Science and Conservation of Vernal Pools

in Northeastern North America

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3 Hydrology and Landscape Connectivity of Vernal Pools

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CONTENTS

Hydrology is fundamental to wetland establishment and maintenance of wetland processes (Cole et al. 2002). Hydrology has been shown to affect, if not control, many aspects of wetland ecology, including litter decomposition and the accumulation of organic matter and sediment (Bärlocher et al. 1978), the composition and productivity of pool fauna (Paton and Couch 2002), and amphibian diversity (Burne and Griffin 2005).

Vernal pools are a type of wetland that normally experiences drawdowns and dry periods. Tiner (2003) notes that although alternating wet and dry periods occur in most wetlands, vernal pools experience extreme fluctuations in moisture conditions. This hydrologic variability, both within- and between-year, is a primary factor influencing species composition and productivity (Paton and Couch 2002).

Vernal pool organisms have special life history strategies for completing their life cycle under fluctuating wet and dry conditions (Chapter 6, Colburn et al., Colburn 2004). Despite these strategies, a pool species can go locally extinct if hydrologic conditions are sufficiently harsh. In spite of this, the biotic diversity of vernal pools can be maintained over time if local extinctions are offset by recolonizations from surrounding sites. This can occur through passive or active dispersal of organisms between pools, either over the ground or through the air. Recolonization may also occur, to a more limited extent, through surface-water connections. Landscape connectivity between vernal pools can be a major factor that influences recolonization of unoccupied pools.

This chapter examines the hydrology and landscape connectivity of vernal pools of glaciated northeastern North America. We begin by defining vernal pools and addressing their relationship to isolated wetlands. We then review the hydrology of northeastern pools, and population dynamics and landscape connectivity. The chapter concludes with a discussion of conservation implications.

DEFINITIONS

Northeastern vernal pools are temporary to semipermanent bodies of water occurring in shallow depressions that typically fill during the spring or fall and may dry during the summer or in drought years. These systems are bounded on the drier end by ephemeral pools that do not normally contain standing water, and on the wetter end by semipermanent ponds that only rarely dry (see Preface, Calhoun and deMaynadier). This book focuses on vernal pools associated with forests in the glaciated northeast of North America. Distinguishing features of these pools include fluctuating hydrologic conditions, presence of seasonally standing water, and occurrence within the glaciated forest biome (see Figure 1, Preface).

Vernal pools often occur as depressional wetlands surrounded by uplands. These pools conform to Tiner's (2003: 495) definition of a *geographically isolated wetland*: "wetlands that are completely surrounded by upland at the local scale." However, vernal pools are often embedded within larger wetlands, and they can also occur in floodplains (Preface, Calhoun and deMaynadier, and Chapter 2, Rheinhardt and Hollands). For example, Colburn (2004) reports that 7% of 48 vernal pools in the glaciated northeast were found in flood plain settings. Although they are often included as a type of isolated wetland (Tiner 2003), northeastern vernal pools do not have geographic isolation as a distinguishing feature.

VERNAL POOL HYDROLOGY

The hydrology of vernal pools is determined by patterns in precipitation and temperature, connections to ground- and surface-water resources, losses from evapotranspiration, and the physical and biotic features (including plant community composition and structure) of pool basins and catchments. Factors related to weather are external to the pools and vary with time; physical site characteristics are intrinsic to each pool, are essentially fixed, and vary spatially among pools.

The hydrology of vernal pools is characterized by both *hydroregime*, which is the temporal pattern of inundation, drying, and water-level change, and *hydroperiod*, or the duration of inundation (a component of hydroregime). The physical attributes of pools determine the general length of pool hydroperiod, whereas annual patterns in precipitation and temperature-driven evapotranspiration determine the year-to-year variation in hydroregime and hydroperiod.

In the following, we discuss the hydrologic budget of vernal pools, some of the physical characteristics of pools and their basins that affect pool hydrology, and their hydrologic dynamics and connectivity. As there are few published studies on the hydrology of northeastern vernal pools, we also draw on information from other ephemeral, ponded wetland systems.

Hydrologic Budget

The hydrology of vernal pools can be characterized by a simplified climate–water balance equation where the change in the amount of water in a pool is equal to the sum of inputs from precipitation, groundwater, and surface water, minus loss from evapotranspiration (Lide et al. 1995; Figure 3.1); note that groundwater or surface water inputs can be negative, representing net losses. Studies have shown that wetlands in different hydrogeologic and climatic settings vary considerably in the influence of these factors on the change in storage (Winter et al. 2001).

Precipitation

Precipitation is, almost by definition, a major source of water input to many types of wetlands such as vernal pools. Precipitation can enter a vernal pool directly at the pool surface or indirectly as surface runoff from the adjacent catchment during a rainfall event. In a 10-year study of geographically isolated pools in central Massachusetts, Brooks (2004) showed that amounts of weekly precipitation accounted for more than half the variation in the change in weekly pool depths. The importance of precipitation as a major water source has also been reported for some California vernal pools (Zedler 1987; Pyke 2004), Carolina bays (Lide et al. 1995), cypress pond–pine flatwood ecosystems (Mansell et al. 2000), Mississippi forest pools (Bonner et al. 1997), and prairie potholes (Hayashi et al. 1998).

Groundwater

Groundwater–surface water interactions occur in nearly all freshwater systems, including wetlands and vernal pools (Winter and LaBaugh 2003). The interactions

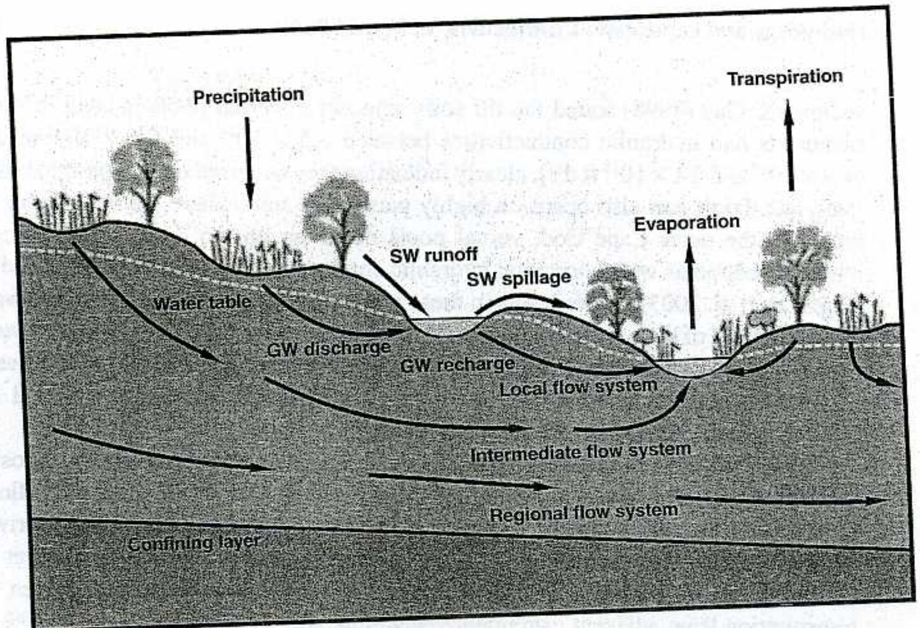

FIGURE 3.1 Schematic diagram illustrating elements of a vernal pool water budget. Inputs can include precipitation, ground water discharge, and surface-water runoff. Ground water can originate from local, intermediate, or regional flow systems. Outputs can include evaporation, transpiration, ground water discharge, and intermittent surface-water spillage. Vernal pools in riverine settings can also have stream input and output (not shown). (Adapted from Sando, S.K. (1996). South Dakota wetland resources. In Fretwell, J.D., Williams, J.S., and Redman, P.J. [compilers] National Water Summary on Wetland Resources. U.S. Geological Survey, Reston, VA. Water-Supply Paper 2425, pp. 351–356.)

are affected by the positions of the pools relative to groundwater level or flow and the geologic, climatic, and edaphic (soil-related) settings of the pools (Chapter 3, Rheinhardt and Hollands). Groundwater flow can occur at scales ranging from regional to local (Winter and LaBaugh 2003; Figure 3.1). On a regional scale, topographically high locations function as recharge areas and topographic lows are discharge areas. Local groundwater flow, relative elevations, and site-specific hydrologic processes also need to be considered and may have greater influence (Rains et al. 2006). Changes in direction of groundwater flow, from recharge (outflow of pool water to groundwater) to discharge (inflow of groundwater to the pool), are determined by the relative elevations of a pool and local groundwater. These directional changes are mostly climate driven, as long-term weather patterns control groundwater levels.

The hydraulic conductivity (rate of water movement through the soil) of pool basins and catchments depends on soil permeability and controls the exchange of pool water and groundwater (Winter and LaBaugh 2003). These authors suggest that a hydraulic conductivity of 0.3 m d^{-1} (1.0 ft d^{-1}) separates permeable from nonpermeable soils. Vernal pools often occur because local soils have relatively low hydraulic conductivity or because topographic depressions have filled with impervious sediments. Gay (1998) found the till soils adjacent to vernal pools in central Massachusetts had hydraulic conductivities between 1.5×10^{-3} and 6.4×10^{-6} m d^{-1} (4.9×10^{-3} and 2.1×10^{-5} ft d^{-1}), clearly indicating they occurred on low-permeability materials. Pools can also occur on highly permeable soils where the water table is high. On the outer Cape Cod, vernal pools occur on fine to coarse grain glacial outwash sediments with horizontal hydraulic conductivities of 100 m d^{-1} (328 ft d^{-1}) (Sobczak et al. 2003). Water levels in these pools match regional groundwater levels during periods of high groundwater levels. During periods of low groundwater levels, pool levels are perched above the ground water with exchange restricted by relatively impervious peat mats. At these times, pool water levels are largely affected by frequency and intensity of precipitation events.

Where it has been investigated, groundwater exchange appears to occur mostly at the pool margins, resulting in short groundwater flow paths (Phillips and Shedlock 1993). Loss of pool water to adjacent catchment groundwater seems to be driven mainly by transpiration from plants along the margins of the pools (Hayashi et al. 1998). In prairie potholes, lateral infiltration to shallow groundwater, driven by transpiration from adjacent catchment vegetation, was estimated to be up to 70% of total pool water loss in the summer months (Parsons et al. 2004).

Pool water specific conductance measures that are in excess of precipitation conductance values indicate the contribution of groundwater, which has a greater mineral concentration than precipitation or surface runoff. Palik et al. (2001) suggested that conductance measurements above 100 μS cm^{-1} indicate groundwater contributions for seasonal pools in Minnesota forests. For 65 vernal pools in Rhode Island, pool water conductance measurements ranged between 19 and 376 μS cm^{-1}, with a mean of 64 μS cm^{-1} (Skidds and Golet 2005).

Surface Water

Surface water can enter a pool through runoff or surface water inlets and exit through surface water outlets. There is no published quantification of surface water inputs to, or outflow from, geographically isolated vernal pools, and groundwater is assumed to be a more significant water source (Brooks 2005). However, surface runoff from the adjacent catchment should play a significant role during snow melt or rainfall events when soils are saturated (Chapter 2, Rheinhardt and Hollands, Colburn 2004). Small depressional wetlands that have low storage capacity, such as some vernal pools, are vulnerable to filling at these times, which can cause surface-water overflow or spillage. Whether spillage will enter neighboring water bodies depends on the volume of outflow, the distance to the neighboring surface water, the permeability of the soils over which the flow travels, and the elevational difference between the water bodies (Leibowitz and Vining 2003; Winter and LaBaugh 2003). Low-volume surface outflows will generally infiltrate into the ground before reaching neighboring waters. However, intermittent connections between isolated wetlands and other waters have been reported (Leibowitz 2003; Leibowitz and Vining 2003). In addition, vernal pools that occur within riverine settings are not strictly isolated and can be connected by surface waters from ephemeral or intermittent streams or be inundated by flooding of larger streams and rivers. Thus, surface-water