Glyphosate and other pesticides in vernal pools and streams in parks

HERBICIDES CONTAINING GLYPHOSATE are used in more than 130 countries on more than 100 crops (Monsanto 2009). Part of the reason for their popularity is the perception that glyphosate is an "environmentally benign" herbicide (Giesy et al. 2000; Duke and Powles 2008) that has low toxicity and little mobility or persistence in the environment. Recent studies, however, suggest that glyphosate is more mobile and occurs more widely in the environment than was previously thought (Battaglin et al. 2005; Baker et al. 2006; Kolpin et al. 2006; Scribner et al. 2007; Battaglin et al. 2008).

Glyphosate is a nonselective contact herbicide that kills plants by inhibiting synthesis of aromatic amino acids needed for protein formation. Glyphosate is the most commonly used pesticide for agriculture, and the second most commonly used pesticide for "home and garden" and "commercial and industrial" uses in the United States (Kiely et al. 2004). Glyphosate use in the United States has increased dramatically in recent years as a result of its use on soybean, cotton, and corn crops that have been genetically modified to tolerate it. In national parks and national wildlife refuges (parks), glyphosate has been recommended for control of some noxious or nonindigenous plant species in select settings. Deleterious effects on the development and survival of amphibians have been observed at various levels of exposure to commercial glyphosate formulations, in some cases at concentrations of 1,000 µg/L or less (Cauble and Wagner 2005; Edginton et al. 2004; Howe et al. 2004; Relyea 2005; Dinehart et al. 2009). Most of these studies indicate that commercial glyphosate formulations are more toxic than pure glyphosate due to the effects of the surfactants used (Howe et al. 2004: Bringolf et al. 2007). However, surfactant concentrations were not measured in this study (Battaglin et al. 2008) or any of the other studies referenced.

Vernal pools are sensitive environments that provide critical habitats for many species, including amphibians. In 2005 and 2006, water samples were collected from vernal pools and adjacent flowing waters in parks in Iowa, Washington, D.C., and Maryland, prior to and just after the local use of glyphosate (Battaglin et al. 2008). At each site there was a treatment pool (with adjacent glyphosate use), a control pool (with no glyphosate use nearby), and a flowing stream (with multiple potential glyphosate sources). In addition, a park in Wyoming was a study control with no reported glyphosate use nearby. Results indicate that vernal pools and adjacent streams can be contaminated by the use of herbicides within parks to control weeds in cropped areas or to kill noxious or nonindigenous plants. Contamination also originates from pesticide use occurring outside park boundaries (Battaglin

SUMMARIES (CONT'D)

et al. 2008). Glyphosate was detected in 31 of 76 samples with a maximum concentration of 328 µg/L, measured in a sample collected from a vernal pool in Rock Creek Park, Washington, D.C. That sample was collected seven days after glyphosate was applied by backpack sprayer in the area near the site to control lesser celandine (*Ranunculus ficaria*) and one day after approximately 3 cm of rain fell at the site. Glyphosate was not the only pesticide found; 27 other pesticides or pesticide degradation products, including atrazine, triclopyr, and 2,4-D, were detected at concentrations ranging from less than 0.01 to more than 10 µg/L. The results of this study provide a baseline of information on the occurrence of glyphosate and other pesticides in selected national parks and wildlife refuges that is relevant to studies of the ecology, hydrology, and biology of water-related habitats at those sites.

References

Baker, N. T., W. W. Stone, J. T. Wilson, and M. T. Meyer. 2006. Occurrence and transport of agricultural chemicals in Leary Weber Ditch Basin, Hancock County, Indiana, 2003–04. Scientific Investigations Report 2006-5251. U.S. Geological Survey, Washington, D.C., USA.

Battaglin, W. A., D. W. Kolpin, E. A. Scribner, K. M. Kuivila, and M. W. Sandstrom. 2005. Glyphosate, other herbicides, and transformation products in Midwestern streams, 2002. Journal of the American Water Resources Association 41(2):323–332.

Battaglin, W. A., K. C. Rice, M. J. Focazio, S. Salmons, and R. X. Barry. 2009. The occurrence of glyphosate, atrazine, and other pesticides in vernal pools and adjacent streams in Washington, D.C., Maryland, Iowa, and Wyoming, 2005–2006. Environmental Monitoring and Assessment 155:281–307.

Bringolf, R. B., W. G. Cope, S. Mosher, M. C. Barnhart, and D. Shea. 2007. Acute and chronic toxicity of glyphosate compounds to glochidia and juveniles of *Lampsilis siliquoidea* (Unionidae). Environmental Toxicology and Chemistry 26(10):2094–2100.

Cauble, K., and R. S. Wagner. 2005. Sublethal effects of herbicide glyphosate on amphibian metamorphosis and development. Bulletin of Environmental Contamination and Toxicology 75:429–435.

Dinehart, S. K., L. M. Smith, S. T. McMurry, T. A. Anderson, P. N. Smith, and D. A. Haukos. 2009. Toxicity of a glufosinate- and several glyphosate-based herbicides to juvenile amphibians from the Southern High Plains, USA. Science of the Total Environment 407:1065–1071.

Duke, S. O., and S. B. Powles. 2008. Mini-review Glyphosate: A once-in-a-century herbicide. Pest Management Science 64:319–325.

Edginton, A. N., P. M. Sheridan, G. R. Stephenson, D. G. Thompson, and H. J. Boermans. 2004. Comparative effects of pH and Vision® on two life stages of four anuran amphibian species. Environmental Toxicology and Chemistry 23(4):815–822.

Giesy, J. P., S. Dobson, and K. Solomon. 2000. Ecotoxicological risk assessment for Roundup® herbicide. Reviews of Environmental Contaminant Toxicology 167:35–120.

Howe, C. M., M. Berrill, B. D. Pauli, C. C. Helbing, K. Werry, and N. Veldhoen. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry 23(8):1928–1934.

Kiely, T., D. Donaldson, and A. Grube. 2004. Pesticide industry sales and usage: 2000 and 2001 market estimates. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances (7503C) EPA-733-R-04-001. Washington, D.C., USA.

Kolpin, D. W., E. M. Thurman, E. A. Lee, M. T. Meyer, E. T. Furlong, and S. T. Glassmeyer. 2006. Urban contributions of glyphosate and its degradate AMPA to streams in the United States. Science of the Total Environment 354:191–197.

Monsanto. 2005. Backgrounder: History of Monsanto's glyphosate herbicides. Available at http://www.monsanto.com/monsanto/content/products/productivity/roundup/back_history.pdf (accessed January 2009).

Relyea, R. A. 2005. The lethal impacts of Roundup® and predatory stress on six species of North American tadpoles. Archives of Environmental Contaminant Toxicology 48:351–357.

Scribner, E. A., W. A. Battaglin, R. J. Gilliom, and M. T. Meyer. 2007. Concentrations of glyphosate, its degradation product, aminomethylphosphonic acid, and glufosinate in ground- and surface-water, rainfall, and soil samples collected in the United States, 2001–2006. Scientific Investigations Report 2007-5122. U.S. Geological Survey, Washington, D.C., USA.

—William Battaglin
Research hydrologist, U.S. Geological Survey, Denver, Colorado. Contact: 303-236-4882, ext. 256; e-mail: wbattagl@usgs.gov.

▪ ▪ ▪