A Comprehensive Suitability Assessment of Vermont Waterbodies for Spiny Water Flea (*Bythotrephes longimanus*), Zebra Mussel (*Dreissena polymorpha*), and Starry Stonewort (*Nitellopsis obtusa*)

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INTRODUCTION

Invasive species pose a serious threat to the health of aquatic ecosystems throughout the state of Vermont (Modley, 2008). Invaders not only decrease the native biodiversity of an ecosystem, but they are also one of the leading causes of extinction events worldwide (Clavero and Garcia-Berthou, 2005). The introduction of an invader can have both acute and chronic effects, such as trophic cascades and the disruption of overall ecosystem function and stability. As such, it is crucial to understand the life history traits and habitat characteristics of invasive organisms that allow them to establish populations. Increased knowledge of what allows them to be successful assists with the prevention and mitigation of spread. Invasive removal after population establishment poses a significant financial burden and a very low success rate, the ideal strategy to deal with invasive species involves a proactive effort to eliminate the possibility of range expansion (Pimentel et al., 2005).

The Three Invaders:

The zebra mussel (*Dreissena polymorpha*), spiny water flea (*Bythotrephes longimanus*) and starry stonewort (*Nitellopsis obtusa*) are three aquatic invasive species that have been recently identified in Vermont. Each of these invaders have been known to cause harm to the ecosystems that they infiltrate, and therefore present a serious concern to the native biodiversity of the state.

Spiny water flea (*B. longimanus*) has an insatiable appetite for crustacean zooplankton, and is capable of completely de-stabilizing the trophic structure of an aquatic ecosystem. Past invasions of this species have shown significant reductions in zooplankton and cladoceran species richness: two aquatic taxa that are crucial to nutrient cycling (Kelly et al., 2013).
Zebra mussels (*D. polymorpha*) are capable of attaching themselves to any surface in the water, including other native clams and mussels, causing their asphyxiation and eventual death (Johnson and Padilla, 1996).
Starry stonewort (*N. obtusa*) can have negative impacts on fish spawning, foraging, and nesting habitat, altering the ecosystem and abundance of aquatic species (Pullman, 2010; Midwood et al., 2016).

Project Need:

Vermont has not formulated a comprehensive environmental suitability and vessel-based introduction risk assessment for these three aquatic invasive species. Our statewide assessment will determine the waters in Vermont which are at the highest risk of introduction by vessel travel and establishment in native suitable habitat. This will help the state of Vermont determine which aquatic ecosystems should be prioritized for invasive prevention planning, monitoring, and control measures in the future.

OBJECTIVES AND TASKS

1. Conduct a literature review for the three focal species (*B. longimanus*, *D. polymorpha* and *N. obtusa*) on water chemistry data and abiotic factors that render habitats suitable for the establishment of a population
   - Examine scholarly literature on each species to understand their respective life history traits and ideal habitat conditions
   - Analyze parameters of water quality: pH, conductivity, salinity, hardness, depth, dissolved oxygen, chlorophyll-a concentration, and total phosphorus to determine which environmental factors are most pertinent to their establishment

2. Use the information from the literature review on species tolerance ranges to determine which Vermont waterbodies are at low, moderate or high risk of invasion
   - Receive water quality data from our community partner for each waterbody in Vermont
   - Define risk as the possibility of invasive population establishment should introduction occur
   - Classify risk as low, moderate or high in terms of the waterbody meeting either none, one or two of the water quality parameters we previously identified as necessary for establishment

3. Citing personal watercraft as the main vector for the spread of aquatic invasive species, we will use data from the VT DEC's greeter program to create a map of vessel-based spread risk for all waterbodies that possess VT state check stations
   - Determine quantitative value for risk of invasive transport by watercraft using two criteria: The waterbody the boat was last used in and the time since the boat was last used

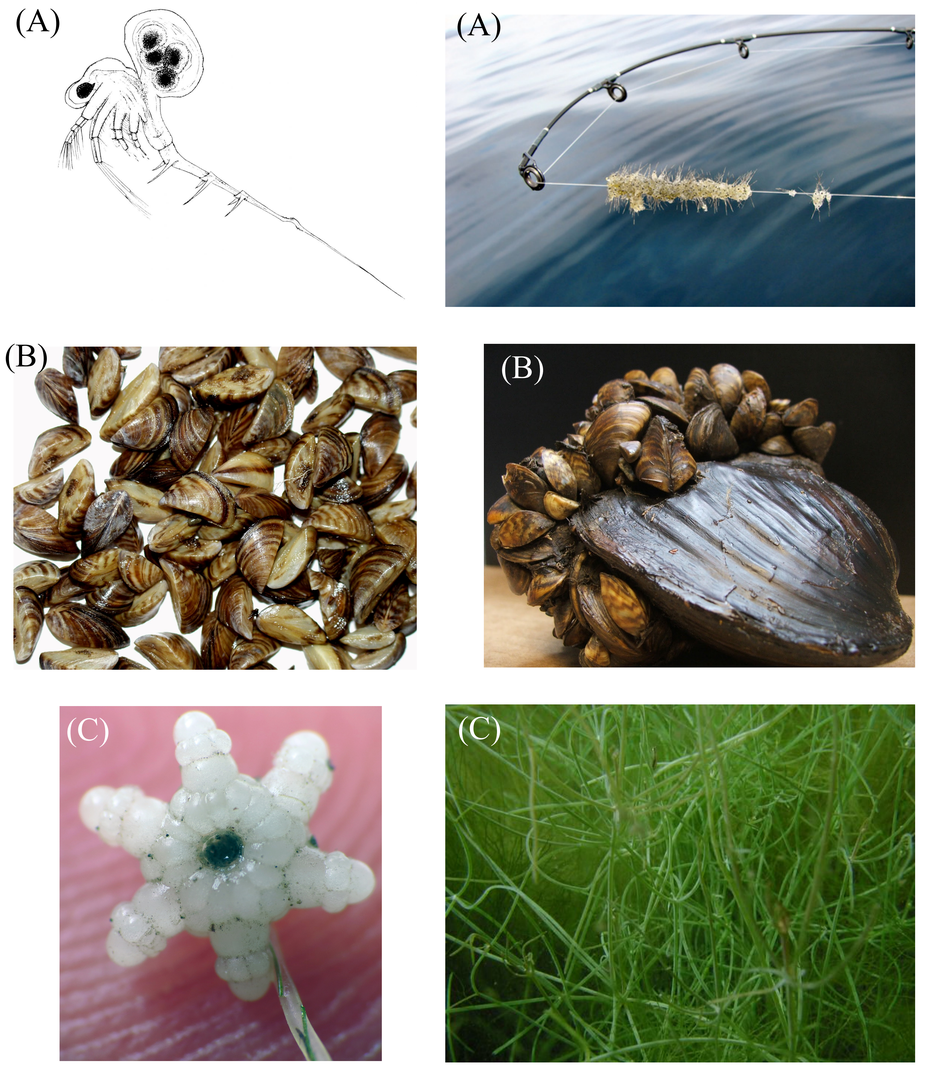

Figure 1: Focal invasive species for our study. (A) – *B. longimanus*, (B) – *D. polymorpha*, (C) – *N. obtusa*

RESULTS

Table 1: Summary tables representing the percentages of all Vermont waterbodies that meet the most pertinent species tolerance range criteria. (A) – *B. longimanus*, (B) - *D. polymorpha*, (C) – *N. obtusa.* The 'total' row denotes the amount of lakes with sufficient data to evaluate whether they met/did not meet criteria (max. = 374)

(A)	Phosphorous	Alkalinity	pH	Secchi Disk
"Meets"	212	158	301	118
"Does not meet"	162	212	0	91
Total	374	370	301	209
% Meets	56.68	42.7	100	56.46

(B)	Phosphorous	Hardness	pH	Chlorophyll-a	Secchi Disk
"Meets"	93	352	132	55	49
"Does not meet"	245	18	242	104	159
Total	338	370	374	159	208
% Meets	27.51	95.14	35.29	34.59	23.56

(C)	Phosphorous	Hardness	pH	Chlorophyll-a
"Meets"	372	338	128	160
"Does not meet"	2	0	173	1
Total	374	338	301	161
% Meets	99.47	100	42.52	99.38

Table 2: Total counts of Vermont waterbodies from our data (n=374), separated into our categories of population establishment risk for each invader. Risk is classified as low, moderate or high in terms of the waterbody meeting either none, one or two of the water quality parameters we previously identified as necessary for establishment (Table 1). Values within parentheses represent percentages for each count.

Species	High Risk (%)	Moderate Risk (%)	Low Risk (%)
Spiny Water Flea (Bythotrephes longimanus)	266 (71.1%)	90 (24.1%)	18 (4.8%)
Zebra Mussels (Dreissena polymorpha)	193 (51.6%)	161 (43.0%)	20 (5.4%)
Starry Stonewort (Nitellopsis obtusa)	348 (93.0%)	26 (7.0%)	0 (0%)

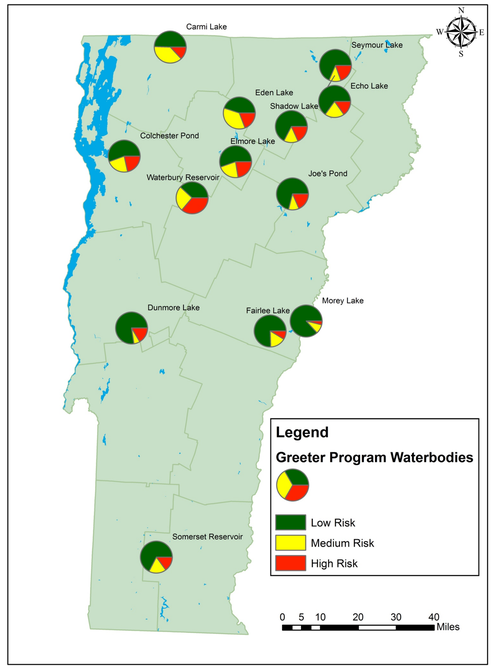

Figure 2: A comprehensive map representing the risk of invasive introduction by watercraft for each waterbody with a DEC greeter program check station. Risk has been summarized based on two criteria: which waterbody the boat was last in and the time since the boat was last used. Each criteria was then assigned numerical values (Last waterbody: 1= no target AIS present, 2=unconfirmed presence, 3=confirmed target AIS presence; Time since last used: 1=longer than 2 weeks, 2= between 5 days and 2 weeks, 3= within 5 days). Both criteria values were calculated for all surveyed boats in each waterbody and combined to create categories of total perceived risk: 2-3 = Low risk (green), 4 = Medium risk (yellow), 5-6 = High risk (red).

CONCLUSIONS

- We found that the most limiting habitat characteristic for starry stonewort is water velocity, and such its potential for population establishment in lakes is dramatically high (Table 2)
- Research has yet to identify a specific water quality characteristic or environmental factor that prevents the establishment of spiny water flea within aquatic ecosystems. Due to its high tolerance of a variety of conditions, its potential for establishment throughout the state's waterbodies is relatively high
- Due to specific water quality constraints of pH and hardness, less waterbodies throughout the state are at risk of zebra mussel invasion relative to the other two invaders
- We conclude that the state should continue its proactive efforts to reduce the spread of AIS. Our calculated risk establishment and spread data should be used to concentrate efforts on the most threatened waterbodies and the most likely invaders

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