Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

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Project Title:

Wastewater Estrogen: Removal Options, Fish Abundance, and Cost

Category: B. Water Resources

Total Project Budget: $ 516,000

Proposed Project Time Period for the Funding Requested: 3 Years, July 2014 - June 2017

Other Non-State Funds: $ 0

Summary:

Estrogen in wastewater impacts fish but is unregulated. Nitrogen is increasingly regulated and treatment can also remove estrogen. Our research will improve nitrogen removal while reducing estrogen and safeguarding fish.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

MP: 0613-2-074-proposa
Budget: 0613-2-074-bud
Qual: 0613-2-074-qualifi
Map: 0613-2-074-map-G
Resolution:
List:

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

Environment and Natural Resources Trust Fund (ENRTF)
2014 Main Proposal
Project Title: Wastewater estrogen: removal options, fish abundance, and cost

I. PROJECT STATEMENT

Wastewater treatment plants discharge effluent that contains contaminants of emerging concern (CECs), including estrogens. These estrogens have caused dramatic ecological effects such as fish feminization and fish population collapses, with unknown long-term consequences. The most important estrogen exiting wastewater treatment plants, in terms of contributing to the feminization potential of effluent, is a chemical called estrone, which is an estrogen that is released naturally from women via the waste stream. Although this and other estrogens are present in Minnesota lakes and rivers and can be ecologically harmful, their treatment and discharge are not regulated.

Interestingly, the discharge of estrone and other estrogens is a function of how (and how well) a treatment plant removes nitrogen. Nitrogen discharge is regulated in Minnesota and the same processes that remove nitrogen also remove estrone/estrogens. Given that:

1) nitrogen removal is becoming increasingly strict in Minnesota,
2) treatment plants are expected to control nitrogen while minimizing energy use and costs, and
3) some nitrogen-removal processes are likely to remove estrone better than others,

there is a clear opportunity to understand the operational trade-offs between treatment, fish health, and cost.

We have performed, and the LCCMR has supported, research on the fate of CECs and their effects on fish health and reproduction. This work has laid the foundation for understanding how estrogens in particular are removed in traditional treatment systems and how fish are impacted by these compounds. With the proposed research, however, we have an opportunity to address gaps in our knowledge of CEC removal and effects, while also being proactive regarding the need to remove nitrogen during wastewater treatment. New processes to remove nitrogen exist and will likely be implemented in Minnesota; we should determine how these processes perform over the range of temperatures experienced in Minnesota with respect to both CEC and nitrogen removal so that the very best processes for the protection of Minnesota's natural resources can be put into place. In addition, we should determine how fish vulnerability changes seasonally so that treatment to extremely low levels of CECs is only required during critical periods (e.g., during egg maturation or spawning) to save energy and costs from excessive (and unnecessarily rigorous) treatment. Finally, we should combine laboratory efforts with predictive mathematical models so that we can extrapolate to cost and whole population behavior.

In essence, we will determine:

- **The cost to improve the removal of a regulated compound (nitrogen) during wastewater treatment, and the impact of different treatment options on the removal unregulated estrogens,**
- **The energy savings associated with various treatment options, and**
- **How to tailor treatment seasonally to reduce CEC impacts on fish, essentially providing the monetary value of safeguarding Minnesota fish populations.**

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Determine the performance of different wastewater treatment processes with respect to nitrogen removal, CEC and estrone removal, energy use, and cost. **Budget: $171,000**

We will set-up laboratory-scale reactors to mimic traditional wastewater treatment and four new wastewater treatment processes designed for nitrogen removal. Reactors will be operated at 72°F and 50°F to model temperature ranges inside Minnesota wastewater treatment plants. Experiments will be performed with synthetic wastewater amended with estrone and real wastewater.

Outcome	Completion Date
1. Nitrogen removal efficiency in five different wastewater treatment plant configurations.	*10/31/2016*
2. Estrone/CEC removal efficiency in five different wastewater treatment plant configurations.	*10/31/2016*
3. An estimate of the energy use for the various treatment options.	*02/28/2017*

4. An estimate for the cost of the various treatment options.	*02/28/2017*

Activity 2: Determine how temperature and life stage alter the reproduction and survival of fathead minnows and smallmouth bass after exposure to treated synthetic or real wastewater. **Budget: $188,700**

Minnows and bass will be exposed to synthetic and real wastewater treated by a model traditional wastewater treatment process or models of four new wastewater treatment processes designed for nitrogen removal. Exposures will occur at two life stages that coincide with different water temperatures (50-60°F and 72°F):

- a larval stage during which sexual differentiation is occurring, and
- an adult stage during which sexual maturation occurs.

Outcome	Completion Date
1. Reproduction and survival data for larval and adult fathead minnows exposed to differentially treated wastewater at seasonally-appropriate temperatures	*03/31/2016*
2. Reproduction and survival data for larval and adult smallmouth bass exposed to differentially treated wastewater at seasonally-appropriate temperatures	*03/31/2017*

Activity 3: Conduct a cost-benefit analysis that links the cost of different wastewater treatment options to mathematical predictions of fathead minnow and smallmouth bass abundance. **Budget: $156,300**

To link treatment options to fish abundance, we will develop a mathematical simulation model that uses environmental cues (e.g., seasonal temperature) and fish biology to predict minnow and bass abundance under various scenarios of exposure to treated effluent. This information will allow us to express the cost of treating effluent in terms of benefits related to the abundance of different fish species.

Outcome	Completion Date
1. A predictive mathematical model that simulates minnow and bass abundance in a pristine, Minnesota river during different seasons	*12/30/2015*
2. A predictive mathematical model that simulates minnow and bass abundance under exposure to treated wastewater effluent during different seasons	*12/30/2016*
3. A cost-benefit analysis of treatment options and fish abundance	*05/31/2017*

III. PROJECT STRATEGY

A. Project Team/Partners

The project team consists of the Principal Investigator (PI) Paige Novak (University of Minnesota) and co-PIs Dr. Heiko Schoenfuss (St. Cloud State University), Paul Venturelli (UMN), and Frances Homans (UMN). Novak will direct Activity 1; Schoenfuss will direct Activity 2; Venturelli will direct Activity 3; Homans will direct the cost analysis and economic modeling efforts. MCES has agreed to provide access to wastewater.

B. Timeline Requirements

Three years

C. Long-Term Strategy and Future Funding Needs

The proposed work fits into a larger research agenda centered at UMN and St. Cloud State focused on environmental estrogens and improved wastewater treatment. The proposed research complements current and prior research in this area. This project builds on what we have learned and takes it further, factoring in cost, how CEC removal is impacted by changes in treatment (focused on nitrogen removal), and how temperature impacts both removal efficiency and fish vulnerability. It also expands the impact of the research by incorporating fish population modeling to scale the findings to a whole-state level. When taken together, this research will provide a more complete picture of how to improve treatment, decrease costs and energy use, and safeguard our fish populations.

2014 Detailed Project Budget

Project Title: Wastewater estrogen: removal options, fish abundance, and cost

IV. TOTAL ENRTF REQUEST BUDGET 3 years

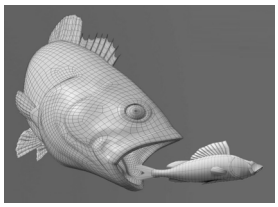
BUDGET ITEM	AMOUNT
Paige Novak, PI ($12,700 salary, $4,300 fringe, 33.6% fringe rate; total for 2 years; 3.8% effort)	$ 17,000
Paul Venturelli, Co-PI ($8,600 salary, $1,700 fringe, 19.8% fringe rate; total for 2 years; 3.8% effort)	$ 10,300
Frances Homans, Co-PI ($11,300 salary, $3,700 fringe, 24.7% fringe rate; total for 2 years; 3.8% effort)	$ 15,000
One Postdoctoral Researcher ($82,400 salary, $17,100 fringe (includes healthcare); total for 2 years; performing the mathematical modeling of fish populations)	$ 99,500
Two Graduate Research Assistants ($85,100 salary, $69,700 fringe (includes healthcare and tuition); total for 2 years for each student; one student will perform the research on the removal of nitrogen and CECs during wastewater treatment and the other will perform research onthe cost and value of wastewater treatment upgrades with respect to the preservation of fish populations))	$ 154,800
Subcontract: Some of the work will be conducted at St. Cloud State University (Activity 2). The subcontract amount will include salary for a research technician ($55,000 salary, $11,400 fringe (20.75% fringe rate) per year for 2 years) and supplies for experiments (fish, chemicals, pumps, aquaria maintenance, etc., $55,600/3 years).	$ 188,400
Equipment/Tools/Supplies: Laboratory supplies and analytical costs (includes, but is not limited to, chemicals for all analyses, supplies to maintain analytical equipment, supplies for reactor construction, and pumps ($30,000/3 years)).	$ 30,000
Travel: Travel between St. Cloud and Minneapolis for research progress meetings (in state)	$ 1,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 516,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period: none.	$ -	
Other State $ Being Applied to Project During Project Period: none.	$ -	
In-kind Services During Project Period: Novak will provide unpaid time to the project (1% cost-share). Because the project is overhead-free, laboratory space, electricity, and other overhead costs are provided in kind. The University of Minnesota overhead rate is 52%.	$ 232,000	Estimated
Remaining $ from Current ENRTF Appropriation (if applicable): no prior projects directly related to proposed project.	$ -	
Funding History: The PIs have been suppored by various agencies to study estrogen biodegration in wastewater treatment plants and the impacts of estrogens on fish.	$ -	Cannot be estimated

What we have learned from previous research (ENRTF-funded and funded by other sources)

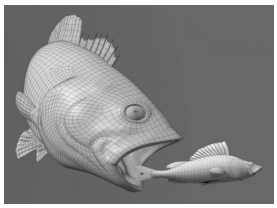




	Wastewater treatment	Contaminant effects	Fish abundance
 Operation	• MN effluent contains CECs and nitrogen (N) • N treatment removes CECs	• Estrogen harms vulnerable minnow stages (sexual differentiation, spawning, early development)	
 Temperature	• N removal declines in cold weather		
 Cost	• N treatment is expensive		

Questions to relate CEC removal costs to fish abundance (proposed ENRTF project)



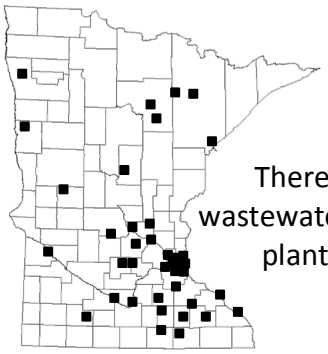


	Activity 1	Activity 2	Activity 3
 Operation	• How well do more efficient N-removal systems remove CECs?	• Do CECs affect minnows and bass differently?	• How do changes in minnows affect bass and vice versa?
 Temperature	• How does seasonality affect CEC removal?	• How does CEC seasonality correspond to vulnerable life stages?	• How does CEC seasonality affect abundance?
 Cost	• What does it cost to operate more efficient N-removal systems?		• How can more efficient N-removal systems benefit fish abundance?

Why?

- Improve N-removal systems to save money, decrease energy use, and **provide the added benefit of CEC removal**
- **Safeguard** Minnesota's **fish populations for the long-term**

Where?



There are ~35 wastewater treatment plants in MN

Project Manager Qualifications and Organization Description

Paige J. Novak
Professor, Environmental Engineering, Department of Civil Engineering and Resident Fellow of the Institute on the Environment, University of Minnesota

B.S., Chemical Engineering, 1992, The University of Virginia, Charlottesville, VA.
M.S., Environmental Engineering, 1994, The University of Iowa, Iowa City, IA.
Ph.D., Environmental Engineering, 1997, The University of Iowa, Iowa City, IA.

Dr. Paige Novak will be responsible for overall project coordination. She has been studying the fate and biological transformation of micropollutants for over ten years. Recent work has focused on the presence and fate of estrogenic compounds in wastewater, including the effect of wastewater treatment and operation on estrone degradation. Dr. Novak was the 2007 recipient of the Paul L. Busch Award (Water Environment Research Foundation) for her research on industrial phytoestrogens, the 2013 Bill Boyle Educator of the Year Award (Central States Water Environment Association), and the 2011 Samuel Arnold Greeley Award (American Society of Civil Engineers). She, Dr. Heiko Schoenfuss, and Dr. William Arnold will complete an LCCMR-funded project on the fate and effects of phytoestrogens in the environment. Four to five manuscripts will be (or have been) submitted for publication from this work.

Dr. Frances Homans (University of Minnesota) is an expert in applied environmental economics, and specifically, the regulation of renewable natural resources, both in commercial and recreational settings. She generally studies natural resource economics, applied microeconomics, and environmental economics.

Dr. Heiko Schoenfuss (St. Cloud State University) has been studying the biological effects of environmental estrogens for the past 10 years. His laboratory has pioneered exposure systems at environmentally relevant concentrations in the ng/L range and has integrated field and laboratory studies over multiple levels of organsimal complexity.

Dr. Paul Venturelli (University of Minnesota) is an expert on fish population dynamics and modeling. His research examines how temperature, habitat, life history (e.g., growth, maturity, reproduction, longevity) and human activities shape the population dynamics of fish species that are of interest to management and policy.

Organization Description
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The laboratories and offices of the PI and co-PIs contain all of the necessary fixed and moveable equipment and facilities needed for the proposed studies.