Nitrogen pollution of stormwater ponds: Potential for toxic effects on amphibian embryos and larvae

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Abstract. Runoff from impervious surfaces associated with areas of residential, commercial and industrial development is commonly managed through the construction of stormwater ponds that are designed to slow runoff and reduce pollutant inputs to streams. It has been suggested that stormwater ponds may also provide habitat for wildlife. However, wildlife attracted to ponds may be exposed to pollutants entering ponds in runoff. To assess the potential toxicity of nitrogen pollution of stormwater ponds to pond-breeding amphibians we monitored nitrogen levels in waters of eleven ponds in Baltimore County, Maryland. Levels of NH₃, NO₂⁻ and NO₃⁻ exceeded lowest sublethal effects concentrations reported in the literature in <2% of the water samples collected, and when relatively high concentrations did occur they were restricted to only a portion of the pond. Water sampling during and following rain events also indicated little input of nitrogen to stormwater ponds through runoff. While the number of amphibians recorded at ponds varied from three to six species, there was no relationship between nitrogen levels and amphibian occurrence at ponds. Overall, nitrogen pollution of stormwater ponds in our study area appears to represent little or no direct risk to developing embryos and larvae of pond-breeding amphibians, although indirect effects and interaction of inorganic nitrogen with other pollutants warrant further investigation.

Key words: Amphibians; pond-breeding; stormwater management; urbanization; water quality.

Introduction

Stormwater management basins are an integral part of the aquatic landscape in many urbanized areas. Semi-aquatic wildlife with limited dispersal ability, such as amphibians, may utilize stormwater basins as alternative habitat (Bascietto and Adams, 1983; Bishop et al., 2000a), and it has been suggested that stormwater basins may be acceptable wildlife habitat (Stahre and Urbonas, 1990; Butler and Davies, 2000). However, stormwater basins are designed to trap pollutants from stormwater runoff (Novotny, 1995), which may degrade their habitat value.
Inorganic nitrogen compounds are common pollutants in runoff from urbanized landscapes (Wren et al., 1997) and result primarily from fertilizer application and atmospheric deposition. Nitrate in aquatic ecosystems in North America may range from less than 1 mg NO$_3^-$·L$^{-1}$ to higher than 100 mg NO$_3^-$·L$^{-1}$ in extreme cases of anthropogenic disturbance (Rouse et al., 1999). Nitrite and NH$_3$ are more often associated with point sources of pollution (Rouse et al., 1999) and are less frequently encountered in runoff (Casey and Klaine, 2001).

Laboratory research has shown that low levels of NO$_3^-$ can be harmful to both larval and adult amphibians, with sensitivity varying among species and with duration of exposure (Rouse et al., 1999; Camargo et al., 2005). Sublethal effects have been observed at concentrations as low as 4.5 mg NO$_3^-$·L$^{-1}$ (Hatch and Blaustein, 2000), and lethal effects have been observed at 12.5 mg NO$_3^-$·L$^{-1}$ (Marco et al., 1999). Although less common in urban runoff, NO$_2^-$ and unionized NH$_3$ are both more toxic to amphibians than NO$_3^-$. Lethal effects from NO$_2^-$ and NH$_3$ exposures have been observed respectively at 0.33 mg NO$_2^-$·L$^{-1}$ (Huey and Beitinger, 1980) and 0.33 mg NH$_3$·L$^{-1}$ (as total NH$_3$; Schuytema and Nebeker, 1999a, b).

Because amphibians utilize stormwater basins for breeding and subsequent larval growth (Bascietto and Adams, 1983; Bishop et al., 2000a), the purpose of this study was to determine whether nitrogen pollution could reach levels toxic to developing amphibian larvae in retention ponds. We used water quality sampling, comparison of nitrogen levels with published values of water quality criteria, and the occurrence of amphibians at ponds to assess potential toxicity of inorganic nitrogen forms. If pond-breeding amphibians are attracted to retention ponds only to have eggs and larvae suffer high rates of mortality as a result of pollutants arriving at ponds in pulses of runoff during and following rain events, these habitats may act as ecological traps (Battin, 2004) for pond-breeding amphibians.

**Materials and Methods**

Water column NO$_3^-$, NO$_2^-$, and NH$_3$ concentrations and the occurrence of amphibians were investigated in 11 stormwater basins in the Red Run watershed, located in a rapidly developing suburb of Baltimore County, Maryland, USA. Land use in this area is primarily residential with approximately 5 stormwater basins km$^{-2}$ as of 2000 (J.W. Snodgrass, unpublished data).

Water samples were collected both seasonally and following storm events. Seasonal samples were collected at least four days following a rain event ($\geq 0.4$ cm precipitation as reported at Baltimore/Washington International Airport) from all sites that contained water in June 2001 (11 basins, 21 samples), October 2001 (9 basins, 27 samples), February 2002 (8 basins, 21 samples), and May 2002 (10 basins, 26 samples). These sampling dates encompassed the breeding and larval periods of all pond-breeding amphibians known to breed in our study area. Basins were sampled at three locations: 1) near an inflow, 2) near an outflow, and 3) in...