



**Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2013 Minnesota Aquatic Invasive Species Research Center
Sub-Project Work Plan**

Date of Report: June 26, 2017

Date of Next Status Update Report: January 31, 2018

Date of Work Plan Approval:

Sub-Project Completion Date: June 30, 2019

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

SUB-PROJECT TITLE: MAISRC Sub-Project 19: Decision-making tool for optimal management of AIS

Sub-Project Manager: Dr. Nicholas Phelps

Organization: University of Minnesota/Minnesota Aquatic Invasive Species Research Center

Mailing Address: 2003 Upper Bufford Circle, Skok Hall 135,

City/State/Zip Code: St. Paul, MN 55108

Telephone Number: (612) 624-7450

Email Address: phelp083@umn.edu

Web Address: www.maisrc.umn.edu

Location: Statewide

Total ENRTF Sub-Project Budget:

Sub-Project Budget:

\$172,465

Amount Spent:

\$0

Balance:

\$172,465

Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 06a

Appropriation Language:

\$4,350,000 the first year and \$4,350,000 the second year are from the trust fund to the Board of Regents of the University of Minnesota to develop and support an aquatic invasive species (AIS) research center at the University of Minnesota that will develop new techniques to control aquatic invasive species including Asian carp, zebra mussels, and plant species. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. SUB-PROJECT TITLE: Decision making tool for optimal management of AIS

II. SUB-PROJECT STATEMENT:

Effective management of aquatic invasive species (AIS) in complex and dynamic systems, considering variable needs, values, and constraints, has proven difficult. AIS managers at the local and state levels urgently need science-based tools to inform planning and decision-making. For example, mathematical and optimization models using robust and updated information can be used for developing effective intervention strategies, predicting impacts, testing what-if scenarios, increasing stakeholder buy in, and designing cost-effective surveillance programs to mitigate and prevent AIS spread. We have been moving in this direction with previous and ongoing research led by the Project Manager and collaborators to describe environmental suitability and pathways of spread for high priority AIS. We have reached a point where the previously developed risk maps could be incorporated into dynamic system models to visualize risk and evaluate optimization approaches for management.

The aim of this proposal is to build upon and refine previous research to develop and deploy a decision-making tool for optimal management intervention on a county and statewide scale to minimize the spread of high priority AIS.

Based on the dynamics of AIS and the systems in which they live and move, we will develop models to forecast the invasion of zebra mussels and Eurasian watermilfoil in Minnesota at the lake level. These models will be subjected to strict verification and cross-validation to ensure confidence in model predictions. The risk scores for each waterbody will then be used to inform AIS management optimization models at the county level. Optimization models are a useful approach to identify a set of actions that make the best use of available resources while achieving a desired outcome. Therefore, in addition to the risk scores, values and management objectives such as types of lakes to prioritize for prevention (e.g. All lakes equally? Large/popular lakes?) will be incorporated to recommend the allocation of available funds and strategic locations for prevention and control activities to reduce the risk of new AIS introductions within each county. Similarly, cumulative risk models will be developed to help inform statewide allocation of the County AIS Prevention Aid, compared to the current approach of total boat ramps and parking spots. Local and state AIS managers will be engaged throughout the project to ensure consistency with management goals and realities. Ultimately, the models will be visualized through a user-friendly and interactive application for online or mobile viewing to empower AIS management stakeholders.

III. SUB-PROJECT STATUS UPDATES:

Sub-Project Status as of January 31, 2018:

Sub-Project Status as of July 31, 2018:

Sub-Project Status as of January 31, 2019:

Overall Sub-Project Outcomes and Results:

IV. SUB-PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Development of a multiplex network metacommunity model for AIS

Description: Mathematical models can be developed to understand a wide variety of complex systems and interactions. In the case of AIS, we have previously used two primary types, Maxent models (e.g. environmental suitability) and network models (e.g. connectivity). Our research shows that these models can predict invasion

far better than chance – a useful tool when prioritizing management efforts. Integrating these two models and visualizing risk on the landscape is the next step.

In Activity 1, we will develop a new multiplex network metacommunity (MnM) model to forecast the invasion of zebra mussels and Eurasian watermilfoil. To summarize our approach, we will first evaluate the role of invasion drivers, including water connectivity and boat movement. For each type of connection, we have already created a matrix of all Minnesota lakes as part of MAISRC SubProject 13. The matrix for water connectivity includes both direction and river distance, and we aim to add rate of flow as part of this Activity. The matrix for boat movement includes the number of boats and direction of travel. We will update the existing matrix with new data provided by the MN DNR watercraft inspection program during the course of this Activity. These invasion drivers will incorporate lake-specific demographics for AIS suitability developed as part of MAISRC SubProject 13 to answer the question ‘if the AIS arrives, can it survive?’ Parameters of connectivity and suitability will be incorporated into a mathematical model, similar to:

$$\frac{dx_i}{dt} = M_0(x_i(t)) + \sum_{j=1}^N A_{ij}M(x_i(t), x_j(t)) \quad (1)$$

We will begin with this general reaction diffusion model, where species are within defined boundaries and then include ‘noise’ to consider variability of the environment and other factors. The outputs from this model will provide a lake-specific risk score for establishment of zebra mussels and Eurasian watermilfoil.

For each model prediction, validation will be performed comparing the model’s predicted outcome with historical AIS spread within Minnesota based on speed, extent, and pervasiveness of invasion. Ultimately, by using non-linear analyses and uncertainty estimates, we will learn from the invasion histories of zebra mussels and Eurasian watermilfoil in Minnesota to forecast future areas associated with high risk. Generating these risk maps is critical to informed and optimized decision-making in Activity 2.

All findings will be widely available through MAISRC communications (i.e. website, newsletter, social media, presentations, etc), one scientific presentation and one peer-reviewed open access publication.

Summary Budget Information for Activity 1:

ENRTF Budget: \$62,250
Amount Spent: \$ 0
Balance: \$62,250

Activity Completion Date:

Outcome	Completion Date
1. Development and validation of multiplex network metacommunity (MnM) model	May 2018
2. Result dissemination: MAISRC communications, scientific presentation, peer-reviewed publication	August 2018

Activity Status as of January 31, 2018:

Activity Status as of July 31, 2018:

Activity Status as of January 31, 2019:

Final Report Summary:

ACTIVITY 2: Development of county and statewide optimization models for AIS management

Description: In 2014 the State of Minnesota created the AIS County Prevention Aid Program, with annual support of \$10,000,000 direct to counties. The use of these funds has varied widely, based on expertise, local

values, concerns, and total funding available. Specific activities have included new personnel, education, watercraft inspection, and decontamination units to name a few. While there is little doubt these activities help in the fight against AIS, counties are asking for help in determining the most effective use of their funds.

In Activity 2, we aim to develop risk-based optimization models to inform county AIS prevention and management activities. To that end, we will intensively interview representatives from two Minnesota counties and the MN DNR to better understand management objectives, ongoing activities and associated costs, personnel requirements, tradeoffs and budget constraints. We will use this information, combined with lake-level risk from Activity 1, to develop an optimization model for each county. The models will be spatially explicit, including location of lakes, pathways of boat movement, and locations for potential intervention activities. The participating managers will review the final models for relevance and consistency with their expectations. We will also socialize the models with representatives from all other counties and receive feedback during regional AIS coordination meetings hosted by the MN DNR. Assuming the management objective (e.g. prevent the introduction of AIS into new lakes) is widely accepted, we will build generic optimization models for all counties based on local AIS risk and funding levels.

In addition, we aim to develop an alternative strategy for statewide allocation of the AIS County Prevention Aid Program. Currently, the funding allocation is based on the number of boat ramps and parking spots within each county as a crude measure of risk. Through the research in Activity 1 and Activity 2, we will estimate cost curves for management and levels of cumulative risk for each county to quantify total need. This approach will be compared against the status quo.

All findings will be widely available through MAISRC communications (i.e. website, newsletter, social media, presentations, etc), one scientific presentation and one peer-reviewed open access publication.

Summary Budget Information for Activity 2:

ENRTF Budget: \$51,250
Amount Spent: \$ 0
Balance: \$51,250

Activity Completion Date:

Outcome	Completion Date
1. Development of county-based AIS management optimization models	September 2018
2. Development of risk-based statewide funding allocation model	September 2018
3. Deploy models at AIS manager workshops	October 2018
4. Result dissemination: MAISRC communications, scientific presentation, peer-reviewed publication	January 2018

Activity Status as of January 31, 2018:

Activity Status as of July 31, 2018:

Activity Status as of January 31, 2019:

Final Report Summary:

ACTIVITY 3: Development and deployment of visualization tool for the AIS decision-making

Description: The Questions and Decisions (QnD) model system has previously been used for other systems by project collaborators to provide an effective and efficient, open-source, decision research and education tool that can visualize scenarios of model outputs that incorporate management decisions. This would be a very useful tool to empower AIS managers with real-time access to our models.

We aim to construct a QnD model using a combination of occurrence data and interactions of ecosystem elements embedded in the MnM model developed in Activity 1 and the management optimization Activity 2. The model will include real-time information of AIS infestations (e.g. new reports from EDDmapS) and produce updated model predications. For visualization of the QnD model, we will develop an online interface and mobile app written in object-oriented Java.

We will socialize the interface throughout the course of the Activity to ensure usability. Ultimately, the online QnD interface and mobile app will be deployed to county and MN DNR AIS managers during a final project workshop, MAISRC communications (i.e. website, newsletter, social media, presentations, etc) and peer-reviewed publication.

Summary Budget Information for Activity 3:

ENRTF Budget: \$58,965
Amount Spent: \$ 0
Balance: \$58,965

Activity Completion Date:

Outcome	Completion Date
<i>1. Development of visualization tool for AIS management</i>	April 2019
<i>2. Deployment of visualization tool to AIS managers</i>	June 2019
<i>3. Result dissemination: MAISRC communications, peer-reviewed publication</i>	June 2019

Activity Status as of January 31, 2018:

Activity Status as of July 31, 2018:

Activity Status as of January 31, 2019:

Final Report Summary:

V. DISSEMINATION:

Description: Dissemination of project findings is a critical component of this project. Efforts will be made throughout the project to engage end-users, share findings and make deliverables broadly available. Specifically, at least three peer-reviewed manuscripts are expected to be published in open-access scientific journals. Results will be presented at two scientific conference, including the Upper Midwest Invasive Species Conference (location TBD, likely Duluth, MN) and the International Conference on Aquatic Invasive Species (ICAIS; location TBD). If ICAIS is located outside of the USA, another conference will be selected. The project team will also contribute to MAISRC communications, including information for the website, newsletter, social media, presentations at the annual Research Showcase, news media, etc. We will share downloadable material (i.e. maps, tables, reports) on the MAISRC website.

Status as of January 31, 2018:

Status as of July 31, 2018:

Status as of January 31, 2019:

Final Report Summary:

VI. SUB-PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview:

Budget Category	\$ Amount	Explanation
Personnel:	\$127,465	Dr. Matteo Convertino (5% FTE per year, \$13,848) and a to-be-determined post-doctoral researcher (Yr 1: 75% FTE, Yr2: 100% for FTE; \$113, 617). No salary support is requested for Dr. Nick Phelps or Dr. Robert Haight.
Professional/Technical Services and Contracts:	\$37,000	Contract with TheBlackTechGuy (Mondo Davidson) for website/app development to visualize outputs (\$25,000), purchase GAMS-CPLEX optimization software essential for Activity 2 (\$10,000), and peer-reviewed publications (\$2,000).
Equipment/Tools/Supplies:	\$3,000	One macbook pro (\$1,500; Computer will be retained by MAISRC at the end of the project), two external hard drives (\$500), and materials for final workshop (\$1,000).
Capital Expenditures over \$5,000:	\$0	None.
Travel:	\$5,000	Travel within Minnesota to participate in regional AIS coordination meetings (\$1,000) and domestic travel outside of Minnesota to present the findings of this project at two scientific conference and get feedback from other experts and to learn about the newest developments in the field – expected conferences include the Upper Midwest Invasive Species Conference and the International Conference on Aquatic Invasive Species (only if location is domestic) (\$4,000).
Other:	\$0	None.
TOTAL ENRTF BUDGET: \$172,465		

Explanation of Use of Classified Staff: NA

Explanation of Capital Expenditures Greater Than \$5,000: NA

Number of Full-time Equivalent (FTE) Directly Funded with this ENRTF Appropriation: 2.1 FTE

Number of Full-time Equivalent (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.25FTE

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
	\$0	\$0	
State			
	\$0	\$0	

TOTAL OTHER FUNDS:	\$0	\$0	
---------------------------	------------	------------	--

VII. SUB-PROJECT STRATEGY:

A. Sub-Project Team/Partners:

This highly collaborative project will be managed by Dr. Nicholas Phelps (Project Manager; MAISRC). He will be involved in all aspects and provide overall guidance for the project. Dr. Phelps has ongoing research efforts focused on modeling the establishment and introduction risk of AIS in Minnesota, as well as intervention strategies at all levels of management. Dr. Matteo Convertino (UMN-School of Public Health and Systems Engineering) will lead Activity 1 and 3 and has research expertise that broadly focuses on modeling and management of nature-inspired complex systems (using information, network, and decision theories) to inform decision-making. Dr. Robert Haight (US Forest Service) will lead Activity 2 and has research expertise in optimal control of invasive species and building models to allocate scarce resources for prevention, detection, control and rehabilitation. A postdoctoral associate will assist with all aspects of the project.

MN DNR and County-based AIS managers will be included during the early stages of the project to solicit management objectives informing the models. The same individuals will be re-engaged at the end of the project to discuss findings. The project team has a history of successful collaboration with agency partners.

B. Sub-Project Impact and Long-term Strategy:

MAISRC’s 2017-2018 Research Needs Assessment identified this type of project as a High Priority Research Need. This project will fill key knowledge gaps and provide immediate and long-term benefits to resource management and allocation at the state and county levels. Working closely with AIS managers at all levels will help facilitate the translation of the research into action. This is the third phase of a long-term effort (previous two projects funded by MnDRIVE and MAISRC).

In addition, the outputs generated will also have value beyond the management of the considered AIS. Other AIS can be used in the same modeling framework and the partnership with DNR can lead to systemic ecosystem health management, where all species are taken into account simultaneously. The multidisciplinary and collaborative nature of this project will enhance the collaboration among AIS management agencies including the MN DNR and county-based managers, and the research efforts of MAISRC.

Importantly, as management goals change and new data becomes available, the optimization models will need updating to remain relevant. Future research to refine and update this tool based on the discovery of new species/locations, changes in introduction risk or environmental suitability, and other information gained overtime would be warranted.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): N/A

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH PROPOSAL:

XII. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 31, 2018, July 31, 2018 and January 31, 2019. A final report and associated products will be submitted within two months of the anticipated sub-project completion of June 30, 2019.