Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 143-D**

Innovative and Ecological Coatings to Mitigate Invasive Species

Category: D. Aquatic and Terrestrial Invasive Species

Total Project Budget: $ 321,500

Proposed Project Time Period for the Funding Requested: 2 years, July 2018 to June 2020

Summary:

We propose to develop innovative coatings containing a revolutionary antifouling biological molecule: these coatings will contribute to coastal economy competitiveness and to mitigate the spread of invasive species.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Proposal Strategy for Testing New Antifouling Coatings in Minnesota Waters

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

PROJECT TITLE: Innovative and Ecological Coatings to Mitigate Invasive Species

I. PROJECT STATEMENT

Synopsis: Biofouling is a natural phenomenon that sticks on structures, boats, docks, anchors. It adds costs to our coastal industries, and is a vector for the spread of numerous invasive species in Minnesota waters. We propose to develop a new generation of coatings containing a new antifouling biological molecule: these coatings will contribute to coastal economy competitiveness and to mitigate the spread of invasive species.

Biofouling is a spontaneous phenomenon of colonization of submerged natural or artificial structures by a broad spectrum of aquatic organisms (e.g. bacteria, diatoms, algae, protozoan, sponges, mussels). This natural process affects ships or pipes, port infrastructures and water treatment plants. This colonization has negative effects on the hydrodynamic performances of ships and their fuel consumption. It is mainly due to the added weight on the structure and an increased roughness of the surface. Biofouling also represents a significant risk for ecosystems because of its ability to host numerous organisms considered invasive on structures moved from a one body of water to another one.

The economies of coastal communities around the Great Lakes are profoundly affected by biofouling. They have historically been dependent upon maritime transportation. Shipping through the Duluth-Superior Harbor (DSH) (northern Minnesota), the largest port by total cargo volume in the Great Lakes, has a $1.5 billion annual impact on Minnesota's economy. And these economies are facing severe challenges that all have a biological origin – biofouling by aquatic plants and sessile invasive species like Zebra mussels. The DSH has 14 miles of structures, and biofouling has significant impact on industries, and specifically on the power industry that use water for cooling purposes. Maintenance of pipes clogged by Zebra mussels is estimated to cost $60 million annually in the Great Lakes, and the Zebra mussel invasion is estimated to cost industrial plants $3.1 billion from 2008-2018 (US State Department website). **Therefore, the need for new strategies to fight biofouling is critical for Minnesota's economy and environment.**

Here **we propose to develop a new ecological antifouling coating technology** that specifically targets bacteria forming the biofouling, and prevents them from attaching to any surfaces. Such a coating could reduce transportation costs, but also contribute to mitigation of invasive species by minimizing the possibilities of transferring them to new bodies of water when ships, pleasure craft, portable docks, and anchors and their chains are transferred to new bodies of water.

To achieve these objectives, we will take advantage of our recent discovery of a natural biofouling inhibitor. This molecule is harmless to bacteria, as well as to any living organisms: it simply disrupts bacterial communication. Without any ability to communicate, bacteria are unable to attach to surfaces, biofouling cannot form, and organisms like Zebra mussels cannot subsequently attach. This molecule has a tremendous potential for translated research in numerous fields, and was recently recognized by the University of Minnesota with an Early Innovator Award given to Dr. Elias. We will develop coatings formulations in the lab, and conduct pilot and field testing experiments on Lake Superior, in the Duluth-Superior Harbor (DSH). In collaboration with key strategic stakeholders in the field, including the Duluth Seaway Port Authority, a Minnesota company (AMI Consulting Engineers), a French company (Gene&GreenTK), and the Minnesota painters union, our group has a unique collection of skills, expertise, knowledge and contacts to collect the necessary data that are necessary to transfer this technology to the market.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Improve our current enzymatic antifouling coatings **Budget: $153,250**

We will optimize our coating formulation to improve efficacy, stability, and durability of the coating. Tests will be performed in the lab in water, and in water from the DSH. The goal is to make coating formulations containing our enzymatic biofouling inhibitors that are as durable as the best coatings on the market (2 years).

Outcome	Completion Date

1. Improve the coating antifouling properties	November 1, 2018
2. Improve the coating durability	June 30, 2019

Activity 2: Conduct a field experiment in the Duluth-Superior Harbor (DSH). **Budget: $168,250**

In these field tests, we will investigate biofouling, the half-life of lactonase enzyme (our inhibitor) in various coatings, the kinetics of biofouling inhibition by these enzymes as well as the adhesion of zebra mussels on coated coupons. We will also analyze how changes in biofouling compares with alterations in bacterial community compositions. Sample coupons (steel, fiberglass) will be taken out of the harbor and analyzed after 3,6,10, and 16 months.

Outcome	Completion Date
1. Coupon preparation and installation in the harbor	July 30, 2019
2. Sampling and analysis of the coupons.	June 30, 2020

III. PROJECT STRATEGY

A. Project Team/Partners

The project will be carried out by a strong team that covers complementary areas. Collectively, the team covers environmental science, biology, and engineering expertise. The teams consists of a Biochemistry assistant professor, Mikael Elias, and biology professor Randall Hicks. Mikael Elias discovered the biofilm inhibitory molecule, while Randall Hicks has extensive expertise in microbiological processes underlining biofouling, and has performed field experiments in the DSH for many years. The team will also benefit from an already established collaboration with the Duluth Seaway Port Authority, a Minnesota company (AMI Consulting Engineers), and a French company (Gene&GreenTK) that will provide key feedback and contacts with other stakeholders. Additionally, contacts were made with the local painters union that will be used to get feedback, and disseminate our discoveries and technology to end users.

B. Project Impact and Long-Term Strategy

We have previously demonstrated that a coating containing our biofouling inhibitor can effectively inhibit biofouling. We now propose to take advantage of our competitive advantage (i.e., novel, potent, patent protected biofouling inhibitor) to investigate the activity and the durability of these coatings under harsher real world conditions over a longer duration than our initial laboratory studies. This innovative project may lead to a viable solution that increases the maritime shipping industry efficiency and economy by using an eco-friendly coating to protect the maritime transportation infrastructure not only in Minnesota but worldwide. Cost-effective mitigation strategies will be invaluable not only in the DSH but in other Great Lakes and marine areas where biofouling is a problem. The direct economic cost of biofouling control in aquaculture is estimated around 5-10% of production costs, equating to 1.5 to 3 billion dollars per year in the U.S. The maintenance associated with biofouling costs the U.S. Navy over $6 billion annually, and at least $200 billion annually overall in the U.S. alone.

Additionally, coatings with no biofouling also means less spread of undesired, or invasive species from a body of water to another while moving pleasure craft, portable docks or anchors. Such a product will be a new asset to help preserve our environment. We, and now other firms and stakeholders we have contacted (Gene&GreenTK), The Duluth Seaway Port Authority and the Minnesota Painters Union), feel that the future potential of this innovative technology is enormous.

C. Timeline 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.

2017 Detailed Project Budget

Project Title: *Innovative and Ecological Coatings to Mitigate Invasive Species*

IV. TOTAL ENRTF REQUEST BUDGET *2* **years**

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel: Mikael Elias, project manager, PI: 8% time; 66.3% salary; 33.7% benefits, 1 month/year for 2 years . Dr Elias will be in charge of the completion of all project activities.	$ 26,000
Personnel: Randall Hicks, co-PI: 8% time. 66.3% salary; 33.7% benefits, 1 month/year for 2 years .	$ 29,000
Personnel: Postdoc Researcher: (77.6% salary, 22.4% benefits); 100% FTE for 1 year. Funds are requested for 1.5 year to support a postdoctoral fellow to fulfill activity 1 and 2.	$ 88,500
Personnel: Postdoc Researcher: (77.6% salary, 22.4% benefits); 100% FTE for 1 year. Funds are requested for 2 years to support a postdoctoral fellow to fulfill activity 1 and 2.	$ 118,000
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.	$ 15,000
Equipment/Tools/Supplies: Funds are for producing and optimizing presticide-degrading materials for lab testing, as well as routine lab supplies (chemicals, flasks, pipetters, disposable plasticware, for example test tubes and petri plates, as well as media needed for production of molecular biology reagents made in the lab).	$ 25,000
Equipment/Tools/Supplies: 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	$ 20,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 321,500

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	$ -	*Indicate: Secured or Pending*
Other State $ To Be Applied To Project During Project Period: MnDrive Initiation funding to Mikael Elias and Randall Hicks to perform preliminary field testing and development of anticorrosion and antifouling coatings**.**	$ 296,276	*Secured*
In-kind Services To Be Applied To Project During Project Period: Faculty salary time paid by the University of Minnesota that will be devoted on the project over the rest of summer months and university indirect cost matching (53% mtdc)	$ 186,825	*Secured*
In-kind Services To Be Applied To Project During Project Period: BioTechnology Institute Pilot Plant fee waiver. Since the PIs are members of the BioTechnology Institute, this project will have the entry fee waived for the use of the facilities to prepare pesticides-degrading biocatalysts to be used in this proposal. The project will only be charged for materials used in production and the hourly wages of the staff at the facility that they work on this specific project.	$ 15,000	*Secured*
Remaining $ From Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	$ -	

Innovative and Ecological Coatings to Mitigate Invasive Species

Mikael Elias, Randall Hicks

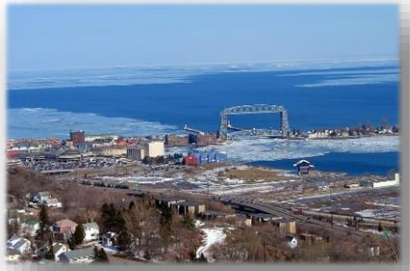
Biological, potent, Biofouling inhibitory molecule

***Activity 1*: improving coating formulations**

***Activity 2*: Field-testing in the Duluth-Superior Harbor**

Regular coating

New coating technology



Test coupon

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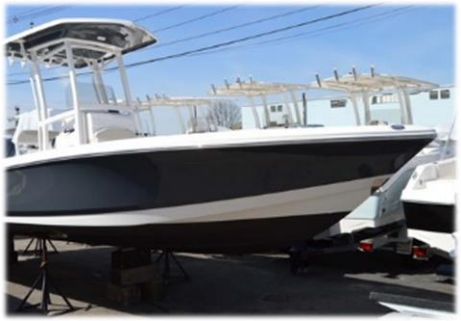

Covered by biofouling and shells

Biofouling-free surfaces

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 >10 articles on this topic alone, including in prestigious journals (*JACS*, *Nature*) 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. 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, work with radioisotopes, 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 Northeast-Midwest Institute oversees the operation of the Great Ships Initiative ballast water testing facility in Superior, WI. These facilities include laboratories to test new ballast water treatment technologies at the bench-scale and mesocoms, a full-scale, on-land testing facility, and scientific labs to process samples.

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.