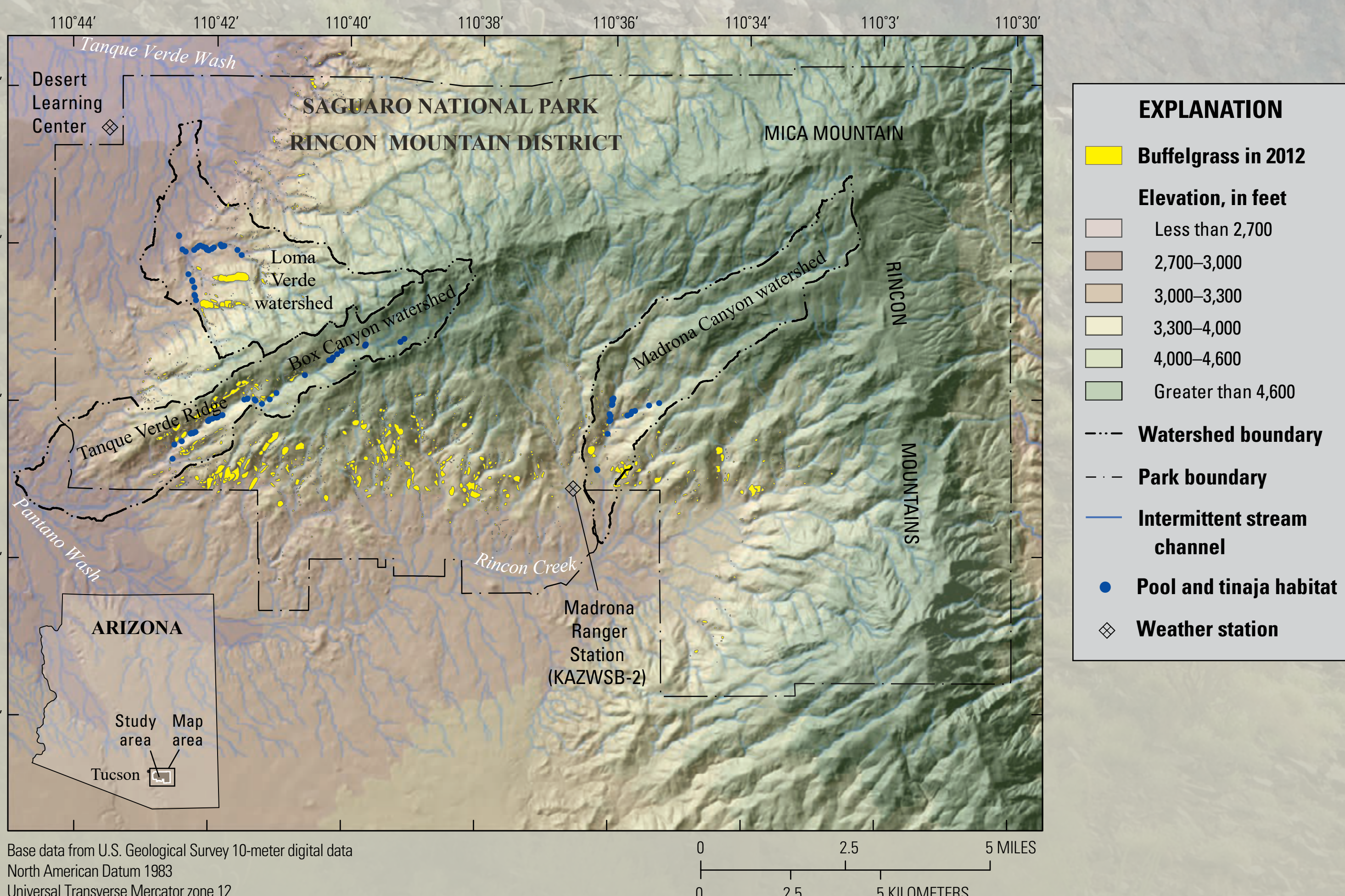
Occurrence and Transport of Aerially Applied Herbicides to Control Invasive Buffelgrass in Rincon Mountain District, Saguaro National Park, Arizona

Resource managers of the Saguaro National Park are concerned about the spread of the invasive species *Cenchrus ciliaris* L. (buffelgrass) and the threat it poses to desert ecosystems. Glyphosate-based herbicide treatments seem to be one of a few viable options to control the spread of buffelgrass in the mountainous terrain of the National Park. The U.S. Geological Survey completed a 4-year study with the National Park Service that investigated the potential for glyphosate and associated byproducts to remain in soil and transport with stormwater runoff to ecologically important surface waters after aerial application of glyphosate-based herbicides. The results of this study are helping managers and park administrators better understand the long-term effects of treating buffelgrass with glyphosate-based herbicides.

Introduction

In 2010, Saguaro National Park participated in a trial project to evaluate the effects of aerial application of glyphosate-based herbicides on dense areas of *Cenchrus ciliaris* L. (buffelgrass). In 2014, more than 250 acres of buffelgrass in the Rincon Mountain District, east of Tucson, Arizona, were treated with the aerial application of glyphosate-based herbicides. The aerial application was determined to be a successful strategy in managing the spread buffelgrass and continues to this day. However, the potential transport to and effects on aquatic ecosystems have never been fully assessed.

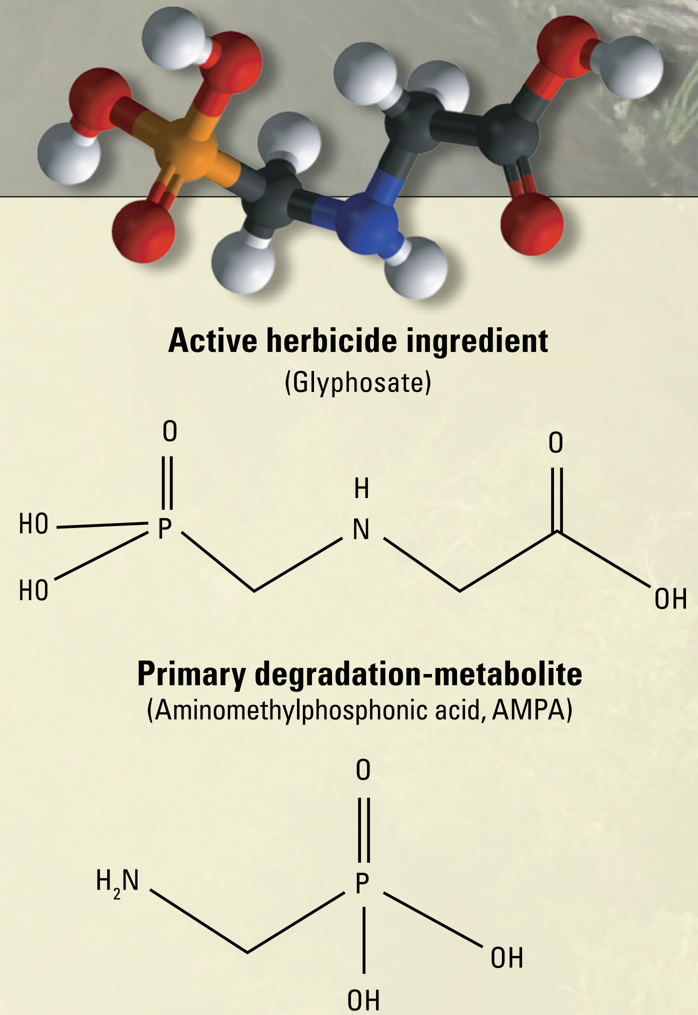


Map of Rincon Mountain District of Saguaro National Park, southern Arizona.

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2022–3029
July 2022

The U.S. Geological Survey (USGS), in cooperation with the Saguaro National Park, conducted a 4-year study (2015 to 2018; see https://doi.org/10.3133/sir20215039) to understand the occurrence, distribution, fate, and transport of glyphosate and its primary byproduct from degradation, aminomethylphosphonic acid (AMPA), in surface water and sediments that originated in areas subject to aerial glyphosate-based herbicide applications. Glyphosate itself has not been shown to be highly toxic in tested animal species, but the toxicity of trade-marked glyphosate formulations in herbicides include surfactants that have been shown to have adverse effects, particularly on amphibians. Surfactants are difficult to measure, and the presence of glyphosate during this study was used as a proxy for the presence of surfactants. The information gained through this 4-year study allows Saguaro National Park to identify unanticipated effects of the application program, like the transport of glyphosate-based herbicides to aquatic habitat, and to adjust its herbicide application approach to reduce or mitigate negative effects of the program on the aquatic ecosystem. The results from this investigation will also be important to other Federal, State, and local agencies when assessing their own buffelgrass remediation strategies.



Stick diagram and chemical structures of glyphosate and its primary byproduct from degradation, aminomethylphosphonic acid (AMPA). Stick diagram from Benjah-bmm27, 2016 (https://en.wikipedia.org/wiki/Glyphosate#/media/File:Glyphosate-3D-balls.png)

Approach: Measuring Glyphosate in Saguaro National Park

Three watersheds (Box Canyon, Madrona Canyon, and Loma Verde) in the Rincon Mountain District of Saguaro National Park have been treated with glyphosate-based herbicides since 2014. The study included collecting and analyzing samples of terrestrial soil, surface water, and of fine sediments found in water (silts and muck) from each of the three watersheds. USGS scientists used this information to help understand the transport and fate of glyphosate and AMPA from treatment areas to downstream canyon bedrock pools (also known as tinajas) and washes.

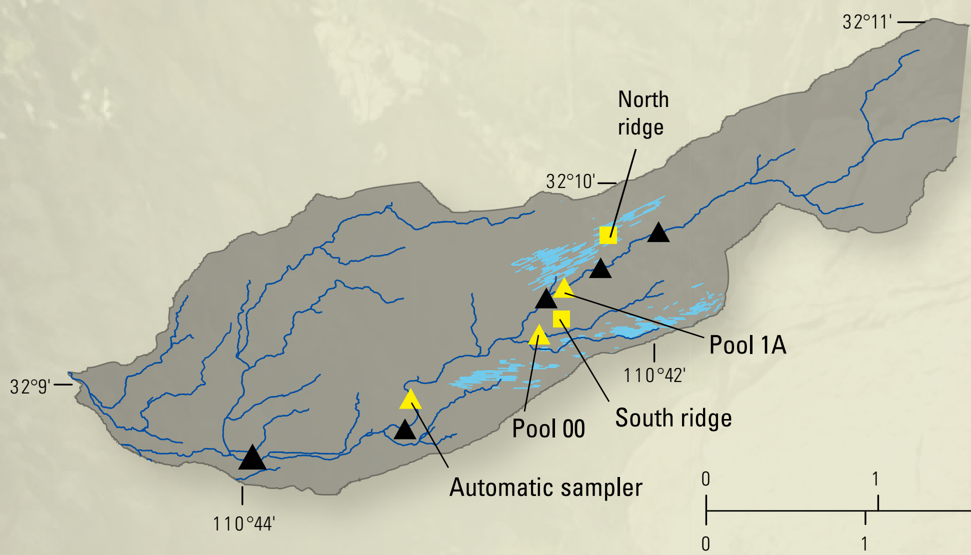
Results

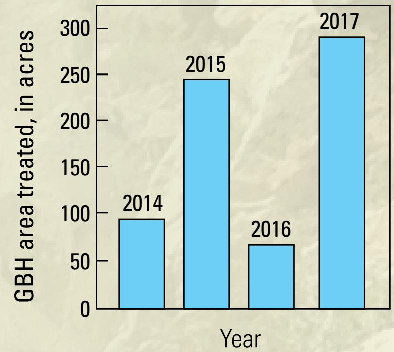
Water samples collected in all watersheds during baseflow conditions rarely had detectable concentrations of either glyphosate or the degradation byproduct of glyphosate, AMPA. About 19 percent (9 of 48) had one or both compounds present and six of those samples with detections came from a small tributary watershed to Box Canyon whose upper landscape was intensely treated with glyphosate-based herbicides (Pool 00). The timing of the detections indicates that sprayed debris and soils were washed into this canyon bedrock pool during runoff usually within a few months after treatment. Three samples found to have glyphosate or AMPA were collected during runoff events in the summer of 2017 in Madrona Canyon and the winter of 2018 in Box Canyon.

Glyphosate and AMPA often bind to sediment and soils, which necessitates sampling fine sediments in water. Detections of these two compounds in fine sediments and water samples followed a similar pattern. Roughly 25-percent of the sediment samples (7 of 28 samples) had detections of one or both compounds. Detections were mostly found in two pools in Box Canyon, one of which was the same small tributary where most of the glyphosate and AMPA detections were found in the water samples (Pool 00). The other was a series of pools (Box Canyon pool 01A, pool 01, and downstream of pool 01) below another heavily treated area. One fine sediment sample collected from a pool in Madrona Canyon (Lower Madrona Canyon pool 02) had glyphosate and AMPA detections, and this pool is documented lowland leopard frog habitat. Overall, the detection of glyphosate and AMPA in water and aquatic sediments was infrequent and appeared to be associated with stormwater runoff.

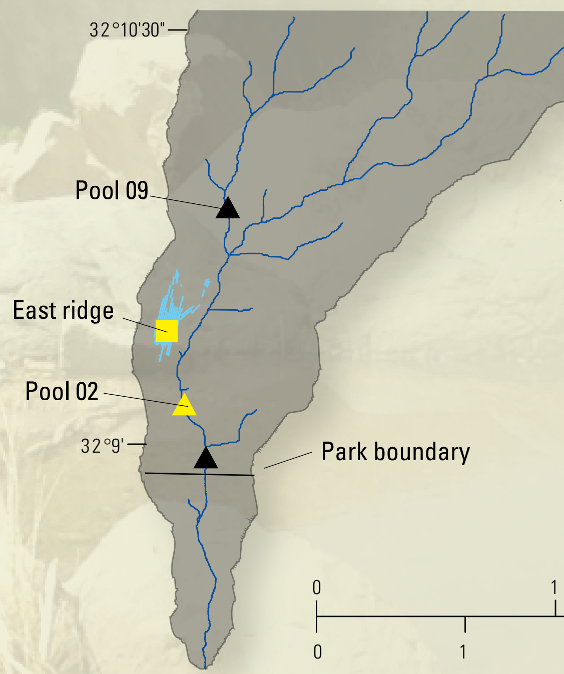
To better understand how glyphosate and AMPA are transported or dissipated after treatment, soils were sampled from the three watershed areas before and post-treatment application. One watershed, Loma Verde, had not been treated for about a year and a half (592 days) yet still had measurable amounts of glyphosate and AMPA. The concentrations were very low, which indicated that

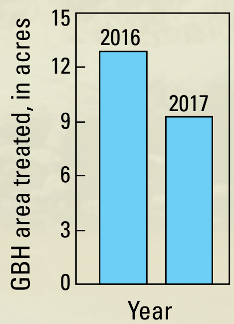
Box Canyon Watershed 2016–2017
Glyphosate-based herbicide application and sample collection





Madrona Canyon Watershed 2016
Glyphosate-based herbicide application and sample collection





EXPLANATION

- **Glyphosate-based herbicide treatment area**
- **Glyphosate and aminomethylphosphonic acid detected**
- **No detections**

Sample type

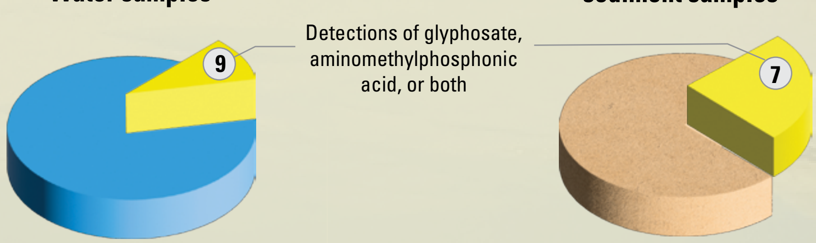
- △ Pools or surface water runoff- water and aquatic sediment samples
- □ Soil samples

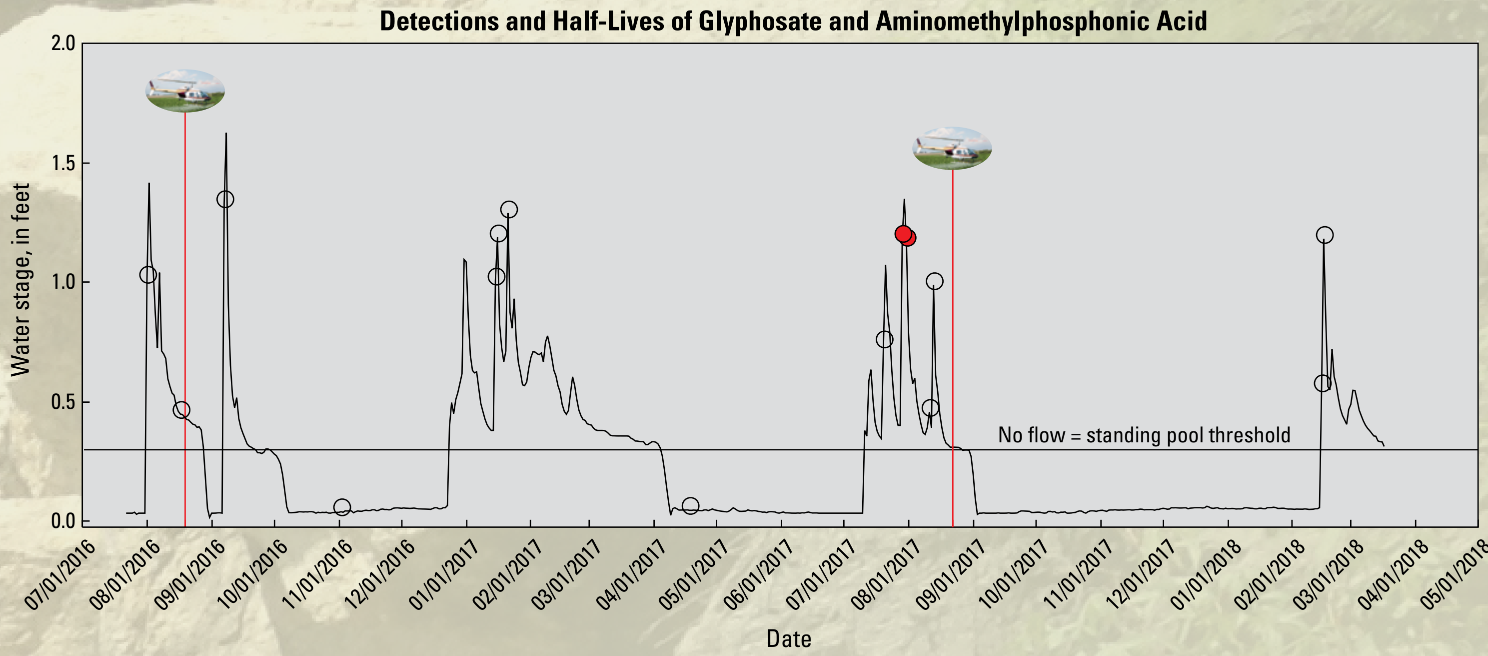
Maps and graphs showing areas sprayed with and detections of glyphosate-based herbicide (GBH).

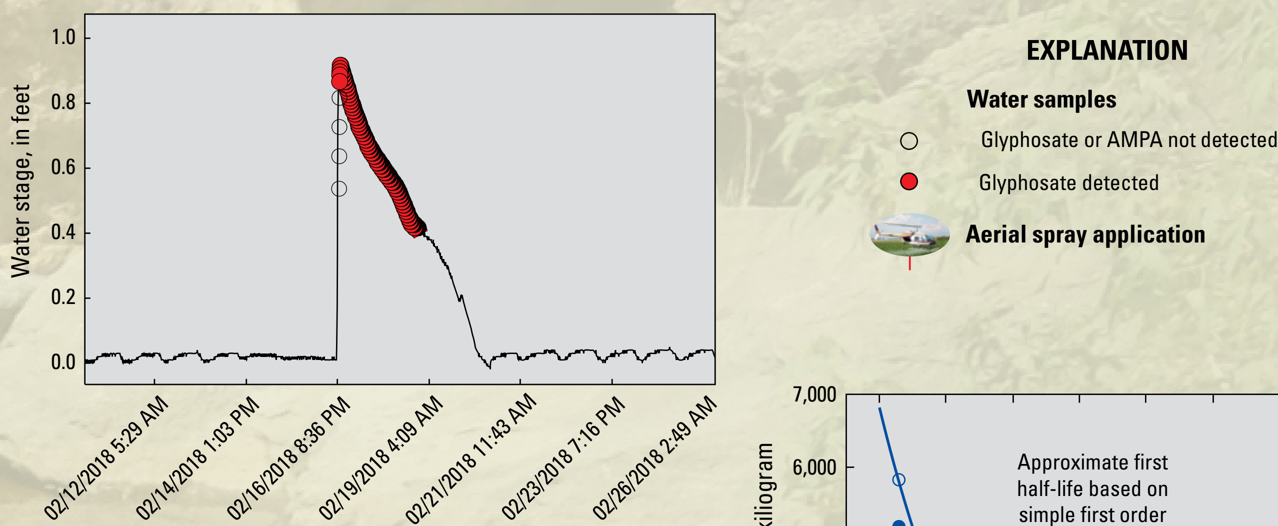
Detections of glyphosate, aminomethylphosphonic acid, or both (yellow) found in water (48 total) and fine aquatic sediment (28 total) samples using laboratory analytical methods.

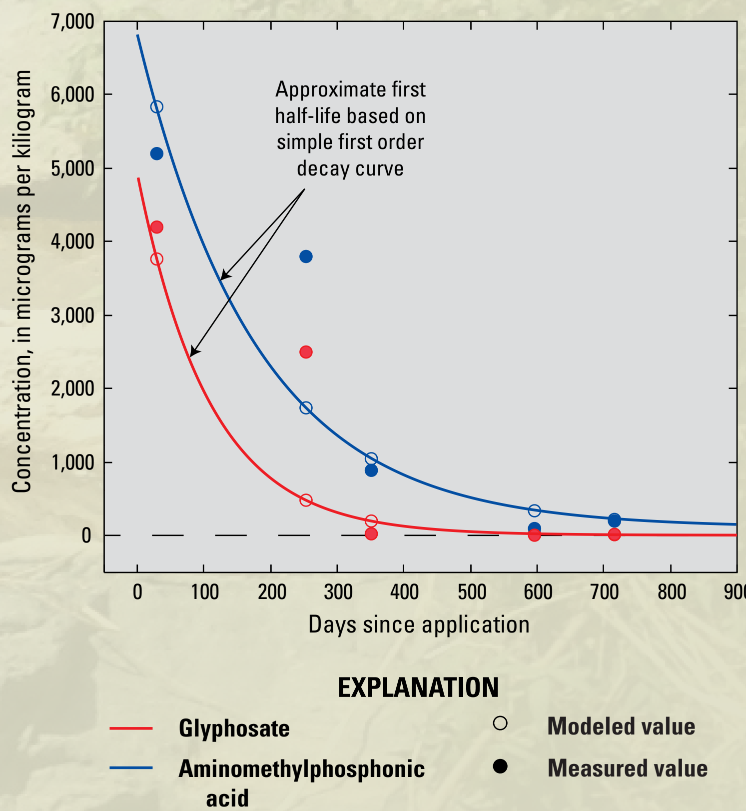
Water samples

Fine aqautic sediment samples









Water stage hydrographs for the Madrona Canyon (top) and Box Canyon (composite sample; middle left) watersheds showing the timing of detections and graph (right) showing half-lives of glyphosate and aminomethylphosphonic acid at about 75 and 125 days, respectively.

although these compounds are persistent, they dissipate over time, such as through microbial degradation. Two Box Canyon areas that received consistent yearly treatments were sampled multiple times during the study. The concentration information yielded estimates of the time it takes for half of the concentration of glyphosate and AMPA to disappear. These estimates were about 75 and 125 days for glyphosate and AMPA, respectively. Findings from the soil sampling suggested the areal extent and amount of herbicide sprayed was proportional to the likelihood of detecting one or both compounds downstream, especially after a stormwater runoff event.

Buffelgrass and its Effects

The most common type of buffelgrass found in southern Arizona originated in the Turkana region of northern Kenya and was introduced first into southern Arizona and later in the 1970s and 1980s in areas near Saguaro National park for erosion control. Buffelgrass was first recorded in Saguaro National Park in 1989, but it was not recognized as a threat until the early 1990s. By 2012, buffelgrass covered more than 2,000 acres at a rate of increase more than 25 percent per year.

Buffelgrass grows best on rocky hillsides and in desert washes from seeds dispersing by wind, water, or by attaching to passing animals. It grows rapidly, is fire adapted, burns easily and at relatively high temperatures, and outcompetes native vegetation. This leads to monocultural grasslands dominated by increased fuel loads that form multiple wildfire corridors throughout the region.

Historically, the Sonoran Desert burned infrequently as patchy non-intense fires because grass vegetation was sparse. Without mitigation, the increased frequency of large, high-temperature buffelgrass-fueled fires puts native Sonoran Desert vegetation and long-lived species, such as the iconic *Carnegia gigantea* (saguaro cacti), at risk. Other negative effects from these fires include accelerated erosion, increased sediment transport, and the destruction of scarce high-quality aquatic habitat in the Rincon Mountain District for which many sensitive species, such as *Lithobates yavapaiensis* (lowland leopard frog) depend.

Read about buffelgrass in Saguaro National Park at https://www.nps.gov/sagu/learn/nature/buffelgrass.htm and see a video of a buffelgrass fire at https://www.nps.gov/sagu/learn/nature/how-bad-are-buffelgrass-fires.htm.

Broader Context and Ecological Implications

Although large areas of the landscape were treated with glyphosate-based herbicides the findings from this study indicate that very little glyphosate and related compounds were transported downstream relative to the amounts sprayed. Glyphosate that was found in bedrock pools and in runoff waters occurred infrequently and in low concentrations, which indicates that the potential for compounds to transport a long distance downstream or recharge into the subsurface was minimized because the herbicide compounds attached to fine sediments likely remaining near the surface or dissipated after settling out in pools.

All measured water concentrations in the current study were far below any federal water quality criteria for drinking water standard (maximum contaminant level is 700 μg/L for glyphosate) or aquatic-life benchmarks (chronic levels of glyphosate for fish and invertebrates are 25,700 and 49,900 μg/L, respectively) established for surface water and freshwater organisms. The highest concentration recorded in this study was 0.2 μg/L, and about 90 percent of the water samples collected were below the analytical detection limit of 0.02 μg/L. Little is known however about the ecological effects of low-level concentrations, inconsistent exposure to glyphosate and AMPA, or multiple sources (water and sediment) of exposure within a semiarid aquatic ecosystem.

Although glyphosate shows little toxicity for several species studied, the added surfactant to many formulations is shown to be more harmful. Surfactants were added to glyphosate formulations used by Saguaro National Park to help the water and glyphosate mixture penetrate the protective surface of buffelgrass leaves and stems to increase the absorption of glyphosate. Unfortunately, surfactants are difficult to measure in the environment; surfactant concentrations were not measured during this study, but glyphosate detection was considered an indicator that surfactants were also likely present.

Although glyphosate concentrations measured in the samples collected in this study are likely to be of low toxicity particularly to the lowland leopard frog, future studies would benefit from a laboratory setting, where the focus can be on relevant concentrations consistent with those measured in the Rincon Mountain District to determine potential effects. A laboratory setting will help reduce the environmental variability that might be observed in frogs found in the wild, and in turn help scientists understand how timing of exposure might affect their metamorphosis.

Other USGS studies looking at the prevalence and occurrence of glyphosate

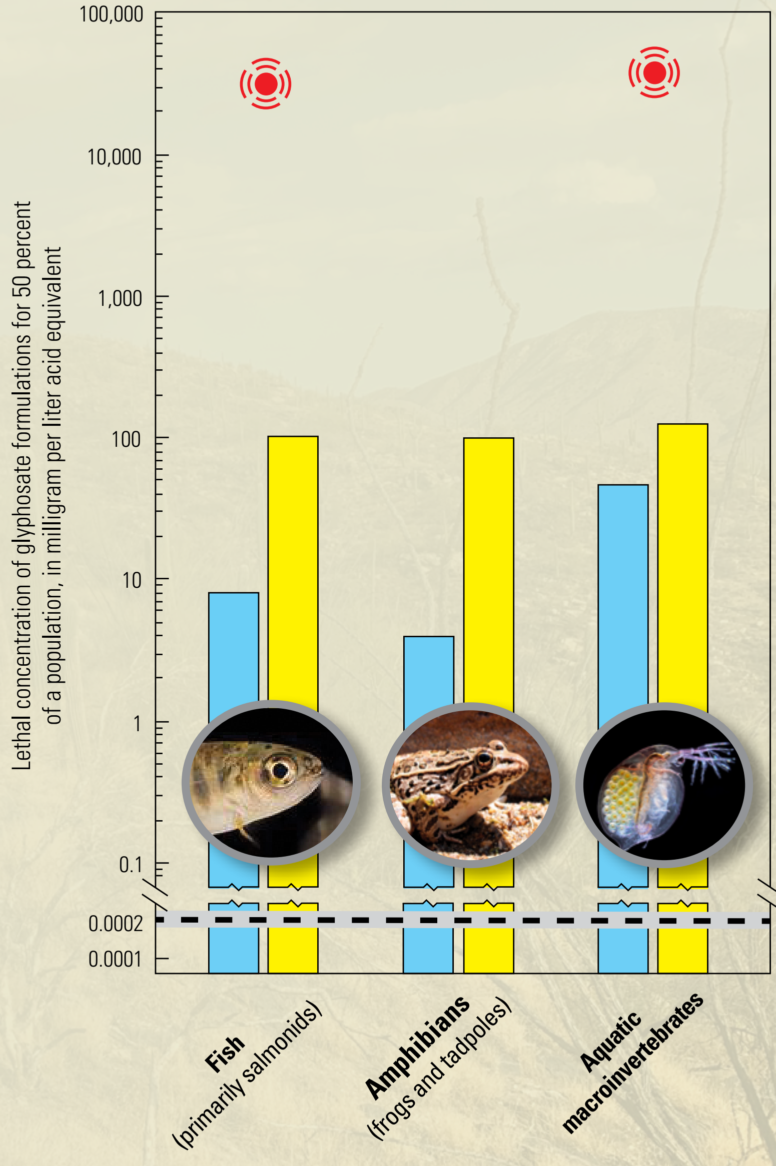
EXPLANATION

Median glyphosate lethal concentration from Durkin (2011)

- Glyphosate with surfactants and additives
- Glyphosate without surfactants and additives

Maximum concentration of glyphosate measured in Saguaro National Park water samples

Environmental Protection Agency acute toxicity



Comparison of lethal concentrations of glyphosate with and without surfactants and additives for three general groups of aquatic organisms. Formulation values detailed in Durkin (2011). Photograph of Salmonid from https://home.nps.gov. Photograph of Daphnia from shutterstock.com.

have primarily focused on areas affected by urban or agricultural land use. The treatment of buffelgrass with glyphosate-based herbicides in the Rincon Mountain District is a unique application. Unlike agricultural fields in the Midwest, treatments are once a year, in steep rocky terrain, and in the semi-arid conditions of the desert southwest. These factors may prolong chemical persistence but also reduce the potential for transport into groundwater and surface waters.

Nonetheless, for general comparison, the median and maximum water and sediment concentrations of glyphosate and AMPA found in this study were much lower than the same statistical measures from data compiled on areas affected by urban or agricultural land use. The comparison indicates that the aerial application approach used in Saguaro National Park is not resulting in the levels of glyphosate that are observed in runoff coming from an agricultural or urban setting.

Further Reading

Detailed discussion of specific datasets and data resources are provided in

Paretti, N.V., Beisner, K.R., Gungle, B., Meyer, M.T., Kunz, B.K., Hermosillo, E., Cederberg, J.R., and Mayo, J.P., 2021, Occurrence, fate, and transport of aerially applied herbicides to control invasive buffelgrass within Saguaro National Park Rincon Mountain District, Arizona, 2015–18: U.S. Geological Survey Scientific Investigations Report 2021–5039, 65 p., https://doi.org/10.3133/sir20215039.

Detailed discussion of lethal glyphosate values for select aquatic organisms can be found in

Durkin, P.R., 2011, Glyphosate—Human health and ecological risk assessment, final report: Syracuse Research Associated, Inc., administrative report SERA TR-052-22-03b, submitted to U.S. Department of Agriculture Forest Service, Southern Region, Atlanta, Ga., 313 p.

By *Nicholas V. Paretti* and *Bruce Gungle*
Edited by *Phil Frederick*
Layout and design by *Cory Hurd*

COOPERATING ORGANIZATIONS
National Park Service
Saguaro National Park

For more information:
Center Director (dc_az@usgs.gov)
Arizona Water Science
U.S. Geological Survey
520 N. Park Ave
Tucson, AZ 85719
https://az.water.usgs.gov/

https://answers.usgs.gov
1-888-ASK-USGS
(1-888-275-8747)

ISSN 2327-6916 (print)
ISSN 2327-6932 (online)
https://doi.org/10.3133/fs20223029