown Formation	Dolomite	154
ESP46	Little Mountain 7	54	Snyder	Reedsville Formation	Shale	99
ESP47	Mulls Gap 9	54	Snyder	Reedsville Formation	Shale	99
ESP48	Little Mountain 13	54	Snyder	Reedsville Formation	Shale	99
ESP49	Grass Mountain 17	54	Snyder	Reedsville Formation	Shale	99
ESP50	Grass Mountain 18	54	Snyder	Reedsville Formation	Shale	99
ESP51	Grass Mountain 19	54	Snyder	Reedsville Formation	Shale	99
ESP52	Warrior Ridge 5	31	Huntingdon	Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided	Limestone	83
ESP53	Warrior Ridge 9	31	Huntingdon	Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided	Limestone	83
ESP54	Warrior Ridge 0	31	Huntingdon	Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided	Limestone	83
ESP55	Warrior Ridge B	31	Huntingdon	Shriver, Mandata, Corriganville, and New Creek Members of Old Port Formation, undivided	Limestone	83

Pool num	Pool name	Cnty num	County	Surficial geology name	Primary lithosome	Geo num
ESP56	West Rim North 2	58	Tioga	Burgoon Sandstone	Sandstone	36
ESP57	West Rim North 11	58	Tioga	Pottsville Formation	Sandstone	33
ESP58	West Rim South 2	58	Tioga	Pottsville Formation	Sandstone	33
ESP59	West Rim South 3	58	Tioga	Pottsville Formation	Sandstone	33
ESP60	West Rim South 7	58	Tioga	Pottsville Formation	Sandstone	33
ESP61	West Rim South 11	58	Tioga	Pottsville Formation	Sandstone	33
ESP62	2nd Narrows 5	50	Perry	Juniata and Bald Eagle Formations, undivided	Sandstone	96
ESP63	2nd Narrows 1	50	Perry	Juniata and Bald Eagle Formations, undivided	Sandstone	96
ESP64	2nd Narrows 6	50	Perry	Juniata and Bald Eagle Formations, undivided	Sandstone	96
ESP65	2nd Narrows 4	50	Perry	Juniata and Bald Eagle Formations, undivided	Sandstone	96
ESP66	3 Square Hollow 3	50	Perry	Clinton Group	Shale	94
ESP67	Meadow Grounds 4	29	Fulton	Mauch Chunk Formation	Shale	34
ESP68	SGL 300-1	63	Wayne	Duncannon Member of Catskill Formation	Sandstone	53
ESP69	SGL 300-2	35	Lackawanna	Duncannon Member of Catskill Formation	Sandstone	53
ESP70	Irishtown 1	13	Carbon	Pocono Formation	Sandstone	37
ESP71	Kidder 2	13	Carbon	Pocono Formation	Sandstone	37
ESP72	Kidder 9	13	Carbon	Pocono Formation	Sandstone	37
ESP73	DSF14	45	Monroe	Long Run and Walcksville Members of Catskill Formation, undivided	Sandstone	67
ESP74	DSF32	51	Pike	Long Run and Walcksville Members of Catskill Formation, undivided	Sandstone	67
ESP75	5MW2 Evergreen	9	Bucks	Bryn Mawr Formation	Gravelly sand	4
ESP76	DSF46	51	Pike	Long Run and Walcksville Members of Catskill Formation, undivided	Sandstone	67
ESP77	Bowers Creek 1	45	Monroe	Long Run Member of Catskill Formation	Sandstone	63
ESP78	Bowers Creek 3	45	Monroe	Long Run Member of Catskill Formation	Sandstone	63
ESP79	Bowers Creek 8	45	Monroe	Long Run Member of Catskill Formation	Sandstone	63
ESP80	Minsi 1	48	Northampton	Martinsburg Formation	Shale	100
ESP81	Minsi 4	48	Northampton	Martinsburg Formation	Shale	100
ESP82	Minsi 9	48	Northampton	Martinsburg Formation	Shale	100
ESP83	5MW1 Sphagnum	9	Bucks	Bryn Mawr Formation	Gravelly sand	4

Pool num	Pool name	Cnty num	County	Surficial geology name	Primary lithosome	Geo num
ESP84	Pinchot 1 Gray Tree Frog	66	York	Diabase	Diabase	8
ESP85	Pinchot 2 Barn	66	York	Diabase	Diabase	8
ESP86	W1	28	Franklin	Tomstown Formation	Dolomite	154
ESP87	W16	28	Franklin	Tomstown Formation	Dolomite	154
ESP88	S1	28	Franklin	Tomstown Formation	Dolomite	154
ESP89	Lily Pond	28	Franklin	Tomstown Formation	Dolomite	154

Appendix 6. Landscape context analysis of the eighty nine EPA study seasonal pools. Descriptions of each landscape variable are presented in Appendix 2.

Pool num	Pool name	Frst Buf1	Frst Buff2	Frst Buff3	Dist dist	Dist type	Dist amt	Strm dist	Strm type	Wet dist	Wetland type	Wet code	Road dist	Road type
ESP01	Roaring Run 1	98	98	98	18	3	1	0	1	56	PUB	2	18	1
ESP02	Roaring Run 2 Bear Wallow	100	100	98	65	3	1	637	1	3222	PUB	2	59	1
ESP03	Plain Grove 1	100	100	80	74	7	1	598	2	85	vp	1	543	2
ESP04	Plain Grove 2	100	100	66	61	7	1	722	2	170	vp	1	349	2
ESP05	Plain Grove 3	100	100	75	158	7	1	512	2	85	vp	1	569	2
ESP06	Wolf Creek Narrows	100	100	70	142	6	2	78	2	347	fldpln wtlnd	2	257	2
ESP07	Lisica 1	100	100	70	95	6	2	78	1	63	PFO (vp)	1	211	1
ESP08	Jennings 1	65	50	70	11	1	1	203	2	74	vp	1	126	2
ESP09	Jennings 2	100	90	70	24	1	1	152	2	42	vp	1	145	2
ESP10	Jennings 3	100	100	75	70	1	1	121	2	42	vp	1	143	2
ESP11	Jennings 4	100	100	90	296	1	1	185	2	417	vp	1	468	2
ESP12	Lisica 2	100	100	70	45	6	2	0	1	73	PFO (vp)	1	198	2
ESP13	Lisica 3	100	100	75	0	6	2	314	1	96	PFO (vp)	1	126	2
ESP14	SGL 216-1	100	97	65	52	7	2	201	1	196	PUB	2	47	1
ESP15	SGL 216-2	100	100	70	71	7	2	935	2	668	vp	1	71	2
ESP16	SGL 216-3	100	97	70	116	1	2	246	2	263	PFO	2	374	2
ESP17	SGL 95	100	98	70	512	6	2	297	1	739	PUB	2	20	1
ESP18	Sproul 1	100	100	85	184	5	1	322	1	1318	PUB	2	148	2
ESP19	Sproul 2	40	50	40	27	1	2	88	1	340	PUB	2	41	1
ESP20	Sproul 3 Yost Run BDA	80	80	45	33	1	2	144	1	0	PFO	2	40	1
ESP21	Sproul 4	100	100	75	45	3	1	5	1	1275	PFO	2	45	2
ESP22	Spring Creek 1	100	100	80	172	4	1	128	2	117	PSS	2	383	1
ESP23	Spring Creek 2	100	100	85	45	1	1	390	2	292	PFO	2	42	1
ESP24	SGL 102-1	100	90	75	240	7	1	197	1	276	PFO	2	121	1
ESP25	SGL 102-2	100	100	90	100	1	1	246	1	611	PFO	2	134	1
ESP26	W3	100	100	95	211	4	1	265	2	102	POW	2	185	1
ESP27	Wolf Rocks	100	100	98	69	3	1	723	1	667	PUB	2	69	1
ESP28	Ellisburg 1	100	95	98	43	2	1	775	1	107	vp	1	1334	2
ESP29	Ellisburg 2	100	98	98	42	2	1	739	1	69	vp	1	1412	2
ESP30	Ellisburg 3	100	100	98	113	2	1	806	1	54	PEM (vp)	1	1294	2
ESP31	Ellisburg 4	100	100	98	116	2	1	802	1	54	vp	1	1368	2
ESP32	Lisica 4	100	100	70	132	7	2	0	1	63	vp	1	208	2
ESP33	ANF Marienville	100	100	95	140	4	1	485	2	1510	PUB	2	188	1
ESP34	Black Mo 5	100	98	98	54	3	1	113	1	126	PEM (vp)	1	54	1
ESP35	Black Mo 6	100	96	98	41	3	1	35	1	126	PEM (vp)	1	41	1
ESP36	French Creek 3	100	100	99	234	3	1	1075	1	210	PFO	2	234	1
ESP37	French Creek 5	100	100	80	187	8	1	647	2	274	PSS	2	2	1
ESP38	French Creek 6	100	100	100	369	2	1	1006	1	1849	PFO	2	1228	1
ESP39	Butler Knob 4	100	97	90	53	1	1	0	1	25	PSS (vp)	1	53	1
ESP40	Butler Knob 12b	100	100	95	67	3	1	0	1	37	vp	1	64	1
ESP41	Butler Knob 14	100	100	99	94	3	1	0	1	32	PSS (vp)	1	92	1
ESP42	Mulls Gap 4	100	99	96	57	3	1	578	1	51	PSS (vp)	1	57	1
ESP43	Kreb Trail 5 (D)	100	100	99	68	3	1	667	1	47	PSS (vp)	1	68	1
ESP44	Kreb Trail 6 (C)	100	100	99	97	3	1	730	1	47	PSS (vp)	1	97	1
ESP45	W2	100	100	95	179	4	1	101	1	59	vp	1	149	1
ESP46	Little Mountain 7	100	100	98	28	3	1	269	1	31	PSS (vp)	1	28	1
ESP47	Mulls Gap 9	99	96	96	23	3	1	725	1	73	PSS (vp)	1	23	1
ESP48	Little Mountain 13	100	100	98	59	3	1	263	1	70	PSS (vp)	1	59	1
ESP49	Grass Mountain 17	95	97	99	18	3	1	747	1	35	vp	1	18	1
ESP50	Grass Mountain 18	100	100	99	107	3	1	783	1	35	vp	1	107	1
ESP51	Grass Mountain 19	100	100	99	59	3	1	793	1	35	PSS (vp)	1	59	1

Pool num	Pool name	Frst Buf1	Frst Buff2	Frst Buff3	Dist dist	Dist type	Dist amt	Strm dist	Strm type	Wet dist	Wetland type	Wet code	Road dist	Road type
ESP52	Warrior Ridge 5	100	99	98	24	3	1	618	1	34	PFO (vp)	1	24	1
ESP53	Warrior Ridge 9	100	100	98	58	3	1	890	1	45	PEM (vp)	1	58	1
ESP54	Warrior Ridge 0	100	99	98	23	3	1	1009	1	45	PEM (vp)	1	23	1
ESP55	Warrior Ridge B	100	99	98	50	3	1	708	1	50	PFO (vp)	1	50	1
ESP56	West Rim North 2	100	100	99	234	3	1	614	1	73	PEM (vp)	1	234	1
ESP57	West Rim North 11	100	100	98	102	3	1	554	1	129	PEM (vp)	1	102	1
ESP58	West Rim South 2	100	100	100	521	3	1	883	1	56	vp	1	521	1
ESP59	West Rim South 3	100	100	100	555	3	1	853	1	56	vp	1	555	1
ESP60	West Rim South 7	100	100	100	58	2	1	514	1	38	PEM (vp)	1	758	1
ESP61	West Rim South 11	100	100	100	969	3	1	563	1	58	PEM (vp)	1	969	1
ESP62	2nd Narrows 5	100	100	99	129	3	1	78	1	40	vp	1	129	1
ESP63	2nd Narrows 1	100	99	99	31	3	1	0	1	25	vp	1	31	1
ESP64	2nd Narrows 6	100	100	99	79	3	1	0	1	46	vp	1	79	1
ESP65	2nd Narrows 4	100	100	99	73	3	1	0	1	40	vp	1	73	1
ESP66	3 Square Hollow 3	100	100	99	253	3	1	0	1	32	vp	1	253	1
ESP67	Meadow Grounds 4	10	10	30	532	1	1	132	1	381	PFO	2	349	1
ESP68	SGL 300-1	100	100	100	384	3	1	508	2	98	POW	2	384	1
ESP69	SGL 300-2	100	100	99	287	3	1	814	2	295	POW	2	287	2
ESP70	Irishtown 1	100	100	100	321	3	1	0	1	40	POW (vp)	1	321	2
ESP71	Kidder 2	100	100	90	170	7	1	377	1	202	POW	2	79	2
ESP72	Kidder 9	100	100	100	52	2	1	0	1	283	PFO	2	787	1
ESP73	DSF14	100	100	100	655	3	1	1105	1	85	PUB	2	655	1
ESP74	DSF32	100	100	99	232	3	1	114	2	116	PFO	2	232	1
ESP75	5MW2 Evergreen	100	100	100	467	8	2	980	1	411	POW	2	335	2
ESP76	DSF46	100	100	100	1045	3	1	91	2	73	PFO	2	1045	1
ESP77	Bowers Creek 1	100	100	99	113	3	1	298	2	97	vp	1	113	1
ESP78	Bowers Creek 3	100	100	99	190	3	1	243	2	44	vp	1	190	1
ESP79	Bowers Creek 8	100	100	99	103	3	1	338	2	27	vp	1	103	1
ESP80	Minsi 1	100	100	100	456	3	1	51	2	77	PFO (vp)	1	456	1
ESP81	Minsi 4	100	100	97	358	7	1	151	2	37	PFO (vp)	1	330	1
ESP82	Minsi 9	100	100	100	537	3	1	38	2	68	PFO (vp)	1	537	1
ESP83	5MW1 Sphagnum	100	100	75	81	8	2	757	1	828	PFO	2	78	2
ESP84	Pinchot 1 Gray Tree Frog	100	95	70	151	7	2	234	1	527	L	3	144	2
ESP85	Pinchot 2 Barn	100	100	99	397	7	1	549	1	548	L	3	208	2
ESP86	W1	100	100	98	282	4	1	62	1	77	vp	1	124	1
ESP87	W16	100	100	98	317	4	1	197	1	58	vp	1	176	1
ESP88	S1	100	100	97	355	7	1	79	2	103	PFO	2	26	1
ESP89	Lily Pond	100	100	95	509	9	1	0	1	85	POW	2	69	1

Appendix 7. Physical qualities measured for the eighty-nine EPA study seasonal pools. Descriptions of each landscape variable are presented in Appendix 2.

Pool num	Pool name	Length (m)	Width (m)	Area (m^2)	Depth (m)	% Full-ness	Water color	Depth to clay (cm)	Organic depth (cm)	Veg Ave	Veg Min
ESP01	Roaring Run 1	18	9	127	0.70	98	1	99	20	40.5	2.0
ESP02	Roaring Run 2 Bear Wallow	12	12	113	0.18	45	1	28	7	15.0	0.0
ESP03	Plain Grove 1	50	22	864	1.30	100	1	21	12	30.0	5.0
ESP04	Plain Grove 2	40	22	691	1.50	99	1	25	23	62.1	50.0
ESP05	Plain Grove 3	35	11	302	1.00	98	1	35	26	38.3	10.0
ESP06	Wolf Creek Narrows	50	20	785	0.90	98	1	27	18	60.0	25.0
ESP07	Lisica 1	18	8	113	0.40	90	1	50	4	90.0	80.0
ESP08	Jennings 1	18	12	170	0.60	95	1	8	7	33.0	3.0
ESP09	Jennings 2	11	6	52	0.50	40	1	20	8	70.0	70.0
ESP10	Jennings 3	20	16	251	0.70	85	1	12	12	51.0	5.0
ESP11	Jennings 4	10	6	47	0.40	15	1	44	21	75.0	70.0
ESP12	Lisica 2	32	21	528	0.90	100	1	20	10	39.4	0.0
ESP13	Lisica 3	24	20	377	0.60	75	2	49	20	35.8	5.0
ESP14	SGL 216-1	59	36	1668	2.00	95	2	40	6	49.1	2.0
ESP15	SGL 216-2	77	31	1875	1.20	80	2	48	7	63.8	30.0
ESP16	SGL 216-3	40	24	754	1.10	100	2	61	9	77.0	75.0
ESP17	SGL 95	48	34	1282	1.00	90	1	27	10	30.0	0.0
ESP18	Sproul 1	26	26	531	0.25	95	1	39	9	3.3	0.0
ESP19	Sproul 2	14	12	132	0.15	80	1	72	19	0.0	0.0
ESP20	Sproul 3 Yost Run BDA	22	18	311	0.18	95	1	51	9	7.5	0.0
ESP21	Sproul 4	30	30	707	0.23	70	1	62	9	36.7	0.0
ESP22	Spring Creek 1	26	26	531	1.40	98	1	68	68	60.0	0.0
ESP23	Spring Creek 2	37	15	436	1.30	87	1	45	45	19.0	0.0
ESP24	SGL 102-1	30	12	283	1.00	98	2	10	10	30.0	0.0
ESP25	SGL 102-2	28	18	396	1.60	95	1	24	24	36.7	0.0
ESP26	W3	62	22	1071	0.90	95	2	44	44	69.5	40.0
ESP27	Wolf Rocks	38	28	836	0.20	80	1	6	6	0.0	0.0
ESP28	Ellisburg 1	15	6	71	0.50	60	1	30	7	40.0	20.0
ESP29	Ellisburg 2	20	11	173	0.60	95	1	45	6	80.0	80.0
ESP30	Ellisburg 3	10	8	63	0.60	80	1	29	10	45.0	15.0
ESP31	Ellisburg 4	22	12	207	0.80	85	1	32	3	35.0	10.0
ESP32	Lisica 4	30	12	283	0.70	95	3	10	3	75.0	70.0
ESP33	ANF Marienville	8	8	50	0.30	100	2	39	4	72.5	70.0
ESP34	Black Mo 5	35	23	632	0.25	55	1	18	12	0.0	0.0
ESP35	Black Mo 6	52	22	898	0.30	80	1	23	26	1.7	0.0
ESP36	French Creek 3	18	13	184	0.21	90	1	12	12	92.5	85.0
ESP37	French Creek 5	13	6	61	0.16	90	1	9	9	45.0	45.0
ESP38	French Creek 6	9	3	21	0.37	90	2	7	7	81.7	70.0
ESP39	Butler Knob 4	29	29	661	0.50	100	1	31	30	36.7	0.0
ESP40	Butler Knob 12b	62	20	974	0.31	100	1	47	46	40.0	0.0
ESP41	Butler Knob 14	18	15	212	0.54	100	1	15	14	0.0	0.0

Pool num	Pool name	Lenth (m)	Width (m)	Area (m^2)	Depth (m)	% Full-ness	Water color	Depth to clay (cm)	Organic depth (cm)	Veg Ave	Veg Min
ESP42	Mulls Gap 4	66	20	1037	0.35	100	2	11	10	51.7	0.0
ESP43	Kreb Trail 5 (D)	68	32	1709	0.30	90	2	58	31	0.0	0.0
ESP44	Kreb Trail 6 (C)	33	19	492	1.10	95	2	39	31	40.0	0.0
ESP45	W2	60	34	1602	0.70	95	2	99	76	33.8	0.0
ESP46	Little Mountain 7	56	28	1232	0.60	100	2	21	20	50.0	0.0
ESP47	Mulls Gap 9	30	27	636	0.35	90	2	6	5	100.0	100.0
ESP48	Little Mountain 13	38	22	657	0.58	100	2	32	12	60.0	0.0
ESP49	Grass Mountain 17	86	14	946	0.57	90	2	38	37	45.0	0.0
ESP50	Grass Mountain 18	12	7	66	0.37	85	2	11	7	50.0	50.0
ESP51	Grass Mountain 19	14	10	110	0.90	100	2	18	18	70.0	70.0
ESP52	Warrior Ridge 5	58	15	683	0.60	95	2	37	36	35.0	0.0
ESP53	Warrior Ridge 9	104	24	1960	0.50	95	2	67	66	32.5	0.0
ESP54	Warrior Ridge 0	60	20	942	0.24	80	1	25	7	48.0	20.0
ESP55	Warrior Ridge B	87	21	1435	0.55	95	1	64	30	70.0	40.0
ESP56	West Rim North 2	44	32	1106	0.42	90	1	36	10	45.0	20.0
ESP57	West Rim North 11	77	11	665	0.59	90	1	54	12	41.7	15.0
ESP58	West Rim South 2	44	10	346	0.17	50	2	24	17	51.3	0.0
ESP59	West Rim South 3	88	13	898	0.39	95	2	21	20	63.3	30.0
ESP60	West Rim South 7	34	13	347	0.60	95	2	31	20	67.5	40.0
ESP61	West Rim South 11	14	12	132	0.26	95	2	23	22	32.7	0.0
ESP62	2nd Narrows 5	8	6	38	0.30	100	1	12	11	85.0	85.0
ESP63	2nd Narrows 1	23	18	325	0.60	90	1	21	10	70.0	60.0
ESP64	2nd Narrows 6	32	18	452	0.70	100	2	45	45	36.7	0.0
ESP65	2nd Narrows 4	60	36	1696	0.30	95	1	16	11	13.3	0.0
ESP66	3 Square Hollow 3	50	13	511	0.30	95	1	99	0	44.0	10.0
ESP67	Meadow Grounds 4	15	15	177	0.40	98	1	8	7	53.3	0.0
ESP68	SGL 300-1	35	12	330	0.70	100	1	7	43	77.5	60.0
ESP69	SGL 300-2	35	14	385	1.00	100	1	20	8	37.5	5.0
ESP70	Irishtown 1	34	34	908	1.50	100	1	8	7	2.5	0.0
ESP71	Kidder 2	22	15	259	0.50	95	1	3	3	70.0	60.0
ESP72	Kidder 9	90	35	2474	0.90	100	1	9	2	25.0	0.0
ESP73	DSF14	16	16	201	0.30	0	0	6	6	35.0	10.0
ESP74	DSF32	22	17	294	0.50	95	2	16	5	36.3	0.0
ESP75	5MW2 Evergreen	21	18	297	0.30	80	1	22	9	92.5	85.0
ESP76	DSF46	24	7	132	0.90	95	1	12	11	60.0	60.0
ESP77	Bowers Creek 1	13	10	102	0.20	75	1	12	2	0.0	0.0
ESP78	Bowers Creek 3	13	10	102	0.20	75	2	4	2	40.0	40.0
ESP79	Bowers Creek 8	33	9	233	0.50	70	1	40	3	63.3	0.0
ESP80	Minsi 1	3	2	5	0.50	25	1	9	9	57.5	30.0
ESP81	Minsi 4	30	10	236	0.35	85	1	39	20	31.7	5.0
ESP82	Minsi 9	32	16	402	0.40	95	1	40	40	72.5	45.0
ESP83	5MW1 Sphagnum	36	25	707	0.40	85	2	20	5	33.3	0.0
ESP84	Pinchot 1 Gray Tree Frog	34	17	454	0.45	100	1	5	3	61.7	45.0
ESP85	Pinchot 2 Barn	12	8	75	0.80	90	1	99	3	50.0	50.0
ESP86	W1	40	22	691	0.70	90	1	3	3	50.0	0.0
ESP87	W16	24	14	264	0.50	90	2	99	11	100.0	100.0
ESP88	S1	70	32	1759	0.52	95	1	99	50	27.5	0.0
ESP89	Lily Pond	35	32	880	1.75	95	2	20	20	49.0	0.0

Appendix 8. Water chemistry results presented for the eighty nine EPA study seasonal pools. Descriptions of each water chemistry variable are presented first and followed by results of the analysis.

Water chemistry variable (Code)	Units	Kit / meter	Definition of variable measured
Air temp (AirTemp)	degrees Celsius	Kestrel 4000 Pocket Weather Tracker	Current air temperature recorded as part of herptile surveys, relates to reptile and amphibian activity
Water temp (H_2OTemp)	degrees Celsius	YSI meter 556 mps	Temperatures vary seasonally and temporally. Temperatures are affected by canopy cover, pool depth and the water source.
Dissolved oxygen (Oxygen)	mg/l	YSI meter 556 mps	Amount of oxygen dissolved in water. Often higher during the day due to photosynthesis. The amount of dissolved oxygen the water can hold decreases as water temperatures increase. Low dissolved oxygen may be due to high levels of organic matter or nutrients that are decomposing.
Oxidation reduction potential (ORP)	mV	YSI meter 556 mps	In general a measure of the oxidative state of a given environment and dictates what biogeochemical reactions can occur (i.e., high values indicate oxygen is the primary substrate for respiration, decreasing values indicate changes to moderate and then strongly anaerobic respiration, with carbon dioxide reduced to methane at the strongly negative ORP values).
pH (pH)	values between 0 and 14	YSI meter 556 mps	A measure of the activity of dissolved hydrogen ions. A value of 7 is considered neutral on a sliding scale from 0 - 14. Values below 7 are acidic; those above 7 are alkaline. Acids may enter pools from the surrounding soil, precipitation or groundwater. Pure water is neutral.
Conductivity (Conduct)	mS/cm	YSI meter 556 mps	Amount of ionic material dissolved in water. Freshwater is low in conductivity; sea water is high. Conductivity may spike after a rainfall if runoff containing road salts or fertilizers contaminates a pool.
Total alkalinity (TotAlk)	ppm/$CaCO_3$	LaMotte (model DR-A)	Measures the capacity to neutralize acids. Carbonates are the most common natural buffers.
Total hardness (TotHard)	ppm/$CaCO_3$	LaMotte (model PHT-CM-DR-LT)	A measure of the total concentration of dissolved calcium and magnesium ions.
Calcium hardness (CalcHard)	ppm/$CaCO_3$	LaMotte (model PHT-CM-DR-LT)	A measure of the total concentration of calcium ions in the water.
Magnesium hardness (MgHard)	ppm/$CaCO_3$	LaMotte (model PHT-CM-DR-LT)	A measure of the total concentration of magnesium ions in the water. This value is calculated by subtracting the calcium hardness from the total hardness value.

Pool num	Pool name	Primary lithosome	pH	TotHard	CalcHard	MgHard	Tot Alk	Conduct	ORP	Elev_m	Jul Day	Air Temp	H_20 Temp	Oxygen
ESP01	Roaring Run 1	Sandstone	5.08	10	4	6	12	29	223.7	522.0	92	12.9	9.7	7.08
ESP02	Roaring Run 2 Bear Wallow	Argillaceous sandstone	5.16	18	10	8	10	38	128.2	643.2	92	7.8	13.9	8.32
ESP03	Plain Grove 1	Sandstone	5.49	30	20	10	13	42	472.0	383.1	105	12.6	12.2	11.76
ESP04	Plain Grove 2	Sandstone	5.25	24	16	8	12	37	275.6	387.0	105	11.3	8.9	8.72
ESP05	Plain Grove 3	Sandstone	5.40	20	16	4	8	35	257.0	385.3	105	8.1	7.2	11.12
ESP06	Wolf Creek Narrows	Sandstone	6.91	144	128	16	132	196	300.3	372.8	107	19.0	9.0	6.52
ESP07	Lisica 1	Sandstone	6.52	52	21	31	24	37	264.8	424.8	114	17.1	10.8	3.72
ESP08	Jennings 1	Sandstone	5.92	32	12	20	7	27	378.1	364.8	106	15.9	8.2	11.30
ESP09	Jennings 2	Sandstone	6.60	40	17	23	6	48	244.0	364.7	106	17.4	15.6	8.30
ESP10	Jennings 3	Sandstone	5.85	40	20	20	9	41	356.0	367.4	106	15.9	12.9	11.05
ESP11	Jennings 4	Sandstone	6.60	28	16	12	5	50	237.4	371.2	106	21.0	20.0	8.30
ESP12	Lisica 2	Sandstone	6.92	24	12	12	8	45	246.4	420.3	114	17.5	12.5	1.87
ESP13	Lisica 3	Sandstone	7.53	76	12	64	12	27	264.4	421.3	114	13.2	10.8	4.26
ESP14	SGL 216-1	Sandstone	5.25	32	16	16	4	41	286.1	384.7	108	22.5	12.7	7.44
ESP15	SGL 216-2	Sandstone	6.20	58	16	32	5	41	250.1	383.6	108	25.5	14.0	7.98
ESP16	SGL 216-3	Sandstone	5.42	36	16	20	4	36	353.6	366.0	108	24.8	12.5	11.90
ESP17	SGL 95	Sandstone	6.82	12	9	3	4	24	273.8	452.1	107	21.7	10.8	7.46
ESP18	Sproul 1	Shale	4.60	12	12	0	4	228	277.0	582.5	105	10.0	6.0	10.00
ESP19	Sproul 2	Sandstone	4.03	2	2	0	22	26	253.7	658.4	105	11.0	16.3	10.79
ESP20	Sproul 3 Yost Run BDA	Sandstone	3.91	2	2	0	30	29	-60.6	658.4	105	12.8	11.3	11.00
ESP21	Sproul 4	Sandstone	4.93	26	22	4	30	517	241.1	658.4	105	10.0	10.0	10.73
ESP22	Spring Creek 1	Siltstone	6.44	28	22	6	26	37	592.4	432.1	119	10.1	10.1	5.42
ESP23	Spring Creek 2	Siltstone	6.10	20	11	9	8	15	529.9	432.1	119	9.3	10.5	6.40
ESP24	SGL 102-1	Siltstone	6.34	28	8	20	16	52	377.7	428.9	119	7.7	9.6	8.90
ESP25	SGL 102-2	Siltstone	6.20	124	101	23	105	176	420.3	445.8	119	8.2	9.8	10.87
ESP26	W3	Dolomite	4.55	6	6	0	6	250	248.4	296.0	95	2.7	7.5	5.02
ESP27	Wolf Rocks	Sandstone	3.97	8	8	0	4	39	312.6	620.3	98	11.0	8.2	4.75
ESP28	Ellisburg 1	Sandstone	6.53	30	6	24	8	23	243.1	758.9	122	16.5	12.5	6.70
ESP29	Ellisburg 2	Sandstone	5.75	13	5	8	4	25	261.3	758.3	122	17.8	14.3	5.95
ESP30	Ellisburg 3	Sandstone	4.98	14	6	8	4	19	268.3	766.1	122	18.0	9.1	7.54
ESP31	Ellisburg 4	Sandstone	5.86	14	4	10	4	22	265.3	762.4	122	17.5	11.6	9.63
ESP32	Lisica 4	Sandstone	5.85	23	9	14	14	24	295.0	423.4	114	14.7	11.5	2.84
ESP33	ANF Marienville	Sandstone	7.70	20	6	12	2	26	245.5	568.2	118	15.6	13.9	6.16
ESP34	Black Mo 5	Shale	3.96	2	2	0	6	28	300.9	704.3	98	10.0	7.4	8.07
ESP35	Black Mo 6	Shale	4.58	2	1	1	6	25	252.0	706.0	98	5.6	6.0	10.90

Pool num	Pool name	Primary lithosome	pH	TotHard	CalcHard	MgHard	Tot Alk	Conduct	ORP	Elev_m	Jul Day	Air Temp	H_20 Temp	Oxygen
ESP36	French Creek 3	Quartz conglomerate	4.58	18	6	12	10	43	296.6	258.2	110	19.4	14.1	6.01
ESP37	French Creek 5	Arkosic sandstone	6.47	48	30	18	50	128	-48.0	159.4	110	20.1	13.3	5.64
ESP38	French Creek 6	Quartz conglomerate	4.89	20	6	14	6	24	244.6	299.5	110	25.0	15.2	11.07
ESP39	Butler Knob 4	Shale	3.90	2	8	0	2	28	132.1	563.8	108	10.3	7.7	5.43
ESP40	Butler Knob 12b	Shale	3.79	8	4	4	6	38	174.2	566.2	108	9.8	7.1	9.37
ESP41	Butler Knob 14	Shale	3.94	16	6	10	6	28	273.9	563.3	108	8.4	6.6	7.99
ESP42	Mulls Gap 4	Shale	6.57	8	6	2	14	19	142.8	469.0	123	16.0	13.4	3.77
ESP43	Kreb Trail 5 (D)	Sandstone	4.23	4	2	2	4	20	-9.6	595.5	122	25.0	17.8	1.58
ESP44	Kreb Trail 6 (C)	Sandstone	4.00	4	2	2	4	27	244.6	593.1	131	24.0	18.4	6.89
ESP45	W2	Dolomite	4.57	6	4	2	12	15	147.5	297.4	95	1.6	5.6	4.28
ESP46	Little Mountain 7	Shale	4.41	2	2	0	10	51	92.9	484.3	123	23.0	13.0	10.90
ESP47	Mulls Gap 9	Shale	4.83	8	8	0	8	25	190.6	467.1	123	23.3	14.9	5.39
ESP48	Little Mountain 13	Shale	4.36	8	6	2	10	16	120.9	488.1	124	19.6	12.0	3.52
ESP49	Grass Mountain 17	Shale	4.98	4	4	0	10	18	78.7	491.7	124	23.3	15.8	3.24
ESP50	Grass Mountain 18	Shale	4.67	8	6	2	10	23	194.3	501.9	124	13.7	19.1	3.02
ESP51	Grass Mountain 19	Shale	4.30	4	4	0	10	21	169.0	498.2	124	16.9	17.1	1.70
ESP52	Warrior Ridge 5	Limestone	3.99	14	6	8	6	33	309.9	336.6	103	7.9	7.8	14.02
ESP53	Warrior Ridge 9	Limestone	3.93	10	8	2	12	35	334.3	336.6	100	7.9	8.7	8.07
ESP54	Warrior Ridge 0	Limestone	4.24	14	8	6	10	111	236.3	335.4	100	6.8	8.5	10.78
ESP55	Warrior Ridge B	Limestone	4.01	14	10	4	10	330	322.7	339.3	100	7.9	6.8	10.73
ESP56	West Rim North 2	Sandstone	4.73	16	6	10	10	24	-85.9	585.5	129	29.7	15.3	0.89
ESP57	West Rim North 11	Sandstone	4.40	18	12	6	10	24	19.2	580.2	129	29.7	14.9	1.90
ESP58	West Rim South 2	Sandstone	4.00	12	8	4	10	34	297.5	557.4	129	25.4	18.2	1.01
ESP59	West Rim South 3	Sandstone	4.82	14	6	8	4	21	1.5	557.6	137	11.4	13.0	1.55
ESP60	West Rim South 7	Sandstone	4.39	8	6	2	16	20	-4.9	563.9	130	21.7	12.8	0.28
ESP61	West Rim South 11	Sandstone	4.31	8	4	2	8	25	182.8	571.6	129	21.9	18.8	3.92
ESP62	2nd Narrows 5	Sandstone	4.03	12	8	4	14	28	226.8	500.8	117	18.5	13.1	4.73
ESP63	2nd Narrows 1	Sandstone	6.20	14	6	8	10	22	181.6	500.8	117	12.1	11.1	4.20
ESP64	2nd Narrows 6	Sandstone	4.50	10	8	2	10	24	177.2	496.0	117	17.2	13.3	11.10
ESP65	2nd Narrows 4	Sandstone	4.62	14	8	6	6	19	92.7	500.8	117	12.7	10.9	4.59
ESP66	3 Square Hollow 3	Shale	4.29	4	2	2	8	16	39.6	578.6	117	15.9	13.5	2.12
ESP67	Meadow Grounds 4	Shale	5.18	16	8	8	12	127	178.1	468.3	92	6.7	4.0	6.82
ESP68	SGL 300-1	Sandstone	4.85	18	6	12	10	27	166.6	516.5	134	28.1	14.1	2.75
ESP69	SGL 300-2	Sandstone	5.73	20	18	2	20	138	56.1	555.2	134	21.6	10.8	6.79

Pool num	Pool name	Primary lithosome	pH	TotHard	CalcHard	MgHard	Tot Alk	Conduct	ORP	Elev_m	Jul Day	Air Temp	H_20 Temp	Oxygen
ESP70	Irishtown 1	Sandstone	4.57	10	4	6	4	63	272.1	373.6	140	11.5	9.7	6.20
ESP71	Kidder 2	Sandstone	4.29	18	4	14	8	264	256.2	437.8	140	9.0	8.3	1.50
ESP72	Kidder 9	Sandstone	4.43	10	6	4	16	243	247.1	450.1	140	10.3	8.0	2.80
ESP73	DSF14	Sandstone	na	na	na	na	na	0	0.0	362.1	133	0.0	0.0	0.00
ESP74	DSF32	Sandstone	6.42	18	6	12	10	22	112.1	381.1	133	24.8	18.1	16.00
ESP75	5MW2 Evergreen	Gravelly sand	5.61	30	12	18	56	70	17.4	61.0	125	22.0	14.5	0.32
ESP76	DSF46	Sandstone	4.45	18	4	14	18	25	208.9	397.0	133	25.2	10.4	2.40
ESP77	Bowers Creek 1	Sandstone	4.72	10	6	4	6	33	258.3	399.7	141	13.1	8.8	5.06
ESP78	Bowers Creek 3	Sandstone	3.90	6	0	6	6	33	261.3	394.7	141	15.5	9.1	2.80
ESP79	Bowers Creek 8	Sandstone	4.26	6	4	2	6	22	230.9	390.2	141	16.1	9.7	1.25
ESP80	Minsi 1	Shale	4.89	38	8	30	28	32	13.7	227.7	126	24.2	16.3	1.12
ESP81	Minsi 4	Shale	5.12	18	16	2	40	39	20.6	230.9	126	24.4	12.4	0.42
ESP82	Minsi 9	Shale	4.96	16	16	0	56	30	113.6	226.7	126	23.1	13.7	2.78
ESP83	5MW1 Sphagnum	Gravelly sand	4.92	28	10	18	52	43	-136.4	61.0	125	23.9	12.6	1.58
ESP84	Pinchot 1 Gray Tree Frog	Diabase	6.96	68	52	16	78	154	127.2	157.2	114	17.1	15.8	4.00
ESP85	Pinchot 2 Barn	Diabase	6.61	66	34	32	120	168	38.0	158.3	127	27.7	20.1	1.90
ESP86	W1	Dolomite	5.17	8	6	2	10	20	204.9	291.2	96	6.3	9.2	7.70
ESP87	W16	Dolomite	4.86	20	8	12	6	17	120.6	300.5	94	12.8	11.6	4.62
ESP88	S1	Dolomite	4.36	20	8	12	11	29	51.7	274.5	94	9.9	11.6	2.75
ESP89	Lily Pond	Dolomite	4.74	10	10	0	14	35	237.6	280.3	95	1.8	8.7	6.79

Appendix 9. Plant species documented in survey of eighty-nine seasonal pools in PA.

Family	Scientific Name	Common Name
Aceraceae	*Acer pensylvanicum*	moosewood
	Acer rubrum	red maple
	Acer saccharum	sugar maple
Alismataceae	*Alisma subcordatum*	Broad-leaved water-plantain
Anacardiaceae	*Toxicodendron radicans*	poison-ivy
Aquifoliaceae	*Ilex verticillata*	winterberry
Araceae	*Symplocarpus foetidus*	skunk cabbage
Asclepiadaceae	*Asclepias incarnata ssp. incarnata*	swamp milkweed
Asteraceae	*Bidens*	beggarticks
	Bidens cernua	bur-marigold
	Bidens connata	beggar-ticks
	Bidens discoidea	small beggar-ticks
	Bidens frondosa	beggar-ticks
	Bidens tripartita	beggar-ticks
	Doellingeria umbellata	flat-topped white aster
	Erechtites hieraciifolia	fireweed
	Euthamia graminifolia	grass-leaved goldenrod
	Packera obovata	ragwort
	Solidago rugosa	wrinkle-leaf goldenrod
	Symphyotrichum lateriflorum	calico aster
	Taraxacum officinale	common dandelion
Balsaminaceae	*Impatiens*	jewelweed
	Impatiens capensis	jewelweed
Betulaceae	*Betula*	birch
	Betula alleghaniensis	yellow birch
	Betula lenta	black birch
	Betula papyrifera	paper birch
	Betula populifolia	gray birch
	Carpinus caroliniana	hornbeam
	Ostrya virginiana	hop-hornbeam
Blechnaceae	*Woodwardia virginica*	Virginia chain fern
Campanulaceae	*Lobelia cardinalis*	cardinal-flower
Caprifoliaceae	*Sambucus canadensis*	American elder
	Viburnum recognitum	northern arrowwood
Clusiaceae	*Hypericum*	St. Johnswort
	Hypericum ellipticum	pale St. Johnswort
	Triadenum virginicum	marsh St. Johnswort
Cornaceae	*Cornus racemosa*	gray dogwood
Cuscutaceae	*Cuscuta gronovii*	Common dodder
Cyperaceae	*Carex*	sedge
	Carex baileyi	sedge
	Carex brunnescens	sedge
	Carex canescensvar canescens	sedge
	Carex crinita var. crinita	short-hair sedge
	Carex debilis var. debilis	sedge
	Carex deweyana	sedge
	Carex folliculata	sedge
	Carex grayi	sedge
	Carex gynandra	sedge
	Carex intumescens	sedge
	Carex lupulina	sedge
	Carex lurida	sedge
	Carex pellita	sedge
	Carex projecta	sedge
	Carex scoparia	broom sedge

Family	Scientific Name	Common Name
Cyperacea cont.		
	Carex stipata	sedge
	Carex stricta	tussock sedge
	Carex tribuloides	sedge
	Carex utriculata	sedge
	Carex vesicaria	sedge
	Dulichium arundinaceumv ar. arundinaceum	three-way sedge
	Eleocharis	spikerush
	Eleocharis acicularis	needle spike-rush
	Eleocharis obtusa	spike-rush
	Eleocharis palustris	creeping spike-rush
	Eleocharis tenuis	spike-rush
	Rhynchospora alba	white beak-rush
	Schoenoplectus tabernaemontani	great bulrush
	Scirpus ancistrochaetus	northeastern bulrush
	Scirpus cyperinus	wool-grass
Dryopteridaceae	*Dryopteris*	wood fern
	Dryopteris intermedia	evergreen woodfern
	Onoclea sensibilis	sensitive fern
Ericaceae	*Gaylussacia frondosa*	dangleberry
	Lyonia ligustrina	maleberry
	Rhododendron maximum	Rosbay
	Vaccinium	blueberry
	Vaccinium corymbosum	highbush blueberry
	Vaccinium macrocarpon	cranberry
	Vaccinium myrtilloides	sour-top blueberry
Fabaceae	*Robinia pseudoacacia*	black locust
Fagaceae	*Fagus grandifolia*	American beech
	Quercus alba	white oak
	Quercus bicolor	swamp white oak
	Quercus imbricaria	shingle oak
	Quercus palustris	pin oak
	Quercus prinus	chestnut oak
	Quercus rubra	northern red oak
	Quercus velutina	black oak
Haloragaceae	*Proserpinaca palustris*	common mermaid-weed
Hamamelidaceae	*Hamamelis virginiana*	witch-hazel
	Liquidambar styraciflua	sweetgum
Iridaceae	*Iris*	iris
	Iris versicolor	northern blue flag
Juglandaceae	*Carya*	hickory
	Carya ovata	shagbark hickory
Juncaceae	*Juncus*	rush
	Juncus canadensis	Canada rush
	Juncus effusus	soft rush
	Juncus subcaudatus	rush
Lamiaceae	*Lycopus americanus*	water-horehound
	Lycopus uniflorus	bugleweed
	Lycopus virginicus	bugleweed
	Scutellaria lateriflora	mad-dog skullcap
Lauraceae	*Lindera benzoin*	spicebush
	Sassafras albidum	sassafras
Lemnaceae	*Lemna minor*	duckweed
Liliaceae	*Maianthemum canadense*	Canada mayflower
	Medeola virginiana	Indian cucumber-root
Magnoliaceae	*Liriodendron tulipifera*	tuliptree
Nymphaeaceae	*Nuphar variagata*	spatterdock
Nyssaceae	*Nyssa sylvatica*	Sourgum

Family	Scientific Name	Common Name
Oleaceae	*Fraxinus americana var. americana*	white ash
	Fraxinus nigra	black ash
Onagraceae	*Ludwigia palustris*	marsh-purslane
Osmundaceae	*Osmunda cinnamomea*	cinnamon fern
	Osmunda regalis	royal fern
Pinaceae	*Pinus rigida*	pitch pine
	Pinus strobus	eastern white pine
	Tsuga canadensis	canada hemlock
Poaceae	*Agrostis*	bentgrass
	Agrostis capillaris	Rhode Island bent
	Agrostis gigantea	redtop
	Agrostis perennans	Autumn bent
	Agrostis stolonifera var. palustris	carpet bentgrass
	Brachyelytrum erectum	Brachyelytrum
	Bromus pubescens	Canada brome
	Calamagrostis canadensis var. canadensis	Canada bluejoint
	Cinna arundinacea	woo reedgrass
	Cinna latifolia	drooping woodreed
	Danthonia compressa	northern oatgrass
	Dichanthelium acuminatum	Panic grass
	Echinochloa crus-galli	barnyard-grass
	Echinochloa muricata	barnyard-grass
	Glyceria	mannagrass
	Glyceria acutiflora	mannagrass
	Glyceria canadensis	rattlesnake mannagrass
	Glyceria grandis	American mannagrass
	Glyceria melicaria	slender mannagrass
	Glyceria septentrionalis	floating mannagrass
	Glyceria striata	fowl mannagrass
	Holcus lanatus	velvetgrass
	Leersia oryzoides	rice cutgrass
	Leersia virginica	cutgrass
	Muhlenbergia	muhly
	Panicum	panic grass
	Panicum rigidulum	panic grass
	Phalaris arundinacea	reed canary-grass
	Poa compressa	Canada bluegrass
	Poa saltuensis	old-pasture bluegrass
	Sphenopholis obtusata	slender wedgegrass
	Torreyochloa pallida	pale mannagrass
Polygonaceae	*Persicaria*	smartweed
	Persicaria hydropiperoides	mild waterpepper
	Persicaria punctata	dotted smartweed
	Persicaria hydropiper	smartweed
	Persicaria lapathifolium	dock-leaf smartweed
	Persicaria longiseta	low smartweed
	Persicaria sagittata	tearthumb
	Persicaria virginianum	jumpseed
Primulaceae	*Lysimachia nummularia*	creeping-charlie
	Lysimachia terrestris	swamp-candles
	Trientalis borealis	star-flower
Ranunculaceae	*Clematis virginiana*	Virgin's-bower
	Geum canadense	white avens
	Ranunculus abortivus	small-flowered crowfoot
Rosaceae	*Amelanchier*	serviceberry
	Photinia melanocarpa	black chokeberry
	Prunus serotina	wild black cherry
	Rosa palustris	swamp rose

Family	Scientific Name	Common Name
Rosaceae cont.	*Rubus flagellaris*	prickly dewberry
	Rubus hispidus	swamp dewberry
	Spiraea alba	meadow-sweet
	Spiraea tomentosa	hardhack
Rubiaceae	*Cephalanthus occidentalis*	buttonbush
	Galium	bedstraw
	Galium aparine	bedstraw
	Galium asprellum	rough bedstraw
	Galium tinctorium	bedstraw
	Mitchella repens	partridge-berry
Salicaceae	*Populus tremuloides*	quaking aspen
	Salix	willow
	Salix eriocephala	diamond willow
	Salix sericea	silky willow
Smilacaceae	*Smilax rotundifolia*	catbrier
Solanaceae	*Solanum dulcamara*	trailing nightshade
Sparganiaceae	*Sparganium americanum*	bur-reed
	Sparganium eurycarpum	bur-reed
Thelypteridaceae	*Thelypteris palustris*	marsh fern
Ulmaceae	*Celtis occidentalis*	hackberry
	Ulmus americana	American elm
Urticaceae	*Boehmeria cylindrica var. cylindrica*	false nettle
	Pilea pumila	clearweed
	Urtica dioica	great nettle
Violaceae	*Viola*	violet
	Viola lanceolata	lance-leaved violet
	Viola sagittata	arrow-leaved violet
	Viola sororia	common blue violet
Vitaceae	*Parthenocissus quinquefolia*	Virginia-creeper

Appendix 10. Bryophyte species documented in eighty-nine seasonal pools in PA. Determinations by John Atwood of the Bryophyte Herbarium at the Missouri Botanical Garden.

Family	Scientific Name
Amblystegiaceae	*Campylium chrysophyllum* (Brid.) Lange
	Campylium polygamum (Schimp.) C. E. O. Jensen
	Campylium radicale (P. Beauv.) Grout
	Leptodictyum riparium (Hedw.) Warnst.
	Trichocolea tomentella (Ehrh.) Dum.
	Warnstorfia fluitans (Hedw.) Loeske
Aulacomniaceae	*Aulacomnium palustre* (Hedw.) Schwägr.
Bartramiaceae	*Philonotis fontana (*Hedw.) Brid.
Brachytheciaceae	*Brachythecium laetum* (Brid.) Schimp.
	Brachythecium rutabulum (Hedw.) Schimp.
	Bryhnia novae-angliae (Sull. & Lesq.) Grout
	Steerecleus serrulatus (Hedw.) H. Rob.
Bryaceae	*Pohlia nutans* (Hedw.) Lindb.
Climaciaceae	*Climacium americanum var. americanum* Brid.
	Climacium americanum var. kindbergii Renauld & Cardot
Dicranaceae	*Dicranella heteromalla* (Hedw.) Schimp
	Dicranum flagellare Hedw.
	Dicranum montanum Hedw.
	Dicranum scoparium Hedw.
	Orthodicranum flagellare Hedw.
	Orthodicranum fulvum Hook.
	Orthodicranum montanum Hedw.
	Campylopus tallulensis Sull. & Lesq. ex Sull.
	Dicranella heteromalla (Hedw.) Schimp.
Entodontaceae	*Entodon seductrix* (Hedw.) Müll. Hal.
Fontinalaceae	*Fontinalis flaccida* Renauld & Cardot
Hedwigiaceae	*Hedwigia ciliata* (Hedw.) P. Beauv.
Helodiaceae	*Helodium paludosum* (Austin) Broth.
Hypnaceae	*Callicladium haldanianum* (Grev.) H. A. Crum
	Hypnum imponens Hedw.
	Hypnum imponens Hedw.
	Hypnum lindbergii Mitt.
	Platygyrium repens (Brid.) Schimp.
Leucobryaceae	*Leucobryum glaucum* (Hedw.) Ångstr. in Fries
Mniaceae	*Plagiomnium cuspidatum* (Hedw.) T. J. Kop.
Plagiomniaceae	*Plagiomnium ciliare* (Müll. Hal.) T. J. Kop.
Plagiomniaceae	*Plagiomnium cuspidatum* (Hedw.) T. J. Kop.
Plagiotheciaceae	*Plagiothecium laetum* Schimp.
	Pseudotaxiphyllum elegans (Brid.) Z. Iwats.
Polytrichaceae	*Atrichum angustatum* (Brid.) Bruch & Schimp.
	Polytrichastrum ohioense (Renauld & Cardot) G. L. Smith
	Polytrichum commune Hedw.
	Polytrichum commune var. commune Hedw.
	Polytrichum juniperinum Hedw.
Sematophyllaceae	*Sematophyllum demissum* (Wilson) Mitt.
cont.	

Family	Scientific Name
Sphagnaceae	*Sphagnum angustifolium* (C. E. O. Jensen ex Russow) C. E. O. Jensen in Tolf
	Sphagnum centrale C. E. O. Jensen
	Sphagnum fallax (H. Klinggr.) H. Klinggr.
	Sphagnum fimbriatum Wilson in Wilson & Hook.
	Sphagnum lescurii Sull. in A. Gray
	Sphagnum magellanicum Brid.
	Sphagnum palustre L.
	Sphagnum papillosum Lindb.
	Sphagnum pylaesii Brid.
	Sphagnum squarrosum Crome
Tetraphidaceae	*Tetraphis pellucida* Hedw.
Thuidiaceae	*Thuidium delicatulum* (Hedw.) Schimp.

Appendix 11. Invertebrates documented in eighty-nine seasonal pools in PA. Presented with analysis code for taxon, trophic group, number of pools, and ecoregional distribution. The ecoregion where each taxon showed the greatest relative abundance is indicated by **bold font** of the code for that ecoregion. Descriptions of the trophic groups and ecoregional codes are presented first and followed by the summary of results.

Trophic group	Trophic code	Analysis grouping code
Collector-gatherer	CG	CG
Detritivore	D	CG
Filterer	F	CG
Herbivore	H	CG
Predator	P	P
Parasite	Pa	P
Scraper	Sc	CG
Shredder	Sh	Sh
Scavenger	Sv	P

Ecoregion description	Code
Western Allegheny Plateau (WAP)	W
Central Appalachian Forest (CAP	C
High Allegheny Plateau (HAL)	H
Lower New England / Northern Piedmont (LNE/NP)	L

Taxon	Analysis code	Trophic group	# pools	Eco-regions
Annelida, Hirudinea	HIRUDINE	PPa	9	**W** H
Annelida, Oligochaeta	OLIGOCHT	CG	66	**W C H** L
Arachnida, Acari, Hydrachnida	HYDRACHN	PPa	62	**W C H L**
Crustacea, Branchiopoda, Anostraca, Chirocephalidae, *Eubranchipus holmani*	Eub_holm	CGF	1	**C**
Crustacea, Branchiopoda, Anostraca, Chirocephalidae, *Eubranchipus vernalis*	Eub_vern	CGF	10	W **C**
Crustacea, Branchiopoda, Cladocera	CLADOCER	CGP	59	**W C H L**
Crustacea, Malacostraca, Amphipoda, Crangonyctidae	CRANGONY	CGDP	4	**W H**
Crustacea, Malacostraca, Amphipoda, Hyalellidae	HYLALELL	CGDP	1	**H**
Crustacea, Malacostraca, Isopoda, Asellidae	ASELLID	CGDP	6	**W H**
Crustacea, Maxillopoda, Copepoda	COPEPOD	CGPSc	53	**W C H L**
Crustacea, Ostracoda	OSTRACOD	CGD	50	**W C H L**
Insecta, Coleoptera, Dytiscidae, *Acilius*	Acilius	P	12	W C **H** L
Insecta, Coleoptera, Dytiscidae, *Agabus*	Agabus	P	20	W **C** H L
Insecta, Coleoptera, Dytiscidae, *Bidessnotus*	Bidsnots	P	2	**W L**
Insecta, Coleoptera, Dytiscidae, *Copelatus*	Copelats	P	3	**W** C H
Insecta, Coleoptera, Dytiscidae, *Coptotomus*	Cptotoms	P	2	**W H**
Insecta, Coleoptera, Dytiscidae, *Desmopachria*	Dsmpchra	P	7	W **C H** L
Insecta, Coleoptera, Dytiscidae, *Dytiscus*	Dytiscus	P	4	W **H**
Insecta, Coleoptera, Dytiscidae, *Hydaticus*	Hydatics	P	1	**C**
Insecta, Coleoptera, Dytiscidae, *Hydroporus*	Hydrpors	P	27	**W C** H L
Insecta, Coleoptera, Dytiscidae, *Hydrovatus*	Hydrvats	P	1	**L**

Taxon	Analysis code	Trophic group	# pools	Eco-regions
Insecta, Coleoptera, Dytiscidae, *Hygrotus*	Hygrotus	P	5	**W** C
Insecta, Coleoptera, Dytiscidae, *Laccodytes*	Lacodyts	P	1	**C**
Insecta, Coleoptera, Dytiscidae, *Laccophilis*	Lacophls	P	1	**C**
Insecta, Coleoptera, Dytiscidae, *Laccornis*	Laccorns	P	3	**W C H**
Insecta, Coleoptera, Dytiscidae, *Liodessus*	Liodesus	P	26	W **C** H
Insecta, Coleoptera, Dytiscidae, *Neoporus*	Neoporus	P	2	**C H**
Insecta, Coleoptera, Dytiscidae, nr *Agabetes*	Agabetes	P	2	H **L**
Insecta, Coleoptera, Dytiscidae, *Rhantus*	Rhantus	P	1	**W**
Insecta, Coleoptera, Dytiscidae, *Uvarus*	Uvarus	P	6	W **C** H L
Insecta, Coleptera, Gyrinidae, *Dineutus*	Dineutus	PSv	2	**C**
Insecta, Coleptera, Haliplidae, *Haliplus*	Haliplus	ShH	3	**W C H**
Insecta, Coleptera, Haliplidae, *Peltodytes*	Peltdyte	ShHP	1	**W**
Insecta, Coleptera, Hydrophilidae, *Anacaena*	Anacaena	CG	1	**W**
Insecta, Coleptera, Hydrophilidae, *Cymbiodyta*	Cymbdyta	CG	1	**W**
Insecta, Coleptera, Hydrophilidae, *Enochrus*	Enochrus	H	4	W **C**
Insecta, Coleptera, Hydrophilidae, *Helochares*	Helochar	CG	1	**W**
Insecta, Coleptera, Hydrophilidae, *Hydraena*	Hydraena	ScCG	4	**W H L**
Insecta, Coleptera, Hydrophilidae, *Hydrobius*	Hydrbius	P	2	W **L**
Insecta, Coleptera, Hydrophilidae, *Hydrochara*	Hydrchar	P	1	**L**
Insecta, Coleptera, Hydrophilidae, *Hydrochus*	Hydrchus	ShH	4	**C**
Insecta, Coleptera, Hydrophilidae, Sphaeridiinae	Spaerid	CG	2	**C**
Insecta, Coleptera, Scirtidae, *Cyphon*	Cyphon	ScCGShH	24	**W C** H L
Insecta, Coleptera, Scirtidae, *Prionocyphon*	Prcyphon	ScCGShH	2	**W**
Insecta, Collembola, Isotomidae	ISOTOMID	CGSv	15	W C **H L**
Insecta, Collembola, Poduridae, *Podura aquatica*	PODURA	CGSv	14	W **C** H
Insecta, Collembola, Sminthuridae	SMINTHUR	CGSv	6	**C H**
Insecta, Diptera, Brachycera-Cyclorrhapha	BRACHY	CG	1	**C**
Insecta, Diptera, Ceratopogonidae	CERATOPO	P	19	**W C H** L
Insecta, Diptera, Chaoboridae, *Chaborus*	Chaborus	P	1	**W**
Insecta, Diptera, Chaoboridae, *Mochlonyx*	Mochlnyx	P	75	**W C H** L
Insecta, Diptera, Chironomidae	CHIRONOM	CGP	77	**W C H L**
Insecta, Diptera, Chironomidae morpho A (pupae)	ChironAp	CGP	14	W **C** H
Insecta, Diptera, Chironomidae morpho B (pupae)	ChironBp	CG	5	**C H**
Insecta, Diptera, Culicidae, *Aedes vexans*	Aed_vex	CGF	6	W **C**
Insecta, Diptera, Culicidae, not ID'd past family	CULICID	CGF	27	W **C H**
Insecta, Diptera, Culicidae, *Ochlerotatus abserratus*	Och_abs	CGF	8	**C H**
Insecta, Diptera, Culicidae, *Ochlerotatus canadensis canadensis*	Och_can	CGF	40	**W C H L**
Insecta, Diptera, Culicidae, *Ochlerotatus excrucians*	Och_exc	CGF	54	**W C H**
Insecta, Diptera, Dixadae, *Dixa*	Dixa	CG	1	**H**
Insecta, Diptera, Dixadae, *Dixella*	Dixella	CG	1	**H**
Insecta, Diptera, nr Empididae	EMPIDID	CGP	1	**C**
Insecta, Diptera, Stratiomyiidae	STRATIOM	CG	2	**H L**
Insecta, Diptera, Tipulidae	TIPULID	ShDCG	4	**W** C H
Insecta, Ephemeroptera, Leptophlebiidae	LEPTOPHL	CG	3	**W**
Insecta, Ephemeroptera, Siphlonuridae, *Siphlonurus*	SIPHLONR	CGScPSh	1	**W**
Insecta, Hemiptera, Heteroptera, Belostomatidae, *Belastoma*	BELOSTOM	P	2	**W C**
Insecta, Hemiptera, Heteroptera, Corixidae	CORIXIDA	P	5	W **C**
Insecta, Hemiptera, Heteroptera, Gerridae	GERRIDAE	PSv	3	**C**
Insecta, Hemiptera, Heteroptera, Notonectidae	NOTONECT	P	3	W C **L**

Taxon	Analysis code	Trophic group	# pools	Eco-regions
Insecta, Megaloptera, Corydalidae, *Chauliodes*	Chauliod	P	16	W **C** H L
Insecta, Odonata, Anisoptera, Aeshnidae, *Aeshna umbrosa*	Aes_umbr	P	1	**H**
Insecta, Odonata, Anisoptera, Aeshnidae, *Aeshna verticalis*	Aes_vert	P	2	**H**
Insecta, Odonata, Anisoptera, Aeshnidae, *Epiaeshna heros*	Epi_hero	P	15	W **C H** L
Insecta, Odonata, Anisoptera, Corduliidae, nr *Cordulia shurtleffii*	Cor_shur	P	1	**H**
Insecta, Odonata, Anisoptera, Libellulidae	LIBELLUL	P	18	W **C** H
Insecta, Odonata, Anisoptera, Libellulidae, nr *Leucorrhinia*	Lucorina	P	2	W **L**
Insecta, Odonata, Anisoptera, Libellulidae, *Sympetrum*	Sympetrm	P	2	**C**
Insecta, Odonata, Zygoptera, Coenagrionidae	Coenagri	P	3	**H**
Insecta, Odonata, Zygoptera, Coenagrionidae, *Chromagrion conditum*	Chr_cond	P	2	**C H**
Insecta, Odonata, Zygoptera, Coenagrionidae, nr *Chromagrion resolutum*	Chr_reso	P	1	**C**
Insecta, Odonata, Zygoptera, Coenagrionidae, *Nehalennia irene*	Neh_iren	P	2	**H**
Insecta, Odonata, Zygoptera, Lestidae, *Lestes*	Lestes	P	17	**W C** H L
Insecta, Trichoptera, Limnephilidae, *Hesperophylax*	Hesperop	ShDH	6	**W**
Insecta, Trichoptera, Limnephilidae, *Ironoquia*	Ironoqua	Sh	2	**C**
Insecta, Trichoptera, Limnephilidae, *Limnephilus*	Limnphls	ShDHCG	31	**W C** H
Insecta, Trichoptera, Phryganeidae, *Banksiola*	Banksola	ShHP	8	W C **H**
Insecta, Trichoptera, Phryganeidae, *Ptilostomis*	Ptilostm	ShHDP	7	**C** H
Insecta, Trichoptera, Polycentropidae, *Cernotina*	Cernotin	P	1	**C**
Mollusca, Bivalvia, Veneroida, Sphaeriidae, *Pisidium*	Pisidium	F	7	**W** C L
Mollusca, Bivalvia, Veneroida, Sphaeriidae, *Sphaerium*	Sphaerum	F	6	**W** L
Mollusca, Gastropoda, Lymnaeidae, *Stagnicola elodes*	Sta_elod	Sc	1	**W**
Mollusca, Gastropoda, Lymnaeidae, *Stagnicola emarginata*	Sta_emar	Sc	2	**W** C
Mollusca, Gastropoda, Physidae, *Physa*	Physa	D	3	**W**
Mollusca, Gastropoda, Planorbidae	PLANORB	D	6	**W**

Appendix 12. Reptiles and amphibians (herptiles) documented in eighty-nine seasonal pools in PA. Presented with analysis code for taxon, common name, vernal pool habitat use, number of pools, and ecoregional distribution. The ecoregion where each taxon showed the greatest relative abundance is indicated by **bold font** of the code for that ecoregion. Descriptions of the ecoregional codes are presented first and followed by the summary of results.

Ecoregion description	Code
Western Allegheny Plateau (WAP)	W
Central Appalachian Forest (CAP	C
High Allegheny Plateau (HAL)	H
Lower New England / Northern Piedmont (LNE/NP)	L

Taxon	Analysis code	Common name	Vernal pool habitat use	# pools	Eco-regions
Amphibia, Anura, Bufonidae, *Anaxyrus americanus*	Aname	American Toad	aquatic, facultative	1	**C**
Amphibia, Anura, Hylidae, *Hyla versicolor*	Hylver	Gray Treefrog	aquatic, facultative	5	W **C** H
Amphibia, Anura, Hylidae, *Pseudacris crucifer*	Psecru	Spring Peeper	aquatic, facultative	26	W **C** H L
Amphibia, Anura, Ranidae, *Lithobates catesbeianus*	Litcat	Bull Frog	aquatic, facultative	2	**H**
Amphibia, Anura, Ranidae, *Lithobates clamitans*	Litcla	Green Frog	aquatic, facultative	8	C **H**
Amphibia, Anura, Ranidae, *Lithobates sylvaticus*	Litsyl	Wood Frog	aquatic, indicator	67	**W C H L**
Amphibia, Caudata, Ambystomatidae, *Ambystoma jeffersonianum*	Ambjef	Jefferson Salamander	aquatic, indicator	29	**W C** H
Amphibia, Caudata, Ambystomatidae, *Ambystoma maculatum*	Ambmac	Spotted Salamander	aquatic, indicator	62	**W C H** L
Amphibia, Caudata, Ambystomatidae, *Ambystoma opacum*	Ambopa	Marbled Salamander	aquatic, indicator	3	**C** H **L**
Amphibia, Caudata, Plethodontidae, *Hemidactylium scutatum*	Hemscu	Four-toed Salamander	aquatic, facultative	2	**C**
Amphibia, Caudata, Plethodontidae, *Plethodon cinereus*	Plecin	Redback Salamander	terrestrial	31	**W C H L**
Amphibia, Caudata, Plethodontidae, *Plethodon glutinosus*	Pleglu	Slimy Salamander	terrestrial	1	**C**
Amphibia, Caudata, Salamandridae, *Notophthalmus viridescens*	Notvir_a	Red-spotted Newt	aquatic, facultative	23	**W C H**
Reptilia, Serpentes, Culubridae, *Nerodia sipedon*	Nersip	Water Snake	aquatic, facultative	2	**W C**
Reptilia, Serpentes, Culubridae, *Thamnophis sirtalis*	Thasir	Garter Snake	terrestrial	3	**W H L**
Reptilia, Testudines, Chelydridae, *Chelydra serpentina*	Cheser	Snapping Turtle	aquatic, facultative	1	**L**
Reptilia, Testudines, Embydidae, *Clemmys guttata*	Clegut	Spotted Turtle	aquatic, facultative	1	**W**

Appendix 13. Pool abundance, density, and richness for taxonomic groupings. Definitions for codes are found in Appendix 2.

Pool num	Pool name	Invt abun	Shred abun	CG abun	Pred abun	Invt dens	Shred dens	CG dens	Pred dens	Invt rich	Shred rich	CG rich	Pred rich	Indi rich	Aqua rich	Terr rich	Herp rich	Egg abun	Egg dens
ESP01	Roaring Run 1	71	3	54	14	35.5	1.5	27.0	7.0	11	2	7	2	4	4	0	4	180	1.415
ESP02	Roaring Run 2 Bear Wallow	334	1	328	5	167.0	0.5	164.0	2.5	9	1	6	2	2	2	0	2	157	1.388
ESP03	Plain Grove 1	440	84	303	53	73.3	14.0	50.5	8.8	20	2	11	7	2	2	0	2	166	0.192
ESP04	Plain Grove 2	495	23	384	88	99.0	4.6	76.8	17.6	18	2	9	7	2	2	0	2	189	0.273
ESP05	Plain Grove 3	406	6	386	14	203.0	3.0	193.0	7.0	11	2	7	2	2	3	0	3	37	0.122
ESP06	Wolf Creek Narrows	556	30	505	21	111.2	6.0	101.0	4.2	18	2	12	4	4	3	0	3	208	0.265
ESP07	Lisica 1	467	0	443	24	233.5	0.0	221.5	12.0	20	0	13	7	0	0	0	0	0	0.000
ESP08	Jennings 1	347	0	340	7	173.5	0.0	170.0	3.5	12	0	9	3	2	2	1	3	55	0.324
ESP09	Jennings 2	176	0	158	18	88.0	0.0	79.0	9.0	13	0	11	2	0	0	1	1	0	0.000
ESP10	Jennings 3	435	0	418	17	217.5	0.0	209.0	8.5	13	0	9	4	2	3	0	3	79	0.314
ESP11	Jennings 4	177	0	160	17	88.5	0.0	80.0	8.5	10	0	7	3	0	0	1	1	0	0.000
ESP12	Lisica 2	646	5	527	114	161.5	1.3	131.8	28.5	28	2	15	11	2	5	0	5	18	0.034
ESP13	Lisica 3	277	7	239	31	138.5	3.5	119.5	15.5	11	1	7	3	2	2	1	3	8	0.021
ESP14	SGL 216-1	323	1	286	36	29.4	0.1	26.0	3.3	12	1	8	3	2	3	0	3	51	0.031
ESP15	SGL 216-2	482	0	329	153	48.2	0.0	32.9	15.3	11	0	7	4	2	2	1	3	304	0.162
ESP16	SGL 216-3	296	0	245	51	59.2	0.0	49.0	10.2	9	0	7	2	2	2	1	3	24	0.032
ESP17	SGL 95	374	2	344	28	46.8	0.3	43.0	3.5	13	1	6	6	2	4	0	4	129	0.101
ESP18	Sproul 1	536	5	424	107	178.7	1.7	141.3	35.7	10	1	5	4	3	4	0	4	83	0.156
ESP19	Sproul 2	47	0	31	16	23.5	0.0	15.5	8.0	9	0	5	4	2	3	0	3	13	0.099
ESP20	Sproul 3 Yost Run BDA	126	0	82	44	63.0	0.0	41.0	22.0	14	0	5	9	3	5	0	5	56	0.180
ESP21	Sproul 4	217	3	182	32	72.3	1.0	60.7	10.7	10	2	6	2	2	2	0	2	51	0.072
ESP22	Spring Creek 1	514	31	372	111	128.5	7.8	93.0	27.8	21	3	9	9	2	4	0	4	38	0.072
ESP23	Spring Creek 2	178	6	134	38	59.3	2.0	44.7	12.7	18	1	10	7	2	3	0	3	28	0.064
ESP24	SGL 102-1	172	1	165	6	86.0	0.5	82.5	3.0	12	1	7	4	2	3	0	3	86	0.304
ESP25	SGL 102-2	58	1	42	15	19.3	0.3	14.0	5.0	8	1	4	3	2	2	1	3	111	0.280
ESP26	W3	70	3	64	3	17.5	0.8	16.0	0.8	8	1	4	3	3	1	0	1	87	0.081
ESP27	Wolf Rocks	170	7	150	13	34.0	1.4	30.0	2.6	6	1	3	2	3	3	0	3	291	0.348
ESP28	Ellisburg 1	120	0	120	0	60.0	0.0	60.0	0.0	1	0	1	0	0	0	1	1	0	0.000
ESP29	Ellisburg 2	149	0	142	7	74.5	0.0	71.0	3.5	11	0	9	2	1	2	1	3	0	0.000
ESP30	Ellisburg 3	168	0	164	4	84.0	0.0	82.0	2.0	10	0	8	2	0	0	1	1	0	0.000
ESP31	Ellisburg 4	36	0	33	3	18.0	0.0	16.5	1.5	7	0	6	1	0	1	0	1	0	0.000
ESP32	Lisica 4	453	0	355	98	226.5	0.0	177.5	49.0	17	0	9	8	2	3	0	3	38	0.134
cont.																			

Pool num	Pool name	Invt abun	Shred abun	CG abun	Pred abun	Invt dens	Shred dens	CG dens	Pred dens	Invt rich	Shred rich	CG rich	Pred rich	Indi rich	Aqua rich	Terr rich	Herp rich	Egg abun	Egg dens
ESP33	ANF Marienville	63	0	60	3	31.5	0.0	30.0	1.5	7	0	5	2	0	1	1	2	0	0.000
ESP34	Black Mo 5	229	0	206	23	76.3	0.0	68.7	7.7	7	0	4	3	3	4	0	4	100	0.158
ESP35	Black Mo 6	303	0	268	35	60.6	0.0	53.6	7.0	8	0	5	3	3	4	0	4	488	0.543
ESP36	French Creek 3	23	0	22	1	11.5	0.0	11.0	0.5	4	0	3	1	1	1	1	2	30	0.163
ESP37	French Creek 5	78	0	76	2	39.0	0.0	38.0	1.0	7	0	5	2	2	2	0	2	16	0.261
ESP38	French Creek 6	46	0	45	1	23.0	0.0	22.5	0.5	7	0	6	1	2	2	1	3	38	1.792
ESP39	Butler Knob 4	236	4	225	7	47.2	0.8	45.0	1.4	9	1	6	2	3	4	1	5	350	0.530
ESP40	Butler Knob 12b	125	6	119	0	17.9	0.9	17.0	0.0	6	1	5	0	3	4	1	5	657	0.675
ESP41	Butler Knob 14	16	0	12	4	4.0	0.0	3.0	1.0	5	0	3	2	2	2	1	3	18	0.085
ESP42	Mulls Gap 4	705	2	429	274	88.1	0.3	53.6	34.3	17	2	7	8	3	4	0	4	582	0.561
ESP43	Kreb Trail 5 (D)	1054	6	912	136	117.1	0.7	101.3	15.1	21	2	11	8	2	4	0	4	3	0.002
ESP44	Kreb Trail 6 (C)	572	4	120	448	143.0	1.0	30.0	112.0	20	2	8	10	2	3	0	3	14	0.028
ESP45	W2	49	4	34	11	8.2	0.7	5.7	1.8	10	1	6	3	1	2	1	3	77	0.048
ESP46	Little Mountain 7	322	1	195	126	40.3	0.1	24.4	15.8	15	1	8	6	1	5	0	5	66	0.054
ESP47	Mulls Gap 9	167	0	159	8	41.8	0.0	39.8	2.0	11	0	9	2	2	3	0	3	24	0.038
ESP48	Little Mountain 13	164	1	66	97	41.0	0.3	16.5	24.3	17	1	7	9	2	3	0	3	26	0.040
ESP49	Grass Mountain 17	358	7	321	30	59.7	1.2	53.5	5.0	15	2	8	5	3	5	0	5	208	0.220
ESP50	Grass Mountain 18	114	0	101	13	57.0	0.0	50.5	6.5	13	0	8	5	4	3	0	3	50	0.758
ESP51	Grass Mountain 19	108	0	98	10	54.0	0.0	49.0	5.0	9	0	6	3	2	2	0	2	38	0.346
ESP52	Warrior Ridge 5	202	7	177	18	25.3	0.9	22.1	2.3	13	2	8	3	3	3	0	3	276	0.404
ESP53	Warrior Ridge 9	399	2	365	32	30.7	0.2	28.1	2.5	17	1	9	7	1	2	0	2	75	0.038
ESP54	Warrior Ridge 0	185	11	148	26	46.3	2.8	37.0	6.5	15	2	7	6	2	4	0	4	120	0.127
ESP55	Warrior Ridge B	214	2	198	14	23.8	0.2	22.0	1.6	11	2	6	3	3	3	0	3	519	0.362
ESP56	West Rim North 2	437	10	322	105	62.4	1.4	46.0	15.0	17	2	6	9	2	6	0	6	10	0.009
ESP57	West Rim North 11	507	7	432	68	126.8	1.8	108.0	17.0	11	1	5	5	3	3	0	3	258	0.388
ESP58	West Rim South 2	1251	2	1133	116	417.0	0.7	377.7	38.7	16	1	9	6	1	1	0	1	15	0.043
ESP59	West Rim South 3	400	4	335	61	57.1	0.6	47.9	8.7	21	1	5	15	2	4	0	4	42	0.047
ESP60	West Rim South 7	240	4	194	42	80.0	1.3	64.7	14.0	13	1	6	6	1	3	0	3	12	0.035
ESP61	West Rim South 11	160	12	51	97	80.0	6.0	25.5	48.5	10	1	5	4	2	2	1	3	2	0.015
ESP62	2nd Narrows 5	408	0	378	30	204.0	0.0	189.0	15.0	9	0	6	3	3	3	0	3	14	0.371
ESP63	2nd Narrows 1	241	2	207	32	80.3	0.7	69.0	10.7	10	1	7	2	4	4	1	5	330	1.015
ESP64	2nd Narrows 6	297	2	272	23	74.3	0.5	68.0	5.8	10	1	6	3	3	5	1	6	85	0.188
ESP65	2nd Narrows 4	990	11	800	179	90.0	1.0	72.7	16.3	20	1	10	9	3	4	1	5	847	0.499
ESP66	3 Square Hollow 3	237	3	211	23	47.4	0.6	42.2	4.6	13	1	8	4	1	2	1	3	53	0.104
cont.																			

Pool num	Pool name	Invt abun	Shred abun	CG abun	Pred abun	Invt dens	Shred dens	CG dens	Pred dens	Invt rich	Shred rich	CG rich	Pred rich	Indi rich	Aqua rich	Terr rich	Herp rich	Egg abun	Egg dens
ESP67	Meadow Grounds 4	183	14	135	34	91.5	7.0	67.5	17.0	10	1	6	3	4	5	1	6	25	0.141
ESP68	SGL 300-1	147	0	112	35	73.5	0.0	56.0	17.5	18	0	12	6	2	4	0	4	10	0.030
ESP69	SGL 300-2	242	2	225	15	80.7	0.7	75.0	5.0	20	2	9	9	1	3	0	3	20	0.052
ESP70	Irishtown 1	256	0	222	34	42.7	0.0	37.0	5.7	13	0	6	7	1	0	2	2	0	0.000
ESP71	Kidder 2	137	0	123	14	68.5	0.0	61.5	7.0	10	0	6	4	1	1	1	2	0	0.000
ESP72	Kidder 9	236	0	205	31	14.8	0.0	12.8	1.9	9	0	4	5	2	3	2	4	6	0.002
ESP73	DSF14	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.000
ESP74	DSF32	122	1	115	6	61.0	0.5	57.5	3.0	12	1	8	3	1	3	0	3	0	0.000
ESP75	5MW2 Evergreen	210	0	193	17	105.0	0.0	96.5	8.5	8	0	4	4	1	1	1	2	0	0.000
ESP76	DSF46	337	0	333	4	168.5	0.0	166.5	2.0	9	0	7	2	2	3	0	3	6	0.045
ESP77	Bowers Creek 1	66	0	23	43	33.0	0.0	11.5	21.5	7	0	3	4	1	1	0	1	0	0.000
ESP78	Bowers Creek 3	96	0	89	7	48.0	0.0	44.5	3.5	6	0	2	4	0	0	0	0	0	0.000
ESP79	Bowers Creek 8	49	0	27	22	24.5	0.0	13.5	11.0	3	0	1	2	2	3	0	3	0	0.000
ESP80	Minsi 1	271	0	241	30	135.5	0.0	120.5	15.0	9	0	6	3	0	2	1	2	0	0.000
ESP81	Minsi 4	188	2	174	12	94.0	1.0	87.0	6.0	14	2	9	3	0	0	1	1	0	0.000
ESP82	Minsi 9	210	0	164	46	70.0	0.0	54.7	15.3	15	0	8	7	2	2	1	3	5	0.012
ESP83	5MW1 Sphagnum	253	0	185	68	63.3	0.0	46.3	17.0	17	0	6	11	2	4	2	6	0	0.000
ESP84	Pinchot 1 Gray Tree Frog	349	0	261	88	116.3	0.0	87.0	29.3	11	0	4	7	2	3	0	3	25	0.055
ESP85	Pinchot 2 Barn	83	0	79	4	41.5	0.0	39.5	2.0	6	0	4	2	1	1	0	1	22	0.292
ESP86	W1	92	1	73	18	23.0	0.3	18.3	4.5	10	1	6	3	3	2	1	3	54	0.078
ESP87	W16	204	0	192	12	51.0	0.0	48.0	3.0	7	0	4	3	5	4	1	5	22	0.083
ESP88	S1	184	4	134	46	30.7	0.7	22.3	7.7	11	1	5	5	2	2	1	3	24	0.014
ESP89	Lily Pond	26	2	19	5	6.5	0.5	4.8	1.3	9	1	5	3	3	3	1	4	124	0.141

Appendix 14. Vegetation, aquatic amphibian, and invertebrate classification groupings identified through cluster analyses and NMS ordinations.
Definitions of each grouping are provided in Appendix 2.

Pool num	Pool name	VegTyp2	VegFinal	VegSub	Structure	AmphSub	InvtFinal	InvtSub
ESP01	Roaring Run 1	1	1	11	1	22	6	61
ESP02	Roaring Run 2 Bear Wallow	4	7	71	1	20	6	61
ESP03	Plain Grove 1	3	3	32	2	20	5	57
ESP04	Plain Grove 2	3	3	33	3	20	5	52
ESP05	Plain Grove 3	1	1	12	2	20	5	52
ESP06	Wolf Creek Narrows	4	9	92	2	20	5	57
ESP07	Lisica 1	2	2	22	2	0	5	57
ESP08	Jennings 1	5	5	51	1	20	5	52
ESP09	Jennings 2	3	3	32	2	30	6	61
ESP10	Jennings 3	3	3	31	1	25	5	52
ESP11	Jennings 4	4	9	92	2	30	5	52
ESP12	Lisica 2	5	5	51	1	20	5	56
ESP13	Lisica 3	5	5	51	1	22	5	52
ESP14	SGL 216-1	2	2	22	2	24	5	52
ESP15	SGL 216-2	2	2	22	2	20	5	52
ESP16	SGL 216-3	4	9	93	3	20	5	52
ESP17	SGL 95	6	6	61	1	20	5	52
ESP18	Sproul 1	4	7	71	1	24	4	44
ESP19	Sproul 2	5	5	51	1	20	6	62
ESP20	Sproul 3 Yost Run BDA	7	7	71	1	24	6	62
ESP21	Sproul 4	4	5	53	3	20	5	51
ESP22	Spring Creek 1	4	10	101	1	22	5	53
ESP23	Spring Creek 2	4	10	101	1	20	5	56
ESP24	SGL 102-1	4	10	101	1	22	6	62
ESP25	SGL 102-2	4	10	101	1	22	3	3
ESP26	W3	3	3	33	3	21	2	2
ESP27	Wolf Rocks	4	7	71	1	20	4	44
ESP28	Ellisburg 1	3	3	32	2	30	1	1
ESP29	Ellisburg 2	3	3	32	2	20	4	41
ESP30	Ellisburg 3	3	3	32	2	30	4	41
ESP31	Ellisburg 4	3	3	31	1	24	3	3
ESP32	Lisica 4	3	3	32	2	24	5	52
ESP33	ANF Marienville	3	3	32	2	24	1	1
ESP34	Black Mo 5	4	7	71	1	20	5	54
ESP35	Black Mo 6	4	7	71	1	20	5	54
ESP36	French Creek 3	6	6	62	2	20	1	1
ESP37	French Creek 5	3	3	32	2	20	1	1
ESP38	French Creek 6	4	1	12	2	20	3	3
ESP39	Butler Knob 4	4	2	21	1	20	4	44
ESP40	Butler Knob 12b	4	2	21	1	20	4	44
ESP41	Butler Knob 14	4	1	12	2	21	2	2
ESP42	Mulls Gap 4	3	3	32	2	21	5	53
ESP43	Kreb Trail 5 (D)	5	5	51	1	25	5	53
ESP44	Kreb Trail 6 (C)	4	8	81	1	20	5	53
ESP45	W2	3	3	33	3	21	2	2
ESP46	Little Mountain 7	3	3	31	1	21	5	53
ESP47	Mulls Gap 9	2	2	22	2	20	5	52
ESP48	Little Mountain 13	5	5	51	1	24	5	53
ESP49	Grass Mountain 17	1	1	12	2	21	5	53
ESP50	Grass Mountain 18	4	2	22	2	20	4	42
ESP51	Grass Mountain 19	4	8	82	2	20	5	53

Pool num	Pool name	VegTyp2	VegFinal	VegSub	Structure	AmphSub	InvtFinal	InvtSub
ESP52	Warrior Ridge 5	1	1	13	3	21	4	44
ESP53	Warrior Ridge 9	4	2	23	3	20	4	43
ESP54	Warrior Ridge 0	4	1	11	1	25	4	44
ESP55	Warrior Ridge B	2	2	23	3	20	4	44
ESP56	West Rim North 2	7	7	71	1	26	5	53
ESP57	West Rim North 11	3	3	32	2	22	5	53
ESP58	West Rim South 2	5	5	51	1	20	4	43
ESP59	West Rim South 3	7	7	71	1	24	5	58
ESP60	West Rim South 7	1	1	12	2	26	5	53
ESP61	West Rim South 11	7	7	71	1	20	5	58
ESP62	2nd Narrows 5	1	1	12	2	20	4	42
ESP63	2nd Narrows 1	1	1	11	1	22	5	52
ESP64	2nd Narrows 6	1	1	11	1	22	5	52
ESP65	2nd Narrows 4	7	7	71	1	21	4	43
ESP66	3 Square Hollow 3	5	5	51	1	21	5	52
ESP67	Meadow Grounds 4	1	1	11	1	22	6	61
ESP68	SGL 300-1	3	3	32	2	20	5	51
ESP69	SGL 300-2	4	1	12	2	21	5	51
ESP70	Irishtown 1	5	5	51	1	30	5	51
ESP71	Kidder 2	3	3	32	2	20	5	51
ESP72	Kidder 9	3	3	31	1	20	5	51
ESP73	DSF14	6	6	61	1	0	0	0
ESP74	DSF32	5	5	53	3	23	5	51
ESP75	5MW2 Evergreen	4	4	42	2	20	5	51
ESP76	DSF46	6	6	62	2	25	8	8
ESP77	Bowers Creek 1	4	4	41	1	20	5	54
ESP78	Bowers Creek 3	4	8	82	2	0	6	61
ESP79	Bowers Creek 8	6	6	61	1	22	7	7
ESP80	Minsi 1	1	1	12	2	26	6	61
ESP81	Minsi 4	3	3	32	2	30	5	55
ESP82	Minsi 9	3	3	33	3	20	5	55
ESP83	5MW1 Sphagnum	5	5	51	1	25	5	55
ESP84	Pinchot 1 Gray Tree Frog	4	4	41	1	25	5	56
ESP85	Pinchot 2 Barn	4	10	102	2	23	6	61
ESP86	W1	3	3	32	2	20	2	2
ESP87	W16	1	1	12	2	23	2	2
ESP88	S1	3	3	31	1	20	5	52
ESP89	Lily Pond	3	3	31	1	21	2	2

Appendix 15. One-way analysis of variance of invertebrate and amphibian density and richness means among environmental groupings.

Significant differences of $p < 0.05$ and $r^2 > 0.15$ reported. Definitions of response variables are provided above the analysis results.

Analysis code	Description
Herptiles	**Density, richness, and abundance groupings**
AquaRich	Aquatic reptile and amphibian richness: tally of herptile taxa found in each pool that are aquatic or semiaquatic.
EggAbun	Egg abundance: original count data of all indicator amphibian species egg masses. Includes egg masses of Ambystoma jeffersonianum, A. maculatum, A. opacum, and Lithobates sylvaticus,
HerpRich	Herptile richness: tally of all herptiles found around each pool including aquatic and terrestrial species
IndiRich	Indicator species richness: tally of the amphibian and invertebrate species documented from each pool that are considered indicators of seasonal pools. In this study indicators were: Ambystoma jeffersonianum, A. maculatum, A. opacum, Lithobates sylvaticus, Eubranchipus holmani, and E. vernalis.
TerrRich	Terrestrial reptile and amphibian richness: tally of herptile taxa found around the perimeter of each pool that are terrestrial (*Notophthalmus viridescens* subadults, *Thamnophis sirtalis, Plethodon cinereus* and *P. glutinosus*).
Invertebrates	**Density and richness groupings**
InvtDens	Invertebrate density: original count of all invertebrate taxon in all trophic groups divided by sample effort per pool.
InvtRich	Invertebrate richness: tally of all invertebrate taxa collected from a pool across all trophic groups.
CGDens	Collector-gatherer density: original count divided by sample effort per pool. Group includes invertebrate taxa in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
CGRich	Collector-gatherer richness: tally of the invertebrate taxa collected from a pool in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
PredDens	Predator density: original count of invertebrates in the predator trophic group divided by sample effort per pool.
PredRich	Predator richness: tally of the invertebrate taxa collected from a pool in the predator trophic groups.
ShrdDens	Shredder density: original count of invertebrates in the shredder trophic group divided by sample effort per pool.
ShrdRich	Shredder richness: tally of the invertebrate taxa collected from a pool in the shredder trophic group.

Response	Grouping variable	Group num(s)	Relationship between means	Group num(s)	p	r^2
AquaRich	Ecoregion subsection	Allegheny Mtn. Plateau (221.26)	higher than	Cattaraugus Highlands (212.61)	0.0201	0.260
	Geology	sandstone (45)	lower than	shale (34), sandstone (36, 96)	0.0069	0.416
CGDens	County	Mercer (43)	higher than	Franklin (28)	0.0361	0.378
	Ecoregion	WAP (49)	higher than	CAP (59)	0.0026	0.155
CGRich	County	Wayne (63)	higher than	Franklin (28), Centre (14), Monroe (45)	<.0001	0.649
	County	Mercer (43)	higher than	Tioga (58), Potter (52), Carbon (13), Bucks (9), Franklin (28), Centre (14), Berks (6), York (66), Monroe (45)	<.0001	0.649
	County	Monroe (45)	lower than	Warren (61), Butler (10), Lawrence (37), Snyder (54), Northampton (48), Huntingdon (31), Perry (50)	<.0001	0.649
	Disturbance type	abandoned mine lands (6)	higher than	powerline ROW/dirt road (2), road (3), logging (4), residential / urban development (8)	0.0217	0.197
	Ecoregion	WAP (49)	higher than	HAL (60), CAP (59), and LNE/NP (61)	<.0001	0.262
	Ecoregion subsection	Allegheny Plateau (221.61)	higher than	221.13, 221.44, 221.26, 221.41	0.0003	0.363
	Geology	sandstone (63)	lower than	sandstone (53, 97), limestone (31), shale (99)	0.0001	0.510
	Geology	limestone (31)	higher than	dolomite (154)	0.0001	0.510
	Glacial	glaciated (2)	higher than	unglaciated (1)	<.0001	0.212
	Physiographic province	NW Glaciated Plateau (3)	higher than	Great Valley (21),Deep Valleys (6), Gettysburg-Newark Lowland (29), Allegheny Front (17), Blue Mountain (20)	<.0001	0.458
	Physiographic province	Blue Mountain (20)	lower than	NW Glaciated Plateau (3), Glaciated Low Plateau (4), Pittsburgh Low Plateau (14), Appalachian Mountain (18)	<.0001	0.458
HerpRich	Geology	sandstone (96)	higher than	sandstone (45, 63)	0.0116	0.401
IndiRich	CntyNum	Potter (52)	lower than	Centre (14), Franklin (28), Fulton (29), Perry (50), Snyder (54), Tioga (58)	0.0008	0.483
	Ecoregion	CAP (59)	higher than	HAL (60)	<.0001	0.241
	Ecoregion subsection	Northern Blue Ridge Mtns (221.44)	higher than	Kittatinny-Shawangunk Ridges (221.24), Cattaraugus Highlands (212.61)	0.0002	0.377
	Ecoregion subsection	Allegheny Mtn. Plateau (221.26)	higher than	Cattaraugus Highlands (212.61)	0.0002	0.377
	Ecoregion subsection	Northern Ridge and Valley (221.13)	higher than	Cattaraugus Highlands (212.61)	0.0002	0.377
	Geology	sandstone (45)	lower than	sandstone (96), shale (34), dolomite (154)	0.0038	0.432

Response	Grouping variable	Group num(s)	Relationship between means	Group num(s)	p	r^2
InvtDens	County	Mercer (43)	higher than	Franklin (28), Huntingdon (31)	0.0135	0.410
	Ecoregion	WAP (49)	higher than	CAP (59)	0.0037	0.148
InvtRich	County	Warren (61)	higher than	Franklin (28), Potter (52), Berks (6), Monroe (45)	<.0001	0.583
	County	Mercer (43)	higher than	Franklin (28), Centre (14), Potter (52), Berks (6), Monroe (45)	<.0001	0.583
	County	Snyder (54)	higher than	Franklin (28), Berks (6), Monroe (45)	<.0001	0.583
	Ecoregion	WAP (49)	higher than	CAP (59), LNE/NP (61)	0.0060	0.137
	Ecoregion subsection	Allegheny Plateau (221.61)	higher than	Cattaraugus Highlands (212.61)	0.0030	0.326
	Geology	sandstone (97)	higher than	sandstone (45, 63)	0.0010	0.465
	Glacial	glaciated (2)	higher than	unglaciated (1)	0.0005	0.130
	Physiographic province	NW Glaciated Plateau (3)	higher than	Gettysburg-Newark Lowland (29), Blue Mountain (20)	0.0014	0.330
PredDens	County	Mercer (43)	higher than	Franklin (28), Potter (52), Berks (6)	0.0019	0.468
	County	58	higher than	Franklin (28), Potter (52)	0.0019	0.468
	Ecoregion subsection	Allegheny Deep Valleys (212.72)	higher than	Northern Blue Ridge Mountains (221.44), Cattaraugus Highlands (212.61)	0.0269	0.254
PredRich	County	Tioga (58)	higher than	Franklin (28), Potter (52)	0.0014	0.470
	Ecoregion subsection	Allegheny Deep Valleys (212.72)	higher than	Cattaraugus Highlands (212.61)	0.0305	0.247
ShrdDens	Ecoregion	WAP (49)	higher than	CAP (59)	0.0230	0.107
	Ecoregion subsection	Northern Ridge and Valley (221.13)	lower than	Allegheny Plateau (221.61)	0.0689	0.221
	Glacial	glaciated (2)	higher than	unglaciated (1)	0.0005	0.133
TerrRich	County	Carbon (13)	higher than	Butler (10), Fulton (29), Lawrence (37), Mercer (43), Tioga (58), Monroe (45), Pike (51), Centre (14), Snyder (54), Huntingdon (31), Warren (61), York (66)	<.0001	0.643
	County	Bucks (9)	higher than	Tioga (58), Monroe (45), Pike (51), Centre (14), Snyder (54), Huntingdon (31), Warren (61), York (66)	<.0001	0.643
	County	Northampton (48)	higher than	Snyder (54)	<.0001	0.643
	County	Franklin (28)	higher than	Centre (14), Snyder (54), Huntingdon (31)	<.0001	0.643
	Ecoregion subsection	Piedmont Upland (221.42)	higher than	Allegheny Mtn. Plateau (221.26)	0.0069	0.290
	Geology	Gravelly sand (4)	higher than	63, 36, 83, 99	<.0001	0.558
	Geology	Sandstone (37)	higher than	33, 63, 36,83, 99	<.0001	0.558

Response	Grouping variable	Group num(s)	Relationship between means	Group num(s)	p	r^2
TerrRich	Physiographic province	Antracite Upland (19)	higher than	Pittsburgh Low Plateau (14), Gettysburg-Newark Lowland (29), Appalachian Mtn (18), Deep Valleys (6), NW Glaciated Plateau (3), Glaciated Low Plateau (4), Blue Mtn (20), Allegheny Front (17)	<.0001	0.428
	Physiographic province	Piedmont Upland (38)	higher than	Appalachian Mtn (18), NW Glaciated Plateau (3), Glaciated Low Plateau (4), Blue Mtn (20), Allegheny Front (17)	<.0001	0.428

Appendix 16. One-way analysis of variance of taxon density and richness means among the plant and animal community groupings determined from cluster analyses.

Significant differences of $p < 0.05$ and $r^2 > 0.15$ reported.
Definitions of response variables are provided above the analysis results.

Analysis Code	Description
All taxa	**Cluster analysis groupings**
AmphSub	Aquatic amphibian cluster analysis subgroupings
InvtSub	Invertebrate cluster analysis subgroupings
Structr	In-pool vegetation structure: Derived from second number in vegetation cluster analysis subgroup (VegSub). 1 = herbaceous; 2 = unvegetated; 3 = shrub
VegFinal	Final vegetation cluster analysis groupings
VegSub	Final vegetation cluster analysis subgroupings
VegTyp2	Initial vegetation cluster analysis groupings
Herptiles	**Density, richness, and abundance groupings**
AquaRich	Aquatic reptile and amphibian richness: tally of herptile taxa found in each pool that are aquatic or semiaquatic.
EggAbun	Egg abundance: original count data of all indicator amphibian species egg masses. Includes egg masses of Ambystoma jeffersonianum, A. maculatum, A. opacum, and Lithobates sylvaticus,
HerpRich	Herptile richness: tally of all herptiles found around each pool including aquatic and terrestrial species
IndiRich	Indicator species richness: tally of the amphibian and invertebrate species documented from each pool that are considered indicators of seasonal pools. In this study indicators were: Ambystoma jeffersonianum, A. maculatum, A. opacum, Lithobates sylvaticus, Eubranchipus holmani, and E. vernalis.
TerrRich	Terrestrial reptile and amphibian richness: tally of herptile taxa found around the perimeter of each pool that are terrestrial (*Notophthalmus viridescens* subadults, *Thamnophis sirtalis, Plethodon cinereus* and *P. glutinosus*).
Invertebrates	**Density and richness groupings**
InvtDens	Invertebrate density: original count of all invertebrate taxon in all trophic groups divided by sample effort per pool.
InvtRich	Invertebrate richness: tally of all invertebrate taxa collected from a pool across all trophic groups.
CGDens	Collector-gatherer density: original count divided by sample effort per pool. Group includes invertebrate taxa in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
CGRich	Collector-gatherer richness: tally of the invertebrate taxa collected from a pool in the collector-gatherer, detritivore, filterer, and scraper trophic groups.
PredDens	Predator density: original count of invertebrates in the predator trophic group divided by sample effort per pool.
PredRich	Predator richness: tally of the invertebrate taxa collected from a pool in the predator trophic groups.
ShrdDens	Shredder density: original count of invertebrates in the shredder trophic group divided by sample effort per pool.
ShrdRich	Shredder richness: tally of the invertebrate taxa collected from a pool in the shredder trophic group.

Response	Grouping variable	Group num(s)	Relationship between means	Group num(s)	p	r^2
AquaRich	AmphSub	0	lower than	26, 25, 22, 21, 24, 20	<0.0001	0.442
	AmphSub	30	lower than	26, 25, 22, 21, 24, 23, 20	<0.0001	0.442
	InvtSub	53	higher than	1	0.0212	0.343
	Structure	1	higher than	2	0.0001	0.188
	VegTyp2	3	lower than	1, 7	0.0026	0.216
	VegFinal	3	lower than	1, 7	0.0052	0.250
	VegSub	32	lower than	11, 71	0.0108	0.403
CGDens	InvtSub	43	higher than	2	0.0388	0.323
	InvtSub	57	higher than	52, 53, 51, 61, 44, 62, 3, 58, 2, 54, 1, 7	<0.0001	0.536
	InvtSub	56, 43	higher than	1, 7	<0.0001	0.536
	InvtSub	52	higher than	1	<0.0001	0.536
EggAbun	InvtSub	44	higher than	51, 52	0.0121	0.360
	VegSub	21	higher than	32, 31, 12, 51	0.0424	0.359
HerpRich	AmphSub	30	lower than	22, 25, 21, 24, 20	<0.0001	0.367
	AmphSub	0	lower than	22, 25, 26, 21, 24, 20	<0.0001	0.367
	Structure	1	higher than	2, 3	<0.0001	0.215
	VegTyp2	3	lower than	1, 7	0.0022	0.220
	VegSub	11	higher than	32, 82	0.0016	0.455
AmphSub	AquaRich	0	lower than	26, 25, 22, 21, 24, 20	<0.0001	0.442
	AquaRich	30	lower than	26, 25, 22, 21, 24, 23, 20	<0.0001	0.442
	HerpRich	30	lower than	22, 25, 21, 24, 20	<0.0001	0.367
	HerpRich	0	lower than	22, 25, 26, 21, 24, 20	<0.0001	0.367
	IndiRich	0	lower than	22, 20	<0.0001	0.385
	IndiRich	30	lower than	22, 23, 21, 20, 25, 24	<0.0001	0.385
IndiRich	AmphSub	0	lower than	22, 20	<0.0001	0.385
	AmphSub	30	lower than	22, 23, 21, 20, 25, 24	<0.0001	0.385
	VegTyp2	1	higher than	3	0.0214	0.164
InvtSub	AquaRich	53	higher than	1	0.0212	0.343
	CGDens	43	higher than	2	0.0388	0.323
	CGRich	57	higher than	52, 53, 51, 61, 44, 62, 3, 58, 2, 54, 1, 7	<0.0001	0.536
	CGRich	56, 43	higher than	1, 7	<0.0001	0.536
	CGRich	52	higher than	1	<0.0001	0.536
	EggAbund	44	higher than	51, 52	0.0121	0.360
	InvtDens	43	higher than	2	0.0390	0.323
	InvtRich	57	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtRich	56	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtRich	43	higher than	61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtRich	53	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtRich	58	higher than	1	<0.0001	0.619
	InvtRich	55	higher than	1	<0.0001	0.619
	InvtRich	51	higher than	1	<0.0001	0.619
	InvtRich	52	higher than	1	<0.0001	0.619
cont.						

Response	Grouping variable	Group num(s)	Relationship between means	Group num(s)	p	r^2
InvtSub	PredRich	58	higher than	44, 2, 61, 3, 1	<0.0001	0.565
	PredRich	56	higher than	44, 2, 61, 3, 1	<0.0001	0.565
	PredRich	43	higher than	1	<0.0001	0.565
	PredRich	53	higher than	52, 44, 2, 61, 3, 1	<0.0001	0.565
	ShrdDens	57	higher than	53, 61, 44, 52, 43, 2, 55, 51, 62, 3, 41, 42, 54, 1	0.0121	0.360
	ShrdRich	53	higher than	1	0.0096	0.367
	TerrRich	55	higher than	53	0.0033	0.396
InvtDens	InvtSub	43	higher than	2	0.0390	0.323
InvtRich	InvtSub	57	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtSub	56	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtSub	43	higher than	61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtSub	53	higher than	44, 61, 2, 54, 3, 1, 7	<0.0001	0.619
	InvtSub	58	higher than	1	<0.0001	0.619
	InvtSub	55	higher than	1	<0.0001	0.619
	InvtSub	51	higher than	1	<0.0001	0.619
	InvtSub	52	higher than	1	<0.0001	0.619
	VegTyp2	5	higher than	6	0.0102	0.183
PredRich	InvtSub	58	higher than	44, 2, 61, 3, 1	<0.0001	0.565
	InvtSub	56	higher than	44, 2, 61, 3, 1	<0.0001	0.565
	InvtSub	43	higher than	1	<0.0001	0.565
	InvtSub	53	higher than	52, 44, 2, 61, 3, 1	<0.0001	0.565
	VegTyp2	7	higher than	3, 4, 2, 1, 6	0.0002	0.273
ShrdDens	InvtSub	57	higher than	53, 61, 44, 52, 43, 2, 55, 51, 62, 3, 41, 42, 54, 1	0.0121	0.360
ShrdRich	InvtSub	53	higher than	1	0.0096	0.367
Structure	AquaRich	1	higher than	2	0.0001	0.188
	HerpRich	1	higher than	2, 3	<0.0001	0.215
TerrRich	InvtSub	55	higher than	53	0.0033	0.396
VegTyp2	AquaRich	3	lower than	1, 7	0.0026	0.216
	HerpRich	3	lower than	1, 7	0.0022	0.220
	IndiRich	1	higher than	3	0.0214	0.164
	InvtRich	5	higher than	6	0.0102	0.183
	PredRich	7	higher than	3, 4, 2, 1, 6	0.0002	0.273
VegFinal	AquaRich	3	lower than	1, 7	0.0052	0.250
VegSub	AquaRich	32	lower than	11, 71	0.0108	0.403
	EggAbun	21	higher than	32, 31, 12, 51	0.0424	0.359
	HerpRich	11	higher than	32, 82	0.0016	0.455

Appendix 17. Conservation Rank Definitions

GLOBAL ELEMENT RANKS

G1 = Critically imperiled globally because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G2 = Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 = Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range or because of other factors making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.

G4 = Apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.

G5 = Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

GH = Of historical occurrence throughout its range, i.e., formerly part of the established biota, with the expectation that it may be rediscovered (e.g., Bachman's Warbler).

GU = Possibly in peril range wide but status uncertain; need more information.

GX = Believed to be extinct throughout its range (e.g., Passenger Pigeon) with virtually no likelihood that it will be rediscovered.

STATE ELEMENT RANKS

S1 = Critically imperiled in state because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation from the state.

S2 = Imperiled in state because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state.

S3 = Rare or uncommon in state (on the order of 21 to 100 occurrences).

S4 = Apparently secure in state, with many occurrences.

S5 = Demonstrably secure in state and essentially ineradicable under present conditions.

SA = Accidental in state, including species which only sporadically breed in the state.

SE = An exotic established in state; may be native elsewhere in North America (e.g., house finch).

SH = Of historical occurrence in the state with the expectation that it may be rediscovered.

SN = Regularly occurring, usually migratory and typically non-breeding species for which no significant or effective habitat conservation measures can be taken in the state.

SR = Reported from the state, but without persuasive documentation which would provide a basis for either accepting or rejecting (e.g., misidentified specimen) the report.

SRF = Reported falsely (in error) from the state but this error persisting in the literature.

SU = Possibly in peril in state but status uncertain; need more information.

SX = Apparently extirpated from the state.

When collecting data on a pool cluster, fill in all survey data in the form for the first pool. For each additional pool, always fill in Date of Visit, Time Start and End, Site Name and Pool Codes; then only fill in only those fields that change from pool to pool.

Appendix 18. EPA/WRCP Seasonal Pool Classification - Spring Fauna Survey

DATE OF VISIT:	**TIME START:**
COUNTY:	**TIME END:**
ATTACH A MAP: (preferably a USGS topo map) with the pool location clearly indicated. See mapping guide for assistance.	
USGS TOPO MAP NAME:	**OTHER MAP TYPE** (describe):
SITE NAME AND POOL CODES:	

CURRENT PRECIPITATION
Fog / Mist ______
Showers ______
Steady rain ______
Heavy rain ______
Sleet / Hail ______
Snow ______

ANY PRECIPITATION FALL THE PREVIOUS DAY?

SKY
Mostly sunny ____
Partly cloudy ____
Mostly cloudy ____

WIND
Calm/Light _____
Breezy _____
Gusty _____

TEMPERATURE
Air _____ F / C
Water _____ F / C

PRIMARY OBSERVER
Name: ______________________
Address: ______________________
____
Phone1: ______________________
Phone2: ______________________
Email: __ ______________________
Source Code: ______________________

Signature: ______________________

Date: ____________

Additional Observers: ______________________
____

LANDOWNER INFORMATION
Name: ______________________
Address: ______________________
Phone1: ______________________
Phone2: ______________________
Email: ______________________
Pools Owned: ______________________
____

LANDOWNER CONSENT? CIRCLE ONE

YES : Verbal or written
NO: Landowner not contacted

Attach a separate page for additional landowners

Land use surrounding 100 ft Estimate cover value (see table of values pg. 3)	
Land use	**% COVER**
Woodland / Forest	
Clear Cut	
Ag / field / meadow	
Developed	
Roads / right of ways	
Wetland / Waterbody	
Other (describe):	

SITE DESCRIPTION: Summarize surrounding landscape (forest composition, disturbances or threats to overall site, land use notable land marks, etc.)

TOPOGRAPHIC POSITION

	VALUE		**CHECK**		**CHECK**
Slope (estimate %)		Ridge top (interfluve)		Step in slope	
Aspect (direction slope faces)		High level (i.e. plateau)		Low slope	
Elevation		Saddle		Toe Slope	
		Shoulder		Low level	
		High slope		Bottomland or floodplain	
		Backslope		Headwaters	
		Midslope		Other (describe)	

COORDINATES	GPS SETTINGS
Latitude:	Projection:
Longitude:	Datum:
Est. Positional Error: (m/ft)	If using UTM coordinates, record zone:

POOL CODE: **DATE:**

POOL SIZE
(measure maximum inundated area at time of visit)

Measurement	VALUE	UNIT (CM/M/FT)
Length		
Width		
Depth		

Estimated percent fullness of pool: ______%

Water Color: Clear or lightly stained____
Moderately stained ____
Highly stained ____
Pool basin dry ____

ESTIMATED MAXIMUM WETTED AREA
Measure the probable maximum length and width of the pool when fully inundated based on clues such as water marks on trees, basin shape, gray leaves, etc.

MEASUREMENT	VALUE (FT OR M)
Length	
Width	

CONNECTIVITY	CHECK
Apparently isolated	
Seasonally connected to another seasonal pool	
Seasonally connected to 1st or 2nd order headwaters / small streams	
Seasonally connected to a permanent wetland	
Seasonally connected to stream/river/floodplain	

Inlet? YES ___ NO ___; if YES, connects to ___________
Outlet? YES __ NO ___: if YES, connects to ____________
Spring / seep influence YES____ NO ____ UNK____

DISTURBANCES	Distance from pool (ft or m)
Berm or dam	
Beaver dam	
All terrain vehicle traffic	
Trash	
Fill	
Excavation	
Siltation	
Road: Circle dirt, grassy, gravel, paved	
Clear-cut	
Development	
Other (describe):	

HYDROPERIOD	*Check*
Ephemeral, dries multiple times a year on average	
Annual, dries one time a year on average	
Semipermanent, dries every few years on average	
Permanent, never dries up completely	
Unknown	

POOL BASIN CANOPY	*Check*	POOL BASIN VEGETATION	*Check*
Closed canopy		few / no aquatic plants	
Partially open canopy		Marshy herbaceous vegetation present	
Open canopy		Shrubby woody vegetation present	
		Trees and/or tree hummocks in pool basin	

WATER CHEMISTRY: report variables measured

MEASUREMENT	UNITS	MEASUREMENT	UNITS
Air Temperature		Total hardness	
Water Temperature		Calcium hardness	
Conductivity		Magnesium hardness	
Dissolved Oxygen		Alkalinity (P)	
pH		Total Alkalinity (T)	
ORP		E. Coli	
Nitrogen			
Phosphorus		Other (describe	

COMMENTS:

POOL CODE: **DATE:**

VEGETATION WITHIN 100 FT. OF POOL(S) – Estimate percent cover using cover values listed below.

T1, T2, T3 = Emergent tree, Tree canopy, and Tree subcanopy
S1, S2 = Tall shrub, Short shrub
H = Herbaceous
V = Vine / liana
N = Nonvascular
E = Epiphyte

VEGETATION COVER TYPE	HEIGHT	UNIT M/FT	COVER VALUE	DOMINANT SPECIES

VEGETATION WITHIN POOL BASIN (AT TIME OF VISIT)

Estimate percent cover using cover values listed below.
T1, T2, T3 = Emergent trees, canopy, and subcanopy
S1, S2 = Tall shrub, short shrubs
H = Herbaceous Vegetation
E = Epiphyte **NM** = Nonvascular - Moss
V = Vine / liana **NA** = Nonvascular - Algae

Estimate abundance as low / medium / high
LL = Leaf Litter Substrate
WD = Woody Debris
RK = Rocks
HM = Hummocks
MK = Muck

VEGETATION COVER TYPE	HEIGHT	UNIT M/FT	COVER VALUE	DOMINANT SPECIES

COVER VALUES	
VALUE	*Range*
R	1 or few
+	Occassional
1	<5%
2-	5-12%
2+	13-25%
3	26-50%
4	51-75%
5	76+%

POOL CODE: **DATE:**

GENERAL DESCRIPTION OF INDIVIDUAL POOL AND THE LANDSCAPE SETTING

POOL DIAGRAM – ARERIAL VIEW

Indicate north heading, vegetation zones, large woody debris, water chemistry stations, location of inlet or outlet, etc.
Use the grid for use grid for length/width axes. Indicate distance units for grid.

POOL CODE: **DATE:**

POOL DIAGRAM – PROFILE VIEW

Indicate profile of pool basin and surrounding upland.

INSTRUCTIONS FOR REPTILE, AMPHIBIAN, AND INVERTEBRATE SURVEYS - CLASSIFICATION STUDY

Call counts

- Surveyors approach the pool quietly. Stop far enough away to avoid detection by the amphibians. Listen for 3 minutes and list species calling and call code. Continue to record species heard during pool sampling.

Egg mass surveys

- Conduct a visual counts of all egg masses. Walk transects through the pool as needed to cover the whole pool.
- Estimate area for wood frogs when there are too many masses to count individually. Indicate unit of area (meters or feet)

D-frame dip netting

- Number of samples taken are based on inundated pool size. Measure pool length and width. Calculate area using the equation 3.14(1/2L)(1/2W)
- Divide total area by 150. This is the number of 'keepers'. Keep the entire contents of this many scoops (after removing leaves and large debris) to process later for invertebrates.
- Divide the total area by 100. The difference between this answer and the previous (area / 150) is the number of 'quick-pick' scoops. These scoopes are intended to increase sample effort for amphibian larvae without increasing collected samples for later processing. Identify, count, and release amphibian larvae. If new macroinvertebrate types are found, pick them out by hand and keep.
- Alternate samples between the shallow edge and deeper water, but generally do not exceed knee to mid-thigh deep. Avoid scooping egg masses. After each dip, examine contents in a white pan. Any amphibian larvae or adults are counted and released. A few larvae may be kept and preserved in order to verify ID in the lab.
- For 'keeper' samples, the remaining sample is cleaned quickly of large debris, then preserved in a whirl-pack baggie with 75% ethanol.

Pool edge survey

- Two people spend 5 minutes each turning logs and stones and investigating sphagnum hummocks around the pool perimeter and but no more than 10 meters from the pool edge.

POOL CODE: **DATE:**

REPTILE / AMPHIBIAN OBSERVATIONS
DATE: TYPE OF SURVEY:
OBSERVER(S) AND SOURCECODE(S):
SUM OF OBSERVER TIME SPENT; RECORD FOR EACH SURVEY METHOD (I.E. EGG MASS CTS, DIP NETTING, & CALL SURVEYS):
LIFE STAGE ABBREVIATIONS: Egg (E), Egg Mass (EM), Larva (L), Metamorph (M), Juvenile (J), Adult (A) Note on egg mass counts: Count each egg mass when possible. Estimate the area covered by large wood frog egg masses. If egg mass counts are not possible, indicate P for Presence and A for absence.
LIST SPECIES OBSERVED, LIFE STAGE, & ABUNDANCE. DESCRIBE ANIMAL ACTIVITIES & ADDITIONAL OBSERVATIONS:

FROG AND TOAD CALLS

Species Heard	Chorus Code (0,1,2,3)	Audio recording Yes or No	Recording description	Additional Comments

Calling Codes*
0) = No frogs or toads calling.
1) = Individual calls can be heard and counted. Calls do not overlap.
2) = Calls overlap but individual calls still discernable.
3) = A full chorus. Cannot distinguish individual calls.

* Adapted from USGS Amphibian Research and Monitoring Initiative, Northeast Region

INVERTEBRATE OBSERVATIONS	**LIST SPECIES OBSERVED, LIFE STAGE, & RELATIVE ABUNDANCE. DESCRIBE ANIMAL ACTIVITIES & ADDITIONAL OBSERVATIONS.**
DATE: OBSERVER(S): TYPE OF SURVEY: SUM OF OBSERVER TIME SPENT ON INVERT SURVEY: LIFE STAGE ABBREVIATIONS: EGG (E), Larva (L), Nymph (N), Adult (A), Exuvia (EX), Empty Case (EC), Empty Shell (ES)	

Appendix 19. EPA/WRCP Seasonal Pools Classification - Quantitative Plant Community Characterization

A. General Information

Site Number:____________________ Site Name:____ County _________________

Survey date: ___________________ Surveyors:____

Easting: _ _ _ _ _ _ _ E Northing:_ _ _ _ _ _ _ _ N Elev:______ DOP:______ Map datum: ___________ Zone:________

B. Environmental Description

Representative sketch of pool site and landscape position: indicate plot location and number, north heading, vegetation zones, large woody debris; note surrounding vegetation communities, center on greatest depth

General description of pool vegetation zones. Note homogeneity of vegetation in plot versus rest of pool.

Picture No.____________

Topographic position of site:

___ Interfluve (ridgetop) ___ Low slope
___ High slope ___ Toe slope
___ High level ___ Low level
___ Midslope ___ Backslope
___ Step in slope ___ Basin Floor
___ Other: ___________________________

Slope: __________ Aspect: ___________

Unvegetated surface:

_____ % Bedrock _____ % Litter, duff
_____ % Water _____ % Bare soil
_____ % Large rocks (> 10 cm)
_____ % Wood (> 1 cm)
_____ % Small rocks (0.2-10 cm)
_____ % Sand (0.1-2 mm)
_____ % Other:

Average soil texture:

___ sand ___ peat
___ clay ___ muck
___ clay loam
___ loam
___ sandy loam
___ silt loam
___ other:_______________

Stoniness:

__ Stone free <0.1%
__ Moderately stony 0.1-1%
__ Stony 3-15%
__ Very stony 15-50%
__ Exceedingly stony 50-90%
__ Stone piles >90%

Soil drainage:

___ Rapidly drained
___ Well drained
___ Moderately well drained
___ Somewhat poorly drained
___ Poorly Drained
___ Very poorly drained

Soil profile description: note depth, texture, and color of each horizon including organic material. Note significant changes such as mottling, depth to water table, root penetration depth. Note presence and depth to impeding layer

Horizon	Depth	Texture	Color	pH	Comments

Surrounding Vegetation Types: note name and approximate boundaries on map

Name:	Name:	Name:	Name:
Dominant Canopy	Dominant Canopy	Dominant Canopy	Dominant Canopy
Dominant Subcanopy	Dominant Subcanopy	Dominant Subcanopy	Dominant Subcanopy
Dominant Tall Shrub	Dominant Tall Shrub	Dominant Tall Shrub	Dominant Tall Shrub
Dominant Short Shrub	Dominant Short Shrub	Dominant Short Shrub	Dominant Short Shrub
Dominant Herbaceous	Dominant Herbaceous	Dominant Herbaceous	Dominant Herbaceous
Environmental Comments: Note surrounding primary land cover/land use, landscape context, herbivory, stand health, recent/historic anthropogenic evidence, etc.	Environmental Comments:	Environmental Comments:	Environmental Comments:

C. Seasonal Pool Vegetation Zone

Plot number:_____________ Plot dimensions:____________________ Seasonal pool zone ____________________ Site Name _____________________

Leaf Type	Leaf Phenology	Physiognomic Type		Unvegetated surface			height	% cover
___ Broad-leaf	___ Deciduous	___ Forest	___ Woodland	_____ % Bedrock	_____ % Litter, duff	T1 Emergent tree		
___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	_____ % Water	_____ % Bare soil	T2 Tree canopy		
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	_____ % Large rocks	_____ % Small rocks	T3 Tree sub-canopy		
				(> 10 cm)	(0.2-10 cm)	S1 Tall shrub		
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket	_____ % Wood	_____ % Sand	S2 Short shrub		
___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous	_____ % Other:		H Herbaceous		
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated			N Non-vascular		
___ Pteridophyte						E Epiphyte		
R = 1 or few (+) = occasional 1 = <5% 2- = 5-12% 2+ = 13-25% 3 = 26-50% 4 = 51-75% 5 = 76+%						V Vine / liana		

Species / percent cover: starting with uppermost stratum, list all species and % cover for each in the stratum. For forest and woodlands, list on a separate line below each tree species the DBH of all trees above 10 cm diameter.

				Additional Species in Zone but not in plot	
				General description of vegetation zone:	
GPS Easting _ _ _ _ _ _ E GPS Northing _ _ _ _ _ _ _ N					

C. Seasonal Pool Vegetation Zone

Plot number:____________ Plot dimensions:____________________ Seasonal pool zone ____________________ Site Name ____________________

Leaf Type	Leaf Phenology	Physiognomic Type		Unvegetated surface			height	% cover
___ Broad-leaf	___ Deciduous	___ Forest	___ Woodland	_____ % Bedrock	_____ % Litter, duff	T1 Emergent tree		
___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	_____ % Water	_____ % Bare soil	T2 Tree canopy		
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	_____ % Large rocks	_____ % Small rocks	T3 Tree sub-canopy		
				(> 10 cm)	(0.2-10 cm)	S1 Tall shrub		
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket	_____ % Wood	_____ % Sand	S2 Short shrub		
___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous	_____ % Other:		H Herbaceous		
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated			N Non-vascular		
___ Pteridophyte						E Epiphyte		
						V Vine / liana		

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___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	_____ % Water	_____ % Bare soil
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	_____ % Large rocks (> 10 cm)	_____ % Small rocks (0.2-10 cm)
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket	_____ % Wood	_____ % Sand
___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous	_____ % Other:	
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated		
___ Pteridophyte					

	height	% cover
T1 Emergent tree		
T2 Tree canopy		
T3 Tree sub-canopy		
S1 Tall shrub		
S2 Short shrub		
H Herbaceous		
N Non-vascular		
E Epiphyte		
V Vine / liana		

R = 1 OR FEW (+) = OCCASIONAL 1 = <5% 2- = 5-12% 2+ = 13-25%

3 = 26-50% 4 = 51-75% 5 = 76+%

Species / percent cover: starting with uppermost stratum, list all species and % cover for each in the stratum. For forest and woodlands, list on a separate line below each tree species the DBH of all trees above 10 cm diameter.

				Additional Species in Zone but not in plot	

General description of vegetation zone:

GPS Easting _ _ _ _ _ _ E GPS Northing _ _ _ _ _ _ _ N

C. Seasonal Pool Vegetation Zone

Plot number:____________ Plot dimensions:_____________________ Seasonal pool zone _____________________ Site Name _____________________

Leaf Type	Leaf Phenology	Physiognomic Type		Unvegetated surface			height	% cover
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___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	_____ % Water	_____ % Bare soil	T2 Tree canopy		
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	_____ % Large rocks	_____ % Small rocks	T3 Tree sub-canopy		
				(> 10 cm)	(0.2-10 cm)	S1 Tall shrub		
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___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous	_____ % Other:		H Herbaceous		
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated			N Non-vascular		
___ Pteridophyte						E Epiphyte		
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				Additional Species in Zone but not in plot	

General description of vegetation zone:

GPS Easting _ _ _ _ _ _ E GPS Northing _ _ _ _ _ _ _ N