Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 082-B**

Is Glyphosate causing harmful Algal Blooms?

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 427,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

This project will determine if the widely used herbicide, glyphosate, is encouraging harmful algal blooms and degrading water quality in our lakes and streams by providing phosphorus to cyanobacteria.

Name: James Cotner

Sponsoring Organization: U of MN

Job Title: Professor

Department: Ecology, Evolution and Behavior

Address: 1479 Gortner, Dept. Ecology, Evolution and Behavior

St. Paul MN 55108

Telephone Number: (612) 625-1706

Email cotne002@umn.edu

Web Address: https://sites.google.com/umn.edu/jamescotner/home

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

It shows that glyphosate use is very high in Minnesota and suggests that high concentrations in our freshwaters may be contributing to blue-green algae blooms.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base	
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency	
_____ Capacity Readiness	_____ Leverage		_____ TOTAL	_____%

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

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

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

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.

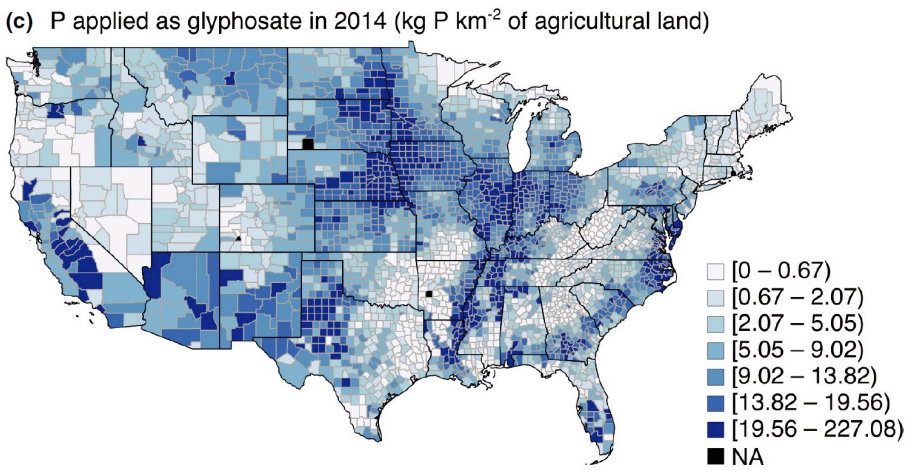
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: James Cotner
Project Title: Is glyphosate causing harmful algal blooms?
Organization: University of Minnesota
Project Budget: $427,000
Project Length and Completion Date: 3 years; 30 Jun 2023
Today's Date: 15 Apr 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 344,000	$ -	$ 344,000
Cotner (PI) - $51,000, 8% FTE, 1 mo/year (74% salary, 26% benefits)			
Post-doc (Hayes) - $106,000, 50% FTE, 6 mo/year (81% salary, 19% benefits)			
Graduate student (1) - $152,000, 50% FTE, 12 mo/year (53% salary, 47% benefits during the academic year and 86% salary, 14% benefits during the summer)			
Undergraduate students - $35,000 - One 25% FTE school year, Three 100% FTEs summer, (100% salary, 0% benefits)			
Professional/Technical/Service Contracts			
Equipment/Tools/Supplies	$ 38,000	$ -	$ 38,000
Phosphate analyses (500 samples times $8 per sample) - $4,000			
Chlorophyll analyses (500 samples times $8 per sample) - $4,000			
Particulate carbon analyses (500 samples times $10 per sample) - $5,000			
Dissolved carbon analyses (500 samples times $20 per sample) - $10,000			
Culture flasks (100)*$15 - $1,500			
Membrane inlet gas analyses $50 per hour * 1500 samples * 0.5 hours - $7,500			
Particulate P analyses (500 samples times $12 per sample) - $6,000			
Capital Expenditures Over $5,000			
Incubator with lighted shelves and shakers	$ 15,000	$ -	$ 15,000
Travel expenses in Minnesota			
Per diem @$55 for three people for 10 days, boat and vehicle rental - $9,000	$ 12,000	$ -	$ 12,000
Travel to regional conferences - $3,000			
Other	$ 18,000	$ -	$ 18,000
Glyphosate analyses: Barbara Cade-Menum Ag and Agri-food, Canada - $6,000			
Sequencing and qPCR at Univ. MN Genomics Center - $12,000			
COLUMN TOTAL	$ 427,000	$ -	$ 427,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Indirect costs associated with this proposal @ 54% MTDC		$ 196,000	$ -	$ 196,000

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

Is glyphosate greening our lakes?



9 billion kg of glyphosate (Roundup) applied globally; highest rates occur in Minnesota.

Glyphosate is a phosphorus (P) fertilizer; harmful algal blooms can use glyphosate for nutrition.

In lakes, does glyphosate act as a source of P for algae or act as an inhibitor of growth?

Glyphosate concentration

High → **Low**

Toxicity

- Inhibit growth of all algae

Blue-green algae blooms

- Inhibit growth of non blue-green algae
- Only blue-green algae can use glyphosate-P

Eutrophic, P-rich conditions

- No toxicity
- All taxa use glyphosate-P

Nutrient-poor lakes

- Limited nutrients
- Diverse taxa, limited blue-green algae

Outcomes: 1) determine glyphosate levels in MN lakes and 2) recommended glyphosate thresholds for lakes that will not stimulate blue-green algae.

Project Manager Qualifications and Organization Description

Project Manager: Dr. James Cotner, Professor, Department of Ecology, Evolution and Behavior, 1479 Gortner, St. Paul 55108, 612-625-1706; cotne002@umn.edu

Education:
Ph.D., University of Michigan, Ann Arbor, 1990, Biology; (Major professor-Dr. Robert Wetzel-deceased).
M.Sc., Kent State University, Kent, Ohio, 1984, Biology; (Major professor-Dr. Robert Heath).
B.A., Wittenberg University, Springfield, Ohio, 1981, Biology.

Organization description: University of Minnesota, Twin Cities Campus; Education and research facility serving the entire state of Minnesota.

Project responsibilities: Professor Cotner will oversee all research activities and personnel. He will assist with the design and implementation of the project and communicate with managers and the Dept. of Agriculture.

Research Interest: Microbial ecology and biogeochemistry of wetlands and large lakes; human influences on water quality in wetlands and lakes.

Relevant Publications:

Ginger, Luke J., Kyle D. Zimmer, Brian R. Herwig, Mark A. Hanson, William O. Hobbs, Gaston E. Small, and James B. Cotner (2017) 'Watershed Versus Within-Lake Drivers of Nitrogen: Phosphorus Dynamics in Shallow Lakes', Ecological Applications, doi: 10.1002/eap.1599.

Phillips, K. N., C. M. Godwin, and J. B. Cotner. 2017. The Effects of Nutrient Imbalances and Temperature on the Biomass Stoichiometry of Freshwater Bacteria. Front. Microbiol. 8. doi:10.3389/fmicb.2017.01692

Cotner, JB, and EK Hall. "Comment on "A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus"." Science (New York, N.Y.) 332, no. 6034 (2011): doi:10.1126/science.1201943.

Kolka, R. K.; Mitchell, C.P.J.; Jeremiason, J. D.; Hines, N. A.; Grigal, D. F.; Engstrom, D. R.; Coleman-Wasik, J.K.; Nater, E. A.; Swain, E.B.; Monson, B. A.; Fleck, J. A.; Johnson, B.; Almendinger, J. E.; Branfireun, B. A.; Brezonik, P.L.; Cotner, J.B. 2011. Mercury cycling in peatland watersheds. In "Kolka, R.K.; Sebestyen, S. .; Verry, E. S.; Brooks, K.N., eds. Peatland biogeochemistry and watershed hydrology at the Marcell Experimental Forest. Boca Raton, FL: CRC Press: 349-370.

Cotner J.B., E.K. Hall, T. Scott and M. Heldal. 2010. Freshwater bacteria are stoichiometrically flexible with a nutrient composition similar to seston. Front. Microbio. doi: 10.3389/fmicb.2010.00132

Cory, R M, K McNeill, J B Cotner, A Amado, J M Purcell, and A G Marshall. 2010. Singlet Oxygen in the Coupled Photochemical and Biochemical Oxidation of Dissolved Organic Matter. Environmental Science & Technology 44: 3683-3689.

Tranvik, L.J., J.A. Downing, J.B. Cotner and others. 2009. Lakes and reservoirs as regulators of carbon cycling and climate. Limnology and Oceanography 54: 2298-2314.

Hall, E.K., A.R. Dzialowski, S. M. Stoxen, and J.B. Cotner. 2009. The effect of temperature on the coupling between phosphorus and growth in natural bacterioplankton communities. Limnology and Oceanography 54: 880-889.

Stets, E.G., and J.B. Cotner. Littoral zones as sources of biodegradable dissolved organic carbon in lakes. Canadian Journal of Fisheries and Aquatic Science 65 :2454-2460.

Cory, R.M., J.B. Cotner and K. McNeill. 2009. Quantifying interactions between singlet oxygen and aquatic fulvic acids. Environmental Science and Technology 43: 718-723.

Hall, E.K., C. Neuhauser and J.B. Cotner. 2008. Toward a mechanistic understanding of how natural bacterial communities respond to changes in temperature in aquatic ecosystems. ISME Journal 2: 471-481.

Stets, E.G. and J.B. Cotner. 2008. The influence of dissolved organic carbon on bacterial phosphorus uptake and bacteria-phytoplankton dynamics in two Minnesota lakes. Limnology and Oceanography 53: 137-147.