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An Introduction to Mid-Atlantic Seasonal Pools









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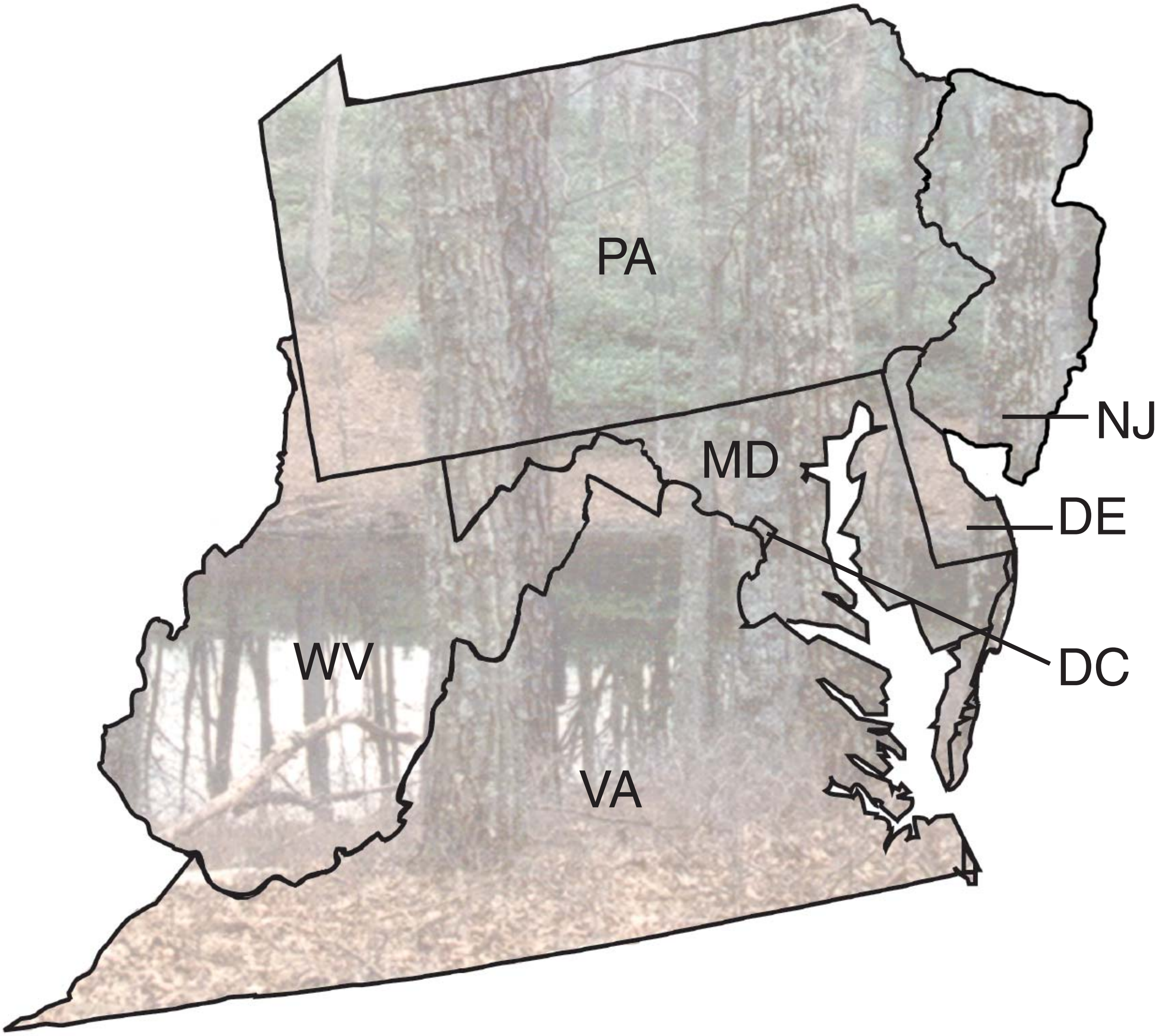

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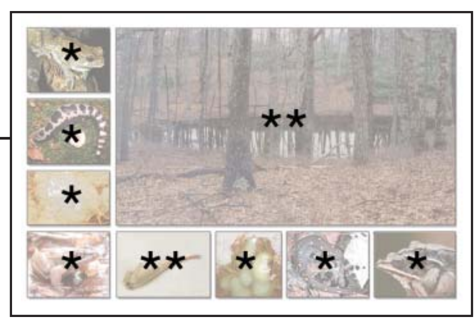

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An Introduction to Mid-Atlantic Seasonal Pools

Prepared for:

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Mid-Atlantic Integrated Assessment
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Notice

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Abstract

Seasonal pools, also known as vernal ponds, provide important ecological services to the mid-Atlantic region. This publication serves as an introduction to seasonal pool ecology and management; it also provides tools for exploring seasonal pools, including a full-color field guide to wildlife. Seasonal pools are defined as having four distinctive features: surface water isolation, periodic drying, small size and shallow depth, and support of a characteristic biological community. Seasonal pools experience regular drying that excludes populations of predatory fish. Thus, pools in the mid-Atlantic region provide critical breeding habitat for amphibian and invertebrate species (e.g., spotted salamander (*Ambystoma maculatum*), wood frog (*Rana sylvatica*), and fairy shrimp (Order Anostraca)) that would be at increased risk of predation in more permanent waters.

The distinctive features of seasonal pools also make them vulnerable to human disturbance. In the mid-Atlantic region, land-use changes pose the greatest challenges to seasonal pool conservation. Seasonal pools are threatened by direct loss (e.g., filling or draining of the pool) as well as by destruction and fragmentation of adjoining terrestrial habitat. Many of the species that depend on seasonal pools for breeding spend the majority of their lives in the surrounding lands that extend a radius of 1000 feet or more from the pools; these vital habitats are being transected by roads and converted to other land uses. Other threats to seasonal pools include biological introductions and removals, mosquito control practices, amphibian diseases, atmospheric deposition, and climate change. The authors recommend a three-pronged strategy for seasonal pool conservation and management in the mid-Atlantic region: education and research, inventory and monitoring of seasonal pools, and landscape-level planning and management.

Key Words: seasonal pools; vernal ponds; wetlands; amphibian conservation; Mid-Atlantic; aquatic ecology

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1 Introduction to Seasonal Pools

1.1: Introduction

Seasonal pools are dynamic habitats that have cycles of standing water (Plate 1-1). These unique pools fill with rainwater, surface runoff, snowmelt, or groundwater in the fall, winter, or spring and may completely dry out by the summer. Seasonal pools are referred to by a variety of names, including vernal pools, spring pools, ephemeral wetlands, autumnal pools, woodland ponds, and temporary ponds. Seasonal pools provide important ecological services to the mid-Atlantic region (Box 1-1).

Photo: Tim Maret

Plate 1-1. Mid-Atlantic seasonal pool. This seasonal forest pool is located in south-central Pennsylvania.

Seasonal pools' periodic dry-downs exclude permanent populations of predatory fish. This reduced-predator environment provides critical breeding habitat for certain species of amphibians whose eggs and larvae would be at increased risk of predation in more permanent waters. In the mid-Atlantic region, seven species in the mole salamander family (*Ambystoma spp.*), the wood frog (*Rana sylvatica*), and the toad-like eastern spadefoot (*Scaphiopus holbrookii*) depend upon seasonal pools for their successful reproduction (Plate 1-2). The fairy shrimp (*Eubranchipus spp., Streptocephalus sealii*) and other invertebrates use seasonal pools for their complete life cycle (Belk, 1975). Some of the species that rely on seasonal pools for optimal breeding are rare, threatened, or endangered in parts of their mid-Atlantic range, such as the eastern tiger salamander (*Ambystoma tigrinum tigrinum*) that is state-listed as endangered in Delaware, New Jersey, and Virginia. In the mid-Atlantic region, 26% of all state-listed threatened and endangered amphibians are dependent on seasonal pools.

Box 1-1
Ecological services provided by seasonal pools

☑ **Important Breeding Habitat**
Supply essential breeding grounds for amphibians, including rare, threatened, or endangered species.

☑ **Unique Invertebrate Community**
Support a diverse invertebrate fauna, including rare species.

☑ **Support of Aquatic and Terrestrial Food Webs** Supply food (amphibian and invertebrate biomass) to wildlife including amphibians, turtles, snakes, birds, and mammals. Serve as "stepping-stones" across the landscape for wetland- or aquatic-dependent organisms.

Photo: Steven M. Roble

Plate 1-2. Spotted salamander (*Ambystoma maculatum*). Spotted salamanders are characteristic members of seasonal pool biological communities of the mid-Atlantic region.

Seasonal pools are inextricably linked to their surrounding terrestrial landscape and support aquatic and terrestrial food webs. Bordering and in-pool vegetation provide organic material to seasonal pools. Bacteria, algae, and fungi colonize this vegetative matter, supplying food for invertebrates and developing tadpoles. Invertebrates and amphibian larvae are, in turn, prey for predatory invertebrates and larger-sized amphibian larvae. Amphibians and some insect species eventually metamorphose, leaving the pools and providing a major source of biomass (i.e., food for other wildlife) to the surrounding terrestrial habitat.

Seasonal pools also serve as "stepping-stones" through the landscape for animals moving among wetlands. By providing feeding and watering opportunities, they support local and regional biodiversity. Developing amphibian larvae and invertebrates in the pools are important prey for visiting turtles, snakes, birds, and mammals.

1.2: Purpose and Scope

Seasonal pools support biological diversity by providing important habitat. However, the same qualities that make seasonal pools uniquely valuable to wildlife render them especially vulnerable to human disturbance. Their small size, surficial hydrologic isolation, lack of fish populations, and impermanent water make them less likely to attract attention for conservation. Also, they generally are not protected by state or federal regulations. Many seasonal pools may not meet the strict hydrologic, soil, and vegetation requirements to be classified as wetlands at the federal or state level (see Cowardin et al., 1979) or may fall beneath the minimum size requirements to be protected under wetlands regulatory programs.

The United States has lost more than half of its original acreage of wetlands due to draining, filling, dredging, flooding, and leveling associated with land development and agriculture (Dahl, 1990). Although seasonal pools are not comprehensively included in studies of wetland loss, partly because methods that inform these studies do not work as well for identifying relatively small seasonal pools, it is highly likely that seasonal pools have been lost at a rate equal to or exceeding that of the larger wetlands included in these studies. The smaller the wetland or pool, the less likely it is to fall under the jurisdiction of federal or state wetlands regulations and the easier it can be filled-in or drained. It is likely that pools continue to be lost at a rapid pace in the mid-Atlantic region.

The purpose of this publication is to introduce readers to seasonal pool ecology and conservation in the mid-Atlantic region, which is comprised of Delaware (Del.), Maryland (Md.), New Jersey (N.J.), Pennsylvania (Pa.), Virginia (Va.), West Virginia (W. Va.), and the District of Columbia (D.C.). For many readers, seasonal pools will be a new subject area or serve as a new synthesis of ecological concepts.

This publication presents a working definition for seasonal pools, describes landscape settings and vegetative communities of seasonal pools, and explores the seasonal pool ecosystem. Following an introduction to seasonal pools and their fauna, conservation challenges facing resource managers and land-use planners wanting to conserve seasonal pools are considered. The authors then put forward recommendations for future directions in the management of seasonal pool resources in the mid-Atlantic region.

A pictorial Field Guide to mid-Atlantic seasonal pool amphibians, invertebrates, amphibian larvae, and amphibian egg masses is provided to aid readers in the field. The Appendices present information on techniques and references for surveying seasonal pools.

1.3: Definition of "Seasonal Pool"

In the mid-Atlantic region and elsewhere, seasonal pools display tremendous diversity in terms of landscape setting, surrounding vegetative community, hydrological source (groundwater, surface runoff, rainfall, snowmelt), hydroperiod, and faunal communities, among other variables. The definition of a seasonal pool must be broad enough to encompass this variation.

For the purposes of this publication, we define seasonal pools based on four distinguishing features: surficial hydrologic isolation, periodic drying, small size and shallow depth, and distinctive biological community (Box 1-2; *cf.* Wiggins et al., 1980, Calhoun and Klemens, 2002; Zedler, 2003; Calhoun and deMaynadier, 2004; Colburn, 2004).

Box 1-2
Definition of a seasonal pool

☑ **Surficial Hydrologic Isolation**
No permanent surface water connections to other water bodies.

☑ **Periodic Drying**
Water levels generally fluctuate by season; pools experience drying or lowered water levels on a regular basis (frequency ranges from every year to just drought years).

☑ **Small Size and Shallow Depth**
Small area and shallow depth compared to other productive aquatic habitats (such as lakes and types of wetlands).

☑ **Distinctive Biological Community**
Support animals that are adapted to seasonal pool drying; support the breeding of animals that reproduce optimally without fish populations; do not support permanent populations of predatory fish.

Surficial Hydrologic Isolation

Isolation from other surface waters is one of the defining characteristics of seasonal pools. The lack of permanent surface water connections protects pools from successful invasion by predatory fish. There is a range in the degree of isolation of pools, however. Some pools are completely surrounded by terrestrial environment with the nearest aquatic habitat a half-mile or farther away, while other pools may occur within a larger wetland complex. Seasonal pools, despite being isolated from permanent surface water connections, are very much connected to the greater hydrology and ecology of the landscape. Isolated pools may receive their water from rainwater, surface water run-off, snowmelt, subsurface flow, groundwater, and possibly intermittent streams (Tiner, 2003b; Whigham and Jordan, 2003; Winter and LaBaugh, 2003). Seasonal pools are connected biologically to both aquatic and terrestrial habitats by the movement of animals (Gibbons, 2003; Leibowitz, 2003).

Periodic Drying

Seasonal pools are water bodies that experience alternating periods of filling and drying. Pools in the Northeast, including the mid-Atlantic region, typically begin to fill with water in mid-autumn to early winter due to the onset of fall rains and decreased water uptake by plants (i.e., the rate of evapotranspiration by trees lessens due to leaf senescence) (Phillips and Shedlock, 1993; Brooks, 2004). However, some seasonal pools may not begin filling until late winter or early spring. Most seasonal pools reach their maximum depth and size in the spring due to snowmelt and spring rains. As spring and summer progress with increasing temperatures and rates of evapotranspiration by trees and other vegetation, water levels decrease and pools may dry completely (Plate 1-3; Fig. 1-1; Brooks, 2004).

Photos: USGS PWRC

Plate 1-3. A seasonal pool's wet stage and dry stage. A seasonal pool in Rock Creek Park, D.C., is shown (A) in spring when the pool is full of water and (B) in fall when the pool has dried.

Seasonal pools display considerable variation in hydroperiods (length of time that a pool is filled with water) and water levels (depth at which the pool is filled) across the landscape (Williams, 1987; Semlitsch, 2000). The hydroperiod is the most powerful abiotic factor determining the composition of a seasonal pool community (Wiggins et al., 1980; Skelly, 1997; Morey, 1998). The differences between pools are due to regional climatic patterns and characteristics of each pool's depression and watershed (Brooks and Hayashi, 2002; Winter and LaBaugh, 2003). In addition to these inter-pool differences, a seasonal pool has intra-pool hydrologic variability, with varying hydroperiods and water levels over time, depending upon the season and the weather conditions (Plate 1-3; Fig. 1-1; e.g., Rowe and Dunson, 1993; Semlitsch et al., 1996; DiMauro and Hunter, 2002).

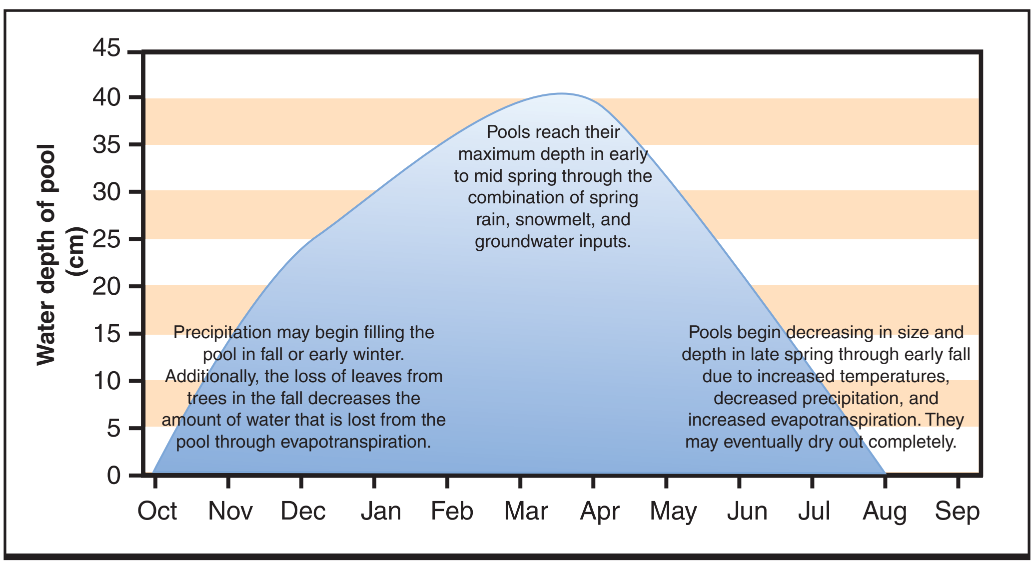


Figure 1-1. Hydrograph of a seasonal pool.* The water depth of a seasonal pool is shown according to month of year. This hydrograph is meant to reflect a typical seasonal pool; individual pools will have different depths and dates of filling and drying due to the characteristics of pool depressions and precipitation and temperature patterns.

** Approximate water depths and dates were derived from Brooks (2004), Rowe and Dunson (1993), and datasets of the U.S. Geological Survey Amphibian Research and Monitoring Initiative - Northeast (USGS ARMI-NE, unpublished data).*

The umbrella term, "seasonal pool," that will be primarily used in this publication, may be further divided into three general types according to length of hydroperiod, which may provide insight into their respective biological communities: ephemeral pools, annual pools, and semipermanent pools (Box 1-3). Due to differences in precipitation and weather from year to year, pools have different durations and timing of flooding from one year to the next. Thus, the designation of a pool type based on hydroperiod is for provisional descriptive purposes only.
Pools with hydroperiods of less than two months during years of average rainfall are "ephemeral pools." They are formed by intense periods of precipitation. Ephemeral pools may be especially valuable to species of clam shrimp (Class Branchiopoda) and other invertebrates as well as the reproduction of eastern spadefoots (*Scaphiopus holbrookii*).

Box 1-3
Types of seasonal pools based on hydroperiod

Ephemeral Pools
Formed by intense periods of precipitation; hydroperiods less than two months.

Annual Pools
Dry annually in typical years; hydroperiods from 2 months to 12 months.

Semipermanent Pools
Undergo seasonal fluctuations in water levels; do not dry annually; hydroperiods of greater than 12 months.

Pools that dry annually and have hydroperiods of 2 months to 12 months are "annual pools." The species composition of an annual pool community may be different depending upon the length of the hydroperiod.

At the other end of the spectrum, pools that do not dry on an annual basis and have hydroperiods of greater than 12 months are "semipermanent pools." They still undergo significant seasonal fluctuations in water levels and dry in years of relatively low precipitation. Their surficial hydrologic isolation and periods of very shallow and anoxic waters still preclude permanent populations of predatory fish, thus they may support seasonal pool-dependent organisms. However, they may not support organisms that depend upon complete dry-downs, such as fairy shrimp. In addition, they may harbor higher populations of predators, such as aquatic salamanders and large-sized invertebrates (Semlitsch et al., 1996; Skelly, 1997; Semlitsch, 2003).

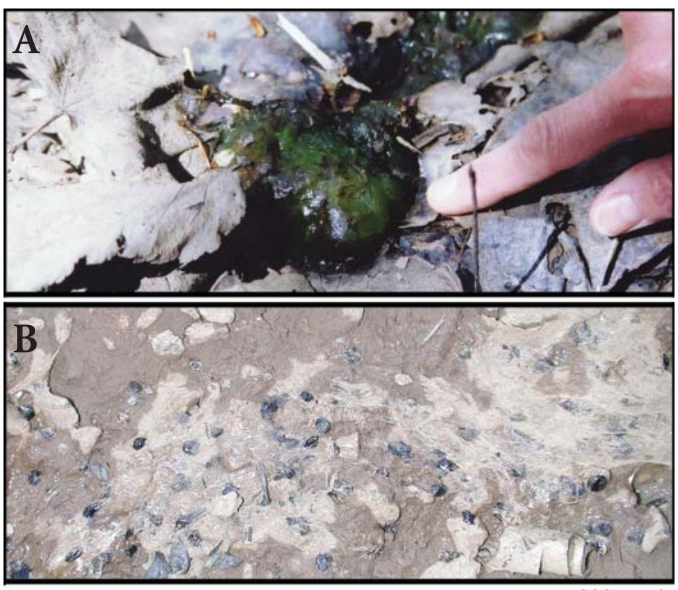
Small Size and Shallow Depth

Most seasonal pools are very small compared to ponds and lakes, which makes them more vulnerable to pressures from development but does not make them less valuable from a biological standpoint. Their relatively small area and shallow depth are what facilitates their dry periods or drawdowns (Brooks and Hayashi, 2002). Their shallow depth allows pools to warm rapidly, particularly important for amphibians breeding during late winter and early spring (Colburn, 2004).

According to the New Jersey Division of Fish and Wildlife, most seasonal pools in New Jersey are less than 0.25 acres (1,012 m^2) in area (Tesauro, 2004). On the Delmarva Peninsula, seasonal pools are reported to be typically less than 0.4 acres (1,619 m^2) in size (Phillips and Shedlock, 1993). Many pools in the mid-Atlantic region are much smaller than these high-range figures suggest. In 2004, 134 seasonal pools of natural origin with standing water and containing wood frog and/or spotted/blue-spotted salamander egg masses were surveyed at National Parks and National Wildlife Refuges in the mid-Atlantic as part of the USGS ARMI-NE program. Pool area (maximum length x maximum width) averaged 0.09 acre (379 m^2) and ranged from 54 ft^2 to 1.1 acres (5 to 4,350 m^2), with 78% of the pools less than 0.1 acre (400 m^2). Pool maximum depth averaged 15.4 inches (39 cm) and ranged from 2.8 to 78.7 inches (7 to 200 cm), with 69% of the pools less than or equal to 15.7 inches (40 cm) maximum depth (USGS ARMI-NE, unpublished data).

Distinctive Biological Community

Seasonal pools of the mid-Atlantic region support characteristic communities of animals due to their unique hydrology and their lack of permanent populations of predatory fish. Many seasonal pool inhabitants lack defenses against predatory fish, and thus are primarily restricted to seasonal pools (Wilbur, 1980; Kats et al., 1988). For example, larvae of species of amphibians that breed in seasonal pools may lack the ability to detect and evade fish by using chemical cues and may be more palatable as prey to fish as compared to species of amphibians that typically breed in permanent waters (Kats et al., 1988). Fish predation may annihilate the entire brood of larvae of these species, resulting in complete reproductive failure (Ireland, 1989). However, not all species of fish pose direct risks to seasonal pool-breeding amphibians; for example, some fish species feed primarily on plankton (Hecnar and M'Closkey, 1997).



Photos: USGS PWRC

Plate 1-4. Seasonal pools drying before metamorphosis. Seasonal pools may dry before metamorphoses of amphibians are complete. (A) A spotted salamander (*Ambystoma maculatum*) egg mass remains in a dry seasonal pool in Rock Creek Park, D.C. (B) Wood frog (*Rana sylvatica*) tadpoles are left behind when a pool dries up in Shenandoah National Park, Va.

Seasonal pool species display structural, physiological, or behavioral adaptations to survive and/or reproduce in these temporary waters (Wiggins et al., 1980; Wilbur, 1980; Williams, 1987). Amphibians and some species of invertebrates metamorphose and leave the pool before it dries. Certain species of invertebrates lay eggs that survive the dry period; larvae or adults of some species may burrow into the pool bottom. However, when there is little rain in the spring, a pool can dry out too quickly, causing embryos and amphibian larvae to become desiccated and die (Plate 1-4; Shoop, 1974; Semlitsch et al., 1988; Rowe and Dunson, 1993; Skelly, 1997; Morey, 1998; DiMauro and Hunter, 2002).

Seasonal pools provide optimal breeding habitat for nine species of amphibians across the region, including seven species of mole salamanders in the family Ambystomatidae as well as two anuran species: wood frog and eastern spadefoot (see Section 3 and the Field Guide for descriptions and photographs of these animals).

Certain invertebrate taxa are common among seasonal pool biological communities, including crustaceans, mites, and three insect groups (true bugs, beetles, and midges) (Williams, 1987; Brooks, 2000; Colburn, 2004). The fairy shrimp is a characteristic member of some seasonal pool biotic communities; seasonal pools are the primary habitats in which fairy shrimp species of the mid-Atlantic region occur.

Depending on the weather, there may be years when little or no breeding activity occurs in a pool (Semlitsch et al., 1996). However, seemingly "empty" pools may still support tremendous biodiversity in years with favorable precipitation and temperature patterns.

Seasonal pools may or may not be vegetated. Although in-pool vegetation is not essential for their role as important animal habitat, some seasonal pools may support rare or endemic species of vegetation, such as the Virginia sneezeweed (*Helenium virginicum*), a state-listed threatened plant endemic to sinkhole ponds of Virginia. More research is needed to catalog these pool-dependent species of flora.

2 The Greater Seasonal Pool Ecosystem

The greater seasonal pool ecosystem is considerably larger than the seasonal pool itself. It extends outwards into the terrestrial landscape via biological connections and the watershed via hydrologic linkages. This section provides an overview of the variety of landscape settings and surrounding vegetative communities, explores the greater seasonal pool ecosystem, and examines the general life histories of seasonal pool-dependent fauna to elucidate the nature of their interactions with the seasonal pool ecosystem.

2.1: Setting and Vegetation of Seasonal Pools

The mid-Atlantic region is a physiographically diverse area of the United States, encompassing the extremes of the low, flat, sandy mid-Atlantic coastal plain to the greater than 5000 foot peaks of the southern Blue Ridge Mountains of Virginia. For example, Delmarva bays that are found on the Delmarva Peninsula coastal plain of Maryland and Delaware (Box 2-1) are very different physiographically as compared to the seasonal sinkhole ponds of the Shenandoah Valley of the Blue Ridge Mountains (Buhlmann et al., 1999). Seasonal pools of the mid-Atlantic reflect physiographic diversity in their wide variety of landscape settings and surrounding vegetative communities.

Seasonal pools can be found in three general landscape settings: surrounded by upland, wetland, or floodplain. Pools surrounded by upland are islands of aquatic habitat within a terrestrial landscape; pools surrounded by wetlands are part of a larger wetland complex; pools surrounded by floodplain are occasionally linked to a riverine system.

Four basic classes of seasonal pools are described below (seasonal forest pools, seasonal open-canopy pools, seasonal scrub-shrub pools, and seasonal forested wetland pools) based on their surrounding vegetative community, with short lists of common, but certainly not inclusive, species of vegetation that may be found in or around these seasonal pools (species were selected by referring to Tiner and Burke, 1995; Rawinski, 1997; Buhlmann et al., 1999; Sipple 1999; Zankel and Olivero, 1999; Colburn, 2004). Compositions of vegetative communities vary from site to site due to local environmental and historical conditions. Some pools may fall into more than one class or may not easily be placed into one. Additionally, vegetative communities are not static – they may change across the seasons and over the long-term (Tiner and Burke, 1995; Rawinski, 1997; Colburn, 2004).

Seasonal Forest Pools

Seasonal forest pools are isolated depressions surrounded by upland deciduous, mixed deciduous-coniferous, or coniferous forest (Plate 2-1). These pools may or may not be clustered in the landscape. Trees that can tolerate seasonally-saturated soils, such as white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), willow oak (*Quercus phellos*), pin oak (*Quercus palustris*), American elm (*Ulmus americana*), loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), American beech (F*agus grandifolia*), and sourwood (*Oxydendrum arboreum*), or trees with flood-resistant adaptations (e.g., buttresses, stilt roots) may be found around the edges of the pool depression; a few may be found in the pool itself, especially during high water levels. Seasonal forest pools are partially or completely

Photo: Lesley J. Brown

Plate 2-1. Seasonal forest pool. This seasonal forest pool is located in western Virginia.

shaded by the overhanging tree canopy but there is little or no plant growth in the pool depression itself (Tiner and Burke, 1995; Rawinski, 1997; Sipple, 1999; Colburn, 2004).

Seasonal Open-Canopy Pools

Seasonal open-canopy pools have open canopies that allow full sunlight to reach the pool (Plate 2-2). The pools may be surrounded by upland, situated within a larger wetland matrix, or in a floodplain. They may be without vegetation or may be vegetated with non-woody plant species. Emergent plants that grow in these pools may include grasses (e.g., manna grasses (*Glyceria spp.*), panic grasses (*Panicum spp.*), giant plumegrass (*Erianthus giganteus*), rice cutgrass (*Leersia oryzoides*)), sedges and rushes (e.g., sedges (*Carex spp.*), creeping rush (*Juncus repens*), woolgrass bulrush (*Scirpus cyperinus*), three-way sedge (*Dulichium arundinaceum*)), and herbs (e.g., Virginia meadow beauty (*Rhexia virginica*), marsh St. John's-wort (*Triadenum virginicum*), Virginia chain fern (*Woodwardia virginica*)).

Photo: Tim Maret

Plate 2-2. Seasonal open-canopy pool. This seasonal open-canopy pool is located in south-central Pennsylvania.

Seasonal Scrub-Shrub Pools

Seasonal scrub-shrub pools are dominated by shrubs or young trees less than 20 feet tall (6 m) growing in the seasonal pool depression (Plate 2-3). Scrub-shrub pools may be surrounded by upland forest, part of a larger wetland system, or in a floodplain. Vegetation may include common greenbrier (*Smilax rotundifolia*), highbush blueberry (*Vaccinium corymbosum*), buttonbush (*Cephalanthus occidentalis*), fetterbush (*Leucothoe racemosa*), dangleberry (*Gaylussacia frondosa*), swamp azalea (*Rhododendron viscosum*), sweet pepperbush (*Clethra alnifolia*), winterberry (*Ilex spp.*), alders (*Alnus spp.*), and water willow (*Decodon verticillatus*).

Photo: USGS PWRC

Plate 2-3. Seasonal scrub-shrub pool. This seasonal scrub-shrub pool is located at U.S. Department of Agriculture's Beltsville Agricultural Research Center, Md.

Seasonal Forested Wetland Pools

Seasonal forested wetland pools are dominated by flood-tolerant trees greater than 20 feet tall (6 m) growing in the pool basin (Plate 2-4). Seasonal forested wetland pools may be surrounded by upland forest or may be situated within a larger wetland matrix, floodplain, or oxbow of a river. Trees may include sweet gum (*Liquidambar styraciflua*), swamp black gum (*Nyssa biflora*), black gum (*Nyssa sylvatica*), laurel oak (*Quercus laurifolia*), overcup oak (*Quercus lyrata*), loblolly pine (*Pinus taeda*), red maple (*Acer rubrum*), willow oak (*Quercus phellos*), sourwood (*Oxydendrum arboreum*), water oak (*Quercus nigra*), pin oak (*Quercus palustris*), American elm (*Ulmus americana*), American holly (*Ilex opaca*), sweet bay (*Magnolia virginiana*), willows (*Salix spp.*), Atlantic white cedar (*Chamaecyperis thyoides*), and green ash (*Fraxinus pennsylvanica*).

Photo: Gary P. Fleming

Plate 2-4. Seasonal forested wetland pool. A seasonally flooded swamp forest of sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and swamp tupelo (*Nyssa biflora*). This pool is located in North Landing River Natural Area Preserve, City of Virginia Beach, Va.

Box 2-1
Example of regional seasonal pools: Delmarva bays

Delmarva bays are an example of a type of seasonal pool that is specific to an area of the mid-Atlantic region. The Delmarva Peninsula is the projection of land into the Chesapeake Bay that encompasses the entire state of Delaware and portions of Maryland and Virginia. On the Delmarva Peninsula, the landscape is pockmarked with thousands of isolated depressional wetlands or pools. These depressions are known by many names, such as Delmarva bays, Delmarva potholes, and whale wallows (Sipple, 1999). They are also sometimes categorized within the larger category of coastal plain ponds or equated with Carolina bays. 'Bay' refers to the trees that are often found in these habitats: sweet bay (*Magnolia virginiana*), red bay (*Persea borbonia*), and loblolly bay (*Gordonia lasianthus*) (Sipple, 1999). The coastal plain's relatively flat topography favors the formation of seasonal pools, fed by both groundwater and high levels of precipitation experienced in this region (Tiner, 2003a).

Delmarva bays are of variable shapes and sizes – elliptical, circular, or irregular with long-axes ranging in length from less than 305 ft to 3050 ft (100 m to 1 km) (Stolt and Rabenhorst, 1987). Their long-axes are often oriented from north to south. They generally have no standing water from midsummer to early winter. Delmarva bays may form seasonal open-canopy pools (known as 'glades') with Walter's sedge (*Carex walteriana*), giant plumegrass, twigrush (*Cladium mariscoides*), and maidencane (*Panicum hemitomon*); seasonal scrub-shrub pools with buttonbush and water willow; and seasonal forested wetland pools with red maple, sweet gum, and oaks (Sipple, 1999).

Delmarva bays are particularly abundant in the central area of the Delmarva Peninsula along the border between Maryland and Delaware, in Queen Anne's County and Caroline County in Maryland and Kent County in Delaware (Stolt and Rabenhorst, 1987). Delmarva bays' abundance over the landscape makes them important for surface water storage and helps control local flooding. During wet seasons, they serve as storage for groundwater discharge; during dry seasons, they serve as sources of groundwater recharge (Phillips and Shedlock, 1993). Delmarva bays serve as important wildlife habitat, and support many of the species described in Section 3.

2.2: Life Zones of Seasonal Pools

The seasonal pool ecosystem can be thought of as being composed of three integrated components, or life zones: the seasonal pool depression, the seasonal pool envelope (100 ft (30.5 m) radius from pool edge), and the seasonal pool terrestrial habitat (1000 ft (305 m) radius from the pool edge) (Fig. 2-1; *cf.* Semlitsch, 1998; Calhoun and Klemens, 2002; Calhoun and deMaynadier, 2004). Conceptualization of three discrete but interdependent physical areas provides insight into the overall functioning of the greater ecosystem and allows tailored conservation strategies to be developed (e.g., Calhoun and Klemens, 2002; Calhoun and deMaynadier, 2004). All three zones provide essential services that contribute to the seasonal pool ecosystem. The three seasonal pool life zones and the more prominent activities that they host are briefly described below.

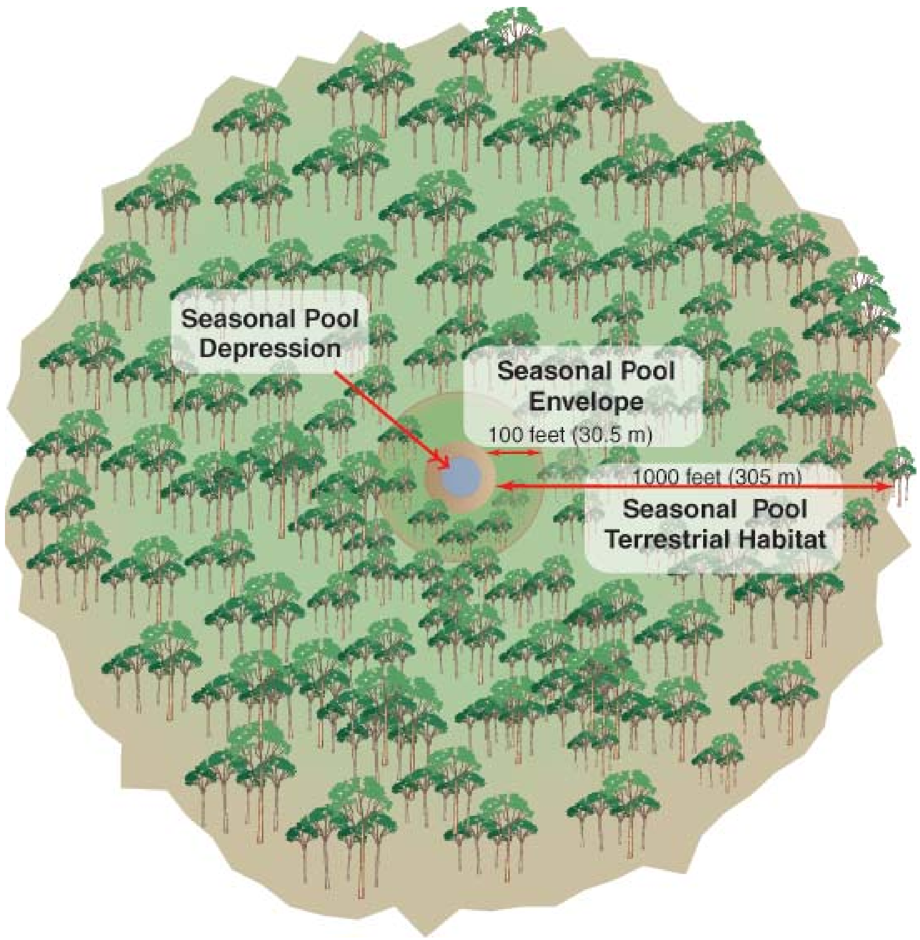


Figure 2-1. Seasonal pool aerial view delineating three life zones.* The seasonal pool depression is the entire area that fills with water during highest water levels. The seasonal pool envelope is the area immediately surrounding the pool depression, extending 100 ft † (30.5 m) beyond the edge of the depression. The seasonal pool terrestrial habitat is the area surrounding the pool that extends 1000 ft ‡ (305 m) beyond the edge of the depression (inclusive of the seasonal pool envelope).

† This width is based on the management zone designed by Calhoun and Klemens (2002).

‡ This width was determined so as to encompass the movements and habitats of pool-breeding salamanders (e.g., Semlitsch, 1998; Faccio, 2003) and to account for their high sensitivity to the amount of forest cover within this zone (e.g., Homan et al., 2004; Porej et al., 2004; Herrmann et al., 2005). However, characteristics of the landscape (e.g., forest cover, road densities) at greater distances from the pool beyond this life zone may also affect seasonal pool fauna (Homan et al., 2004; Porej et al., 2004; Herrmann et al., 2005). Additionally, juvenile wood frogs may migrate to other pools at distances significantly beyond this life zone (average of 3750 ft (1140 m); Berven and Grudzien, 1990).

* *Symbols used for diagram courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science.*

Seasonal Pool Depression

The seasonal pool depression (also known as the seasonal pool basin) is the area that fills with water during highest water levels (Fig. 2-1). If there is no standing water, other visual clues may indicate the pool depression (Box 2-2; Plate 2-7). The seasonal pool depression is the epicenter of the seasonal pool ecosystem in late winter and spring, hosting amphibian breeding, amphibian egg and larval development, invertebrate life cycles, and wildlife feeding.

Amphibian Breeding. Mole salamanders (*Ambystoma spp.*) and wood frogs migrate to the seasonal pool depression from their overwintering terrestrial habitat from late winter to spring, with the exception of the marbled salamander (*Ambystoma opacum*), which migrates to the depression in the fall. The exact migration times or dates depends on the species, region, and weather. Courtship and mating takes place in the seasonal pool depression (Plate 2-5).

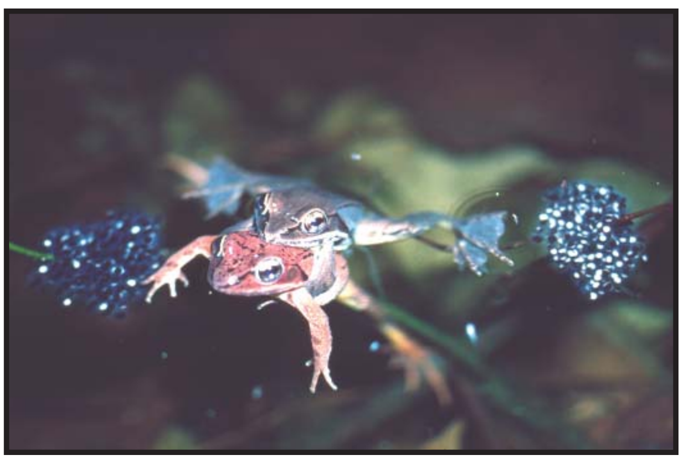


Photo: Steven M. Roble

Plate 2-5. Amplexus between a male and female wood frog (*Rana sylvatica*). The male wood frog clasps the female wood frog from behind while mating. There are wood frog eggs on either side of the mating pair.

Amphibian Egg and Larval Development. Depending on the species, female pool-breeding amphibians lay their eggs singly, in strings, in sheets, or as discrete masses immediately or a few days after mating (Plate 2-6). Eggs and egg masses of seasonal pool-breeders are usually attached to vegetation or woody debris below the water surface (Petranka, 1998). After hatching, salamander larvae and tadpoles develop in the pools. Salamander larvae eat zooplankton, invertebrates, and, for larger individuals, other amphibian larvae (Petranka, 1998); tadpoles primarily eat algae and detritus, although they may also eat smaller amphibian larvae and eggs.

Photo: Steven M. Roble

Plate 2-6. Release of spotted salamander eggs. These female salamanders are laying egg masses in the water of a seasonal pool.

Invertebrate Life Cycles. Seasonal pools provide habitat for a wide variety of invertebrate species. The soil at the bottom of seasonal pools may contain resting eggs from species of crustaceans, including fairy shrimp, clam shrimp, and seed shrimp, and arthropods, including caddisflies (Dodson and Frey, 1991; Hilsenhoff, 1991; Smith, 2001). Adult amphibious snails, fingernail clams, and amphipods may also survive dry conditions or overwinter by burrowing into sediments and organic debris (Smith, 2001).

Support of Terrestrial Food Webs. Invertebrates, amphibians, reptiles, birds, and mammals come to the pool depression to feed (Winfield et al., 1981; Brooks and Doyle, 2001; Kenney and Burne, 2001; Biebighauser, 2002; Colburn, 2004). Amphibian egg masses, invertebrate and amphibian larvae, and emerging insects and amphibians provide a significant food source for visiting predators. Seasonal pools serve as important feeding and watering sites for wetland- or aquatic-dependent animals traveling across the landscape.

Box 2-2
Recognizing dry seasonal pools*

If there is no standing water, other visual clues can be used to identify seasonal pools that fill with water in another season.

Characteristic Topography
- Depressions in otherwise flat topography
- "Pit-and-mound" topography

Clues from Seasonal Pool Biota
- Fingernail clams and clam shells
- Caddisfly cases
- Snails and snail shells
- Fairy shrimp eggs

Evidence of Water
- Stained or sediment-covered leaves
- Trees with flood-resistant adaptations (e.g., buttresses, stilt roots)
- Sphagnum moss, ferns
- Wetland plants growing in dry soil
- Wetland (hydric) soils
- Water stains on trees

** Colburn, 1997; Tappan, 1997; Calhoun, 2003*

Photo: USGS PWRC

Plate 2-7. Recognizing dry seasonal pools. Water stains at the base of trees presents evidence that this area fills with water. This seasonal pool is located at the Patuxent Research Refuge, Laurel, Maryland.

Seasonal Pool Envelope

The seasonal pool envelope is the terrestrial habitat immediately surrounding the pool; it is a management zone that extends approximately 100 feet (30.5 m) from the pool edge (Fig. 2-1; Calhoun and Klemens, 2002; Calhoun and deMaynadier, 2004). This area supports activities related to amphibian breeding, provides terrestrial habitat to juvenile and adult amphibians, and plays a large role in regulating water quality.

Amphibian Breeding. During the amphibian breeding season (from late winter to spring for most species), high densities of adult amphibians may occupy the seasonal pool envelope (Plate 2-8; Calhoun and Klemens, 2002). They spend their days hidden in this area near the edge of the seasonal pool or in the pool itself, and their nights in the pool engaged in breeding activities. Male amphibians may arrive up to several days or weeks earlier than females and wait for females to arrive in this area (Bishop, 1941; Shoop, 1960; Semlitsch, 1981). Marbled salamanders, unlike the other species in the mole salamander family, breed in the late summer or fall and may mate in the seasonal pool envelope. Male marbled salamanders often intercept females en route to the breeding pools, and initiate courtship in the pool envelope before the females reach the pool depression (Bishop, 1941; Krenz and Scott, 1994).

Photo: USGS PWRC

Plate 2-8. Spotted salamanders at pool edge. These salamanders are spending their daylight hours during the breeding season under a cover object in the mud at the margin of a seasonal pool.

Juvenile and Adult Amphibian Habitat. From summer to fall, the seasonal pool envelope is occupied by large numbers of recently metamorphosed juvenile frogs and salamanders. They may burrow into the mud near the pool edge or hide beneath rocks and logs to survive dry weather before making their emigration from the pools to their overwintering habitat (Richmond, 1947; Shoop, 1974). Wintering juvenile and adult wood frogs occur in greatest densities within 30 m of pools and are highly sensitive to disturbances in this area (Homan et al., 2004; Regosin et al., 2005).

Water Quality. The seasonal pool envelope plays a large role in regulating seasonal pool water quality. Soil buffers run-off and snowmelt before it enters the pool (Gascon and Planas, 1986). Vegetation (tree roots and ground cover) traps sediment before it enters the pool. Overhanging vegetation regulates pool temperature and supplies organic material to the pool depression; leaf litter serves as food for fungi, bacteria, and invertebrates (Colburn, 2004). Vegetation also influences a pool's hydrologic regime – trees and shrubs withdraw water from the pools, especially in the spring and summer.

Seasonal Pool Terrestrial Habitat

Seasonal pool terrestrial habitat is the area that extends 1000 ft (305 m) from the edge of the seasonal pool depression (Fig. 2-1). The portion of this life zone that remains forested or unimpacted by human activities provides habitat to pool-breeding amphibians and other wildlife, serves as a terrestrial corridor between pools, and plays a role in regulating water quality.

This management zone encompasses the habitat of over 95% of populations of pool-breeding salamanders (Semlitsch, 1998; Faccio, 2003), although this area is not sufficient to encompass all movements of seasonal pool-breeding amphibians (e.g., juvenile wood frog migrations, Berven and Grudzien, 1990). Also, the seasonal pool biological community may be influenced by characteristics of the landscape (e.g., amount of forest cover, densities of roads) well beyond the seasonal pool terrestrial habitat zone (Homan et al., 2004; Porej et al., 2004).

Amphibian and Other Wildlife Habitat. Seasonal pool-breeding amphibians of the mid-Atlantic region spend approximately 90% of their juvenile and adult lives in the terrestrial landscape (Semlitsch, 1998), and exhibit seasonal variation in terrestrial habitat use. During the winter, wood frogs find shelter and hibernate in upland forests; during their more active period, they forage and find shelter in moist lowland forests (Hulse et al., 2001; Regosin et al., 2003b). Spotted salamanders may occur at uniform densities up to and exceeding 984 ft (300 m) away from seasonal pools (Homan et al., 2004). Seasonal pool-breeding amphibians play important roles in forest ecology, as prey for wildlife and as predators of invertebrates. In a given area of forest, they may comprise a higher biomass than the breeding birds and small mammals combined (Windmiller, 1996). Many other species of wildlife inhabit the seasonal pool terrestrial habitat, including snakes, turtles, birds, and terrestrial amphibians. They feed on the resources produced in the seasonal pool (Winfield et al., 1981; Brooks and Doyle, 2001; Kenney and Burne, 2001; Biebighauser, 2002; Colburn, 2004).

Biological Corridor. The terrestrial forested habitat functions as a biological corridor, whereby animals can travel between pools. Pool-breeding amphibians and other animals may disperse from one pool to another.

Water Quality. The water quality of the pool will be determined by the entire watershed, which will extend into the seasonal pool terrestrial habitat and possibly even farther, depending upon the characteristics of the watershed and the source of the water.

2.3: Life Histories of Seasonal Pool-Dependent Organisms

Seasonal pool-dependent animals have developed behavioral (e.g., effective immigration and emigration strategies), physiological, or structural adaptations that allow them to survive and/or reproduce in the highly dynamic environment of seasonal pools (Wiggins et al., 1980; Williams, 1987). Seasonal pool-dependent animals may be classified into three general life history classes: migratory breeders, non-breeding migrants, and permanent residents (based on Colburn, 2004; builds upon and modifies previous classification systems of Wiggins et al., 1980; Williams, 1987). This classification system is presented below, in the context of mid-Atlantic seasonal pools.

Migratory Breeders

"Migratory breeders" are those animals that breed in seasonal pool depressions during the flooded phase and vacate pools during the dry phase (Colburn, 2004). The most visible members of this life history grouping are pool-breeding amphibians (Box 2-3; see Section 3 for more information).

Besides amphibians, some invertebrate species rely on this life history strategy as well. Limnephilid caddisfly adults spend summers in caves and tree holes and return to the pools to breed (Colburn, 2004). Certain species of predaceous diving beetles, backswimmers, and water boatman spend portions of their life cycles in permanent water bodies away from seasonal pools (Colburn, 2004).

Box 2-3
Life history of pool-breeding amphibians

Amphibian migratory breeders have biphasic life cycles, requiring both aquatic and terrestrial habitats (Semlitsch, 1998, 2003). Early stages of development are spent as eggs and larvae in seasonal pools. The transition from an aquatic to a terrestrial life stage occurs at metamorphosis, when amphibians emerge from their natal pools and enter the terrestrial habitat.

As adults, they return to seasonal pools from their terrestrial habitats to breed. Once having bred in a particular pool, adult wood frogs have been found to be very faithful to their pools (Berven and Grudzien, 1990). There is evidence that other pool-breeding amphibians exhibit similar levels of breeding pool fidelity (e.g., *Ambystoma maculatum*, Scott, 1994) returning to the same pools and following the same migration paths. Males arrive at breeding pools earlier and stay later than females (Bishop, 1941; Shoop, 1960; Semlitsch, 1981).

Dispersal between local populations occurs when animals breed in pools other than their natal pools. Dispersal in wood frogs and other seasonal pool-breeding amphibians is age-specific, with juveniles accounting for most or all of the movements between ponds (Berven and Grudzien, 1990). Wood frogs may emigrate more than 3750 ft (1140 m) from their natal pools to breed as adults in other pools (Berven and Grudzien, 1990).

The behavior and habitat requirements of the terrestrial stage of pool-breeding amphibians are not fully understood, primarily due to the logistical difficulties in their study and the amphibians' nocturnal and belowground habits (Petranka, 1998; Dodd and Smith, 2003; Semlitsch, 2003). Pool-breeding amphibians must keep their skin cool and moist. Thus microclimates play a large role in the suitability of a particular habitat for amphibians (Gibbs, 1998; Guerry and Hunter, 2002); mature forests provide appropriate microclimates (Semlitsch, 1981; Petranka et al., 1994; deMaynadier and Hunter, 1999; Rothermel and Semlitsch, 2002; Faccio, 2003). Mole salamanders require sufficient belowground refugia, which provide protection from predators and freezing temperatures (Madison, 1997; Regosin et al., 2003a). Mole salamanders may emigrate more than 650 ft (200 m) from their breeding pools to their terrestrial habitat (Semlitsch, 1981; Madison, 1997). Females of pool-breeding amphibian populations are more likely to overwinter at greater distances away from pools compared to males (Regosin et al., 2003a, b).

Non-Breeding Migrants

"Non-breeding migrants" are those animals that migrate to seasonal pools for feeding, rather than breeding, a behavioral adaptation used to exploit seasonal pool resources (Williams, 1987; Colburn, 2004). This group may include species of predaceous diving beetles, turtles, snakes, birds, and mammals. Freshwater turtles that frequent seasonal pools generally feed on algae, terrestrial and aquatic plants, and invertebrates. Snakes that have aquatic or semi-aquatic life histories, such as the ribbonsnake, may hunt for amphibians in the water of a seasonal pool. Birds and mammals use seasonal pools as sources of water and food (see Section 3).

Permanent Residents

"Permanent residents" are those animals that do not spend significant amounts of time away from the seasonal pool (Colburn, 2004). Permanent residents are those with unique physiological and behavioral adaptations to withstand drying and extreme temperature changes. Some beetles, fingernail clams, and other invertebrates spend the dry phase or winter season aestivating in the sediment of pool depressions. One of the most distinctive inhabitants of some seasonal pools, fairy shrimp, as well as species of flatworms, mosquitoes, and beetles, survive pool drying as drought-resistant eggs or cysts that hatch upon flooding (Smith, 2001). This life history group also includes insects that spend their larval stages in seasonal pools and become aerial as adults but do not travel far from pools (Colburn, 2004).

3 Introduction to Seasonal Pool Fauna

3.1: Introduction to Seasonal Pool Fauna

Seasonal pools provide important habitats for invertebrates, amphibians, reptiles, birds, and mammals. Amphibians are among the most conspicuous visitors to seasonal pools, especially between late winter and summer. During the breeding season, congresses of salamanders and choruses of frogs provide visual and auditory notice of their presence. For a period of time after adults breed and return to their terrestrial habitat, egg masses and then larvae remain in the pool.

The hydroperiod of a seasonal pool plays a significant role in determining the community of animals it will support (Wiggins et al., 1980; Semlitsch et al., 1996; Skelly, 1997; Morey, 1998; Semlitsch, 2003). A hydroperiod shorter than one month will not support the reproduction of most seasonal pool-breeding amphibians. Conversely, efficient predators of seasonal pool-dependent species, such as aquatic salamanders, bullfrogs, and large-sized predatory invertebrates, may potentially colonize pools that have longer hydroperiods (Thompson et al., 1980; Wilbur, 1980; Semlitsch et al., 1996; Skelly, 1997; Semlitsch, 2003). A given seasonal pool may be suitable habitat for only a subset of seasonal pool-dependent species (Zedler, 2003). Hydroperiod affects invertebrate community composition, abundance, biomass, and biological production (Leeper and Taylor, 1998). As characteristics of pools change over time (e.g., succession of vegetation, lengthening or shortening of hydroperiod), the amphibian and invertebrate communities' species compositions may shift.

This section introduces the faunal communities of seasonal pools. The Field Guide found on pages 37-68 provides more detailed information on these species. It contains descriptions of the physical characteristics, behavior, phenology, reproductive biology, and geographic range of these species and provides photographs to aid in their identification.

***Note:** This section and the Field Guide primarily focus on the faunal communities of annual pools. Many of these animals also successfully inhabit or breed in other seasonal pools (i.e., ephemeral pools or semipermanent pools). Additional research is needed to adequately describe the faunal communities of ephemeral pools and semipermanent pools.*

3.2: Indicator and Facultative Species

Indicator species rely on seasonal pools as essential habitat for a portion of their life cycles. These species, sometimes also referred to as obligate species, are dependent upon seasonal pools for their continued existence (Box 3-1). Indicator species have evolved to exploit seasonal pools: they respond rapidly to the filling of the pool and their populations persist through dry periods, due to structural, behavioral, or physiological adaptations (Wiggins et al., 1980; Williams, 1987; Zedler, 2003). Indicator species of annual pools in the mid-Atlantic region include nine species of amphibians (seven species of mole salamanders, the wood frog, and the eastern spadefoot) (Figure 3-1) and a crustacean group (the fairy shrimp). As research on the natural history of amphibians and invertebrates of seasonal pools continues, there may be additional species that are determined to be indicators.

Some of the amphibian indicator species may sometimes breed in other pool types, such as small permanent ponds, road-rut pools, or roadside ditches (Petranka, 1998; Hulse et al., 2001; DiMauro and Hunter, 2002). However, these alternate breeding sites may result in reduced survival of eggs and larvae. Roadside ditches and other anthropogenic pools may dry too quickly to allow species of amphibians to reach metamorphosis (DiMauro and Hunter, 2002). More permanent pools may harbor fish and other vertebrate predators that prey heavily on developing invertebrates and amphibians (Ireland, 1989). Seasonal pools represent the most desirable breeding habitat for these indicator species because of the higher likelihood of successful reproduction.

There are also numerous facultative species that use seasonal pools – the more common or significant facultative species are included in this section and the Field Guide. Facultative species use seasonal pools for foraging, shelter, water, or breeding, although they can successfully breed in other habitat types (Box 3-1). Facultative species of seasonal pools in the mid-Atlantic region include many aquatic invertebrates, amphibians, turtles, snakes, birds, and mammals.

Box 3-1
Indicator vs. facultative species in seasonal pools

Indicator species REQUIRE seasonal pools for optimal breeding conditions.

Facultative species USE seasonal pools for obtaining food, water, temporary cover, or breeding, although they can also successfully breed in other habitats.

Common Name	Scientific Name	STATES					
		Del.	Md.	N.J.	Pa.	Va.	W. Va.
Spotted Salamander	*Ambystoma maculatum*	Northern 1/2	Entire except southern Eastern Shore	Northern 3/4	Entire	Entire	Entire
Marbled Salamander	*Ambystoma opacum*	Entire[1]	Entire except far western	Entire	Scattered distribution southern & eastern 1/2	Mainly eastern & southeastern	Mainly eastern, southeastern, & western
Eastern Tiger Salamander	*Ambystoma t. tigrinum*	Entire[1]	Eastern Shore & southern tip[2]	Southern 1/3	1 county[3]	Southeastern & 1 county in Shenandoah Valley	X
Jefferson Salamander	*Ambystoma jeffersonianum*	X	Western 1/3	Northern 1/3	Scattered distribution[4]	Western (Blue Ridge, Valley & Ridge, Allegheny)	Scattered distribution (mainly along Allegheny)
Blue-Spotted Salamander	*Ambystoma laterale*	X	X	Northern 1/3	X	X	X
Mabee's Salamander	*Ambystoma mabeei*	X	X	X	X	Southeastern	X
Mole Salamander	*Ambystoma talpoideum*	X	X	X	X	Isolated south-central	X
Wood Frog	*Rana sylvatica*	Entire	Entire	Entire	Entire	Entire except southeastern	Entire though scattered distribution
Eastern Spadefoot	*Scaphiopus holbrookii*	Entire[1]	Southern & eastern; Eastern Shore	Entire, though scattered distribution in northern 1/2	Parts of eastern & south-central	Eastern & southeastern; scattered western distribution	Isolated, scattered distribution

Figure 3-1. Distribution of amphibian indicator species in mid-Atlantic seasonal pools.* Cells marked with "X" indicate that the species is not currently present in that state. Fractions indicate the approximate proportion of the state in which the species occurs.

[1]Not found north of Fall Line in extreme northern Del. (White and White, 2002); [2]Extirpated from Charles County, Md.; [3]Record from Chester County is historical; they are likely extirpated from Pa. (Hulse et al., 2001); [4]Hybrid populations of Jefferson and blue-spotted salamanders may occur in several locations in Pa., but genetic analyses need to be conducted to clarify this issue (Hulse et al., 2001).

** Distribution information for the mid-Atlantic states was primarily obtained from the ARMI National Atlas for Amphibian Distributions (http://www.pwrc.usgs.gov/armiatlas/) and Petranka (1998). Information on ranges in specific states was supplemented with Harris (1975) and White and White (2002) for Del. and Md., Schwartz and Golden (2002) for N.J., Hulse et al. (2001) for Pa., Martof et al. (1980) and Mitchell and Reay (1999) for Va., and Green and Pauley (1987) for W. Va.*

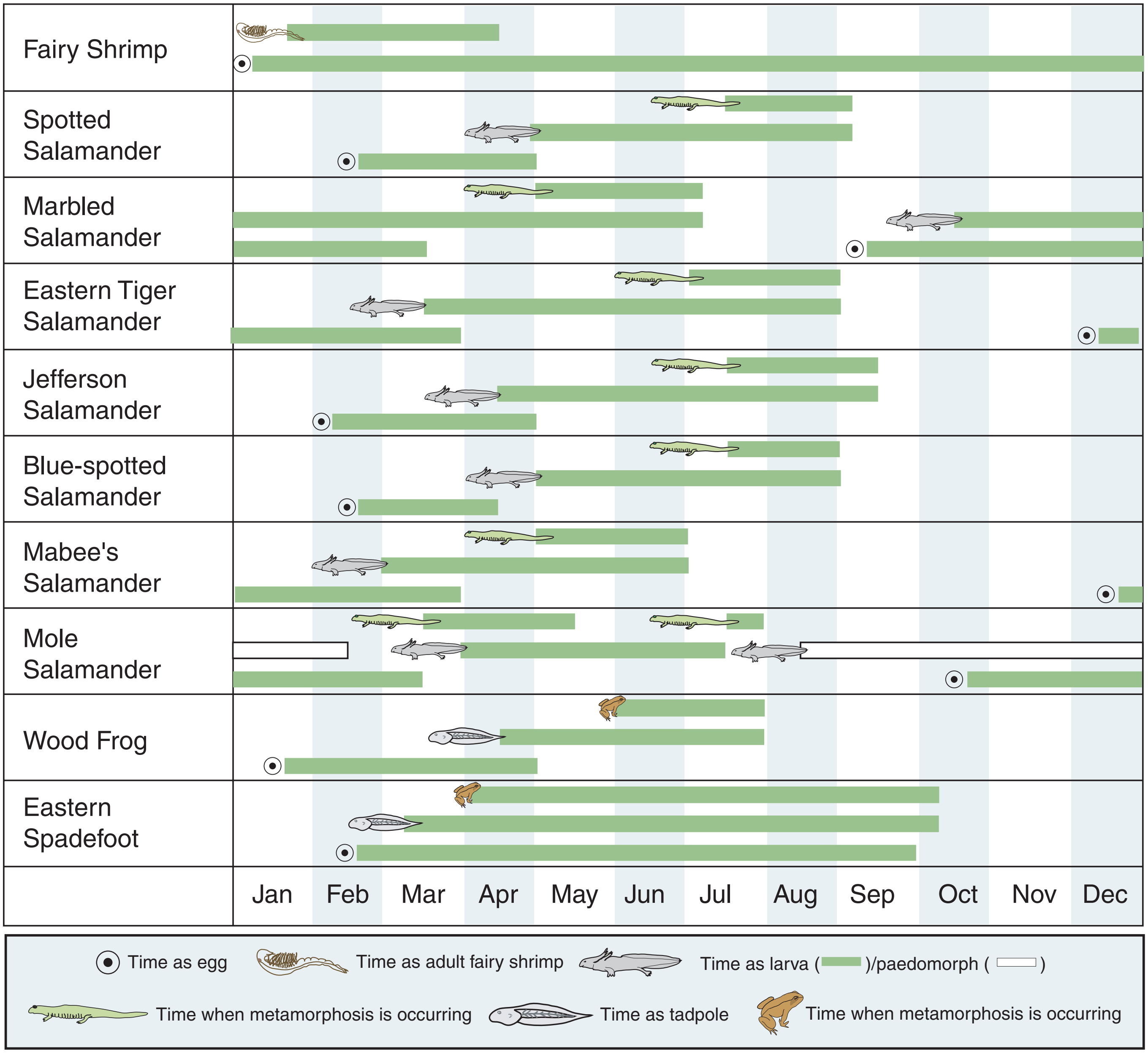


Figure 3-2. Breeding phenologies of seasonal pool indicator species.* This chart displays the life stages of indicator species in the mid-Atlantic region according to time of year. The combined length of the illustration and the green/white bar represents: the approximate time duration for when amphibian eggs and larvae may be present, when eggs and adult fairy shrimp may be found, and when amphibian metamorphosis may occur.

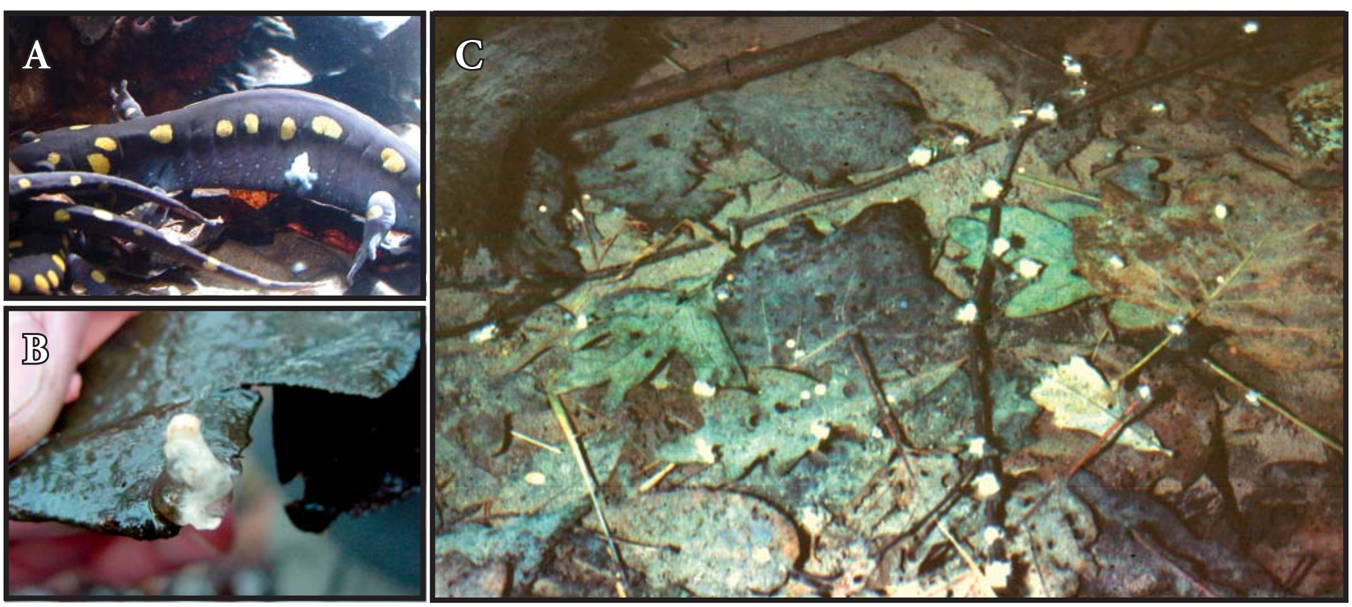
** References include Bishop (1941), Green and Pauley (1987), Tyning (1990), Petranka (1998), Hulse et al. (2001), Smith (2001), Schwartz and Golden (2002), and White and White (2002).*

3.3: Salamanders in Seasonal Pools

Salamanders are four-limbed amphibians with long tails and smooth skin that live in moist or wet environments to avoid desiccation. In mid-Atlantic seasonal pools, there are seven species of salamanders that are indicators (Fig. 3-1, 3-2). These salamanders are in the mole salamander family, Ambystomatidae. The mole salamander family derives its common name from the terrestrial behavior of adults, who spend much of their lifetimes underground, often in shrew or other small mammal burrows, or beneath debris. These salamanders emerge above ground primarily during the breeding season when they migrate to and breed in seasonal pools. Mole salamanders tend to be very faithful to their breeding sites, often returning each year (although individuals may skip years) to the same pools following the same migration paths (Box 2-3; Shoop, 1968; Stenhouse, 1985; Scott, 1994; Windmiller, 1996).

On land, adult salamanders play important roles in forest ecology as major predators of forest floor arthropods and as prey to reptiles, birds, and mammals (Windmiller, 1996). In seasonal pools, smaller-sized ambystomatid salamander larvae are a food source for backswimmers, predaceous diving beetles, and other predators; larger-sized (later-development stage) larvae may function as top predators of aquatic invertebrates and other developing amphibians, including conspecifics. Salamanders may exert a controlling effect on mosquito populations; mosquito larvae density was 98% lower in wetlands with ambystomatid salamanders compared to wetlands with no salamanders (Brodman et al., 2003).

Ambystomatid salamanders have internal fertilization with a sperm transfer mechanism using spermatophores (Plate 3-1). Males deposit spermatophores (sperm capsules atop conical gelatinous bases) on pool bottoms, vegetation, rocks, or land. Males court individually or in groups, known as congresses, by performing underwater courtship dances for the females (Tyning, 1990).



Photos: (A, B) Michael Male, (C) Steven M. Roble

Plate 3-1. Spermatophores of spotted salamanders. (A) A spermatophore is shown next to an underwater salamander and (B) in close-up on a leaf. (C) Males deposit dozens of spermatophores on floors of pools.

Courtship stimulates a female to position herself over the spermatophore and then pick up the sperm capsule in her cloaca where internal fertilization occurs (Pough et al., 2004). Females of some mole salamander species (e.g., spotted, eastern tiger) lay egg masses that are large and conspicuous (Plate 3-2); others lay single eggs or short strands.

Larvae develop in water and have wide heads, bushy external gills (three per side), and a long dorsal fin that stretches from behind the head to the end of the tail (Plate 3-2).

Ambystomatid salamanders are generally long-lived, with some surviving 20 years or longer. Males may be distinguished from females by their enlarged cloacal glands (noticeable bulges under the base of the tail) and more laterally compressed tails. In the breeding season, pregnant females can be identified by their enlarged sausage-like bodies full of eggs.

Photos: Steven M. Roble

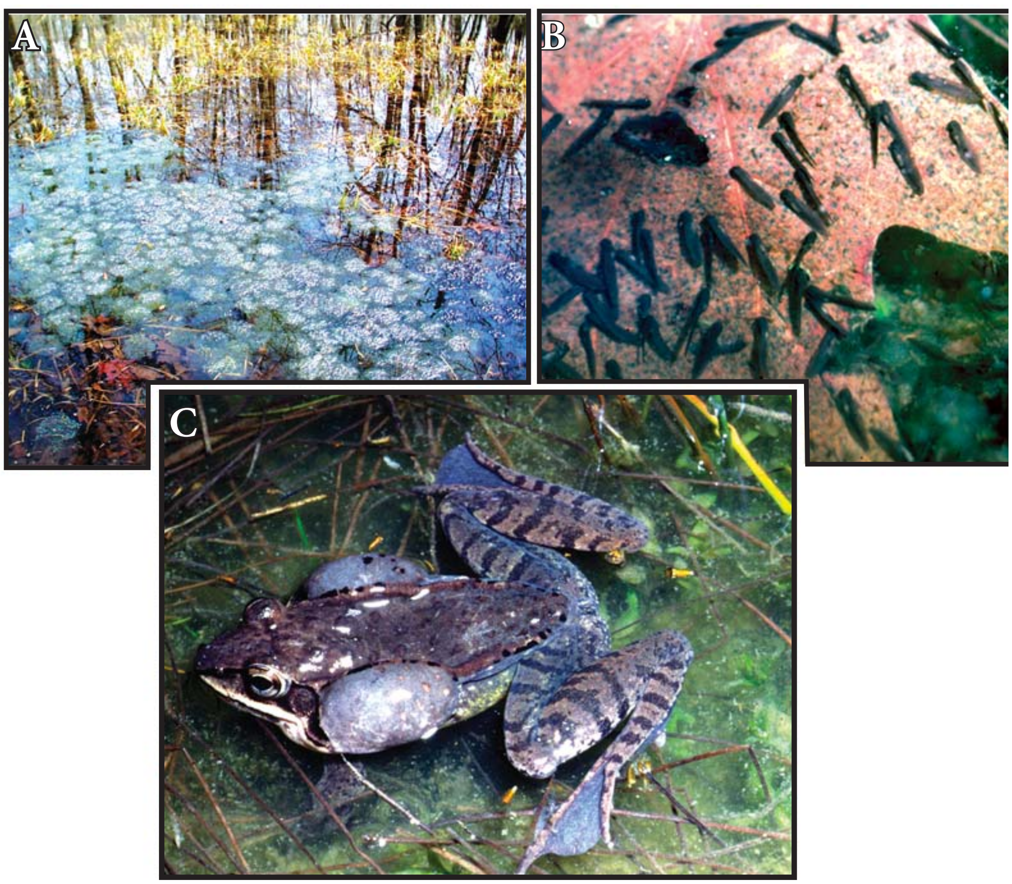
Plate 3-2. Egg mass, larva, and adult salamander. (A) A spotted salamander egg mass, (B) blue-spotted salamander larva, and (C) eastern tiger salamander adult represent the various life stages of species of mole salamanders seasonal pools.

3.4: Frogs and Toads in Seasonal Pools

Frogs are four-limbed, tailless amphibians. Vocalizations, identifiable calls made primarily by adult male frogs, play important roles in frog behavior, including mating and defending territories (Plate 3-3). Seasonal pool-breeding frogs have external fertilization, with males releasing their sperm onto eggs as they are deposited by females. Many male frogs clasp their female partners from behind while mating (a behavior called amplexus) to ensure that their sperm fertilizes the females' eggs. Frog egg masses are less cohesive than the egg masses of most mole salamander species (Plate 3-3).

Eggs laid in the water hatch into aquatic larvae (tadpoles) (Plate 3-3), which are primarily suspension feeders; however, tadpoles of some species may also feed on smaller-sized larvae or amphibian eggs. Tadpoles undergo a remarkable metamorphosis from herbivorous or omnivorous, aquatic tadpoles to carnivorous, terrestrial adults (Plate 3-3; Pough et al., 2004).

In mid-Atlantic seasonal pools, there are two species of frogs that are indicators: the wood frog (*Rana sylvatica*) and the eastern spadefoot (*Scaphiopus holbrookii*). There are also many other facultative species of frogs and toads that use mid-Atlantic seasonal pools, among them: barking treefrog (*Hyla gratiosa*), gray treefrog (*Hyla versicolor/Hyla chrysoscelis*), upland chorus frog (*Pseudacris feriarum feriarum*), and spring peeper (*Pseudacris crucifer crucifer*) (see Field Guide, page 41).



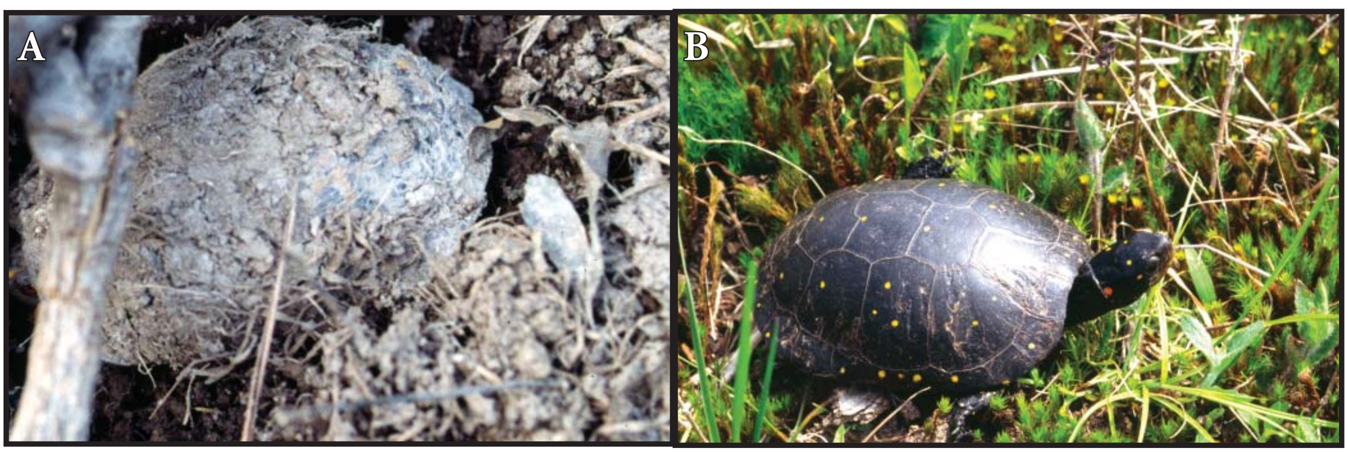
Photos: (A) Tim Maret, (B, C) Steven M. Roble

Plate 3-3. Egg masses, tadpoles, and adult frog. (A) Egg masses, (B) recently-hatched tadpoles, and (C) adult are the various life stages of the wood frog, a seasonal pool indicator species. The adult wood frog pictured is a male making vocalizations.

3.5: Reptiles, Birds, and Mammals in Seasonal Pools

There are many species of reptiles, birds, and mammals in the mid-Atlantic region that feed on prey in or near seasonal pools. Freshwater turtles visit seasonal pools in the spring or summer to feed on algae, terrestrial and aquatic plants, and invertebrates; several species also feed on amphibian eggs, larvae, and adults. Freshwater turtles may be observed in seasonal pools basking out of water on emergent vegetation or logs during warm weather. Spotted turtles (*Clemmys guttata*) inhabit shallow, soft-bottomed freshwater habitats with aquatic vegetation that are in close proximity to woodlands (Plate 3-4). Spotted turtles feed in seasonal pools extensively in the early spring; individuals have been known to spend up to three to four months in seasonal pools (Mitchell, 1994; Milam and Melvin, 2001). Other turtle species that visit seasonal pools in the mid-Atlantic region include eastern snapping turtles (*Chelydra serpentina serpentina*), eastern mud turtles (*Kinosternon subrubrum subrubrum*), eastern box turtles (*Terrapene carolina*) (Plate 3-4), and painted turtles (*Chrysemys picta*) (Ernst et al., 1994).

Snakes that have aquatic or semi-aquatic life histories may be observed hunting in seasonal pools. More terrestrial snakes may also visit seasonal pools to drink water or to feed, particularly when amphibian larvae are concentrated in shallow pools (J.C. Mitchell, pers. comm.). Snake species that visit seasonal pools to feed primarily on amphibians include, among others, northern watersnakes (*Nerodia sipedon sipedon*), eastern gartersnakes (*Thamnophis sirtalis sirtalis*), and eastern ribbonsnakes (*Thamnophis sauritus*) (Ernst and Barbour, 1989; Mitchell, 1994; Windmiller, 1996).



Photos: Steven M. Roble

Plate 3-4. Turtles of seasonal pools. (A) Eastern box turtles may aestivate in the mud of seasonal pools during hot weather. (B) Spotted turtles visit seasonal pools to feed on invertebrates, amphibian eggs, and other food items.

Birds also prey on animals in or near seasonal pools. Wading birds, such as great blue herons (*Ardea herodias*) (Roble and Stevenson, 1998), waterfowl, such as wood ducks (*Aix sponsa*), and woodland birds visit the pools to feed on insect and amphibian larvae. At coastal plain seasonal pools, yellow legs (*Tringa melanoleuca, Tringa flavipes*), little blue herons (*Egretta caerulea*), and green herons (*Butorides virescens*) feed on amphibian larvae (Hassinger et al., 1970). Owls prey on amphibians migrating to and from seasonal pools; birds of prey, such as red-shouldered hawks, feed on seasonal pool animals.

Seasonal pools also serve as important sources of water and food for many mammals in the mid-Atlantic region. Deer drink water and forage on aquatic vegetation in seasonal pools (Plate 3-5). Raccoons feed on amphibian larvae and adults, large insects, and other inhabitants of seasonal pools (Seale, 1982; Kenney and Burne, 2001). Shrews visit seasonal pools to forage on insects (Winfield et al., 1981; Brooks and Doyle, 2001). Bats visit seasonal pools to drink water and to feed on flying insect prey (Biebighauser, 2002). Scavenging carnivorous mammals are likely to feed on animals trapped, dying, or desiccated in the shallow drying or dried beds of seasonal pools (Winfield et al., 1981), including red fox, striped skunk, gray fox, bear, and opossums.

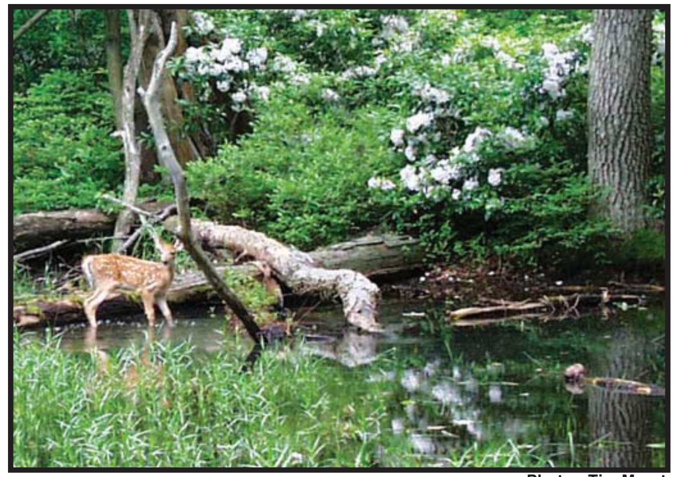


Photo: Tim Maret

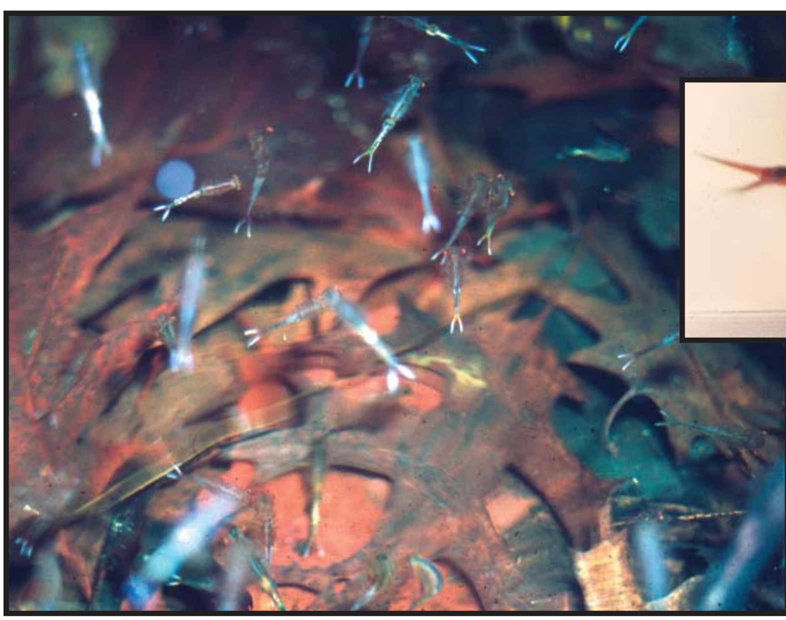
Plate 3-5. Deer in an open-canopy seasonal pool. White-tailed deer visit seasonal pools to drink water and to forage on vegetation growing in and around the pool basin.

3.6: Invertebrates in Seasonal Pools

Seasonal pools provide habitat to a wide variety of invertebrate species. Invertebrates in seasonal pools play important ecological roles, as a food source to amphibians and other invertebrates, as consumers of detritus, and as predators of smaller-sized amphibian larvae and invertebrates.

Fairy shrimp, crustaceans in the Order Anostraca, are an indicator group found in mid-Atlantic seasonal pools. Fairy shrimp do not have defenses against predators; therefore, they are very rarely reported in pools with predatory fish and are found in lower abundances in pools with predatory insects. Adults appear in pools in late winter or early spring before predatory insects reach maximum densities (Wiggins et al., 1980). Five species of fairy shrimp may occur in pools in the mid-Atlantic region, although their distribution is not well known (Field Guide; Belk, 1975; Belk et al., 1998). Fairy shrimp glide upside-down and filter-feed microbes and detritus from the water column or substrate (Plate 3-6; Smith, 2001). Fairy shrimp produce eggs that can survive the drying and freezing of pool sediments; they may remain viable for many years before finally hatching. Adult fairy shrimp have patchy and unpredictable presence and abundance in pools across the landscape. There is very little published research on these animals in the mid-Atlantic region.

In addition to the indicator fairy shrimp, there are numerous facultative invertebrates found in or on the surface of seasonal pools. The more distinctive facultative classes and orders are included in the Field Guide; the following is an incomplete list of classes found in the seasonal pool invertebrate community with the common names of some of their members. Crustaceans include the classes Branchiopoda (clam shrimp and cladocera), Ostracoda (seed shrimp), Malacostraca (isopod and amphipod), and Copepoda (copepod). Molluscs include the classes Gastropoda (amphibious snail) and Pelecypoda (fingernail clam). Arthropods include the classes Insecta (predaceous diving beetle, caddisfly larva, phantom midge larva, chironomid midge larva, and mosquito larva) and Hydrachnidia (water mite). Annelids include the classes Hirudinae (leech) and Oligochaeta (aquatic oligochaete worm).



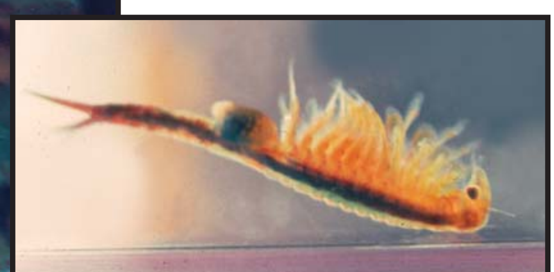


Photo: Steven M. Roble

Plate 3-6. Fairy shrimp in seasonal pools. Seasonal pools may contain the indicator group of crustaceans, the fairy shrimp. In pools where they occur, they may be abundant in the late winter or early spring; notice the eleven pairs of swimming legs.

4 Conservation Challenges Facing Seasonal Pools

Habitat loss and alteration associated with land development present the greatest challenges to the existence and health of seasonal pool ecosystems in the mid-Atlantic region. Seasonal pools, and the wildlife they support, are threatened by direct loss (e.g., through filling or draining), as well as by practices that degrade the pool: terrestrial habitat loss and fragmentation, biological introductions and removals, mosquito control practices, amphibian diseases, atmospheric deposition, and climate change.

4.1: Direct Loss of Seasonal Pools

The direct loss of seasonal pools due to draining, filling, and dredging in association with human activities presents a major threat to the persistence of seasonal pool-dependent biota. According to a U.S. Fish & Wildlife Service study, the following land development activities accounted for losses in freshwater wetlands in the time period between 1986 and 1997: 30% of losses were due to urban development, 26% of losses were due to agriculture, 23% of losses were due to silviculture, and 20% of losses were due to rural development (Dahl, 2000). Although seasonal pools, because of their small sizes and impermanent waters, were largely not accounted for in these statistics, it is likely that they are being lost in a similar manner.

Destruction of individual seasonal pools will eliminate populations of permanent residents, such as fairy shrimp, at those pools (Colburn, 2004). Also at risk are migratory residents of seasonal pools. Because of their limited dispersal abilities and site fidelity to breeding pools (Berven and Grudzien, 1990; Scott, 1994), adult pool-breeding amphibians are unlikely to make use of other pools in lieu of lost pools. In fact, adult amphibians may continue to return to the site of former (destroyed) pools throughout their lifetimes, rather than seeking out new breeding pools.

The loss of a seasonal pool may negatively impact other seasonal pool communities in the surrounding area. As seasonal pools and other wetlands become fewer in number, the distances between pools become greater, eventually exceeding the dispersal abilities of amphibians and reptiles (Gibbs, 1993; Semlitsch and Bodie, 1998; Gibbs, 2000). When seasonal pools are destroyed, the number of individuals that would have potentially dispersed to other pools is reduced (Gibbs, 1993; Semlitsch and Bodie, 1998), thus decreasing the rate of genetic exchange among populations and potentially inhibiting the rescue of locally declining or extinct populations (Laan and Verboom, 1990; Marsh and Trenham, 2001). For larger-bodied species that visit pools for food (e.g., waterfowl), these increased travel distances between pools may have important energetic implications (Gibbs, 2000).

4.2: Terrestrial Habitat Loss and Fragmentation

Urbanization, intensification of agriculture, increased density of roads, and timber harvesting have caused massive transformations of the landscape in the eastern United States. Changes in land-use in the mid-Atlantic region and their consequences for wildlife habitat, landscape connectivity (the extent to which the landscape facilitates wildlife movement), and hydrology present the largest challenges to seasonal pool conservation (Plate 4-1).

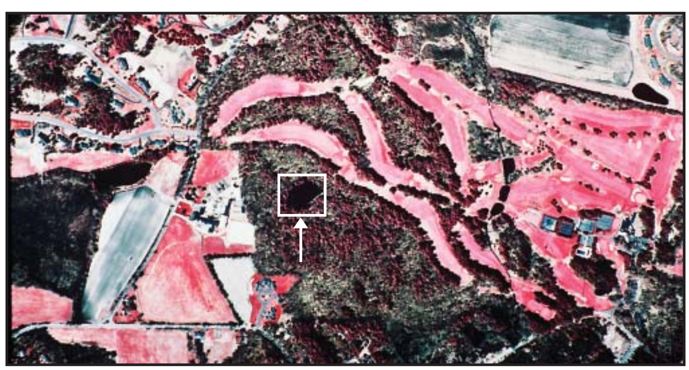


Photo: Massachusetts Department of Environmental Protection

Plate 4-1. Aerial view of landscape fragmentation. This color infrared aerial photograph shows a seasonal pool (dark circle marked by arrow) surrounded by human development.

Biological Effects of Habitat Loss and Fragmentation

Many of the wildlife species that use seasonal pools for breeding and feeding spend the majority of their lives in the forests and grasslands that are being lost to increasing human development. Thus, the conversion of terrestrial habitat directly threatens many members of the biological communities of seasonal pools by taking away their sustaining environment.

Land conversion also indirectly affects seasonal pool biological communities by restricting wildlife movements and facilitating invasion by disturbance-tolerant organisms. Land-use changes translate into fragmentation of the landscape, as forest patch to forest patch and forest patch to seasonal pool distances increase and the pathways of travel become more difficult for animals to traverse (Plate 4-1).

The conversion of natural habitats (forests and grasslands) to open land-uses, such as lawns, agricultural lands, and impervious surfaces (i.e., any surface that prevents water from infiltration into the soil, such as roads, buildings, and parking lots) creates barriers to movement and decreases landscape connectivity (Plate 4-2; Forman et al., 2003). Amphibians have difficulty traversing open landscapes due to higher temperatures and lower soil moisture (deMaynadier and Hunter, 1999; Rothermel and Semlitsch, 2002; Rothermel, 2004). Studies have documented pool-breeding amphibians' preference for forested habitat in the eastern United States. Spotted salamanders and wood frogs favor forests and avoid open-canopy habitats in their migrations (Semlitsch, 1981; Raymond and Hardy, 1991; Petranka et al., 1994; deMaynadier and Hunter, 1999; Rothermel and Semlitsch, 2002; Faccio, 2003). Mature forests provide moist microhabitats for amphibians: the thick leaf litter traps and stores moisture, the coarse woody debris provides cover and prevents soil drying, and a closed canopy with an understory offers shade and slows evaporation from the forest floor (Petranka et al., 1994). As juveniles and adults, pool-breeding amphibians are carnivorous, feeding on invertebrates such as earthworms, snails, slugs, spiders, crickets, beetles, and ants (Bishop, 1941; Petranka, 1998). They find this food in the leaf litter of forested areas beneath woody debris and below ground. Underground mammal burrows provide protection for mole salamanders from predators and freezing temperatures (Madison, 1997; Regosin et al., 2003a). Destruction or degradation of forested habitat as a result of poor forestry and land development practices negatively impact amphibian populations (Windmiller et al., 2006).

Photos: Bryan Windmiller

Plate 4-2. Terrestrial habitat fragmentation. Conversion of land near seasonal pools for (A) residential development, (B) golf courses, and other land uses will impact the faunal populations of these pools.

Fragmentation of the terrestrial landscape inhibits migrations of amphibians between the terrestrial habitat (where they spend greater than 90% of their juvenile and adult lives) and their breeding pools (Laan and Verboom, 1990; deMaynadier and Hunter, 1999; Rothermel and Semlitsch, 2002; Rothermel, 2004), decreasing or arresting their reproductive success. Decreased landscape connectivity may impede the dispersal of individuals between ponds, reducing rates of genetic exchange and potentially increasing the risk of local extinctions (Reh and Seitz, 1990; Laan and Verboom, 1990; Marsh and Trenham, 2001).

Roads, a pervasive and ever-increasing feature of the human-altered landscape, affect the survival and health of seasonal pool-dependent wildlife populations and the persistence of seasonal pools. Roads are a major source of fatalities (both directly as road kill and indirectly due to increased vulnerability to predators) and present a formidable physical barrier to animal migrations (Gibbs and Shriver, 2005). Amphibians and reptiles that try to cross roads experience high traffic mortality, particularly during the mass seasonal migrations of frogs and salamanders in early spring. Traffic mortality may cause significant declines in amphibian populations (Plate 4-3; Fahrig et al., 1995; Gibbs and Shriver, 2005). Amphibians' small body size makes overcoming man-made obstacles such as levees, ditches, and curbed roads a slow and difficult venture (Gibbs, 1998). Their small size and slow speed also makes them very vulnerable to predation when they are physically exposed due to the human-altered landscape (Gibbs, 1998; Rothermel, 2004).

Photos: James P. Gibbs

Plate 4-3. Spotted salamander roadkill. Particularly where roads separate seasonal pools from their terrestrial habitat, road mortality is a serious threat to amphibian populations.

The loss of reproductively-mature amphibians killed en route to breeding pools will have a significant impact on the population due to the additional loss of all of their potential future offspring (Dodd and Smith, 2003). The negative ecological effects of road construction on wetland biodiversity are cumulative over time (Findlay and Bourdages, 2000). The loss of amphibian and reptile species as a result of road construction may take an average of eight years to detect, and the full effects may not become apparent for decades (Findlay and Bourdages, 2000). When a threshold of road mortality has been crossed, populations may go into rapid decline and eventually become locally extinct (Gibbs and Shriver, 2005). Watershed and ecological impacts of roads on seasonal pools, such as altered wetland hydrology, road salt pollution, and reduced amphibian habitat and movement, may extend 984 ft (300 m) or more in each direction from a road edge (Forman and Deblinger, 2000). For example, the presence of tiger salamanders is negatively associated with the cumulative length of paved roads within 3281 ft (1 km) of their breeding pools (Porej et al., 2004).

The extent and pattern of terrestrial habitat degradation and loss that seasonal pool-dependent animals can tolerate without experiencing population declines and local extinctions depends upon the characteristics of the species and local conditions (Fahrig, 2002; Homan et al., 2004). Amount of forest cover, length and density of roads, and the degree of wetland isolation (distance to nearest wetland neighbor) have been shown to be among the most important predictors of amphibian species richness (Lehtinen et al., 1999; Porej et al., 2004; Herrmann et al., 2005).

Physical Effects of Habitat Loss and Fragmentation

Land transformations in seasonal pools' watersheds may directly affect the physical properties of seasonal pools in a variety of ways. These may include altered water chemistry, altered water regime (decreased or increased hydroperiods and higher or lower water levels), temporal variation in hydrology, altered water temperature, and increased sedimentation or erosion. Physical impacts to the seasonal pool due to land-use change, in turn, affect the biological community. Land-use practices in the watershed may alter the distribution of pool hydroperiods, either by a change in the amount and timing of water inputs to the pool or a change in the canopy cover. Surface water run-off to pools in impacted watersheds will have elevated temperatures due to the elimination of overhanging canopy and the path of water flow along heated impervious surfaces (Schueler, 1994).

Roads act as conduits for pollution, channeling fast-moving run-off that can contain car by-products, road salts, sediments, lawn applications, and other chemicals (Jones et al., 1992; Jones and Sroka, 1997). Increasing impervious surface area in a watershed potentially adds to the amount of non-point source pollution entering freshwater systems, including nutrients and chemicals (Wernick et al., 1998; Sonoda et al., 2001). Roadside seasonal pools have higher specific conductance and higher sodium and chloride levels compared to woodland seasonal pools away from roads (Turtle, 2000). Land cover change can also modify the quantity and type of sediment input into freshwater bodies (Jones et al., 2001). Pollution may affect seasonal pools disproportionately more than other aquatic habitats, such as rivers and lakes, because of the pools' small size and isolation from other water bodies. In late spring and summer, evaporation may result in very high concentrations of ions or toxins in the remaining seasonal pool water. Also, seasonal pools are filled partially or entirely by precipitation, runoff, and snowmelt that have undergone little to no buffering by the soil (Gascon and Planas, 1986; Wyman, 1990; Whigham and Jordan, 2003). Thus local events (such as nearby house or road construction) may have a great impact on the pools' water quality. Chemicals in the watershed, including pesticides from agricultural, residential, and industrial activities, may alter food web dynamics and decrease populations of invertebrates or amphibians (Boone and Bridges, 2003). Proximity to human development also increases the risk of pollution of pools by illegal dumping (Plate 4-4).

Photo: Michael S. Hayslett

Plate 4-4. Garbage fills this seasonal pool. This pool in southern Virginia has been used as a trash dumping site.

4.3: Other Conservation Challenges

Biological Introductions and Removals

Seasonal pools may be dredged or impounded for conversion to permanent water, for use as farm ponds or stock tanks. Once the hydrology is altered from seasonal to permanent, predators such as bullfrogs and fish may invade the pool and increase predation pressure on seasonal pool-dependent animals. Purposeful introductions of fish to seasonal pools for recreational fishing and/or mosquito control may also occur, which will likely have negative impacts on indigenous species of amphibians (Thompson et al., 1980; Hecnar and M'Closkey, 1997; Kiesecker, 2003; Colburn, 2004). For example, bluegill sunfish (*Lepomis macrochirus*) stocked in a Shenandoah Valley sinkhole pond may be responsible for declines in eastern tiger salamander populations (Buhlmann et al., 1999; Buhlmann and Mitchell, 2000).

Seasonal pool-dependent amphibians are collected as adults for consumption or laboratory use, or as larvae for use as fishing bait. According to a survey of fourteen scientific products suppliers, nine suppliers offer species of mole salamanders for sale for educational purposes (Jensen and Camp, 2003). The majority of these animals are likely captured in or around wetlands and seasonal pools, rather than being captive-bred (Jensen and Camp, 2003). Eastern tiger salamander larvae are sold in baitshops as "water dogs" (Jensen and Camp, 2003). The cumulative impact of collection of seasonal pool-dependent fauna is unknown in the mid-Atlantic region.

Mosquito Control Practices

Mosquito control practices may target seasonal pools. The most damaging practice employed for mosquito control is the filling or draining of seasonal pools. Other mosquito control methods include the application of surface films (oils added to ponded waters to suffocate mosquito larvae), chemical larvicides, and biological control agents. The effects of these mosquito control practices on seasonal pool food webs and pool-breeding amphibian eggs, larvae, and adults have not been extensively studied (Colburn, 2004). However, it is known that these control methods may impact groups of animals other than mosquito larvae and negative effects may take two years or longer to observe (Templeton and Laufer, 1983; Hershey et al., 1998). Control agents that reduce population sizes of plankton and invertebrates may, in turn, affect pool-breeding amphibians by reducing their food supply (Boone and Bridges, 2003). Additionally, the interaction of mosquito control techniques with other anthropogenic stressors may negatively impact the seasonal pool community (Boone and Bridges, 2003).

Amphibian Diseases

Another threat posed to seasonal pool-dependent amphibians is disease. Recent mortality events and increased susceptibility to diseases may be partially the result of reduced immune function from increased stress associated with habitat degradation (Blaustein and Kiesecker, 2002). Chytrid fungus (*Batrachochytrium dentrobatidis*) and ranaviruses can cause mass mortality in amphibian larvae, metamorphosing individuals, juveniles, and adults. These diseases may be transported by field equipment, fishing gear, or introduction of invasive species (Semlitsch, 2000; Carey et al., 2003). Ichthyophonus fungus and ranavirus infections have caused deaths of wood frog larvae and recently metamorphosed individuals, and ranavirus has caused deaths of spotted salamander larvae in seasonal pools in the mid-Atlantic region (D.E. Green, pers. comm.). For field work practices that minimize the spread of these diseases, refer to Appendix B.

Atmospheric Deposition

Atmospheric deposition may impact the water chemistry of seasonal pools to a greater extent than other aquatic habitats because many pools are primarily filled by precipitation and surface run-off (Gascon and Planas, 1986; Wyman, 1990). Acidification of pools through acid deposition does not have straightforward impacts on pool biological communities and may differ according to characteristics of the pool. Some studies show negative impacts of low pH on amphibian reproductive success (e.g., Pough, 1976; Gascon and Planas, 1986; Sadinski and Dunson, 1992) whereas others show no measurable impacts (e.g., Cook, 1983; Albers and Prouty, 1987). However, acidification elevates and makes more soluble and hence more bioavailable concentrations of metals in seasonal pool waters. High levels of metals, such as aluminum, copper, iron, lead, silicon, and zinc, may reduce hatching success of amphibian eggs, reduce larval survival, and increase the prevalence of amphibian deformities (Albers and Prouty, 1987; Blem and Blem, 1989, 1991; Rowe and Dunson, 1993; Horne and Dunson, 1995; Jung and Jagoe, 1995). Acid precipitation and atmospheric deposition of metals from industrial and residential sources may act synergistically to affect seasonal pool communities.

Climate Change

Seasonal pools face uncertain impacts from the climate change projected to occur over the next century. In the mid-Atlantic region, air temperatures and average precipitation are projected to increase; however, precipitation events are predicted to be of higher intensity and more erratic in timing (U.S. EPA, 2001). These precipitation and temperature patterns have implications for hydroperiods and water temperatures of seasonal pools, which will, in turn, affect amphibian egg and larval survival (Brooks, 2004). Climate changes may also affect the seasonal timing of animal activity. There is evidence to suggest that the warming of the climate over the last century has affected the breeding patterns of amphibians in the northeastern United States (Gibbs and Breisch, 2001).

5 Future Directions: Conservation of Seasonal Pools in the Mid-Atlantic Region

5.1: Seasonal Pool Conservation in the Mid-Atlantic Region

As yet, there are few comprehensive efforts to include seasonal pools in natural resources management in most of the mid-Atlantic States. The New Jersey Division of Wildlife Endangered and Nongame Species Program initiated a Vernal Pool Survey Project in 2000, a statewide seasonal pool mapping program. This project's goal is to locate, map, and inventory seasonal pools statewide and monitor their amphibian populations utilizing a trained group of volunteers (Tesauro, 2004). A similar project, the development of a web-based seasonal pool registry and research program, is being prepared for implementation in Pennsylvania by the Western Pennsylvania Conservancy (see Appendix C).

In the other mid-Atlantic states, there have been smaller-scale initiatives undertaken by governmental agencies, nongovernmental organizations, and coalitions. For example, the ARMI-NE of the USGS and partners (U.S. Fish and Wildlife Service and National Park Service) have located, mapped, and surveyed amphibian populations at seasonal forest pools in nine National Parks and National Wildlife Refuges in the mid-Atlantic states (see Appendix C).

Unique systems of seasonal pools in the mid-Atlantic region, such as sinkhole ponds in Virginia and Delmarva bays in Delaware-Maryland, have received attention by naturalists, academics, and agency scientists (e.g., Rawinski, 1997; Roble, 1998; Buhlmann et al., 1999; Zankel and Olivero, 1999). However, there is a considerable need for additional research on seasonal pools. Moreover, existing studies have largely not been translated into conservation or management programs.

Seasonal pools should be valued and managed as important ecosystems for support of biodiversity in the mid-Atlantic region. In recent years, concern over amphibian conservation has escalated due to reports of declines in amphibian populations on a global-scale (Barinaga, 1990; Stuart et al., 2004). Existing amphibian monitoring efforts, such as the National Wildlife Federation's FrogWatch and the USGS North American Amphibian Monitoring Program, provide data on frog and toad populations but do not address the major cause of amphibian declines: the loss of habitat including seasonal pools. There is a need to bring a broader, landscape perspective to the conservation of amphibians in the mid-Atlantic region. There must be adequate protection and management of habitat, which for seasonal pool-breeding amphibians includes the seasonal pool basin and the surrounding terrestrial area that extends 1000 ft (305 m) or farther from the edge of the pool. Characteristics of the landscape up to 3281 ft (1000 m) from the pool edge, such as amount of forest cover or densities of roads, may also strongly influence the presence and densities of amphibian species (Homan et al., 2004; Porej et al., 2004; Herrmann et al., 2005). For successful management of the seasonal pool ecosystem, the seasonal pool itself should not be considered separate from the terrestrial habitat.

The authors recommend that a three-pronged approach be taken for conservation of seasonal pools in the mid-Atlantic region. Simultaneous efforts should be taken in the following areas: education and research, seasonal pool inventory, and landscape-level management. There needs to be a targeted campaign to raise the level of awareness and knowledge about seasonal pools, the reliance of amphibians upon seasonal pools, and the threats that face them. The audience of this campaign should be broad, and include professionals as well as the general public. It is also important to escalate seasonal pool research efforts in the mid-Atlantic region. Second, there needs to be a region-wide initiative to locate and inventory seasonal pools in order to determine their abundance, distribution, and biological resources. Lastly, seasonal pools and their associated life zones should be integrated into landscape-level planning by local, county, and state agencies and nongovernmental organizations. Pools should be prioritized for conservation considering several factors: the degree to which amphibians and invertebrates depend upon them, the condition of the terrestrial life zone, and the proximity to and density of seasonal pools in the landscape (e.g., pool clusters).

5.2: Education and Research on Seasonal Pools

In order to facilitate successful seasonal pool conservation efforts, stakeholders must be identified, information must be disseminated, and the issue has to be publicized. In addition, basic research on seasonal pools in the mid-Atlantic region is needed so as to inform efficacious management strategies.

- ☑ **Establish a Scientific and Management Dialogue.** Regardless of whether there have been local or state efforts at seasonal pool inventory or conservation, there are individuals in each mid-Atlantic state who are working with seasonal pool-related issues. For example, there are nongovernmental organizations working on amphibian conservation research and policy, academics and governmental agencies studying amphibian populations, and naturalists hosting educational programs in local parks. These interested individuals should be brought together. Workshops can be held on locating seasonal pools using various tools such as aerial photography and field verification, or a mid-Atlantic seasonal pools conference can be convened with the participation of experts from states that have seasonal pool programs in place, such as New Jersey, Maine, and Massachusetts.

- ☑ **Increase Public Awareness.** The level of public awareness is very low. Amphibians, such as spotted salamanders and wood frogs, will likely be of greatest interest to the general citizenry. The connection between seasonal pools and these charismatic amphibians must be made. The target audience should be broad and include homeowners, school children, and volunteers.

- ☑ **Raise Level of Knowledge.** Many of the studies on seasonal pools referred to in this publication were carried out in areas other than the mid-Atlantic region, particularly in Maine, Massachusetts, and South Carolina. More studies on the natural history, ecology, hydrology, vegetation, and conservation biology of seasonal pool ecosystems are needed in the mid-Atlantic region. Research partnerships should be explored between academic institutions and governmental agencies.

5.3: Inventory of Seasonal Pools

An important requirement for sustainable management of a resource is an inventory of its distribution and status. Currently, the number of seasonal pools, their distribution in the landscape, and their biological resources are unknown in the mid-Atlantic region, although efforts are underway in New Jersey and are beginning in Pennsylvania.

- ☑ **Locate and Inventory Seasonal Pools.** Seasonal pools in the mid-Atlantic region need to be located and mapped with the data assembled electronically and in GIS format and fauna and flora must be inventoried. This may best be carried out at the county- or state-level through volunteer programs, similar to the New Jersey's Vernal Pool Survey Project. Another approach would be standardizing and housing information on seasonal pools and their fauna in a federal program, similar to the way the North American Breeding Bird Survey is administered (see *http://www.pwrc.usgs.gov/bbs*). (*For techniques to locate seasonal pools refer to Appendix A. For general information on documenting seasonal pools refer to Appendix B. For existing seasonal pool programs, including New Jersey, refer to Appendix C.*)

- ☑ **Monitor Seasonal Pools.** Once seasonal pools are identified, they should be monitored. The rigor and method of monitoring will differ according to the agent undertaking the monitoring and the purpose of the effort. For most seasonal pool efforts, documenting the use of the pool by indicator species (e.g., presence of spotted salamander egg masses) may be sufficient. In other cases, more extensive population studies may be carried out. Long-term, repeated sampling of a subset of seasonal pools throughout the mid-Atlantic region is essential to catalogue the biodiversity and ecosystem health of the pools and to determine amphibian population trends. Herpetofauna that use seasonal pools may take years or longer to document and invertebrate communities may undergo rapid shifts throughout the year and between years (Mahoney et al., 1990; Pechmann et al., 1991; Gibbons et al., 1997; Simovich, 1998). Additionally, it is important to record spatial and temporal changes in seasonal pool communities and other biotic and abiotic parameters in order to understand and forecast responses of seasonal pool communities to climate change, land-use change, and other stressors.

5.4: Landscape-Level Planning and Management

Successful seasonal pool conservation can only occur when integrated into landscape-level planning. All conservation plans must take into account the three life zones described in Section 2. However, in order to adequately protect the seasonal pool biological community, seasonal pools require customized, landscape-level approaches.

☑ **Acquisition and Protection of Intact Habitats.** Although every pool may have value, nonregulatory natural resource conservation tools such as acquisition and conservation easements should initially target seasonal pools that are particularly valuable in terms of biodiversity support. Efforts should be especially directed at protection of contiguous tracts of forested terrestrial habitat containing multiple seasonal pools. Protection of clusters of pools with a range of hydroperiods will provide the best probability of long-term success in supporting indicator species (Semlitsch, 2000).

☑ **Develop Best Management Practices.** Although protection of existing pools is the highest priority for seasonal pool conservation efforts, an active management approach should also be taken to protect populations of seasonal pool-breeding animals (Semlitsch, 2000). Best management practices (BMPs) should be developed for pools with the input of scientists and resource managers. For example, management programs may include the elimination of invasive fish species, the control of sediment from development, or prescribed burns (e.g., Tyndall, 2001). Restoring or creating seasonal pools in strategic locations may also be an effective component of a management program (Biebighauser, 2000), although designing pools to have a specific hydroperiod and/or support a particular community of organisms may be difficult (Pechmann et al., 2001; Lichko and Calhoun, 2003).

☑ **Create Best Development Practices.** Best development practices (BDPs) that focus on lands surrounding seasonal pools need to be established with the participation of resource managers, state agencies, scientists, private businesses, and land developers. Recommendations should be outlined for more sustainable development and forestry practices based on the best available science. BDPs for residential and commercial development and forest habitat management guidelines to protect seasonal pools have already been developed for the northeastern United States (Calhoun and Klemens, 2002; Calhoun and deMaynadier, 2004). These publications may be a useful tool, but BDPs should also be formulated for the mid-Atlantic region. BDPs will likely be different for the mid-Atlantic region due to differences in ecology, regulatory infrastructure, and demographics as compared to New England. Also, the process of developing BDPs with the participation of all stakeholders is an important consensus-building activity that will greatly improve the chances of successful implementation (Preisser et al., 2000).

- ☑ **Improve Transportation Planning.** Roads can be planned and designed to reduce impacts on seasonal pools and their fauna. Road construction that destroys seasonal pools, occurs near seasonal pools, cuts through the terrestrial habitat surrounding seasonal pools, or separates pools from one another should be prevented. If roads must be built through terrestrial habitat or near seasonal pools, road overpasses can be built to allow biological and hydrological flows to remain uninterrupted. Where this is not possible, amphibian tunnels and other wildlife underpasses in conjunction with barriers can be constructed beneath roads to allow migrations (Fahrig et al., 1995; Forman and Alexander, 1998). Further research is needed to design animal tunnels/underpasses so that road mortality is reduced and landscape connectivity is restored in the most effective manner (Forman and Alexander, 1998; Dodd and Smith, 2003). If these design features cannot be installed, then road closures and assisted amphibian crossings can be organized to lower mortalities during major breeding events.

- ☑ **Employ Regulatory Tools.** Seasonal pools that qualify as "waters of the U.S." are under federal jurisdiction, which regulates the disposal of dredge or fill material through a permitting program (Section 404 of the Clean Water Act). For the majority of seasonal pools, which do not fall under federal protection, alternative regulatory tools may be used in order to secure greater levels of protection. State and local wetland and forest regulations may be strengthened to protect seasonal pools and their surrounding terrestrial habitat. Seasonal pools may be identified as important wildlife habitat in comprehensive land use plans (community master plans) or overlay zones may be designed by the local government and concerned stakeholders to protect seasonal pools. The resource overlay zones establish additional standards for development projects on top of the underlying zoning. These new zoning plans can be a mixture of regulations and incentives to conserve seasonal pools and their terrestrial habitats (Nolon, 1998; Calhoun and Klemens, 2002). Voluntary stewardship programs may be initiated whereby landowners conserve their pools and follow best management/development practices in adjacent forest areas and receive tax credits or annual subsidies in return (similar to the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife, see *http://northeast.fws.gov/partners*) (Tiner, 2003a).

Field Guide to Seasonal Pool Fauna

The Field Guide is provided to help interested people identify members of the seasonal pool biological community. Pictorial field guides are included to aid the identification of adults, larvae, and eggs. For those who wish to learn more about the natural history (physical characteristics, behavior, phenology, and reproductive biology) of these indicator species, in-depth information is also provided. Before exploring seasonal pools, please refer to Appendix B for practices to prevent negative impacts to pool animals (p. 74).

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Field Guide 1: Salamanders of seasonal pools in the mid-Atlantic region.*

SPOTTED SALAMANDER
(Ambystoma maculatum)
Indicator Species

Photo: USGS PWRC

4.4 – 7.8 inches
(11 – 20 cm)

Bright yellow to orange spots on black to bluish-black body

Habitat includes deciduous, mixed deciduous-coniferous, and coniferous forests; breeds in seasonal pools

Protected: Del., N.J., Va.

Description: p. 49

MARBLED SALAMANDER
(Ambystoma opacum)
Indicator Species

Photo: USGS PWRC

3.5 – 4.3 inches
(9 – 11 cm)

Silvery-white or gray markings or bands on black body

Habitat includes deciduous, mixed deciduous-coniferous, and coniferous forests; breeds in seasonal pool beds

Note: Unlike the other *Ambystoma spp.* that breed during spring, *A. opacum* breeds during fall

Protected: Del., N.J., Va.

Description: p. 50

EASTERN TIGER SALAMANDER
(Ambystoma tigrinum tigrinum)
Indicator Species

Photo: John F. Bunnell

7 – 8.3 inches
(17 – 21 cm)

Yellowish markings on dark brown or black body

Habitat includes moist deciduous, mixed deciduous-coniferous, and coniferous forests; breeds in seasonal pools or fishless permanent pools; favors sandy soils

Endangered: Del., N.J., Va. Extirpated: Pa.
Threatened: Md.

Description: p. 51

JEFFERSON SALAMANDER
(Ambystoma jeffersonianum)
Indicator Species

Photo: Steven M. Roble

4.3 – 7.5 inches
(11 – 19 cm)

Light blue-gray flecks on brown or gray body

Habitat includes deciduous forests; breeds in seasonal pools or fishless permanent pools

Protected: N.J., Va. Watch list: Md., W. Va.

Description: p. 53

** General information is derived from Bishop (1941) and Petranka (1998). Salamander lengths represent total length of the body and tail. Lengths are primarily from Conant and Collins (1998) and represent the range of average total lengths of these salamanders; where mid-Atlantic literature provided dissimilar total lengths, the widest range of lengths was selected. Distribution maps are adapted from the ARMI National Atlas for Amphibian Distributions (http://www.pwrc.usgs.gov/armiatlas/). Maps may not accurately reflect the current presence of species in counties (see website for more information).*

Field Guide 1: Salamanders of seasonal pools in the mid-Atlantic region.

BLUE-SPOTTED SALAMANDER
(Ambystoma laterale)
Indicator Species

Photo: Solon Morse, RTPI

3 – 5.5 inches
(7.5 – 14 cm)

Bluish-white spots on gray, brown or black body

Habitat includes deciduous and mixed deciduous-coniferous forests with rotting logs and deep humus; also inhabits forests surrounding wetlands; breeds in seasonal pools and fish-free ponds

Endangered: N.J.

Description: p. 54

MABEE'S SALAMANDER
(Ambystoma mabeei)
Indicator Species

Photo: Steven M. Roble

3 – 4.8 inches
(7.5 – 12 cm)

White or gray flecks on sides of gray or black body

Habitat includes pine savanna, wet wood, and swamp habitats; breeds in seasonal pools

Threatened: Va.

Description: p. 55

MOLE SALAMANDER
(Ambystoma talpoideum)
Indicator Species

Photo: Jason D. Gibson

3 – 4.7 inches
(7.5 – 12 cm)

Bluish-white or gray flecks on light brown to black body

Habitat includes hardwood forests or mixed pine-hardwood forests; breeds in seasonal pools and fish-free ponds

Special Concern: Va.

Description: p. 56

Field Guide 1: Salamanders of seasonal pools in the mid-Atlantic region.

RED-SPOTTED NEWT
(Notophthalmus viridescens viridescens)
Facultative Species

Photos: Solon Morse, RTPI

Adult (above):
2.3 – 5 inches
(7 – 13 cm);
olive to brown
with distinctive
black-bordered red spots

Eft (below): 1.5 – 3.5 inches (4 – 9 cm); bright orange to dull red with spots

Adult habitat includes wide-range of semi-permanent and permanent waters

Efts (juveniles) are terrestrial

Protected: Del., N.J., Va.

FOUR-TOED SALAMANDER
(Hemidactylium scutatum)
Facultative Species

Photo: Solon Morse, RTPI

2 – 4 inches
(5 – 10 cm)

Rusty brown body with gray sides; four toes on hind feet; white underside with black spots

Habitat includes mature hardwood forests and oak-pine forests; breeds in seasonal pools or other wetlands; lays eggs above the water line; often nests in sphagnum and other mosses

Protected: Del., N.J., Va.

Field Guide 2: Frogs and toads of seasonal pools in the mid-Atlantic region.*

WOOD FROG
(Rana sylvatica)
Indicator Species

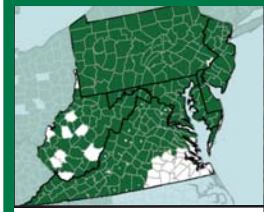


Photo: Steven M. Roble

1.4 – 2.8 inches
(3.5 – 7 cm)

Brown or red-brown with characteristic chocolate mask; white underbelly; two ridges extend along sides of back

Habitat includes moist or lowland deciduous woods; breeds in fish-free seasonal and sometimes permanent pools

Protected: Del., N.J., Va.

Description: p. 57

EASTERN SPADEFOOT
(Scaphiopus holbrookii)
Indicator Species

Photo: John F. Bunnell

1.8 – 3 inches
(4.4 – 7.3 cm)

Smooth skin with scattered warts; sharp black spades on hind feet; vertical pupils and yellow eyes

Habitat includes floodplains of streams and rivers, woods, meadows, or fields with loose, sandy soils; breeds in seasonal pools

Note: Eastern spadefoots primarily breed in seasonal pools with short hydroperiods, including ephemeral pools.

Protected: Del., N.J., Va.
Watch List: W. Va.

Description: p. 59

BARKING TREEFROG
(Hyla gratiosa)
Facultative Species

Photo: Alvin Braswell

2 – 2.6 inches
(5 – 6.6 cm)

Color changes from light green to brown; white stripe on upper lip extends down body sides; usually has dorsal spots; large toe disks

Habitat includes coastal plain woodlands; breeds in seasonal pools

Note: In parts of its range, *H. gratiosa* may be an indicator species.

Endangered: Del., Md.
Threatened: Va.

GRAY TREEFROG
(Hyla versicolor/Hyla chrysoscelis)
Facultative Species

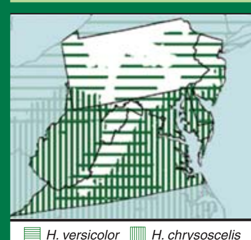


Photo: Farmscape Ecology Program, Hawthorne Valley Farm, NY

1.3 – 2.4 inches
(3.2 – 6 cm)

Highly variable body color changing from gray/green/brown; white spot under eye; large toe disks

Habitat includes forest and seasonal pools, permanent water, and swamps; breeds in seasonal pools

Note: In the southern part of its range, *H. versicolor/chrysoscelis* may be an indicator species.

Protected: Del., N.J., Va.

* *General information on the frogs and toads is derived from Tyning (1990), Green and Pauley (1987), Hulse et al. (2001), Schwartz and Golden (2002), and White and White (2002). All sizes given for frogs and toads represent 'snout to vent' lengths (SVL) and do not include the legs. Lengths are primarily from Conant and Collins (1998) and represent the range of average SVL of these species; where the literature of the mid-Atlantic region gave different figures, the widest range of lengths was selected. Distribution maps are adapted from the ARMI National Atlas for Amphibian Distributions (http://www.pwrc.usgs.gov/armiatlas/). Maps may not accurately reflect the current presence of species in counties (see website for more information).*

Field Guide 2: Frogs and toads of seasonal pools in the mid-Atlantic region.

PINE BARRENS TREEFROG
(Hyla andersonii)
Facultative Species

Photo: John F. Bunnell

1.1 – 2 inches
(2.8 – 5 cm)

Bright green body with purple stripes down sides; white belly; large toe disks

Found in New Jersey Pine Barrens; breeds in seasonal pools to permanent impoundments

Endangered: N.J.

PINE WOODS TREEFROG
(Hyla femoralis)
Facultative Species

Photo: Steven M. Roble

1 – 1.5 inches
(2.5 – 3.8 cm)

Highly variable body color ranging from reddish-brown to green-gray; row of very small orange, yellow, or white spots on rear of thighs; large toe disks

Habitat includes pine flatwoods and cypress swamps on coastal plain; breeds in seasonal pools

Protected: Va.

UPLAND CHORUS FROG/ NEW JERSEY CHORUS FROG
(Pseudacris feriarum feriarum/ Pseudacris feriarum kalmi)
Facultative Species

Photo: John F. Bunnell

0.8 – 1.4 inches
(2 – 3.6 cm)

Brown or gray with 3 dark stripes or broken markings down back; dark stripes from snout to groin, passing through the eye; small toe disks

Habitat includes grassy floodplains and wet woodlands; breeds in shallow annual and semi-permanent pools/ wetlands

(*P. f. f.*) Protected: N.J., Va.
Watch list: W. Va.

(*P. f. k.*) Protected: Del., N.J., Va.
Endangered: Pa.

BRIMLEY'S CHORUS FROG
(Pseudacris brimleyi)
Facultative Species

Photo: Joseph Mitchell

1 – 1.3 inches
(2.5 – 3.3 cm)

Variable color with bold black stripes down sides from snout to groin, passing through eye; 3 brown or gray stripes down back; small toe disks

Habitat includes wet woods and swamps of coastal plain; breeds in shallow annual and semi-permanent pools/wetlands

Protected: Va.

Field Guide 2: Frogs and toads of seasonal pools in the mid-Atlantic region.

SPRING PEEPER
(Pseudacris crucifer crucifer)
Facultative Species

0.7 – 1.3 inches
(1.9 – 3.3 cm)

Variable body color with brown imperfect 'x'-shaped mark on back; small toe disks

Habitat includes forest or field; breeds in shallow seasonal or permanent pools and wetlands

Protected: Del., N.J., Va.

NORTHERN CRICKET FROG
(Acris crepitans)
Facultative Species

0.6 – 1.4 inches
(1.6 – 3.5 cm)

Variable body color; triangular-shaped dark mark between eyes; fully-webbed feet

Habitat includes moist areas near seasonal pools, permanent water and streams; avoids dense vegetation

Protected: Del., N.J., Va.

EASTERN NARROW-MOUTHED TOAD
(Gastrophryne carolinensis)
Facultative Species

0.9 – 1.3 inches
(2.5 – 3.3 cm)

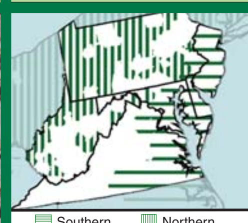
Variable color; fold of skin across back of head; pointed snout

Habitat includes open and forested land; breeds in shallow wetlands, seasonal pools, flooded fields, and ditches

Protected: Va.

Endangered: Md.

NORTHERN/SOUTHERN LEOPARD FROG
(Rana pipiens/Rana sphenocephala)
Facultative Species



2 – 3.5 inches
(5 – 9 cm)

Green and brown with irregular dark spots on back; cream dorsolateral ridges

Habitat includes grassy meadows and fields; breeds in a variety of shallow wetland habitats

(Photograph is of Southern Leopard Frog)

(*R. p.*) Protected: Va.
Watch list: W. Va.

(*R. s.*) Protected: Del., N.J., Va.
Endangered: Pa.

Field Guide 2: Frogs and toads of seasonal pools in the mid-Atlantic region.

CARPENTER FROG
(Rana virgatipes)
Facultative Species


Photo: Steven M. Roble

1.6 – 2.6 inches
(4 – 6.6 cm)

Brown with four coppery stripes running lengthwise on backs and sides

Habitat includes sphagnum bogs, Delmarva bays, some beaver ponds, and swamps

Protected: Del., N.J., Va.

Special Concern: Md., Va.

PICKEREL FROG
(Rana palustris)
Facultative Species

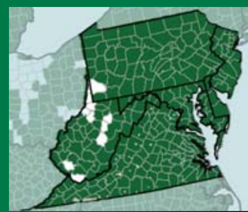



Photo: John F. Bunnell

1.8 – 3 inches
(4.4 – 7.6 cm)

Tan or brown with dark brown square blotches; light-colored dorsolateral ridges

Habitat includes streams, marshes, meadows, and ponds with thick marginal vegetation; breeds in a variety of wetlands

Protected: Del., N.J., Va.

GREEN FROG
(Rana clamitans)
Facultative Species


Photo: John F. Bunnell

2 – 4 inches
(5 – 10.2 cm)

Green to brown; two dorsolateral ridges extending two-thirds of the way down the back; white underside

Habitat and breeding grounds include ephemeral to permanent wetlands and other bodies of water including streams

Protected: Del., N.J., Va.

AMERICAN BULLFROG
(Rana catesbeiana)
Facultative Species

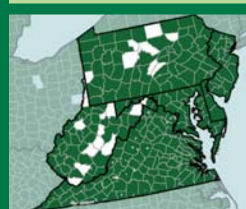



Photo: John F. Bunnell

3.5 – 6 inches
(9 – 15.2 cm); largest frog in mid-Atlantic

Green to brown; no dorsolateral ridges; two ridges extend on sides of face from eye around eardrum to shoulder

Habitat and breeding grounds include mostly deep, sometimes shallow, semi-permanent to permanent bodies of water

Can be a predator of seasonal pool amphibian eggs, larvae and adults

Protected: Del., N.J., Va.

Field Guide 2: Frogs and toads of seasonal pools in the mid-Atlantic region.

AMERICAN TOAD
(Bufo americanus)
Facultative Species

Photo: Steven M. Roble

2 – 3.5 inches
(5 – 9 cm)

Brown with dark brown spots containing 1 to 2 warts; light mid-dorsal stripe may be present; parotoid gland separated from ridge behind eye; often has a spotted underside

Habitat includes woodlands, fields, and human-dominated landscapes; breeds in permanent ponds, seasonal pools, streams, ditches, and road ruts

Protected: Del., N.J., Va.

FOWLER'S TOAD
(Bufo fowleri)
Facultative Species

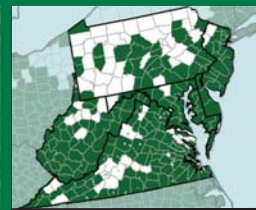


Photo: John F. Bunnell

2 – 3 inches
(5 – 7.5 cm)

Brown with dark brown spots containing 3 - 7 warts; light mid-dorsal stripe often present; parotoid gland in contact with ridge behind eye; unspotted underside

Especially common on Coastal Plain and in sandy areas; breeds in seasonal pools and shallow edges of lakes and streams

Protected: Del., N.J., Va.

Field Guide 3. Invertebrates of seasonal pools in the mid-Atlantic region.*

FAIRY SHRIMP

Crustacea C: Branchiopoda O:Anostraca

Indicator Species


Photo: Lesley J. Brown

Colorful bodies

0.5 – 2 inches (12 – 51 mm)

Swim upside down with their 11 pairs of legs in the water column

Filter microbes and detritus

Resting eggs overwinter and aestivate

Description: p. 60

CLAM SHRIMP

Crustacea *C: Branchiopoda O: Laevicaudata/Spinicaudata*

Facultative Species


Photo: Leo Kenney

Transparent to brown carapace

0.1 – 0.6 inches (2 – 16 mm)

Resemble lentils

Swim slowly with their legs down or forward; associated with aquatic vegetation and the pool bottom; burrow in sediments

Consume detritus or collect plankton

Resting eggs overwinter and aestivate

Note: Clam shrimp inhabit seasonal pools with short hydroperiods, including ephemeral pools. Some species of clam shrimp may be indicator species for ephemeral pools.

SEED SHRIMP

Crustacea C: Ostracoda O: Podocopa

Facultative Species


Photo: Leo Kenney

Variable color

Usually less than 0.04 inches (1 mm)

Resemble miniature mussels or seeds

Filter feeds detritus; may scavenge dead or living animals

Found in sediments

Resting eggs can overwinter and aestivate

CLADOCERA

Crustacea C: Branchiopoda

Facultative Species


Photo: Leo Kenney

"Water fleas" or "Daphnia"

Clear or transparent

Less than 0.2 inches (5 mm); folded carapace

Use antennae strokes for movement; jerky locomotion

Filter feeds detritus, algae, and bacteria

Parthenogenic eggs; also produces resting eggs that can overwinter and aestivate

ISOPOD

Crustacea C: Malacostraca O: Isopoda

Facultative Species


Photo: Solon Morse, RTPI

Brown to light gray

Less than 0.7 inches (18 mm)

Flattened and broad-bodied; 7 pairs of legs

Crawl along pool bottoms

Consume detritus; scavenge on dead organisms

Do not have physiological adaptations to withstand drying

AMPHIPOD

Crustacea C: Malacostraca O: Amphipoda

Facultative Species


Photo: Solon Morse, RTPI

"Scuds"

Variable color: pink, gray, or light green

0.2 – 0.4 inches (5 – 10 mm); narrow-bodied

Swim in quick bursts

Consume detritus; found among detritus on pool bottom or buried in soft-bottom

May survive short dry periods by burrowing in bottom

P = Phylum C = Class O = Order F = Family

** Invertebrates were selected for Field Guide 3 based on the results of fieldwork conducted in seasonal pools by Mahoney et al. (1990), Leeper and Taylor (1998), and Brooks (2000). Descriptions of these invertebrates were based on Wiggins et al. (1980), Kenney and Burne (2001), Smith (2001), Colburn (2004), and several chapters from the edited volume of Thorp and Covich (1991): Dodson and Frey, Hilsenhoff, and Smith and Cook.*

Field Guide 3: Invertebrates of seasonal pools in the mid-Atlantic region.

COPEPOD

Crustacea C: Copepoda

Facultative Species


Photo: Leo Kenney

Up to 0.1 inches (2.5 mm)

Different species are filter feeders or predators

Adults of some species may form cocoons to survive droughts; many species produce eggs that may enter diapause

AMPHIBIOUS SNAIL

P: Mollusca C: Gastropoda

Facultative Species


Photos: Wayne Davis

Shells are dull brown or light gray; pink bodies

Feeds on detritus and algae

Some species are annual; other species may overwinter by burrowing in frozen mud; also may burrow in leaf litter or sediments to survive dry season

Shells can be found in dry pool beds

FINGERNAIL CLAM

P: Mollusca C: Pelecypoda

Facultative Species

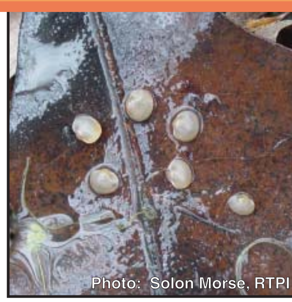


Photo: Solon Morse, RTPI

Cream to light brown

Less than 0.5 inches (13 mm)

Filters detritus, algae, and bacteria

Some species burrow in sediments to survive dry periods

Shells can be found in dry seasonal pool beds

PREDACEOUS DIVING BEETLE

P: Arthropoda C: Insecta O: Coleoptera F: Dytiscidae

Facultative Species


Photo: Leo Kenney

Oval body shape; long linear antennae

0.1 – 1.75 inches (2 – 45 mm)

Hind swimming legs are fringed with hairs and kick simultaneously

Feed on invertebrates and amphibian larvae

Some species survive dry periods by burrowing in pool sediments, others by migrating to permanent waters; some species lay diapausing eggs

CADDISFLY LARVA

P: Arthropoda C: Insecta O: Trichoptera

Facultative Species


Photo: Leo Kenney

Photo: Solon Morse, RTPI

Sheltered in self-constructed cases

Two seasonal pool families:

1) Limnephilidae: "log cabin" cases (above)
2) Phryganeidae: grass and leaf cases (below)

Shred decaying leaves and detritus; some species also feed on mosquito larvae and amphibian egg masses

Live in seasonal pools and other aquatic habitats; adults emerge before pools dry out; cases found in dry pool beds

Eggs may overwinter

PHANTOM MIDGE LARVA

P: Arthropoda C: Insecta O: Diptera F: Chaoboridae

Facultative Species


Photo: Leo Kenney

Almost transparent; have distinct heads

Less than 1 inch (25 mm)

Predators of insect larvae and small crustaceans

Live in seasonal pools and permanent waters; adults emerge

Abundant in early spring

Field Guide 3: Invertebrates of seasonal pools in the mid-Atlantic region.

CHIRONOMID MIDGE LARVA

P: Arthropoda C: Insecta O: Diptera F: Chironomidae

Facultative Species


Photo: Leo Kenney

0.1 – 0.8 inches (2 – 20 mm)

Often red due to hemoglobin-like pigment

Worm-shaped and cylindrical

Can survive in low oxygen levels as found in drying seasonal pools

Found in pool bottoms and open water; adults emerge

MOSQUITO LARVA

P: Arthropoda C: Insecta O: Diptera F: Culicidae

Facultative Species


Photo: Leo Kenney

0.3 – 0.5 inches (8 – 13 mm)

Have characteristic flip-flop swimming motion; called "wrigglers"

Feed on detritus and micro-organisms

Live in seasonal pools and other shallow waters; adults emerge

WATER MITE

P: Arthropoda C: Hydrachnidia O: Acariformes

Facultative Species


Photo: Solon Morse, RTPI

Brilliant red or green, or brown, tan, brown, yellow or blue

Less than 0.2 inches (5 mm)

Spherical and resembles tiny spiders

Carnivorous or parasitic

Complex life cycle

PLANARIA

P: Platyhelminthes C: Turbellaria

Facultative Species


Photo: Leo Kenney

Flat and unsegmented

0.2 – 1.2 inches (5 – 30 mm)

Live for a year or less; some species encyst themselves to survive dry period

LEECH

P: Annelida C: Hirundinae

Facultative Species


Photo: Leo Kenney

Flattened and elongated; has oral sucker and larger caudal sucker

Parasites, scavengers, or predators (of aquatic invertebrate larvae and amphibian eggs)

Some species can burrow into pool bottom to survive short dry seasons; some species produce drought-resistant eggs

AQUATIC OLIGOCHAETE WORM

P: Annelida C: Oligochaeta

Facultative Species


Photo: Leo Kenney

Elongated;
up to 1.5 inches (38 mm)

Feed on leaf litter, detritus and soil

Found among detritus and mud in seasonal pools

Produce cocoons that protect them from short periods of drought

In-Depth Information on Seasonal Pool Indicator Species

Mole Salamanders

For the salamander species detailed below, please refer to Field Guide 1 for photographs of adults (p. 38), Field Guide 4 for photographs of eggs (p. 63), and Field Guide 5 for photographs of larvae (p. 66). General information on the salamanders' physical appearance, habitat, and behavior is primarily derived from Petranka (1998), Bishop (1941), and Tyning (1990). Species information was tailored to the mid-Atlantic region by using Green and Pauley (1987), Hulse et al. (2001), Schwartz and Golden (2002), and White and White (2002). When there was a range of figures reported for certain parameters (such as egg clutch size), the figures from fieldwork in the mid-Atlantic region were selected when possible, as is the case for this entire section. Salamander lengths represent total length of the body and tail. The lengths are primarily from Conant and Collins (1998) and represent the range of average total lengths of these salamanders; where mid-Atlantic literature provided dissimilar total lengths, the widest range of lengths was selected.

Spotted Salamander (*Ambystoma maculatum*)

Indicator Species

Adult Description: Spotted salamanders are 4.4 to 7.8 inches (11 – 20 cm) total length. These salamanders have bright yellow or yellow-orange spots in two rows from head to tail on black, bluish-black, brownish-black, or steel gray bodies (Field Guide 1). Their undersides are gray.

Habitat Requirements: As adults, spotted salamanders live primarily below ground, residing in small mammal burrows and beneath logs and leaf litter. They feed on invertebrates (such as earthworms, centipedes, spiders, and insects). Spotted salamanders inhabit moist, mature deciduous forests as well as younger deciduous and mixed deciduous-coniferous forests. Breeding occurs primarily in seasonal forest pools, seasonal forested wetland pools, and fish-free ponds.

Reproduction: On moderate rainy or humid nights from mid-February through April, spotted salamanders emerge from their terrestrial burrows and migrate to pools to breed (Green, 1956; Nyman, 1991). At the pools, salamanders may gather in large congresses. The breeding season may be several days to two months long, with one to three major breeding events per season (Stenhouse, 1985; Harris, 1980; Petranka, 1998). Spotted salamander breeding phenology (time frame in months when eggs, larvae, and metamorphs are present at pools) for the mid-Atlantic region is shown in Fig. 3-2.

Eggs: Within hours to a few days following mating, females lay one to four egg masses on submerged vegetation or debris about 8 – 10 inches (20 – 25 cm) below the water surface (Field Guide 4; Bishop, 1941). Freshly laid egg masses are less than 1 inch diameter but expand within hours as they absorb water (Bishop, 1941). Individual egg masses contain an average of 75 – 110 eggs per mass (range of 15 – 250 eggs) (Bishop, 1941; Wood and Wilkinson, 1952; Shoop, 1974; Harris, 1980). Female spotted salamanders have total clutch sizes (total number of eggs laid per breeding effort) of around 200 eggs (Woodward, 1982; Shoop, 1974; Ireland, 1989). An egg mass is surrounded by a stiff gelatinous matrix, which is either clear or opaque white (the latter is due to the presence of a crystalline protein). This gelatinous matrix decreases predation, although adult red-spotted newts, predatory wood frog tadpoles, and caddisfly and midge larvae may still eat the embryos (Rowe et al., 1994; Stout et al., 1992). A week after being laid, spotted and other mole salamander egg masses may begin to take on a greenish hue caused by the growth of a symbiotic alga, *Oophila amblystomatis*, within the jelly matrix. This alga derives nutrients from the jelly matrix and in turn provides oxygen to the developing embryos (Bachmann et al., 1986; Pinder and Friet, 1994).

Larvae: Spotted salamander larvae hatch from the eggs after about three to seven weeks, depending upon water temperature. Larvae are only 0.5 inch (1 cm) in length at hatching and grow quickly on a diet of zooplankton and other invertebrates to reach about 2 inches (5 cm) at metamorphosis. Larvae are greenish with light-colored underbellies and large feathery gills (Field Guide 5). Spotted salamander larvae are preyed upon by predatory insects and salamander larvae (e.g., marbled and eastern tiger) (Hairston, 1987).

Juveniles: Between six weeks and four months after hatching, mid-June through August, larvae metamorphose into juveniles. Slowly growing larvae in some populations may overwinter and transform the next spring (if the pool remains flooded) (Wilbur, 1977; Phillips, 1992) though this has not been recorded for the mid-Atlantic region. Juveniles are similar to adults but have lighter undersides and less prominent spotting on their backs. Sexual maturity occurs after two to five years, with males typically maturing earlier than females.

Range: Spotted salamanders are found throughout the mid-Atlantic region, although they tend to be absent from coastal areas.

Regional Notes: In Delaware, New Jersey, and Virginia, spotted salamanders are protected (with limits set on take and collection). Major pressures on spotted salamander populations, as with the other species of mole salamanders, come largely from habitat loss and deforestation. Spotted salamander populations appear to have declined in eastern Virginia, which may be related to acidic deposition and concomitant increases in concentrations of various metals (aluminum, copper, silicon, and zinc) (Blem and Blem, 1989, 1991; see Section 4.3).

Marbled Salamander (*Ambystoma opacum*)

Indicator Species

Adult Description: Marbled salamanders are 3.5 to 4.3 inches (9 – 11 cm) total length and thick-bodied with short tails. These salamanders are shiny black to purplish-black with silvery-white or gray markings usually in crossbands, or as stripes in some individuals (Field Guide 1). Males have larger, more distinct silver-white markings compared with females whose markings are more blotchy and gray in coloration.

Habitat Requirements: Marbled salamanders spend most of their adult lives beneath leaf litter, debris, stones, or below ground (up to 1 m in depth) in natural crevices and mammal burrows. In summer and fall after rains, marbled salamanders can be found on the surface of the forest floor. They inhabit deciduous forests as well as mixed deciduous-coniferous and coniferous forests. Marbled salamanders depend upon seasonal pools for breeding; only very rarely will they breed in pools with fish.

Reproduction: Marbled salamanders exhibit a very different breeding behavior than the other mole salamander indicator species. Breeding takes place during a different season and on land rather than in the water. On rainy nights in fall (September to November) courtship and mating begins en route to and in or along the margins of dry seasonal pool beds. In these dry pools, females either find a naturally-occurring depression (e.g., rodent burrow immediately below leaf litter) or scour out their own that will serve as a nest for their eggs. The nest is an oval-shaped depression about 3 inches (7 cm) long, 2 inches (5 cm) wide, and 1 inch (2 cm) deep (Tyning, 1990; Petranka, 1998). Nests are also created beneath logs and stones and at the bases of grass clumps and trees (Bishop, 1941; Petranka, 1998). Marbled salamander breeding phenology for the mid-Atlantic region is shown in Fig. 3-2. In an opposite pattern compared to the other species of mole salamanders, marbled salamander adults breed earlier in their northern range as compared to their southern range and earlier at higher altitudes as compared to lower altitudes.

Eggs: Females lay 37 – 130 eggs in their nests (Green, 1956). Although nests are usually individual, communal nests holding two to seven clutches have also been found (Petranka, 1998). Females often stay with their eggs, curling their bodies around them until the pool is filled – which may be weeks or even months later. This behavior is thought to protect the eggs from desiccation and predation by insects or small mammals. Females deposit eggs singly and they often appear black due to clinging soil and detritus (Field Guide 4; Bishop, 1941; Petranka, 1998).

Larvae: Marbled salamander larvae hatch from eggs within a few days of being submerged by pool flooding. If they hatch in the fall, the larvae will overwinter. During the cold months they undergo only slow growth (Bishop, 1941), but during warm weather larvae grow quickly, first eating zooplankton and later becoming voracious predators of invertebrates and amphibian larvae including sibling marbled salamander larvae (Walls and Blaustein, 1995). In early spring, marbled salamander larvae are likely to be larger in size than other amphibian larvae in seasonal pools due to earlier hatching. Larvae are brown to blackish with a row of light spots on their sides; older larvae develop mottling on a light yellowish-green body (Field Guide 5). Their throats are darkly pigmented, which may distinguish them from lighter-throated spotted salamander larvae.

Juveniles: The larvae begin transforming in the early spring and most leave the pool by May or June. Recent metamorphs have purplish-black or brown bodies with a light-colored spotted or speckled pattern; by one to two months after transformation, the adult pattern begins to appear (Bishop, 1941). Sexual maturation occurs after one to five years.

Range: Marbled salamanders occur throughout the mid-Atlantic region, but appear to be absent from northern and western Pennsylvania, eastern West Virginia, and western Virginia (with the exception of a few scattered records).

Regional Notes: Like the spotted salamander, marbled salamanders are protected (with limits set on take and collection) in Delaware and Virginia and are listed as special concern in New Jersey. Loss of habitat – particularly bottomland deciduous forests and associated seasonal pool habitats – poses the greatest threat to existing populations of marbled salamanders (Petranka, 1998).

Eastern Tiger Salamander (*Ambystoma tigrinum tigrinum*)

Indicator Species

Adult Description: Tiger salamanders are among the largest pool-breeding or terrestrial salamanders in North America. One of the approximately seven recognized subspecies, eastern tiger salamanders are 7.0 to 8.3 inches (17 – 21 cm) total length with a thick body and broad head. Eastern tiger salamanders are dark brown or dull black with a cream, greenish-yellow or brownish-yellow pattern of irregular blotches or spots, sometimes forming tiger-like stripes around their sides (Field Guide 1). They have yellowish undersides with dark marbling.

Habitat Requirements: Adult eastern tiger salamanders are fossorial, spending most of their terrestrial lives in self-dug tunnels or in mammal burrows. They inhabit areas with suitable conditions for burrowing (e.g., woodlands, open areas with sandy soils). Eastern tiger salamanders breed in seasonal pools and fishless permanent ponds (Bishop, 1941; Wilbur and Collins, 1973).

Reproduction: Tiger salamanders migrate to breeding pools from their underground hideaways earlier than spotted salamanders on rainy or damp nights. Their breeding season occurs from December to March across the mid-Atlantic region (Fig. 3-2; Cooper, 1955; Anderson et al., 1971). The breeding season in New Jersey lasts about two months, which may be longer than other mole salamanders in the area (Hassinger et al., 1970). They congress in smaller groups compared to spotted salamanders (White and White 2002). Males produce larger spermatophores than other ambystomatids.

Eggs: Females lay their eggs in globular or oblong gelatinous masses on twigs, weed stems, and other structures in ponds at depths greater than 20 cm (Field Guide 4; Hassinger et al., 1970). Egg masses measure 2.0 by 2.75 inches (5.5 by 7.0 cm) and swell in size and lose their turgidity as they absorb water. Individual egg masses typically contain 30 – 60 eggs (Hassinger et al., 1970; Stine et al., 1954; Bishop, 1941). Females have an average clutch size of 344 – 421 eggs (Wilbur, 1977; Stine et al., 1954).

Larvae: Eastern tiger salamander eggs hatch after four to seven weeks, depending upon water temperature (Stine et al., 1954; Hassinger et al., 1970). Hatchlings have gray bodies with dark bands across or blotches along their backs and whitish bellies; older larvae have olive green bodies with markings (Field Guide 5). Eastern tiger salamander larvae are larger than other *Ambystoma spp.* larvae in the region. Some larvae develop a cannibalistic morphology, typified by larger size and enlarged teeth (though this has not been observed in the mid-Atlantic region) (J.C. Mitchell, pers. comm.).

Juveniles: Larvae transform after two and a half to four months in late spring and summer. Juveniles are initially dark gray or dark brown, and begin to attain adult coloration within one month of transformation. Sexual maturation occurs generally when two to three years old (Semlitsch, 1983).

Range: Eastern tiger salamanders are found mainly in eastern coastal areas of Delaware, Maryland, southern New Jersey, and southeastern Virginia; they are not found in Pennsylvania and West Virginia. There is also one relict population in the Shenandoah Valley (Blue Ridge Mountains) of Virginia disjunct from other populations (Buhlmann and Hoffman, 1990; Church et al., 2003).

Regional Notes: Tiger salamanders are listed as 'Endangered' in Delaware, Maryland, New Jersey, and Virginia. They are considered extirpated from Pennsylvania as a result of habitat alteration and loss (Hulse et al., 2001). The loss of vernal pools, Delmarva bays, and upland forests is threatening these salamanders on the Delmarva Peninsula (Sipple, 1999; White and White, 2002). Fish stocking and acid deposition also have contributed to declines of tiger salamander populations in Virginia (Buhlmann et al., 1999).

Jefferson Salamander (*Ambystoma jeffersonianum*)

Indicator Species

Adult Description: Jefferson salamanders are 4.3 to 7.5 inches (11 – 19 cm) total length and are slender with long tails and elongated limbs and triangular-shaped toes. They are chocolate brown to dark gray and have light blue or gray speckles on their limbs, lower sides and tail (Field Guide 1). Flecks are bright on young adults, but may fade with age. Their undersides are lighter than their sides and are also speckled. Jefferson salamanders are physically distinguished from blue-spotted salamanders by their slightly larger size, smaller markings, gray area around the vent (as compared to black area in the blue-spotted salamander), and broader head.

Habitat Requirements: Juvenile and adult Jefferson salamanders spend a majority of their lifetimes below ground, feeding on earthworms and other invertebrates. They reside in deciduous forests, and are more likely than the other mole salamander species to live in upland forests. In West Virginia, Jefferson salamanders have been found in caves (Green and Brant, 1966). Seasonal forest pools are the usual breeding location, but semipermanent pools, farm ponds, and floodplain pools may also be used (Petranka, 1998).

Reproduction: In the mid-Atlantic region, Jefferson salamanders breed early in the spring, beginning in February or March when evening rains coincide with temperatures of 40° F or more (Fig. 3-2; Petranka, 1998; Hulse et al., 2001). Males often mount the female (dorsally with forelimbs grasped behind the female's) for a time before more courtship occurs and spermatophores are deposited. Jefferson salamander spermatophores are about twice the size of those deposited by blue-spotted salamanders.

Eggs: One or two days after mating, female Jefferson salamanders deposit their eggs as masses attached to submerged vegetation or unattached in the seasonal pool water. When attached to solid structures such as twigs and branches, egg masses tend to be cylindrical and clumped in groups; when attached to more vegetative substrates, such as grass, the egg masses are more irregular in shape and laid further apart from each other (Field Guide 4; Petranka, 1998). Each female lays up to 300 eggs in separate egg masses of 10 – 75 eggs (Martof et al., 1980, Hulse et al., 2001).

Larvae: The eggs usually hatch after four to six weeks, but the embryonic period may last as long as 14 weeks depending upon water temperature (Martof et al., 1980, Petranka, 1998). Hatchlings are olive green to brown with hints of yellow on the sides of the neck, head and dorsal fin (Field Guide 5). Mature larvae have grayish bodies with heavily mottled broad dorsal fins, broad heads, elongated and tapered toes, and a silvery or white belly. Larvae are voracious feeders, eating small zooplankton at first, then progressing to larger invertebrates, including snails and insects. They are also known to eat spotted salamander larvae and other Jefferson salamander larvae (Petranka, 1998).

Juveniles: The larval period lasts two to five months (J.C. Mitchell, pers. comm.). Metamorphs are uniformly gray or brownish above with muted brownish yellow specks on the sides. Jefferson salamanders become sexually mature after two to three years.

Range: Jefferson salamanders are patchily distributed in the mid-Atlantic states. They are found in northern New Jersey, most of Pennsylvania, western Maryland, and along the Blue Ridge and Allegheny Mountains of Virginia and the Allegheny Plateau of West Virginia. They are absent from Delaware.

Regional Notes: Jefferson salamanders are on the watch list (special concern but without legal protection) in Maryland and West Virginia, are of special concern in New Jersey, and are protected (have limits set on take or collecting) in Virginia. Jefferson salamanders appear to be more vulnerable to acidic conditions than other amphibians (Petranka, 1998). Jefferson salamanders were designated by the Northeast Endangered Species Technical Committee as a species of regional conservation concern due to their risk of extirpation (Therres, 1999). Jefferson and blue-spotted salamanders often hybridize in areas where their ranges overlap, resulting primarily in female polyploids, which could lead to a reduction in pure Jefferson salamander populations (Bogart and Klemens, 1997). In the mid-Atlantic states, triploid hybrids known as *Ambystoma platineum* (having two sets of Jefferson salamander chromosomes and one set of blue-spotted salamander chromosomes) have been confirmed genetically in New Jersey (Schwartz and Golden, 2002) and may exist but are not confirmed in eastern Pennsylvania (Hulse et al., 2001).

Blue-spotted Salamander (*Ambystoma laterale*)

Indicator Species

Adult Description: Blue-spotted salamanders are 3 to 5.5 inches (7.5 – 14 cm) total length with bluish white spots and flecks on a purplish-brown, dark gray or black body (Field Guide 1). Blue spots may stand in sharp contrast against the body color or appear rather muted. Compared to the Jefferson salamander, blue-spotted salamanders are generally smaller, have larger bluish spots distributed on the sides as well as the back, and have darker pigmentation around the vent.

Habitat Requirements: Blue-spotted salamanders are fossorial, spending a majority of their time in deciduous or mixed deciduous-coniferous forests with rotting logs and deep humus. They also inhabit forested areas above the water level in swamps and marshlands. However, compared to other ambystomatids, blue-spotted salamanders are more likely to be found active on the surface during warmer months. They feed primarily at night on earthworms, slugs, isopods and other arthropods. Breeding occurs in fish-free pools, including seasonal forest pools, seasonal open-canopy pools, semipermanent pools, wetlands, and ditches.

Reproduction: Mating occurs in water in late winter or early spring, and generally consists of one to three explosive breeding occasions per year, which are triggered by warm, rainy nights. Courtship behavior resembles that of the Jefferson salamander and is described in detail by Storez (1969). Spermatophores of blue-spotted salamanders are about half the size of those of Jefferson salamanders. Blue-spotted salamander breeding phenology for the mid-Atlantic region is shown in Fig. 3-2.

Eggs: Females lay eggs singly, in strings of two to four eggs, or, less frequently, as poorly-defined masses of 2 – 30 eggs, on the pool floor or attached to leaf litter, vegetation, sticks, or rocks (Field Guide 4). The total number of eggs that a female deposits in a breeding season ranges from 100 – 500.

Larvae: Eggs typically hatch about a month after deposition. Larvae are dark brown with yellow blotches and paired black spots on either side of the tail fin on the back. Each side has a light elongated stripe, the undersides are unpigmented, and the tail fins are broad and mottled with black (Field Guide 5). Larvae most likely feed on zooplankton and dipteran larvae (Petranka 1998). The larval period typically lasts two to three months.

Juveniles: Just after metamorphosis, juveniles have yellowish spotting on both their backs and underbellies. Juvenile blue-spotted salamanders become mature in about two years.

Range: In the mid-Atlantic states, blue-spotted salamanders are confirmed only in northern New Jersey (Anderson and Giacosie, 1967).

Regional Notes: This species is listed as Endangered in New Jersey. Blue-spotted salamanders may have a greater tolerance for disturbed areas than Jefferson salamanders, but this tolerance may make them more susceptible to other threats associated with human development (Klemens, 1993). In New Jersey, blue-spotted salamanders have experienced high road mortality and have had lowered reproductive success in degraded pools with poor water quality (Schwartz and Golden, 2002). Blue-spotted salamanders have declined with the conversion of hardwood forests to urban and agricultural areas. Jefferson and blue-spotted salamanders often hybridize when their ranges overlap, which may reduce the population size of pure diploid blue-spotted salamander populations (Bogart and Klemens, 1997).

Mabee's Salamander (*Ambystoma mabeei*)

Indicator Species

Adult Description: Mabee's salamanders are 3 to 4.8 inches (8 – 12 cm) total length and are dark brownish gray to black with silvery white or gray flecks mostly on the sides with a few on the back (Field Guide 1). Mabee's salamanders have a relatively small head and long slender toes. Their undersides are light gray to grayish brown with scattered light-colored flecks.

Habitat Requirements: Mabee's salamanders are found in pine savanna, wet woods, and swamp habitats in southeastern Virginia. In the pine savanna, they inhabit burrows at the edges of bogs and ponds and migrate long distances to forested areas in the non-breeding season (J.C. Mitchell, pers. comm.). Mabee's salamanders breed in fish-free seasonal pools, including seasonal forest pools, sinkhole ponds, Carolina bays, semipermanent farm ponds, and cypress-tupelo ponds in pinewoods (Hardy and Anderson, 1970).

Reproduction: The breeding biology of Mabee's salamanders is not well-studied (Petranka 1998). According to Hardy (1969) breeding occurs from winter to early spring, but according to Martof et al. (1980) breeding starts as early as late fall; it is also reported to occur between December and March in Virginia (Fig. 3-2; J.C. Mitchell, pers. comm.).

Eggs: Females attach eggs singly or in loose chains of two to six eggs to leaves, twigs, and debris on the bottom of shallow pools (Field Guide 4).

Larvae: Hatchlings are 1/3 inch (0.85 cm) total length and have a single yellow stripe on either side of the body, bushy gills, and a broad dorsal fin that extends onto the back (Field Guide 5). Older larvae are brown to blackish with two cream stripes along the sides of the body that are often broken; dorsal and ventral fins are heavily mottled. Mabee's salamander larvae from Virginian populations feed heavily on isopods and amphipods (McCoy and Savitsky, 2004). Larvae transform in late spring at sizes of about 2 inches (5 – 6 cm) total length.

Juveniles: Juveniles are initially black or dark gray above with little or no light flecking. Time to sexual maturation is unknown.

Range: In the mid-Atlantic region, Mabee's salamanders are only found in southeastern Virginia.

Regional Notes: Mabee's salamanders are listed as threatened in Virginia. The range of the Mabee's salamander was not discovered to extend into Virginia until 1979 (Mitchell and Hedges, 1980). The Mabee's salamander is one of the least-studied species of mole salamanders, with many aspects of their biology and natural history unknown (McCoy and Savitsky, 2004). Larval Mabee's salamanders from Virginian populations were found to have significantly higher gastric parasitic nematode loads as compared to those from North and South Carolinian populations (McCoy and Savitsky, 2004). Habitat loss from ditching and draining of breeding sites and conversion of forests to agricultural lands has presumably impacted this species (Petranka, 1998).

Mole Salamander (*Ambystoma talpoideum*)

Indicator Species

Adult Description: Mole salamanders are 3 to 4.7 inches (7.5 – 12 cm) total length, and are stocky with large limbs, short tails, and large heads. Their backs and sides range in color from light brown to light bluish gray to dark brown or blackish and are speckled with small bluish white or grayish flecks (Field Guide 1). Their undersides are bluish gray with light flecks.

Habitat Requirements: Mole salamanders live in underground burrows or tunnels in pine savannas, hardwood forests, floodplain forests, and swamps. In Virginia, mole salamanders are primarily found in upland and lowland deciduous forests or mixed deciduous-coniferous forests. Mole salamanders breed in fish-free pools, including seasonal forest pools, seasonal forested wetland pools, Carolina Bays, and roadside ditches. They are more successful in pools that do not also support populations of spotted salamanders (Hayslett, 2003).

Reproduction: Breeding typically occurs after long sustained rains and cooler temperatures of 40 – 45° F (Hayslett, 2003). Mole salamanders exhibit a range of migration dates to breeding pools and breeding season durations that are dependent upon environmental conditions (Semlitsch, 1985a; Hayslett, 2003). In Virginia, the time spent at breeding pools was found to extend from mid-October to early May during a wet year and from late-January to early-April in a dry year (Hayslett, 2003). Males arrive earlier and stay longer at the pools compared to females (Semlitsch, 1981). Mole salamander breeding phenology for the mid-Atlantic region is shown in Fig. 3-2.

Eggs: Females lay eggs singly along the pool bottom on leaves, grass, and twigs (Semlitsch 1985a) at depths of 2 – 12 inches (A. Braswell, pers. comm.). Total clutch sizes for a single female are approximately 200 – 700 eggs, with clutch size and egg size increasing with female age (Field Guide 4; Semlitsch, 1985a; Hayslett, 2003).

Larvae: Eggs hatch after 30 – 40 days (Semlitsch et al., 1988). Hatchlings have alternating black and yellow blotches along the midline of the back and on the tail fin. Older larvae develop two cream or dull yellow stripes on each side that break up toward the tail, as well as a characteristic dark band that extends along the midline of the belly, which is retained in juveniles and gilled adults (Field Guide 5).

Juveniles: Larvae may start metamorphosing by mid-June (North Carolina, A. Braswell, pers. comm.). If larvae have not metamorphosed by mid-July, they may overwinter, become sexually mature and reproduce as paedomorphs the following spring and then metamorphose to terrestrial form (Hayslett, 2003; A. Braswell, pers. comm.). This reproductive strategy of paedomophosis primarily occurs in pools that do not dry annually (Semlitsch, 1985b). A paedomorph, or gilled adult, is darker than an immature larva and may be lacking the midline dark stripe on its belly. Newly transformed juvenile mole salamanders are brownish green in color. About 2 – 4 weeks after transformation, adult patterns (gray flecking) begin to appear. In South Carolina, the majority of mole salamanders become sexually mature in the first year, within a few months of transformation (Semlitsch et al., 1988).

Range: In the mid-Atlantic region, mole salamanders only occur in south central Virginia in an area geographically disjunct from the rest of the species' range (Bader and Mitchell, 1982).

Regional Notes: The mole salamander is a species of special concern in Virginia. Loss of upland forests as well as seasonal and semipermanent pools impacts populations of this species.

Frogs

For the frog species detailed below, please refer to Field Guide 2 for photographs of adults (p. 41), Field Guide 4 for photographs of eggs (p. 65), and Field Guide 5 for photographs of larvae (p. 68). General information on the frogs' physical appearance, habitat, and behavior were compiled from Tyning (1990), Green and Pauley (1987), Hulse et al. (2001), Schwartz and Golden (2002), and White and White (2002). All sizes given for frogs represent 'snout to vent' lengths (SVL) and do not include the legs. Lengths are primarily from Conant and Collins (1998) and represent the range of average SVL of these species; where the literature of the mid-Atlantic region gave different figures, the widest range of lengths was selected.

Wood Frog (*Rana sylvatica*)

Indicator Species

Adult Description: Wood frogs are 1.4 to 2.8 inches (3.5 – 7 cm) SVL and vary in color from gray brown to dark brown or reddish-brown with a pale white or cream-colored underbelly and dark crossbars on the hind legs (Field Guide 2). Two dorsolateral ridges extend along the sides of the back. Wood frogs have a characteristic dark chocolate brown mask that extends from the snout across the eyes to a point behind the eardrum (tympanic membrane). Males are usually darker and smaller than females. Males are dark gray brown and have enlarged thumbs during the breeding season, while females are usually reddish-brown.

Habitat Requirements: As its common name implies, wood frogs inhabit primarily moist or lowland deciduous woods. In northern Pennsylvania, wood frogs are also found in hemlock-northern hardwood-white pine communities (Hulse et al., 2001). Outside of hibernation and breeding times, wood frogs are active on the forest floor during the day and night if temperatures exceed 53° F and if humidity is high or it has rained. In winter, wood frogs hibernate in deciduous forests underneath leaf litter or cover objects or in shallow burrows rarely below the frostline of the soil, making wood frogs susceptible to freezing conditions. However, wood frogs can withstand temperatures as low as 20° F before freezing because they release high levels of glucose into their body fluids from liver glycogen stores, which acts as an antifreeze agent (cryoprotectant). Wood frogs can also survive up to two weeks of extracellular freezing at moderate subzero temperatures (Storey and Storey, 1986). Wood frogs breed in fish-free seasonal and sometimes permanent pools in or adjacent to forests, including vernal pools, beaver ponds, roadside ditches, canals, and borrow/gravel pits.

Reproduction: Wood frogs are the first anurans to breed in the calendar year in most of the mid-Atlantic region. On a warm, wet evening in late winter or early spring, wood frogs migrate from their woodland habitats to breeding ponds for an explosive two to seven days of mating. Males may vocalize in pools for up to three to four weeks, but females are typically in pools for only one to a few days. Freezing weather may interrupt breeding for a period of time. At the Patuxent Research Refuge, a 13,000 acre refuge in Maryland, wood frogs may breed at some seasonal pool sites a week or more before breeding commences at other sites, most likely a result of variation in temperature and microhabitat. Wood frog breeding phenology for the mid-Atlantic region is shown in Fig. 3-2.

Eggs: Females deposit one egg mass containing approximately 500 – 1000 eggs on vegetation or sticks beneath the surface of the water that the male quickly fertilizes (Field Guide 4). At deposition, wood frog eggs are tightly packed together with no outer surrounding jelly matrix unifying the mass, giving the mass a bumpy appearance on the water surface. Egg masses have a diameter of about 2.5 to 4 inches (6.3 – 10 cm). After a week or more, egg masses become amorphous and harder to count individually and may turn green due to algal growth. Females usually deposit egg masses in the same general area of a pool every year. In a woodland setting, this is often on the north side of the pool where the ice melts first; this area receives the most solar exposure. Eggs are most often laid in large communal oviposition sites or rafts that help to trap heat and accelerate development. Seale (1982) reported one raft of 963 wood frog egg masses at a pool in Pennsylvania.

Larvae: Wood frog eggs hatch after two or three weeks. Tadpoles are medium-sized, up to 2 inches (5 cm) in length and are dark brown to blackish with gold flecking (Field Guide 5). Their underbellies are pale iridescent. Eyes are dorsally located just above the sides, not bulging out on sides laterally like tadpoles in the treefrog (Hylidae) family. Initially, they attach themselves to their disintegrating egg mass with their sucker-like mouths and graze the algae growing on its surface. For the remainder of the larval stage, they feed primarily on algae and detritus (although they may also eat smaller siblings or cohorts) and find refuge in the leaf litter at the bottom of the pool and in large schools in shallow areas of the pool.

Juveniles: Tadpoles metamorphose into their terrestrial form 60 – 113 days later, usually sometime in June and July (Berven, 1988; Tyning, 1990). At metamorphosis, froglets look like miniature adults. Sexual maturation occurs after one to two years for males and after two to three years for females (Berven, 1990).

Vocalizations: Male wood frog advertisement calls during the breeding season sound like duck quacks, repeated one to five times. Males call day and night.

Range: Found throughout the mid-Atlantic region except for southeastern Virginia.

Regional Notes: Wood frogs are protected with limits set on take and collection in Delaware, New Jersey, and Virginia.

Eastern Spadefoot (*Scaphiopus holbrookii*)

Indicator Species

Adult Description: Eastern spadefoots are 1.8 – 3 inches (4.4 – 7.6 cm) SVL, short-legged, and stout. They have bulging eyes, rounded heads and snouts, and smooth skin with scattered small tubercles (warts). Their backs are olive or brown or gray to black with two irregular yellow lines running from behind their eyes down the length of their backs meeting at a midline near the rump (Field Guide 2). Sometimes they have an additional yellowish line on the side of the body. Their throat and chest are white, except during the breeding season when males' throats darken. The spadefoot's common name is derived from the dark, horny growth on the inner sides of each hind foot, which facilitates digging. Unlike almost all North American frogs, spadefoots have vertical pupils; they also have greenish-yellow irises.

Habitat Requirements: Eastern spadefoots live below ground, burrowing in loose, sandy soils in river floodplains, woods, meadows, or fields. Breeding occurs in short-hydroperiod seasonal or ephemeral pools. They are adapted to dry conditions and can survive prolonged droughts, sometimes for years, lying dormant below the surface. During these dry periods they excrete a fluid that hardens around their curled-up bodies to prevent desiccation (Tyning, 1990).

Reproduction: On mild afternoons and evenings in the spring (starting as early as February), summer, or fall, during or just after periods of very heavy rains and low barometric pressure, spadefoots dig out from their burrows to breed in recently filled seasonal pools or ditches. They are explosive and unpredictable breeders and may appear by the dozens or even hundreds to breed following a heavy storm. The male grasps the female in an inguinal amplexus, just above her hind legs; other species of male frogs in the region grasp females behind the front legs. During the breeding season, males develop black cornifications on the first three fingers of the front feet. Eastern spadefoot breeding phenology for the mid-Atlantic region is shown in Fig. 3-2.

Eggs: Eggs are laid and fertilized externally on underwater vegetation. Each female may deposit up to 2500 eggs in strands or bands that are 1 – 2 inches wide (2.5 – 5 cm) and up to 12 inches long (30 cm); as the eggs swell with water, they clump into more irregular bunches (Field Guide 4).

Larvae: Spadefoot eggs hatch very rapidly, after 1 day to one week, depending on water temperature (Richmond, 1947). Tadpoles are dark bronze to dark brown and have close-set eyes near the top of their head (Field Guide 5). The tail fins are translucent and are unmarked. Spadefoot tadpoles spend the first one to four days relatively inactive, attached to their egg mass or other objects. Then, tadpoles swim throughout the pool (near the water surface if the pool is deep) feeding on plankton. Between one and two weeks after they hatch, tadpoles form dense schools, feeding continuously on algae and carrion (Richmond, 1947).

Juveniles: Typically, spadefoots transform into juveniles after about a month (range of two to ten weeks) of larval development, depending upon water temperature and larval density (Richmond, 1947; Semlitsch and Caldwell, 1982; Tyning, 1990). Newly transformed eastern spadefoot juveniles congregate in large numbers around the pool for several days after metamorphosis (Richmond, 1947). They are active during the day foraging near their natal ponds. Juveniles reach maturity at about 2 inches (5 cm) at two years of age (Pearson, 1955).

Vocalizations: The advertisement calls of male spadefoots are loud, abrupt grunts or squawks that sound like a downward-slurred "errrrrrgh," often repeated in rapid succession.

Range: Eastern spadefoots are found in lowland areas of the Coastal Plain and some of the adjacent Piedmont areas, with very scattered distributions in mountainous areas (Martof et al., 1980; Mitchell and Reay, 1999). They are absent from northwestern Maryland, northwestern Pennsylvania, northern Virginia and are known from only a few places in West Virginia.

Regional Notes: Eastern spadefoots are on the watch list (special concern without legal protection) in West Virginia and are protected (with limits set on take and collection) in Delaware, New Jersey, and Virginia. Eastern spadefoots are rarely seen or heard except after heavy rain events, undergo rapid development, and spend much of their lifetime underground. For these reasons, the distribution of this species has not been thoroughly elucidated.

Fairy Shrimp

Crustaceans in the class Branchiopoda include fairy shrimps, tadpole shrimps, clam shrimps, and water fleas. With the exception of water fleas, which occur ubiquitously in many freshwater habitats, the Branchiopods are among the most distinctive inhabitants of seasonal pools (Smith, 2001). The primarily freshwater order Anostraca, the fairy shrimp, has 50 documented species in the United States (Belk, 1975; Smith, 2001). Fairy shrimp in particular have become emblematic of seasonal pools, and are considered an indicator species group of mid-Atlantic seasonal pools.

Fairy shrimp: Order Anostraca

INDICATOR SPECIES

Adult Description: Fairy shrimp adults range in total length from 0.5 to almost 2 inches (1.2 – 5 cm). Their coloration is variable, and may be partially dictated by the food they eat; they occur in colors of gray, blue, green, orange, and red (Field Guide 3; Smith, 2001). These crustaceans glide gracefully about the pool swimming upside down with 11 pairs of swimming legs waving above, filtering their food.

Habitat Requirements: Fairy shrimp feed on microbes and detritus in the water column or substrate (Smith, 2001). Fairy shrimp tend to do better in seasonal pools with short hydroperiods (Mahoney et al., 1990). They appear in seasonal pools in late winter or early spring, completing their life cycle in a short period before predatory insects reach maximum densities (Wiggins et al., 1980).

Reproduction: Detailed species-specific reproductive biology of most fairy shrimps is not well known. The following is a general account; there are likely differences among species. During courtship, male fairy shrimp clasp the female with antennae and they swim together around the pool for days at a time. After copulation, which only lasts several seconds, eggs are carried externally in the female's brood sac for one to several days. During this time the eggs undergo early development. Females lay one to six clutches of eggs per season at two to six day intervals. Clutch size is 10 – 250 eggs (Smith, 2001). Some fairy shrimp may produce two types of eggs – thin-shelled eggs that hatch quickly and thick-shelled eggs that are more hardy. The latter of these two types, the resting (dormant) eggs, allow fairy shrimp to exploit seasonal pools and to maintain their populations through the dry season of the pools and through freezing winter conditions. Fairy shrimp eggs are dormant from 6 to 10 months per year in the mid-Atlantic region before hatching during pool flooding. Not every egg will hatch – eggs may stay viable buried in the seasonal pool bed sediments for many years. Resting eggs may be transported in the wind or by birds, insects, or salamanders (Lowcock and Murphy, 1990; Bohonak and

Whiteman, 1999; Smith, 2001). Metamorphic *Ambystoma* salamanders may ingest female fairy shrimp and defecate in another pool, thereby transporting their eggs (Bohonak and Whiteman, 1999).

Range: Four species from two families have been recorded for the mid-Atlantic region: three species of *Eubranchipus* in the family Chirocephalidae and one species of *Streptocephalus* in the family Streptocephalidae. In addition, another species (*Eubranchipus neglectus*) may be found in the mid-Atlantic region, though this is not confirmed (Belk, 1975, Belk et al., 1998).

Regional Notes: There is very little published research on Anostraca of seasonal pools in the mid-Atlantic region. Additionally, there has been confusion surrounding the records of species distributions due to mistakes in identifying two species (Belk et al., 1998). Adult fairy shrimp tend to be unpredictable in occurrence and abundance and exhibit a patchy distribution across the landscape. They may be sporadic in appearance from one year to the next, or may be abundant for many successive years, then suddenly disappear. Eggs may remain viable in the pool bottom for years until hatching. Pools in close proximity to a pool with a particular species of fairy shrimp may have different species of fairy shrimp or none at all (Smith, 2001).

Family	Scientific Name	States in the Mid-Atlantic Region
Chirocephalidae	*Eubranchipus holmanii*	Md., N.J., Pa., Va.
Chirocephalidae	*Eubranchipus neglectus*	W. Va.* and southwestern Va.*
Chirocephalidae	*Eubranchipus serratus*	Md., Va.
Chirocephalidae	*Eubranchipus vernalis*	Del., Md., N.J., Pa., Va., W. Va.*
Streptocephalidae	*Streptocephalus sealii*	Md., N.J., Va.

Species of fairy shrimp in the mid-Atlantic region. These species distributions are based on Belk (1975) and Belk et al. (1998). Belk (1975) created distributions using published records and specimens from the National Museum of Natural History, Washington, D.C.

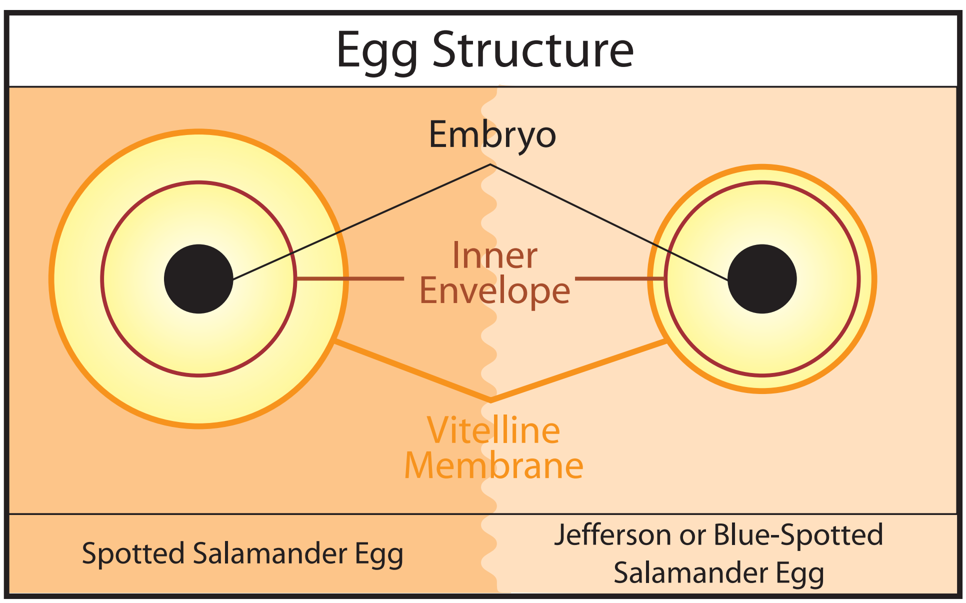
** These species have not been recorded from these states, but according to range maps, they may occur there (see Belk et al., 1998).*

Comparison of Eggs and Larvae of Amphibian Indicator Species

The presence of egg masses and larvae provides evidence of use of the pools by amphibians for breeding. Depending on the species, eggs may be laid singly, in strings, in sheets, or as discrete masses. Females may lay eggs individually or in communal areas of pools. Eggs and egg masses of seasonal pool breeders are usually attached to vegetation or woody debris below the water surface (with the notable exception of the marbled salamander). Egg masses of species of mole salamanders are encapsulated by a jelly matrix that ranges in consistency from very firm (spotted salamanders) to medium-firm (Jefferson salamanders) to soft (blue-spotted salamanders). The jelly matrix is usually clear, although spotted salamander egg masses may be opaque white due to the presence of a crystalline protein. Frog egg masses, in contrast, lack this outer jelly matrix and are less cohesive than mole salamander egg masses. Amphibian egg masses change in appearance over time in the seasonal pools. They swell in size and become more amorphous as they absorb water. Also, egg masses may begin to take on a greenish hue caused by the growth of a symbiotic alga, *Oophila amblystomatis*, within the jelly matrix. This alga derives nutrients from the jelly matrix and in turn provides oxygen to the developing embryos (Pinder and Friet, 1994).

Mole salamander egg masses can also be distinguished from one another based on characteristics of the eggs. Spotted salamander eggs exhibit a large distance between the inner envelope and vitelline membrane, such that the vitelline membrane is much farther from the embryo compared to those of blue-spotted and Jefferson salamanders (Kenney and Burne, 2001). Photographs and descriptions are provided to aid in the identification of eggs of indicator species by highlighting distinctive characteristics (Field Guide 4).

Amphibian larvae are often more difficult to identify to species than the egg masses. Several mole salamander larvae in particular are difficult to distinguish from one another. Photographs and descriptions are provided to aid in the identification of larvae of indicator species by highlighting distinctive characteristics (Field Guide 5).



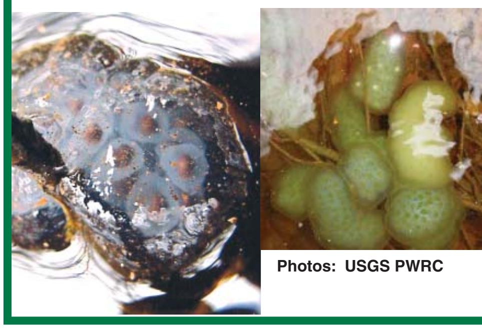
Comparison of relative dimensions of eggs. Spotted salamander eggs (left) exhibit a larger distance between the inner envelope and the vitelline membrane as compared to blue-spotted and Jefferson salamander eggs (right). This characteristic aids in field identification of eggs to the correct species of mole salamander.

Field Guide 4. Amphibian eggs in mid-Atlantic seasonal pools.*

SPECIES	DESCRIPTION	LOCATION

Spotted Salamander

of Eggs per Mass:
Average of 75 – 110
(total clutch up to 250)



Photos: USGS PWRC

DESCRIPTION	LOCATION
Clear or opaque white Globular to oval; very firm jelly-like matrix Large distance between inner envelope and vitelline membrane	Attached to sticks, stems, aquatic vegetation; up to 8 – 10 inches or more below water surface

Marbled Salamander

of Eggs per Mass:
Laid singly
(total clutch 37 – 130)

Photo: USGS PWRC

DESCRIPTION	LOCATION
Eggs often appear black due to clinging dirt Eggs laid singly in nest depression; no cohesive outer envelope, but eggs are grouped Eggs have a firm, sticky outer membrane	Nests located in dried seasonal pool beds; scoured in pool bottom or located in rodent burrows, beneath cover objects, or at water's edge

Eastern Tiger Salamander

of Eggs per Mass:
Average of 30 – 60
(total clutch up to 421)

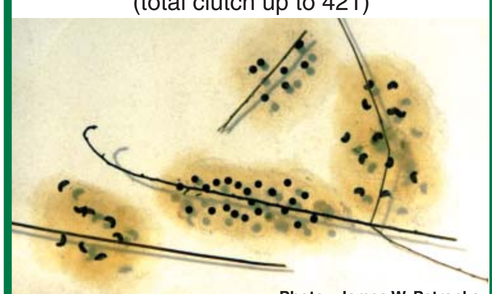
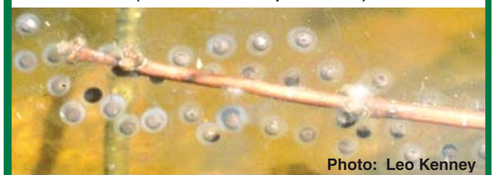
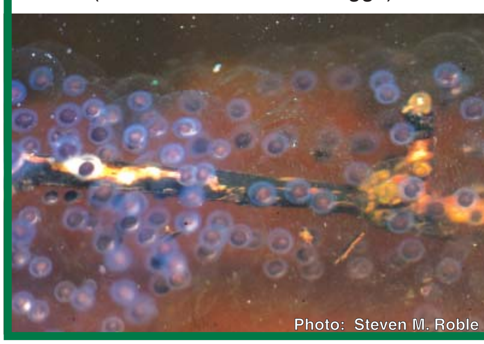


Photo: James W. Petranka

DESCRIPTION	LOCATION
Masses 2 – 2.8 inches diameter Globular or oblong; matrix initially very firm but becomes very loose	Attached to twigs, stems, and vegetation; in water greater than 8 inches deep

** Information on amphibian eggs was primarily derived from Bishop (1941), Tyning (1990), Petranka (1998), and Kenney and Burne (2001).*

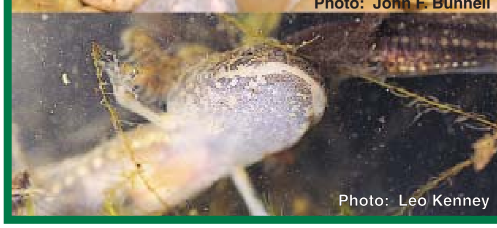
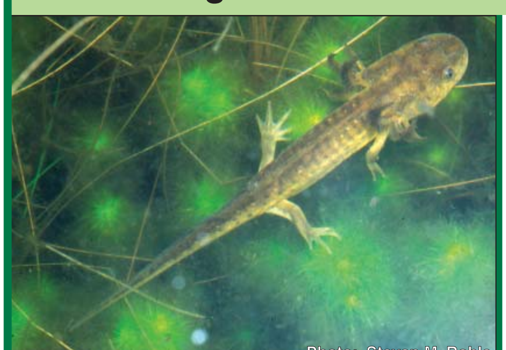
Field Guide 4. Amphibian eggs in mid-Atlantic seasonal pools.

SPECIES	DESCRIPTION	LOCATION
Jefferson Salamander		
# of Eggs per Mass: 10 – 75 (total clutch up to 300)  Photo: Leo Kenney  Photo: Steven M. Roble	Masses clear and cryptic Cylindrical on branches and irregular on grasses; intermediate firm matrix	Attached to submerged branches or grasses
Blue-Spotted Salamander		
# of Eggs per Mass: 1 – 30 (total clutch 100 – 500 eggs)  Photo: Steven M. Roble	Masses clear Eggs laid singly, in strings of 2 – 4, or in poorly-defined masses of 2 – 30	Attached to submerged branches, stems, and leaves; 8 – 10 inches below surface or on pool floor
Mabee's Salamander		
# of Eggs per Mass: 2 – 6 (total clutch size unknown)  Photo: Karen Sheffield	Eggs laid singly or in strings of 2 – 6	Attached to leaves, twigs, and debris in shallow pools

Field Guide 4. Amphibian eggs in mid-Atlantic seasonal pools.

SPECIES	DESCRIPTION	LOCATION
Mole Salamander		
# of Eggs per Mass: Laid singly (total clutch approx. 200 – 700)  Photo: Alvin Braswell	Eggs are darkly pigmented on top and white below Eggs laid singly or in small loose clusters	Attached to submerged twigs and stems in shallow pools
Wood Frog		
# of Eggs per Mass: 500 – 1000  Photo: USGS PWRC	Masses clear Globular; no outer jelly matrix; grape cluster appearance	Often attached to twigs and stems; often deposited communally; look like lumpy sheets just below water surface
Eastern Spadefoot		
# of Eggs per Mass: Up to 2500  Photo: John F. Bunnell	Strands or bands 1 – 2 inches wide and up to 12 inches long	Attached to underwater or floating vegetation in shallow pools

Field Guide 5. Amphibian larvae in mid-Atlantic seasonal pools.*

SPECIES	DESCRIPTION	NOTES
Spotted Salamander  Photos: Solon Morse, RTPI	Hatchlings dull olive; no markings Older larvae greenish-yellow with light ventral surface; no markings on chin and throat; tail fin mottled with black	More slender than blue-spotted larvae; bushier gills
Marbled Salamander  Photo: John F. Bunnell  Photo: Leo Kenney	Hatchlings light gray, becoming brown; row of light spots on sides below limbs Older larvae light olive to brown to almost black; pale spots on head and light yellow-green blotches on back and tail; throat and underside pigmented; row of light spots on sides below limbs	Throats darker than spotted larvae; largest mole salamander larvae in early spring due to earlier hatching
Eastern Tiger Salamander  Photo: Steven M. Roble	Hatchlings gray or yellowish green; dark bands along backs; white undersides Older larvae olive-green or dark brown with black markings; light underside; throats generally lack pigment	Flattened spade- or triangular- shaped toes; all other mole salamanders have rounded toes; larger-sized than other species of mole salamander larvae

** Information on amphibian larvae was primarily derived from Bishop (1941), Tyning (1990), Petranka (1998), and Kenney and Burne (2001).*

Field Guide 5. Amphibian larvae in mid-Atlantic seasonal pools.

SPECIES	DESCRIPTION	NOTES
Jefferson Salamander  Photo: Leo Kenney	Larvae olive green to brown; hints of yellow on sides of neck, head, dorsal fin Older larvae grayish with heavily mottled dorsal fins; broad heads; long toes; silvery or white belly	Difficult to distinguish from other mole salamander larvae
Blue-Spotted Salamander  Photo: Steven M. Roble  Photo: Solon Morse, RTPI	Hatchlings dark brown with a yellow stripe on each side Older larvae dark brown with yellow blotches; paired black spots on either side of tail fin on backs; light lateral bands on sides; unpigmented undersides; broad black-mottled tail fins	Difficult to distinguish from other mole salamander larvae
Mabee's Salamander  Photo: Steven M. Roble	Hatchlings brown with single yellow stripe on each side of body Older larvae brown to blackish with two cream stripes along sides; fins heavily mottled	Only occur in southeast Va. in the mid-Atlantic region

Field Guide 5. Amphibian larvae in mid-Atlantic seasonal pools.

SPECIES	DESCRIPTION	NOTES
Mole Salamander		
  Photos: Alvin Braswell	Hatchlings have black and yellow blotches on back midline and tail fin (above) Older larvae have two cream stripes on each side; on undersides there are single black lines (below)	Only occur in south-central Va. in the mid-Atlantic region The alternative adult form (paedomorph) is darker than the immature larva
Wood Frog		
 Photo: Solon Morse, RTPI	Hatchlings black Older larvae dark brown to blackish with gold fleck-ing; pale underbellies; light line along side of snout where mouth will later form; side of snout darker than rest of body	May form large schools in shallows
Eastern Spadefoot		
 Photo: John F. Bunnell	Dark brown to bronze; close-set eyes near top of head; tail fins translucent	Form dense schools

Appendix A
Techniques to Locate Seasonal Pools

Locating and mapping seasonal pools should be a conservation priority because an inventory of seasonal pool distribution and status is currently unavailable in the mid-Atlantic region. Appendix A gives an overview of techniques that can be used to locate seasonal pools, and points the reader to sources of additional information.

Step 1: Pre-Identification Techniques

The following methods are considered "pre-identification" techniques because they locate potential seasonal pools. These potential pools need to be verified to ascertain that they are indeed seasonal pools (see Step 2).

Aerial Photography

Description: Aerial photography is an unobtrusive method for locating landscape features, such as potential vernal pools, across a large geographic area (Stone, 1992; Jensen, 2000). Seasonal pool identification will be easiest if the photograph is taken during a relatively wet year in late fall, winter, or early spring when deciduous leaves are not on the trees and there is no snow. Larger-scale photographs are better suited for identifying seasonal pools. For example, photos at a scale of 1:4,800 (or 1 inch = 400 feet) are better than photos at a scale of 1:12,000 (or 1 inch = 1000 ft) for correctly identifying seasonal pools (Calhoun et al., 2003). Scales of at least 1:12,000 to 1:4,800 are necessary to identify potential seasonal pools.

Notes: Color infrared (CIR) or black and white film can be used for the aerial photographs (Plate 4-1). CIR is more useful because it highlights the presence of water. On CIR photos, pools appear black because water absorbs color infrared light, contrasting with lighter-colored vegetated areas (pink, orange, yellow). Compared to black and white, CIR film provides better differentiation between tree shadows and small pools, discrimination of depth and permanence of water, detection of pools under dense canopies, and differentiation of land-cover types (Stone, 1992).

The use of black and white aerial photography, though not as consistent and accurate as CIR, is also a valuable tool (and significantly less expensive than CIR). On black and white aerials, pools appear black, though they may also appear in various shades of gray if dominated by vegetation.

Utilizing stereoscopic sets of photographs (viewed with a stereoscope) allows analysis of the landscape in three-dimensions (Jensen, 2000). This technique greatly improves finding seasonal pools and depressions (Calhoun, 2003). Stereoscopes used in previous seasonal pool studies include a 2X pocket stereoscope and a mirror stereoscope (Stone, 1992; Pawlak, 1998). In a study in Massachusetts, 52% of potential vernal pools identified from 1:4,800 black and white photographs, using a 2X pocket stereoscope, were determined to fit the physical description of vernal pools (isolated depressions that hold water for two continuous months) after a field survey (Stone, 1992). In a study in deciduous forests of Maine, 93% of potential vernal pools identified from 1:4,800 scale black and white photographs, using panchromatic stereophotos, were determined to be actual vernal pools after a field survey (Calhoun et al., 2003).

A digital orthophoto quadrangle (DOQ) or quarter-quadrangle (DOQQ) is a computer-generated image of an aerial photograph which has been orthorectified (i.e., altered so that it has the geometric properties of a map) to allow accurate measurements of ground distance on the photos.

This ensures that the photos can be used with automated mapping and Geographic Information System (GIS) software along with other digital cartographic data.

Regardless of film types used, having assistance from someone with photo-interpretation training and experience with local ecology will greatly enhance the success of pre-identification aerial photography (Stone, 1992).

Challenges: Because seasonal pools are typically small, they may be difficult to identify on aerial photos (Tiner, 1990; DiMauro and Hunter, 2002). There are challenges to using aerial photographs: 1) available aerial photographs may be out of date or incomplete and scheduling a fly-over for new aerial photographs is very costly; 2) pools located under dense coniferous, deciduous or mixed canopy cover may be very difficult to pick out; 3) shadows of trees can obscure pools or be mistaken for pools; 4) clusters of conifers on black and white photos often show up as dark spots that look like pools; and 5) small pools are less likely to be identified compared to large pools (Stone, 1992; Calhoun et al., 2003).

Additional Resources: Burne (2001) provides detailed guidance on using aerial photographs to identify potential seasonal pools. Aerial photographs are typically available from federal, state, or county sources, or off the web (e.g., **USGS:** *http://geography.usgs.gov*, **USDA:** *http://www.nrcs.usda.gov/technical/maps.html*).

U.S. Geological Survey Topographic Maps

Description: The U.S. Geological Survey (USGS) produces topographic (topo) maps at a 1:24,000 scale (or 1 inch = 2000 feet), commonly known as 7.5-minute quadrangle maps. These maps utilize contour lines to convey the three-dimensional landscape on a two-dimensional map. Both natural and man-made features are shown on these maps.

Notes: On topo maps, seasonal pools may be associated with or identified by contours designating depressions, wet spot symbols, and small ponds. Concentrations of these features indicate particularly good areas to search for seasonal pools.

Challenges: Because seasonal pools tend to be small in size, only contain water for part of the year, and may be difficult to assess outside of a wet season, they often do not feature on USGS topo maps (Williams, 1987).

Additional Resources: Topographic maps can be purchased from outdoor equipment stores and bookstores or can be ordered from the USGS (*http://geography.usgs.gov*).

U.S. Fish & Wildlife Service National Wetland Inventory Maps

Description: The U.S. Fish and Wildlife Service began developing a series of topical maps of the United States' water resources in 1974 as part of a National Wetland Inventory (NWI) based on a wetland classification system developed by Cowardin et al. (1979) (NWI 2002).

Notes: On NWI maps, areas where seasonal pools are likely to be found can be identified by looking for: 1) wetlands not connected to streams or lakes, 2) wetland classes that are hydrologically isolated, including ponds (PUB (palustrine unconsolidated bottom), POW (palustrine open water)), marshes (PEM (palustrine emergent), PAB (palustrine aquatic bed)), wet meadows (PEM (palustrine emergent)), shrub swamps (PSS (palustrine scrub shrub)) or forested wetlands (PFO (palustrine forested)). In some cases, as on the USGS topo maps, large seasonal pools may be identified on NWI maps as ponds.

Challenges: Only forested wetlands greater than approximately 0.5 – 1.2 ha in size and unforested wetland areas greater than 0.4 ha in size are shown on NWI maps; most seasonal pools are smaller than these sizes and thus will be difficult to detect (Tiner, 1990; DiMauro and Hunter, 2002; Tiner, 2003a, b). NWI maps should not be the only source used to locate potential seasonal pools because they will disproportionately locate the largest pools.

Additional Resources: Full descriptions and definitions of NWI wetland codes (e.g., PFO1A) can be obtained on the NWI website (*http://www.nwi.fws.gov/mapcodes.htm*). Many NWI maps are now available in digital format for public use. A mapping tool called the Wetlands Mapper is offered by the U.S. Fish and Wildlife Service, which allows the user to produce customized maps (*http://wetlandsfws.er.usgs.gov*). Hard copies of NWI maps can be purchased from Cooperator-Run Distribution Centers (*http://wetlands.fws.gov/distribution_ctrs.htm*).

Step 2: Verification

Ground-truthing

Description: Ground-truthing (field surveying), the practice of surveying the land on foot, is essential for validating the presence of a seasonal pool. Ground-truthing is always required to verify whether what you have identified as a potential seasonal pool using an aerial photograph or map is indeed a seasonal pool. Additional pools not previously identified using aerial photographs or maps may be discovered during ground-truthing of potential pools. Ground-truthing can reveal as many as 25% more pools than identified from aerial photographs alone (Calhoun et al., 2003). In a study in Massachusetts, 79% of pools discovered in field surveys that were missed from aerial photographs were within 25 meters of other photo-selected pools (Stone, 1992).

Notes: Once having identified a potential seasonal pool on an aerial photograph, their location should be transferred onto maps to aid in field location (Stone, 1992). Photo-identified seasonal pools should be verified in the field early in the process, which can allow the photo-interpreter to correct or adjust the “search image” or “pool signature” to the conditions of the date and type of aerial photo used (Stone, 1992).

Alternative Techniques:

Systematic Ground-truthing

Description: Ground-truthing has been used to cover areas systematically.

Notes: Stone (1992) searched 201 m long by 20 m wide strip plots selected from a grid array using a stratified random design. DiMauro and Hunter (2002) and Calhoun et al. (2003) used 1200 m stratified random transects (500 m one direction, 200 m at 90 degree turn, 500 m at another 90 degree turn) within 1 km^2 grid squares to ascertain density and characteristics of pools not identified on aerial photographs or NWI maps. Because seasonal pools may be clustered in the landscape, ARMI-NE used an adaptive cluster sampling approach to survey for vernal pools at National Parks (Delaware Water Gap National Recreation Area, Gettysburg National Historic Park, Rock Creek Park, Shenandoah National Park) and National Wildlife Refuges (Canaan Valley, Erie, Great Swamp, Patuxent, Wallkill River) in the mid-Atlantic region. A systematic grid of points set 500 m apart was established on each Park or Refuge and sets of 20 points were randomly selected for survey. After navigating to a point, a 50 m^2 plot around that point was searched for seasonal pools. If no pools were found, the surveyor went to the next point. If pools were found, an adaptive cluster sampling approach was adopted, in which additional 50 m^2 plots adjacent to plots with vernal pools were surveyed, ad infinitum.

GIS-Modeling

Description: Several states and studies have used GIS technology to model the locations of vernal pools across the landscape.

Notes: In New Jersey, the Rutgers University Center for Remote Sensing & Spatial Analysis is using on-screen digitizing, image processing, and GIS coverages including freshwater wetlands, soil type, land use-land cover, digital elevation models, and color infrared digital orthophotography to identify likely areas of vernal pool occurrence. Once areas are identified using GIS, image interpretation and fieldwork were used to verify actual vernal pool occurrence in the Highlands, Pinelands, and Delaware Bayshore landscape regions (*http://www.dbcrssa.rutgers.edu/ims/vernal*). In Massachusetts, Grant (2005) used modeling approaches and found that certain landscape features such as land use, surficial geology, and topography could predict the occurrence of a seasonal pool. Stone (1992) found that the presence and amount of forest cover surrounding a pool, elevation, and surficial geology (glaciolacustrine lake bottom deposits) were characteristics useful in identifying areas with a high potential for supporting seasonal pools with indicator species.

Appendix B
Techniques to Monitor Seasonal Pools

This appendix outlines techniques that may be used to document a pool's location and to record what animals are using the pool. As highlighted in this manual, seasonal pools are a valuable resource, but their distribution is poorly recorded for the mid-Atlantic region. Information on their distribution and the species they support may be incorporated into a monitoring program or database. New Jersey currently has the only formal statewide program for seasonal pool documentation and certification in the mid-Atlantic region; their requirements for documentation are referred to among the techniques. For precise requirements of the New Jersey Department of Environmental Protection Land Use Regulation Program "vernal habitat," refer to the Freshwater Wetlands Vernal Habitat Protocol (*http://www.state.nj.us/dep/landuse/forms/vernalpr.doc or http://www.state.nj.us/dep/landuse/fww/vernal/index.html*).

Documenting the Location of a Seasonal Pool

Note: New Jersey requires 1) a metes and bounds description, aerial photograph, professional survey, or GPS coordinates; 2) a symbol on a standard map (USGS topo) to show the pool's location; and 3) a sketch map/written description.

Metes and Bounds Description

Provide written directions for locating the pool; include compass bearings and accurate measured distances (of 1000 feet or less) from at least two permanent landmarks. Also include distinctive permanent landmarks along the path of travel.

Aerial Photograph

If an aerial photograph is available on which the seasonal pool is clearly visible, highlight its location.

GPS Coordinates

Use a global positioning system (GPS) receiver and record UTM (Universal Transverse Mercator) or latitude and longitude coordinates along with an estimated position error.

Symbol on Standard Map

Mark the pool's location and two permanent landmarks on a photocopy of an 8.5" by 11" section of a USGS topographical map, a tax assessor's map, or a NWI map. Make sure that the map has all the information on it (e.g., quadrangle name, map scale) necessary to relocate the pool.

Sketch Map

Draw the pool relative to at least two permanent landmarks; include distances and compass bearings.

Photograph of the Pool

Take photographs of the pool in its landscape setting to aid relocation of the site and to document the pool's surroundings and hydroperiod at the time. Note the pool location, day and time of the photo, and the direction of the photo.

Finding and Documenting Indicator Species

It is difficult to estimate the population sizes of seasonal pool animals. Except during their brief and weather-dependent breeding seasons, adult pool-breeding amphibians are rarely observed above ground. During winter, adult amphibians hibernate beneath the leaf litter or in small mammal burrows, and thus appear absent from the surrounding landscape (Madison, 1997; Faccio, 2003). If breeding does occur, developing amphibians and invertebrates may be observed in the pool from late winter until they metamorphose or the pool dries out.

Note: To meet the "required field observations for certifying a vernal habitat" in New Jersey, obligate (indicator) or facultative species must be either 1) photographed, 2) videotaped, 3) audio recorded (in the case of frog and toad calling), or 4) described in writing.

Prractices to Prevent Negative Impacts to Pool Inhabitants

Handling of fauna should be avoided unless absolutely necessary for identification and photodocumentation (Box B-1). Handling amphibians presents challenges. Improper handing of amphibians may cause skin damage that could lead to secondary infections or may create bone and muscle injuries (Green, 2001). For detailed information on handling amphibians, refer to the USGS National Wildlife Health Center's Standard Operating Procedure (*http://www.nwhc.usgs.gov/research/amph_dc/sop_restraint.html*). Another major concern is the spread of disease-causing agents such as fungi, bacteria, and viruses between pools or animals. For more information on practices to prevent the spread of amphibian diseases, refer to The Declining Amphibian Population Task Force (DAPTF) Fieldwork Code of Practice (*http://ventura.fws.gov/es/protocols/dafta.pdf*).

Box B-1

Practices for safely handling and reducing disturbance to amphibians*

Do not disturb nesting or mating animals.

Rather than holding amphibians in your hands after capture, immediately place them in a zip lock bag or a plastic tub for a short period of time:

- Zip lock bags or plastic tubs must contain enough seasonal pool water to cover the gills and entire body of larvae.
- Lung-breathing adults should not be submerged and should have access to air as well as moist or wet areas within bags or tubs.

Avoid injury to animals:

- Do not handle amphibians with hands that have been applied with insect repellent or moisturizing lotions.
- Wet hands before handling amphibians to minimize damage to their outer protective layer of skin.
- Never hold or pull a salamander by its tail – it may break off.
- Return animals to their exact place of capture.
- When an animal is removed from beneath an object such as a log or stone, replace the object first, then release the animal next to it so it can crawl back under.

(Continued)

Avoid spreading disease:

- Wash hands thoroughly before and after handling an animal – especially before handling an animal from another pool.
- Thoroughly clean and disinfect boots, waders, nets and any other objects introduced into a pool between sites (remove all mud and debris; use bleach for disinfection).

Do not remove egg masses from the pool or detach them from vegetation:

- They are sensitive to water depth and location.
- The matrix that protects many egg masses may be disturbed with handling, increasing their susceptibility to predators or disease.
- If eggs do become detached, try to reattach them or situate them at the same depth and in the same area. Egg masses on the bottom of pools are subject to siltation and low dissolved oxygen concentrations and are less likely to hatch.

Avoid seining; it causes too much disturbance.

** Beebee, 1996; Green, 2001; White and White, 2002; Calhoun, 2003*

Evidence of Breeding Indicator Species

A minimum of two visits during daylight hours in the spring is recommended to document breeding indicator species at a seasonal pool. Visits during mid- and late summer are also recommended to document larvae and emerging juveniles and to determine whether the pool retained water long enough for successful population recruitment. Visiting pools at night may be treacherous and there is a greater chance for inadvertent disturbance to the pools. In general, avoid unnecessarily walking in or directly around the pool edge. If entering the pool, move slowly and carefully to avoid disturbing the habitat and animals or dislodging egg masses attached to branches in the water.

Evidence of seasonal pool use by indicator species includes the egg masses, larvae, and adults of ambystomatid salamanders, wood frogs, and eastern spadefoots and adult fairy shrimp. Suggestions for finding these species along with tips for photography are below. Unless required by a seasonal pool program that will lead to possible protection of the pool, we recommend taking a 'hands-off' approach to documenting the animals (e.g., photographing and identifying egg masses from the shore of the pool) to minimize impacts to these small ecosystems.

Amphibian Egg Masses: Identifying egg masses is a simple and low-impact way of recognizing use of the pool by indicator species. Refer to Fig. 3-2 to determine what time of year egg masses of indicator species are most likely present. Wearing polarized sunglasses increases clarity and depth of vision beneath the surface of the water. If vegetation is scarce, egg masses, particularly those of ambystomatid salamanders, may be on the bottom of the pool. Search for egg masses primarily in water depths less than three feet within three to ten feet of shore around fallen logs, vegetation or sticks/debris. Distinguish between egg masses of all indicator species in your area (Field Guide 4). Egg masses are best photographed using a polarizing filter on your camera. Wood frog egg masses tend to be in large communal rafts in the parts of the pool that receive the most sunlight and warm up and ice out the earliest.

Amphibian Larvae and Transforming Individuals: Salamander larvae can be easily distinguished from frog and toad larvae (tadpoles) – salamander larvae have bushy external gills while tadpoles do not (refer to Field Guide 5). Refer to Fig. 3-2 for what time of year larvae and transforming individuals of indicator species are most likely to be present. During the day, salamander larvae tend to hide on the bottom of the pool beneath vegetation and detritus. Wood frog and eastern spadefoot tadpoles often congregate in schools in shallow parts of the pool. Dipnets (aquarium dip nets or D-shaped dip nets) or scoops may be used to capture larvae; once captured, they should be transferred quickly into a water-filled container. Transformed individuals respire with lungs rather than gills so they should not be submerged in water. To photograph larvae, keep them in water in a container, place a white background behind the container, and use a camera with a polarized lens. Ideally, try to get photographs of larvae from above, the side, and below.

Adult Amphibians: Adult frogs and salamanders are best found by carefully searching the water's edge and the terrestrial area adjacent to the pool beneath logs, rocks, and other debris. Wood frogs may be found in the pool itself day or night during the breeding season when males are calling. In general, it is not necessary to handle these amphibians in order to identify them. If it is necessary to photograph adults for documentation, follow these suggestions for handling. Most salamanders in cool spring weather move slowly and can be caught by hand by gently grasping in the middle of the body between forelimbs and hindlimbs (Green, 2001). Hold them in your cupped wet hand or place them in a container with a moist surface (e.g., with wet leaves or shallow water). Frogs, however, will require an active pursuit, by quickly bringing a cupped hand over them on land or using a dipnet on land or in water. Hold frogs and toads gently but firmly around the waist with hindlimbs extended to prevent kicking (Green, 2001). Alternatively, place the frog or toad in a deep container or a container with a lid (so it can't leap or hop out) with a moist surface on the bottom. Photograph adults from slightly above and off to one side of the individual and try to fill the frame of the photo with the animal.

Fairy Shrimp: Adult fairy shrimp tend to be unpredictable in occurrence and their distribution is not at all well known for the mid-Atlantic region (see Field Guide for the life history of fairy shimp). Because fairy shrimp are delicate, it is best to catch and examine them using plastic tubs or bins dipped into the water, letting the water and fairy shrimp flow into the container. After describing and photographing them, gently release them back to the pool by submerging the container in the water and letting them swim out. For most purposes, identifying fairy shrimp as in the Order Anostraca is sufficient. Species identification is difficult and requires examining a male specimen under a dissecting microscope (see Belk, 1975 and Belk et al., 1998 for identification).

Appendix C
Programs to Locate, Map, Monitor, and/or Protect Seasonal Pools in the Mid-Atlantic Region

Appendix C gives an overview of seasonal pool-related projects, initiatives, and programs occurring in the mid-Atlantic region, including work carried out by nongovernmental organizations, state and local agencies, and federal agencies. Many universities are also carrying out related research on pool-breeding amphibians and invertebrates, but are not included in this summary.

Regional Programs

There are no comprehensive region-wide initiatives to locate, map, or monitor seasonal pools in the mid-Atlantic. However, efforts sponsored by the USGS span National Parks and National Wildlife Refuges across the region. The USGS Amphibian Research and Monitoring Initiative-Northeast region (ARMI-NE) is mapping seasonal pools and monitoring amphibians at the pools at selected National Parks (Delaware Water Gap National Recreation Area, Gettysburg National Historic Park, Rock Creek Park, Shenandoah National Park) and National Wildlife Refuges (Canaan Valley, Erie, Great Swamp, Patuxent, Wallkill River) in the mid-Atlantic region (see *http://www.pwrc.usgs.gov/nearmi* for more information). Also, scientists at the USGS Leetown Science Center (LSC) have mapped all and monitored many seasonal pools in Delaware Water Gap National Recreation Area.

Mid-Atlantic State and Local Programs

District of Columbia

We are aware of two efforts to locate and map seasonal pools taking place in D.C. ARMI-NE (see "Regional Programs") has mapped seasonal pools and monitors seasonal pool-breeding amphibians in Rock Creek Park, a 1755-acre National Park. The Nature Conservancy has mapped seasonal pools in the Potomac Gorge area of the Chesapeake and Ohio Canal National Historic Park that traverses both D.C. and Maryland.

Delaware

There has not been a program undertaken at the state level to locate, map, monitor, or protect seasonal pools in Delaware. However, state wetland maps and GIS data layers show locations of approximately 1,500 Coastal Plain Ponds (CPP) in Delaware (isolated wetlands that may be seasonal). Only CPP greater than 0.25 acre are comprehensively included, but some as small as 0.10 acre may also be included. The coding for CPP wetlands, which follows a modified National Wetlands Inventory and Cowardin et al. (1979) alpha-numeric scheme for a given polygon, includes palustrine forested (PFO), palustrine shrub-scrub (PSS), and palustrine emergent (PEM) categories followed by a "2". Contact staff at the Delaware Department of Natural Resources and Environmental Control, Division of Water Resources for more information (see *http://www.dnrec.state.de.us/water2000/DWRStaff1.asp* for current staff listing).

The Delaware Natural Heritage Program has natural community information about some CPP, particularly those in Kent and New Castle counties. A report produced by the Delaware Natural Heritage Program helped to determine criteria used to map CPP on the state wetland maps (McAvoy and Clancy, 1994).

The Delaware Chapter of The Nature Conservancy (DE TNC) produced a report which mapped and assessed the conservation status of Delmarva Bays in Delaware (Zankel and Olivero, 1999; copies of the report are available through the DE TNC). DE TNC used a more restrictive definition for these wetlands than was used at the state level for CPP.

Maryland

There has not been a program undertaken at the state level to locate, map, monitor, or protect seasonal pools in Maryland. Wetland geospatial data are available from the Maryland Department of Natural Resources at the 1:12,000 scale (MD DNR Geospatial Data from 1988-1995, GIS download from *http://dnrweb.dnr.state.md.us/gis/data/data.asp*). Wetland geospatial data include all photo-interpretable wetlands greater or equal to 0.5 acres (2,023 m^2), although some wetlands less than or equal to 3 acres (12,141 m^2) obscured by conifers may have been missed.

Some Nontidal Wetlands of Special State Concern identified by the Maryland Department of the Environment and the MD DNR are seasonal pools, especially on the lower coastal plain, but they are not indicated as such on the map (Paula Becker and Scott Smith, pers. comm.). The state typically only identifies vernal pools that have state-rare, threatened or endangered species in them and these seasonal pools are in the MD DNR Heritage Database.

The Montgomery County Department of Environmental Protection (DEP) and the Maryland-National Capital Park & Planning Commission (M-NCPPC) initiated a vernal pool mapping program in 2002 to map seasonal pools throughout Montgomery County, Maryland as part of the Countywide Stream Protection Strategy. DEP is developing a Biological Monitoring Database.

New Jersey

The New Jersey Department of Environmental Protection’s Endangered and Nongame Species Program established the Vernal Pool Survey Project in 2000. The project’s main objectives are to locate, map, and inventory seasonal pools statewide. Additionally, this initiative will monitor the pools’ amphibian populations utilizing a trained group of volunteers. Data collected by volunteers is entered into the Department of Environmental Protection’s land use regulatory databases, which are used to guide land use decisions (Tesauro, 2004).

The Center for Remote Sensing and Spatial Analysis (CRSSA) lab at Rutgers University is a collaborator in New Jersey’s Vernal Pool Survey Project. CRSSA is utilizing GIS data layers (e.g., soils, wetlands, geology) and various maps (e.g., digital elevation models, color orthophotography) to find areas where vernal pools are likely to occur. The Center scans high-resolution orthophotography of these hotspot areas to pinpoint potential vernal pool locations (see *www.dbcrssa.edu/ims/vernal* for more information).

Seasonal pools that are already certified in New Jersey are mapped (see *http://www.state.nj.us/dep/landuse/fww/vernal/index.html*). Volunteers continue to collect biological data about seasonal pools in New Jersey using Freshwater Wetlands Vernal Habitat Protocols (see Appendix B). Volunteer training sessions are held each year; the schedule is posted on their website.

Pennsylvania

In Pennsylvania, there are multiple ongoing collaborative efforts to learn more about seasonal pools and the biota they support. The Pennsylvania Department of Conservation and Natural Resources (DCNR) considers "vernal ponds" as "special habitat." Recently, a major program was initiated that will lead to a state-wide seasonal pool locating and monitoring program. The Pennsylvania Game Commission awarded a State Wildlife Grant to the Western Pennsylvania Conservancy (WPC) (*http://www.paconserve.org*) to develop a web-based seasonal pool registry and research program, beginning in the summer of 2005. This registry program will bring together academic institutions, non-profit organizations, state and federal agencies, and citizen volunteers to identify, locate, and study seasonal pools in Pennsylvania. This grant was awarded in response to DCNR's recognition that vernal pools are integral to the survival of many at-risk species of wildlife, and that the distribution and abundance of seasonal pools are currently unknown in Pennsylvania.

The Pennsylvania DCNR supports other efforts related to seasonal pool conservation and management through its Wildlife Resource Conservation Program (WRCP). In 2002, the WRCP collaborated with DCNR's Bureau of Forestry, The Nature Conservancy, and the WPC to fund a study constructing a set of biological criteria that would facilitate the classification and management of different types of seasonal pools in Pennsylvania. Other research projects include elucidating the population structure of seasonal pool-breeding amphibians using molecular genetics techniques and investigating the impacts of timber harvesting on woodland amphibians.

The Upper Susquehanna Coalition (USC), a network of natural resource professionals from three counties of Pennsylvania and twelve counties of New York that make up the headwaters of the Susquehanna River, has been extremely active in seasonal pool conservation. Through funds provided by the U.S. EPA in support of their ephemeral wetlands/seasonal pool program, USC is mapping pools throughout the upper Susquehanna watershed with the ultimate goal of mapping 940 pools. Additionally, the USC developed a seasonal pool assessment form in 2003, which facilitates a major data collection effort that began in spring of 2004. The seasonal pool assessment form is a GIS user interface that collects and organizes comprehensive information on the surveyed vernal pools. Some of this information will be automatically filled in according to location of data point. Other details recorded by the observer include: pool characteristics, site location, directions to the pool, area of the pool, surrounding habitat/land-use, water chemistry, vegetation and fauna data. For more information contact USC (*http://www.u-s-c.org/html/vernalpoolpage.htm*).

Virginia

There has not been a program undertaken at the state level to locate, map, monitor, or protect seasonal pools in Virginia. There have been exhaustive biological inventories of several seasonal pool systems, including a detailed description of the Shenandoah sinkhole pond system in Virginia (Buhlmann et al., 1999). The Grafton Ponds Sinkhole Complex has also been inventoried and mapped (Rawinski, 1997; Roble, 1998; Roble and Stevenson, 1998), and a comprehensive management plan is in development (Van Alstine et al., 2001).

West Virginia

There has not been a program undertaken at the state level to locate, map, monitor, or protect seasonal pools in West Virginia.

Appendix D
Sources of Additional Information on Seasonal Pools

Amphibian and Seasonal Pool Field Guides:

Altig, R., R.W. McDiarmid, K.A. Nichols, and P.C. Ustach. 1998. Tadpoles of the United States and Canada: A Tutorial and Key. Contemporary Herpetology Information Series 1998. Available from http://www.pwrc.usgs.gov/tadpole.

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White, J.F. and A.W. White. 2002. Amphibians and Reptiles of Delmarva. Tidewater Publishers, Centreville, Maryland.

Seasonal Pool Publications:

Biebighauser, T.R. 2002. A Guide to Creating Vernal Ponds. USDA Forest Service. Available from http://www.fs.fed.us/r8/boone/vernal.pdf.

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.

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

Colburn, E.A. 2004. Vernal pools: Natural history and conservation. McDonald & Woodward Publishing Company, Blacksburg, Va.

Williams, D.D. 1987. The Ecology of Temporary Waters. Timber Press, Portland, Oregon.

Seasonal Pool Educational Programs:

Roger Tory Peterson Institute. Vernal Pool Project: Teacher professional development and classroom pool surveys (http://vernalpools.rtpi.org).

The Vernal Pool Association. Online resources for teachers and students (http://www.vernalpool.org).

Vernal Pool Society of Virginia. The Spring Pools Institute: Field courses for adults and mature youth; Virginia's Disappearing Ponds: Traveling educational outreach (http://www.lynchburgbiz.com/virginiasvernalpools).

Amphibian Monitoring Programs:

Frogwatch USA, National Wildlife Federation (in partnership with USGS). Long-term, volunteer-based frog and toad monitoring program (http://www.nwf.org/frogwatchUSA).

North American Amphibian Monitoring Program, Patuxent Wildlife Research Center, USGS. Collaborative, volunteer-based vocal amphibians monitoring program (http://www.pwrc.usgs.gov/NAAMP).

Glossary

Acid deposition: Nitric acid or sulfuric acid pollution that is deposited in wet forms such as rain and sleet or dry forms including particulates and gases. Derived from chemical processes that transform nitrogen oxides and sulfur dioxide emissions from primarily anthropogenic sources (e.g., coal burning), although also from natural sources (e.g., volcanoes).

Aestivate: Refers to an animal that becomes dormant or torpid during hot summer months.

Amplexus: Copulatory behavior of frogs and toads; males clasp female partners from behind to fertilize the females' eggs as they are released.

Annual pool: Seasonal body of water that dries annually in typical years; they have hydroperiods from 2 months to 12 months.

Anthropogenic: Created by humans or as a side-effect of human activities.

Biodiversity: Shorthand for biological diversity; the variety and variability of life, at the genetic, species, and ecosystem level.

Biomass: The weight of total living organisms per unit of area or of a species' population per unit of area.

Breeding phenology: Reproductive-related activities that occur according to season; time frame in months when eggs, larvae, and metamorphs of amphibians are present at seasonal pools.

Cloaca: In many vertebrates, the cloaca is the last part of the digestive tract which receives feces and urogenital products. In certain invertebrates, the cloaca is a terminal portion of the digestive tract that also serves as respiratory, excretory, or reproductive tract.

Coniferous: Refers to trees that bears seeds in cones; the wood of these trees is known as softwood.

Crustaceans: Arthropods of the subphylum Crustacea; predominantly aquatic; characteristic exoskeleton, segmented body, and jointed limbs. Examples are crabs, amphipods, and fairy shrimp.

Deciduous: Refers to trees that lose all their leaves during cold seasons (e.g., fall and winter in the temperate zone).

Desiccation: Dehydration or the process of drying.

Detritus: Dead organic matter as well as decomposers such as bacteria and fungi associated with the dead organic matter.

Dormant: Refers to resting state when invertebrates and vertebrates undergo periods of reduced metabolic and respiratory activity.

Dorsal: The upper surface or back of an animal.

Dorsolateral: Pertaining to the back and side of an animal. Many species of true frogs have dorsolateral ridges, two ridges that begin at the eye and go all or partially down the back. Tadpoles of many species exhibit dorsolateral eyes, in which the eyes are located on the top but to the side of the head.

Endemic: Exclusively native to or confined to a certain region.

Ephemeral pool: Temporary body of water formed by intense periods of precipitation; hydroperiods less than two months.

Evapotranspiration: The combination of evaporation and transpiration referring to the total water loss from vegetative leaf surfaces and from the soil surface.

Facultative species: Organisms that use seasonal pools for obtaining food, water, temporary cover, or breeding, though they can also successfully breed in other habitats.

Habitat: The physical place, environmental conditions, and set of resources that a population (a group of individuals of the same species that are capable of interacting with each other in a localized area) utilizes.

Habitat Fragmentation: The process or occurrence of the breaking of a larger region of habitat into smaller patches of habitat. For example, a highway that is constructed through a forest creates forest fragmentation; the total area of forest, the size of the forest patches, and the connectedness of the forest decreases as a consequence.

Herpetofauna: Grouping of animals that is composed of amphibians and reptiles.

Hybrid: Progeny of a cross between two different species. For example, salamanders with chromosomes from both Jefferson and blue-spotted salamanders as a result of interbreeding between these two species are considered hybrids.

Hydrology: The scientific study of water, including the occurrence, properties, distribution, circulation and transport of water.

Hydroperiod: The duration of time when a wetland or other water body is saturated or covered with water.

Impervious: Refers to surfaces that do not allow the penetration of water and prevent precipitation and other water to infiltrate soils. Impervious materials include asphalt, concrete, brick and stone; impervious surfaces include rooftops, parking lots, roads, and buildings as well as highly compacted soils in urban areas.

Indicator species: Organisms that depend upon seasonal pools for optimal breeding conditions.

Invertebrates: Animals lacking a backbone or vertebrae.

Landscape connectivity: The extent to which the landscape facilitates wildlife movement.

Landscape: The traits, patterns, and structure of a specific geographic area (e.g., mountain range, watershed, state), including its biological composition, its physical environment, and its anthropogenic or social patterns.

Land use: The way land is developed and used in terms of the kinds of anthropogenic activities that occur (e.g., agricultural areas, industrial areas).

Larva: The immature stage of any animal species. Larvae are typically very different in body form and habit from the adults that they metamorphose into.

Life history: The entire progression of changes that an organism undergoes from inception or conception to death.

Metamorphosis: The dramatic transformation from a larva and/or juvenile form to an adult form; occurs in numerous invertebrates (e.g., insects) and vertebrates (e.g., amphibians).

Mole salamander: Of the family Ambystomatidae; this family contains 30 species of salamanders, seven of which are mid-Atlantic seasonal pool indicator species. The common name of *Ambystoma talpoideum*, one of these indicator species, is also 'mole salamander.'

Paedomorph: A sexually mature individual which fails to metamorphose, retaining its larval morphology; literally means "child-shape" or "underdeveloped."

Physiological: Relating to the science of the bodily functions or organic processes (e.g., metabolism, digestion, reproduction) of an organism.

Semipermanent pool: Body of water that undergoes seasonal fluctuations in water levels; they do not dry annually and have hydroperiods of greater than 12 months.

Spermatophore: A packet or "container" of sperm produced by male animals, which is subsequently taken up by or placed in or on the body of a female. Spermatophores are produced by male Ambystomatid salamanders.

Succession: The gradual change and replacement over time of one group of species in a community by other groups or of one set of conditions by another.

Ventral: The under surface or belly of an animal.

Watershed: The area of land from which runoff of water, sediments, and dissolved materials (e.g., nutrients, contaminants) drain into a river, lake, estuary, or ocean. Watersheds can be viewed at different scales, from very small (e.g., the area draining into a small stream) to very large (e.g., the entire Chesapeake Bay watershed of 64,000 square miles).

Wetland: Transitional areas where land-based and water-based ecosystems overlap. Wetlands are defined for regulatory purposes as "*those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.*" (This definition is from the U.S. Army Corps of Engineers Wetlands Delineation Manual and 33 Code of Federal Regulations 328.3(b)).

Zooplankton: Small, often microscopic animals that feed on detritus, phytoplankton, and other zooplankton and are preyed upon by zooplankton and other seasonal pool animals.

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