**PROJECT TITLE: Is glyphosate causing harmful algal blooms?**

**I. PROJECT STATEMENT:** Cyanobacteria, i.e. blue-green algae, and other harmful algal bloom (HAB) species are increasingly problematic in Minnesota waters. These HABs deplete dissolved oxygen concentrations in lakes and rivers, leading to fish kills, extirpation of game and forage fish species and exacerbation of water quality issues via production of toxins, increased metals concentrations and increased availability of nutrients such as phosphorus. The US EPA estimates that HABs reduce economic output in the US by well over $5 billion due to effects on tourism, commercial fishing, property values, human health, drinking water treatment and mitigation. If we are ever going to be able to manage the increased frequency, duration and impact of HABs, we need to determine what factors are causing them to become increasingly prevalent.

One contributing factor that we will examine in this project is the impact of the herbicide glyphosate, aka, Roundup. Since it was introduced in the 1970s, glyphosate has become the world's most widely used herbicide with global usage rates now at nearly 9 billion kg, and Minnesota is among the regions of the world where this herbicide is used at the highest rates. Glyphosate is an organic phosphorus (P) compound that, in addition to inhibiting plant growth, can be used by some organisms as a nutrient. In fact, recent observations indicate that the amount of P applied as glyphosate is about the same amount that led to the ban of P in detergents back in the 1970s. At the same time that the herbicidal effects of glyphosate are inhibiting growth of some algae that have less potential to form nuisance blooms and excrete toxins, it may actually be promoting the growth of other algal species by providing a readily available source of P. One of the main hypotheses that we will examine in this project is whether cyanobacteria have a selective advantage for using glyphosate as previous work has indicated that most blue-green algae have to capacity to metabolize phosphonates, the class of P compound that includes glyphosate.

In this project, we will use a combination of lab experiments and field work to determine what concentrations of glyphosate are inhibitory to various desirable and undesirable species of algae. We will also determine if the P in glyphosate stimulates algal growth. We will work with partners (MN PCA and Dept. Ag) to implement standards for glyphosate in waterways. **This research will help build MN Department of Agriculture’s existing dataset of glyphosate measurements in surface waters as well as determine whether glyphosate is contributing to HABs. It will also aid in setting standards for glyphosate in lakes and rivers.**

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1 Title: Determine inhibitory concentrations of glyphosate on prokaryotic and eukaryotic algae.****Description:**Isolates of algae will be obtained and grown under optimal conditions. Increasing concentrations of glyphosate will be added and growth efficiency and respiration measured by quantifying changes in carbon and oxygen pools. Glyphosate concentrations will be manipulated to observe effects on growth both in the short (hours) and long-term (days) to determine the threshold values of glyphosate that inhibit growth in these two groups of organisms. We hypothesize that blue-green algae should be more tolerant of glyphosate than other strains. **ENRTF BUDGET: $150,000**

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| **Outcome** | **Completion Date** |
| *1. Experiments to determine glyphosate inhibition concentrations for 15 blue-green algae species.* | *Fall 2020* |
| *2. Experiments to determine glyphosate inhibition concentrations for 15 eukaryote algae species.* | *Spring 2021* |
| *3. Work with MPCA to determine if thresholds should be adjusted* | *Spring 2021* |

**Activity 2 Title: Determine whether glyphosate is stimulatory to the growth of prokaryotic and eukaryotic algae.****Description:**Using isolates from Activity 1, we will determine if glyphosate can be used to promote the growth of the different strains of algae. Each strain will be grown under conditions where P is limiting to algal growth and glyphosate provided at varying concentrations. We will determine the amount of glyphosate taken up into algal cells. We will also grow mixed cultures that contain blue-green algae and other algae to ascertain whether glyphosate promotes algal communities dominated by blue greens. We hypothesize that blue-green algae should be more capable of using glyphosate as a P source than eukaryotic strains and as a result will outcompete eukaryotes in mixed cultures.**ENRTF BUDGET: $150,000**

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| **Outcome** | **Completion Date** |
| *1. Experiments to measure 15 blue-green algae species stimulation by glyphosate.* | *Fall 2021* |
| *2. Experiments to measure 15 eukaryote algae species stimulation by glyphosate.* | *Spring 2022* |
| *3. Determine how whole algae communities respond to low and high levels of glyphosate.* | *Fall 2022* |

**Activity 3 Title: Examine coupling between glyphosate loading and blue-green algae in Minnesota lakes.****Description:** We will collect samples from lakes in Minnesota to quantify the concentrations of glyphosate and its degradation products. We will seasonally survey lakes located in agricultural regions to capture run-off events and periods of herbicide application and quantify blue-green abundance. At each visit we will collect DNA samples to measure the abundance of genes related to glyphosate break-down and to characterize the microbial community. We hypothesize that blue-green algae that are able to breakdown glyphosate will be more abundant in glyphosate-rich lakes in agricultural landscapes. **ENRTF BUDGET: $127,000** |  |
| **Outcome** | **Completion Date** |
| *1. Complete survey of lakes 25 DNR Sentinel lakes* | *Fall 2021* |
| *2. Analyze community data and determine if glyphosate-rich lakes are more likely to have harmful algal blooms.* | *Summer 2022* |
| *3. Establish and share seasonally resolved glyphosate concentrations with the Minnesota Department of Agriculture.* | *Summer 2022* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

Partners receiving funds: James Cotner, PhD (Project manager, Univ. Minnesota); Nicole Hayes, PhD (Collaborator, Univ. Minnesota), Brianna Loeks-Johnson (Collaborator, Univ. Minnesota), Joseph Rabaey (Collaborator, Univ. Minnesota); Partners not receiving funds: MN Dept. of Agriculture, MN DNR, MN PCA.

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

The proposed work expands the focus on novel contaminants in Minnesota’s freshwaters to include unexpected outcomes of agricultural pollutants. As discussed above, we will work with MN PCA to develop standards for glyphosate in freshwaters, which does not presently exist and we will share information on glyphosate with MN Dept. of Ag. We will seek additional funding for this work from MN Sea Grant and the National Science Foundation.