Title: Year 3: Building Sustainable Solutions to the Issue of Ballast Water Treatment: Testing Relationships Between Propagule Pressure and Colonization Success of Invasive Species.

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Executive Summary

This multi-year project addresses the issue of ballast water treatment by examining the efficacy of the standards that will be applied concerning permissible levels of biological pollution. The main objective of the first and second years of work was to characterize the density and diversity of crustacean zooplankton in the Duluth-Superior Harbor and St. Louis Estuary, a necessary first step in developing the experimental context. Our analysis of 9 sites during 2007 and 2008 indicates that zooplankton densities ranged widely over the season from <1,000 to >70,000 individuals m^{-3}. The peaks in midsummer densities were either coincident with, or consistently lagged, peak summer water temperatures. Taxon richness was 5-10 taxa per region (2007) and 5-15 taxa per region (2008) with little variation between regions within year. The results provide valuable context for the development of laboratory based experiments to be conducted in the coming year that will evaluate the relationships between propagule pressure and colonization success by non-native species.

Introduction

Burgeoning human transportation and trade networks are disrupting the natural range boundaries of flora and fauna on a global scale. Ballast water ferried by ships and used to correct imbalance in cargo is believed to be the leading dispersal agent of coastal non-native aquatic biota in North America (Ruiz et al. 2000). In an effort to prevent additional species introductions via this vector, the U.S. Congress passed and reauthorized legislation in the 1990s that requires vessels to manage their ballast water in one of two ways. Ships are required either to carryout Ballast Water Exchange (BWE) by flushing ballast tanks in the open ocean or to perform Ballast Water Treatment (BWT) by proactive decontamination. Because it is widely recognized that no BWT technology can be expected to perform with 100% effectiveness all of the time, accepted standards will allow a certain level of biological pollution (viable non-native organisms) to escape in the post-treated water. The post-treatment standards required of BWT technologies will be guided by standards agreed upon by the International Maritime Organization (IMO), however, few experimental data are available from which to quantify levels of invasion risk associated with specific levels of propagule pressure (MacIsaac et al. 2002). Our project begins to fill this gap and should provide valuable experimental-based information that can guide the IMO regarding post-treatment standards for BWT technologies.

Methods

The main objective of the first and second years of research was to characterize the density and diversity of crustacean zooplankton at 9 sites in the Duluth-Superior Harbor and St. Louis Estuary (see Figure 1). Details of the sampling protocol and some methods were given in an earlier report.

Crustacean zooplankton samples were analyzed for taxonomic composition and abundance in the laboratory with dissecting and compound microscopes. Zooplankton densities (no. m^{-3}) were averaged by site within a region. Taxon richness by region was computed as the number of all unique taxa per region, regardless of their density or site(s) where they were detected within a region. Water temperature was averaged across depths by site, and across sites by region.

Results and Discussion

An earlier report displayed preliminary results for the 2007 sampling year. Here we show the summarized results for 2007 and 2008. Figure 2 shows the seasonal trends in crustacean zooplankton densities by year and by region. On most dates, the majority of zooplankton scored belonged to a single cladoceran family, the Bosminidae. In order to depict this biased composition, for graphical presentation we partitioned the total assemblage of crustacean zooplankton into three groups: non-bosminid cladocerans, bosminids, and copepods. Densities of the total assemblage ranged widely on a seasonal basis from <1,000 to >70,000 individuals m^{-3}. Densities in all three regions generally increased between days 150-200 and consistently peaked between days 200-250. The timing of the buildup in zooplankton densities closely reflected increasing ambient water temperatures, and often lagged temperature by about 1 month. The parallel patterns in zooplankton densities and temperature are broadly consistent with the hypothesis that water temperature is a major environmental factor controlling zooplankton growth potential in this ecosystem.

Taxon richness patterns by region and year are shown in Figure 3. In 2007, richness ranged between 5-10 taxa per region. In 2008, richness ranged more widely from 5-15 taxa per region and there was a trend that year toward increasing richness with time in each region. However, in neither 2007 nor 2008, was there evidence for a disparity in richness by region.

These data offer valuable baseline information for planning the timing of our propagule pressure experiments to be carried out under Objective 3 in the coming year. In those experiments, the background zooplankton communities against which invasive propagules will be challenged will be developed from natural assemblages in the harbor. The information in Figures 2 and 3 will be used to guide the timing of experimental set ups to ensure particular starting densities and levels of taxon richness in the background assemblages.

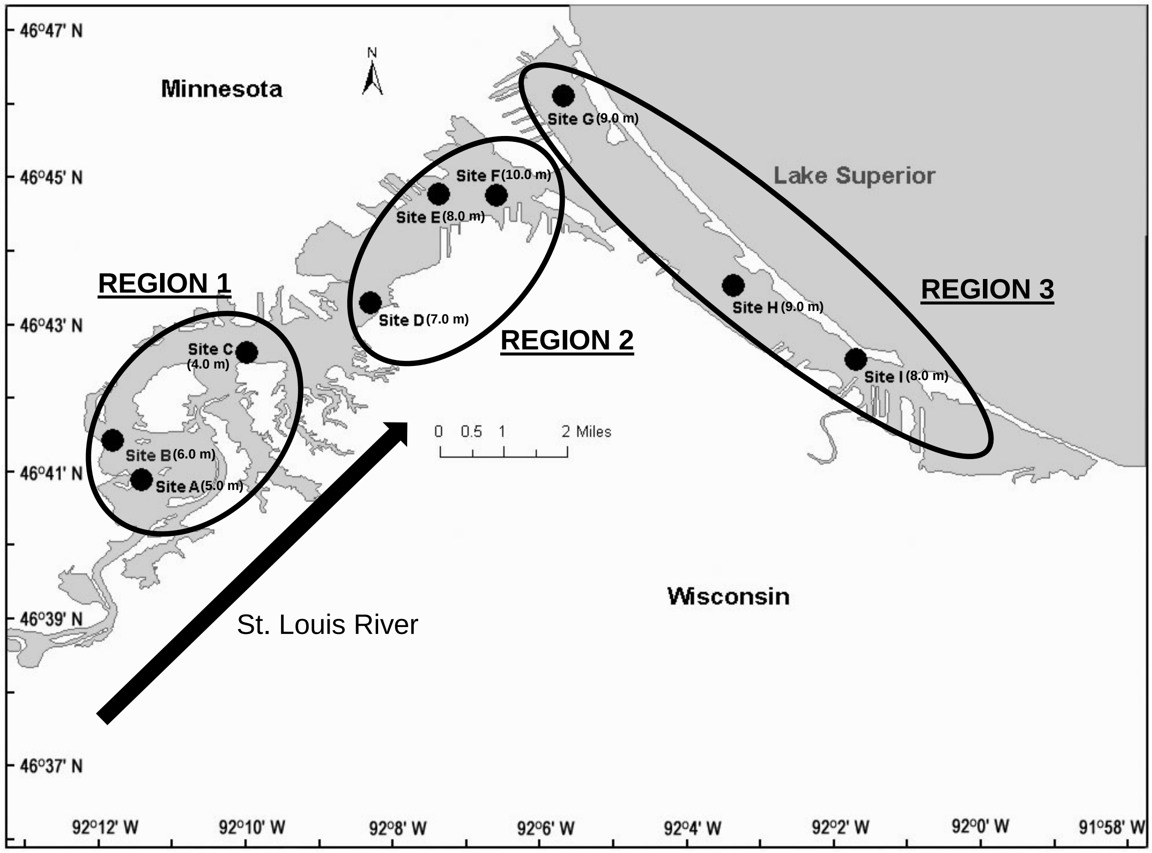

Figure 1. Schematic of the 9 sampling sites A-I (maximum depth) in the Duluth-Superior Harbor and St. Louis Estuary. Circles define sets of sites (Regions 1, 2 or 3) used in the analyses. The large arrow indicates direction of water flow.

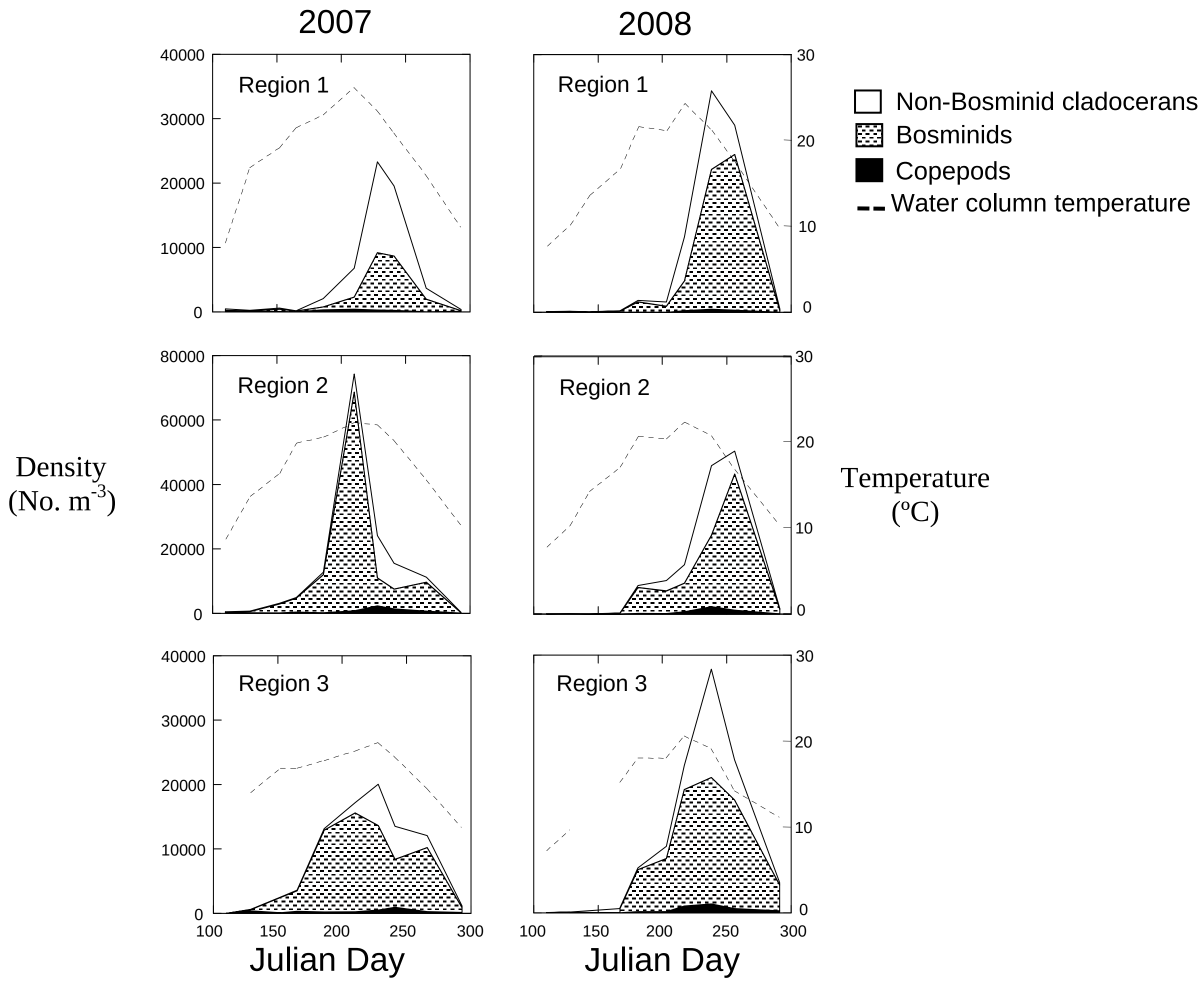

Figure 2. Average water column densities (no. m^{-3}) of crustacean zooplankton as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region (see Figure 1 for region locations). The average integrated water column temperatures by region are also shown. In 2007 and 2008, missing values for temperature in Region 3 reflect instrumentation problems.

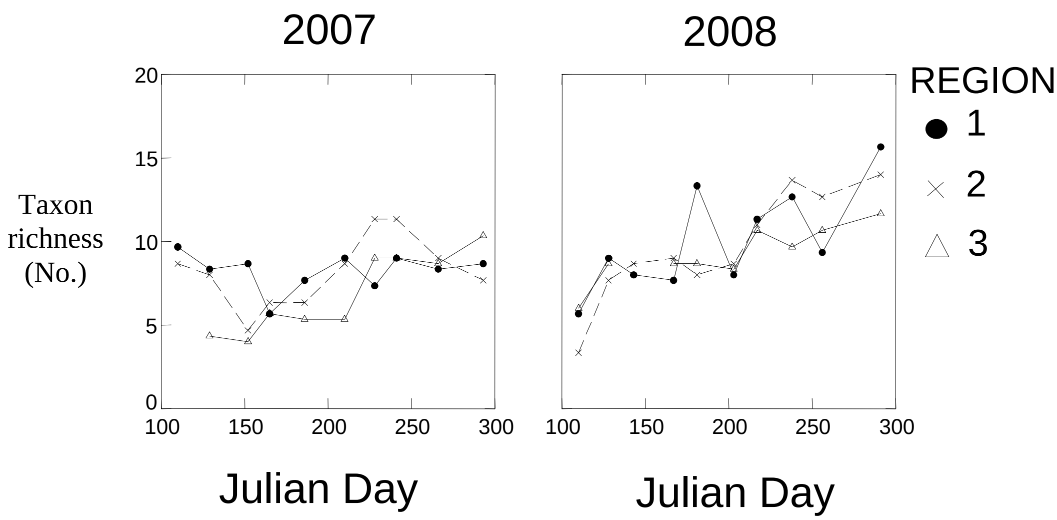

Figure 3. Taxon richness (number of unique taxa present) of crustacean zooplankton as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region (see Figure 1 for region locations).

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