

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

Project Title:

ENRTF ID: 239-F

An Engineered Solution to Toxic Copper Coatings for Boats

Category: F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Sub-Category:

Total Project Budget: \$ 408,000

Proposed Project Time Period for the Funding Requested: June 30, 2022 (2 yrs)

Summary:

We propose to replace toxic antifouling coatings, and prevent the damage they cause, by developing a new and biologically advanced generation of coatings.

Name: Mikael Elias

Sponsoring Organization: U of MN

Job Title: Assistant professor, PhD

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

We propose to replace toxic antifouling coatings, and prevent the damage they cause, by developing a new and biologically advanced generation of coatings.

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



PROJECT TITLE: An engineered solution to toxic copper coatings for boats

I. PROJECT STATEMENT

Aquatic heavy metal pollution is a global problem that may pose a serious threat to human health and have adverse effects on aquatic environments. A major source of metal pollution is copper-rich coatings. These coatings are used worldwide and in Minnesota to prevent biofouling, the natural process by which aquatic organisms attach to boats, docks, and anchors. It is our goal to replace toxic coatings, and prevent the damage they cause, by developing a new and biologically advanced generation of coatings. These coatings will significantly reduce the heavy metal pollution in Minnesota waterways.

Heavy metals are a very potent source of aquatic pollution. Heavy metal pollution originates from mining, but also from other industrial uses such as metal-containing coatings. Heavy metals represent serious environmental and health threats as they can accumulate in the environment (e.g. in the sediments) but also in living organisms (e.g. in fat tissues). Even metals that are essential micronutrients such as copper, iron or zinc, are extremely poisonous when in excess. At the same time, chronic low exposures to metals have serious effects in the long run, affecting primarily the embryonic and larval stages, as demonstrated by studies on rainbow trout and the toxicity of 24-hour exposure to a low concentration of copper. If contaminated water is not properly treated, then these metals cause risks such as bioaccumulation that may prevent the safe consumption of commercial and recreational fish.

One use of heavy metals is in antifouling coatings. These coatings are for the prevention of biofouling, the spontaneous process by which aquatic organisms (e.g. bacteria, diatoms, algae, protozoan, sponges, mussels) colonize on the surface of submerged objects. To prevent biofouling, these coatings contain biocidal compounds to kill bacteria. The antifouling coating market is enormous: nearly \$9 billion in 2018 and growing 8% a year. About 85% of this market is copper-based coatings, formulated with up to 40% (weight/weight) copper oxides.

Regulations against these metal-containing coatings, and in particular those containing copper, are getting harsher both in Europe and in the US because of the highly toxic nature of the metals and the fact that they spontaneously leach out of these coatings [<https://echa.europa.eu/fr/information-on-chemicals/biocidal-active-substances>; Washington Senate Bill 5436, Recreational Water Vessels--Antifouling Paints; 2011; California Senate Bill 623, Vessels: Marine Antifouling Paint; 2011]. **In fact, the U.S Congress approved banning the sale and use of copper-containing coatings in 2011, which has been pushed back to Jan 1, 2021 due to the lack of suitable alternatives. Copper-containing coatings are a major cause of contamination in recreational waters such as harbors, marinas, and lakes. Therefore, new strategies are needed to replace these toxic coatings in Minnesota.**

We propose developing a highly innovative, ecologically safe antifouling coating that will prevent the adhesion of aquatic macroorganisms to solid surfaces. To achieve this goal, we will take advantage of our recent discovery of 100% biological and eco-friendly molecules that make surfaces less adhesive to aquatic species. Our initial pilot and field testing experiments on Lake Superior, in the Duluth-Superior Harbor (DSH), confirmed that coatings containing these eco-friendly molecules were not fouled by aquatic organisms. In addition, our compounds were found to outperform other widely used molecules in coatings.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Optimize the ecological antifouling coatings

ENRTF Budget: 170,000\$

We will optimize our coating formulation to improve the efficacy, stability, and durability of these coatings in aquatic environments. Experiments and tests will be performed at the University of Minnesota using water from the DSH and inland lakes to develop coatings that will later be field tested. Our goal is to make coating formulations containing our enzymatic biofouling inhibitors that are as durable as the best coatings currently available on the market.



**Environment and Natural Resources Trust Fund (ENRTF)
2020 Main Proposal**

Outcome	Completion Date
1. Improve the coating antifouling properties	November 1, 2020
2. Improve the coating durability	April 30, 2021

Activity 2: Conduct field experiments in the Duluth-Superior Harbor (DSH). **ENRTF BUDGET: 238,000\$**
 In these field tests, we will perform a head-to-head comparative test of our ecological coating and the highest performance coatings on the market by measuring the adhesion of biofouling species like algae and invasive species such as zebra mussels to these coated surfaces. Sample coupons (steel, fiberglass) will be taken out of the harbor and analyzed after 1, 2, 5, and 12 months of exposure.

Outcome	Completion Date
1. Sample preparation and installation in the harbor	July 30, 2021
2. Sampling and analysis of the samples.	June 30, 2022

III. PROJECT PARTNERS:

A. Project Team/Partners

The project will be carried out by a strong team that covers complementary areas. Collectively, our team’s expertise covers biochemistry, aquatic biology, environmental sciences, and engineering. The team consists of a Biochemistry Assistant Professor, Mikael Elias, a Biology Professor, Randall Hicks, and an engineering postdoctoral investigator. Dr. Elias discovered the biofouling inhibitory molecule, while Dr. Hicks has extensive expertise in microbiological processes underlining biofouling, and has performed field experiments in the DSH for many years. In collaboration with key strategic stakeholders in the field, including the Duluth Seaway Port Authority and a Minnesota company (AMI Consulting Engineers), our group has a unique collection of skills, expertise, knowledge and contacts to develop the coatings, perform the field testing, and collect the data that are necessary to transfer this technology to the market.

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Mikael Elias	Assistant Professor, PhD	University of Minnesota	Principal Investigator
Randal Hicks	Professor, PhD	University of Minnesota	Co-investigator

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

Our initial pilot and field testing experiments on Lake Superior, in the Duluth-Superior Harbor (DSH), confirmed that our coatings containing these eco-friendly molecules were not fouled by aquatic macroorganisms, and outperformed existing coatings. We now propose to take advantage of our competitive advantage (i.e., novel, potent, patent protected biofouling inhibitor) to refine these coatings and investigate their properties and performance during a longer field study in real conditions. This innovative project may lead to a viable solution that limits heavy metal pollution not only in Minnesota but worldwide. This type of technological breakthrough is essential to help preserve aquatic environments in Minnesota, as well as reduce risks to human health. We and other firms and stakeholders we have contacted feel that the future potential of this innovative technology is enormous.

V. TIME LINE REQUIREMENTS: This project will take 24 months to carry out as described above. Thereafter, it is expected that the products of the project to be handed off to state agencies and the private sector.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet



Legal Citation:

Project Manager: Mikael Elias

Project Title: An engineered solution to toxic copper coatings for boats

Organization: University of Minnesota

Project Budget: 408,000

Project Length and Completion Date: 2 years; June 30th 2022

Today's Date: 3/30/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET		Budget	Amount Spent	Balance
BUDGET ITEM				
Personnel (Wages and Benefits)		\$ 318,000	\$ -	\$ 318,000
Mikael Elias, project manager, PI: 8% time (75% salary; 25% benefits) 1 month/year (summer) for 2 years . Dr Elias will be in charge of the completion of all project activities. \$29,000				
Randall Hicks, co-PI: 8% time (75% salary; 25% benefits) 1.0 month/year (summer) for 2 years . \$31,000				
Postdoc Researcher 1: (82% salary, 18% benefits); 100% FTE for 2 years. Funds are requested for 2.0 year to support a postdoctoral fellow to fulfill activity 1 and 2. \$136,000				
Postdoc Researcher 2: (82% salary, 18% benefits); 100% FTE for 2 years. Funds are requested for 2.0 year to support a postdoctoral fellow to fulfill activity 1 and 2. \$122,000				
Professional/Technical/Service Contracts				
coupons, coupons holders, and coupons installation in the Duluth Superior Harbor to perform the experiments proposed in activity 2. Involves the hiring of professional divers. Core facility costs (DNA sequencing and protein production): will cover costs associated with the production of our biofouling inhibitor and with 'reading' the DNA of microbial communities in experiments to determine success of experiments. \$22,000/year x 2 years = \$44,000.		\$ 44,000	\$ -	\$ 44,000
Equipment/Tools/Supplies				
Funds are for producing and optimizing pesticide-degrading materials for lab testing, as well as routine lab supplies (chemicals, flasks, pipettors, disposable plasticware, for example test tubes and petri plates, as well as media needed for production of molecular biology reagents made in the lab). \$23,000/year x 2 years=\$46,000.		\$ 46,000	\$ -	\$ 46,000
COLUMN TOTAL		\$ 408,000	\$ -	\$ 408,000
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT				
	Status (secured or pending)	Budget	Spent	Balance
Non-State:				\$ -
State:				
In kind: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs.		211000	\$ -	\$ 211,000
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS				
	Amount legally obligated but not yet spent	Budget	Spent	Balance
		\$ -	\$ -	\$ -

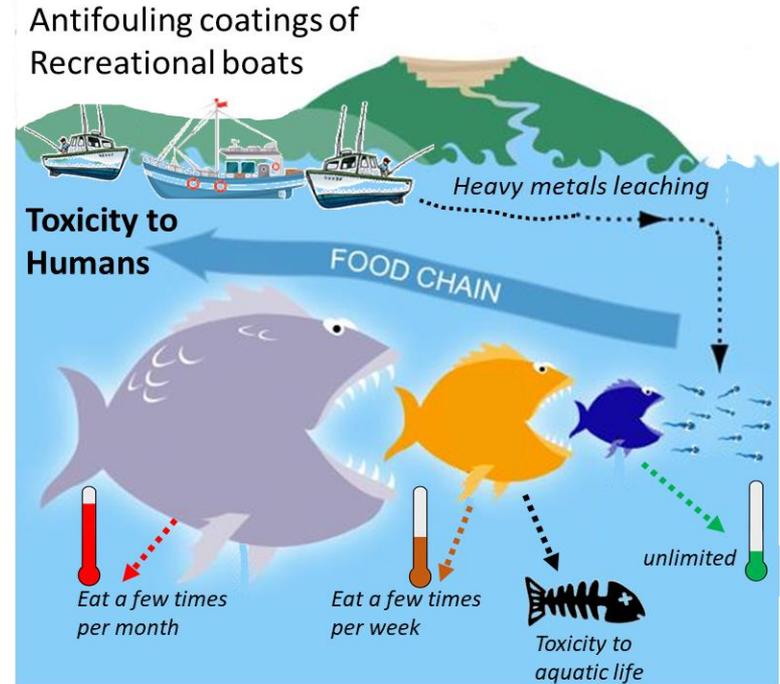
An engineered solution to toxic copper coatings for boats

Mikael Elias, Randall Hicks

Biofouling on recreational boat



Aquatic pollution caused by copper containing coatings and the accumulation of heavy metals



Our proposal: **Ecological, superior performance antifouling coating that replace toxic copper coatings for recreational and transport boats**

Ecological antifouling molecule



05/12/2019



ENRTF ID: 239-F

Eco-friendly, antifouling coatings

Management: The research team will include Prof. Mikael Elias, Prof. Randall Hicks. Prof. Elias will be the project manager. The team assembled has unique, and complementary, skills necessary to achieve the goals of the project. The specific expertise of each team member is described below.

Prof. Mikael Elias, PI, is an Assistant Professor in the Department of Biochemistry, Molecular Biology and Biophysics at the University of Minnesota. Elias has over 10 years of research experience on enzyme interfering with bacteria, producing 4 patents and >30 articles on this topic alone, including in prestigious journals (*JACS*, *Nature*, *PNAS*) and extensive know-how in protein engineering where he pioneered methods, such as the use of ancestral methods. He will invest most of his time on the project, and perform experiments and data analysis. Additionally, he reviews data and meets with laboratory personnel on a daily basis to promote the projects. He also prepares the dissemination of results, such as the proposed conference and publications. As the PI of the project, Dr. Elias will oversee the entire project, design the experiment plans, and draft the project reports.

Prof. Randall Hicks, co-PI is a Professor of Biology at the University of Minnesota Duluth (UMD). Dr. Hicks is an environmental microbiologist who studies the diversity and productivity of aquatic microbial communities, and the survival and virulence of pathogenic microbes in these communities. Much of his current research focuses on biocorrosion. This work has taken him to the bottom of different great lakes using a manned submersible, to Russia, Africa and various oceans, but his current research is focused on the North American Great Lakes. He has published over 40 scientific journal articles and book chapters. Dr. Hicks brings several decades of organizational experience and expertise ranging from heading a large academic department (UMD Biology; 1998-2006), organizing an international scientific conference (IAGLR 2011), to directing a university center (UMD Center for Freshwater Research and Policy; 2007-2011).

Organization: the University of Minnesota has several missions: improve lives through research, education, and outreach. The University possess extensive facilities that ensure high research performance. In particular, for this project:

• **Biotechnology Resource Center:** (<http://www.bti.umn.edu/brc/index.html>) A wide variety of bench-scale to pilot scale fermenters is available, up to 500L, and will be used in this project to produce cost-effective biomaterials.

Elias Lab: 1,800 sq. ft. of renovated research space is dedicated to Dr. Elias. This space is located on the 1st floor of the GortnerLab Building, on the St Paul campus. Elias's office space is adjacent to the laboratory. The lab contains all of the necessary equipment for molecular biology, biochemistry, protein production and purification, enzyme kinetics, and crystallography. Numerous facilities are available, such as microplate readers, spectrophotometers, scintillation counters, fplc, liquid nitrogen storage, -80 freezers, incubators/shakers, autoclave, as well as 4 and -20 rooms.

Hicks Lab: Dr. Hicks's research laboratory is located in the research wing of the Swenson Science Building (SSB 171) on the University of Minnesota Duluth campus. In addition to research laboratories, this wing has special rooms for culturing, epifluorescence microscopy, tissue culture, equipment rooms, cold rooms, and variable temperature rooms. There is a support room on each floor that has an autoclave, dishwasher, and pyrogen-free Milli-Q water system. Dr. Hicks's laboratory (~1,200 ft²) is equipped for research in the areas of microbial ecology, organic geochemistry, and molecular biology and includes computers and special software for genetic and phylogenetic analyses. The Department of Biology is well equipped for microbiological, limnological, and molecular biology research. In addition, his laboratory and this project have access to DNA sequencing facilities at the University of Minnesota Biomedical Genomics Center and the Minnesota Supercomputing Institute for analysis of DNA sequence data generated by this project.

The collective research, organizational, and administrative experiences of the project team members and the resources available to this project from the University of Minnesota should ensure the successful completion of the proposed project goals.