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

Dr. Donn Branstrator
University of Minnesota Duluth

Mr. Matthew TenEyck
University of Minnesota, Water Resources Science Program,
Ph.D. student

Great Lakes Maritime Research Institute

A University of Wisconsin - Superior and University of Minnesota Duluth Consortium

Background

- U.S. Congress passed and reauthorized legislation in the 1990s that requires vessels to manage their ballast water in one of two ways:
  - Ballast Water Exchange (BWE) by flushing ballast tanks in the open ocean
  - Ballast Water Treatment (BWT) by proactive decontamination

Background

- California - . . . move the state expeditiously toward elimination of the discharge of nonindigenous species into the waters of the state or into waters that may impact the waters of the state, based on the best available technology economically achievable (**Title 2, Division 3, Chapter 1, Article 4.7**)

- Duluth News Tribune (Sept 21, 2008)
  - Article title “Our Waters, our rules”
  - Minnesota regulation will require all ballasted ships to apply for a permit and keep track of ballast releases
  - Applies to “salties” and “lakers”
  - By 2016 all ships treat ballast water
  - Patch-work Legislation by other Great Lake States/Provinces

BWT Standards

- International Maritime Organization (IMO) standards
  - Less than 10 viable orgs per cubic meter greater than 50 microns in min dimension
  - Less than 10 viable orgs per mL between 10 - 50 microns in min dimension
- Federal Standard – Coast Guard Authorization Act of 2008
  - 100 times more strict than IMO
- California's standard
  - No detectable living organisms that are greater than 50 microns in minimum dimension
  - Less than 0.01 living orgs per mL between 10-50 microns in min dimension

Background

- No evaluation of the relationships between permissible post-treatment concentration limits (propagule pressure) and the colonization success of non-native species

Background

- Recognize that BWE performs with high variability
- Recognize that no BWT technology can be expected to perform with 100% effectiveness all of the time
- The standards are meant to reduce the RISK OF BIOLOGICAL POLLUTION

Background

- Only recently relationships between the degree of propagule pressure (the size and frequency of a founding population) and the colonization success of invasive organisms have been studied

- Evidence from aquatic ecosystems is limited (Bohonak and Jenkins 2003, Colautti et al. 2006).

Research Objectives

- Evaluate the relationship between propagule pressure and colonization success of zooplankton through dose-gradient experiments

Research Objectives

- Evaluate the relationship between propagule pressure and colonization success of zooplankton through dose-gradient experiments

- Assess seasonal density and diversity of zooplankton at species level in the Duluth-Superior Harbor and the St. Louis River Estuary

Research Objectives

- Evaluate the relationship between propagule pressure and colonization success of zooplankton through dose-gradient experiments
- Assess seasonal density and diversity of zooplankton at species level in the Duluth-Superior Harbor and the St. Louis River Estuary
- Test the hypothesis that seasonal density and diversity of zooplankton in the Duluth-Superior Harbor (a measure of colonization success), is temporally and spatially correlated with seasonal ballast water discharge

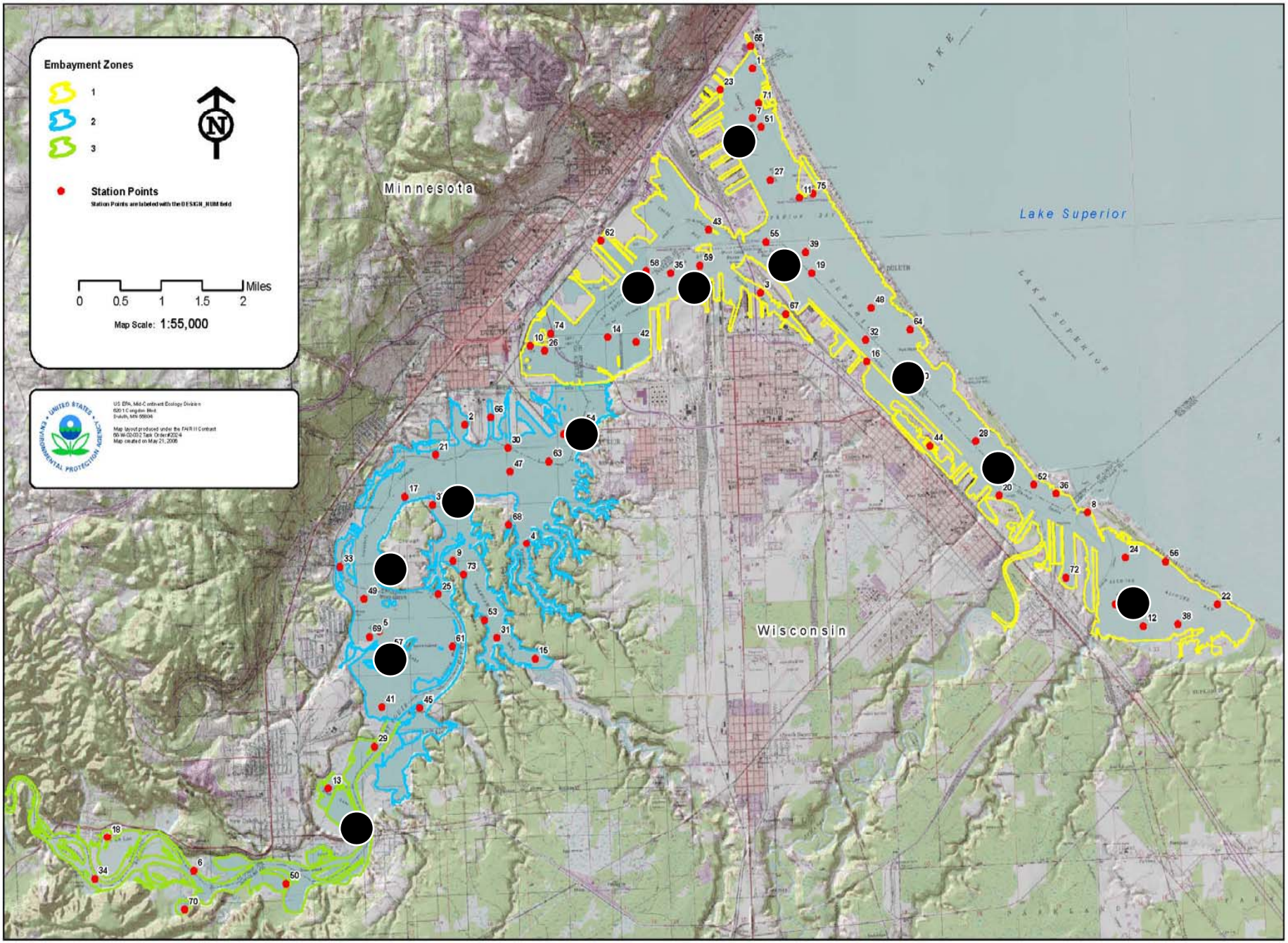
Objective: testing propagule pressure and colonization success

- Nested experimental design – crossed propagule pressure with abiotic and biotic resistance
  - Monitor physical/chemical parameters
  - Monitor invader and ambient orgs abundance

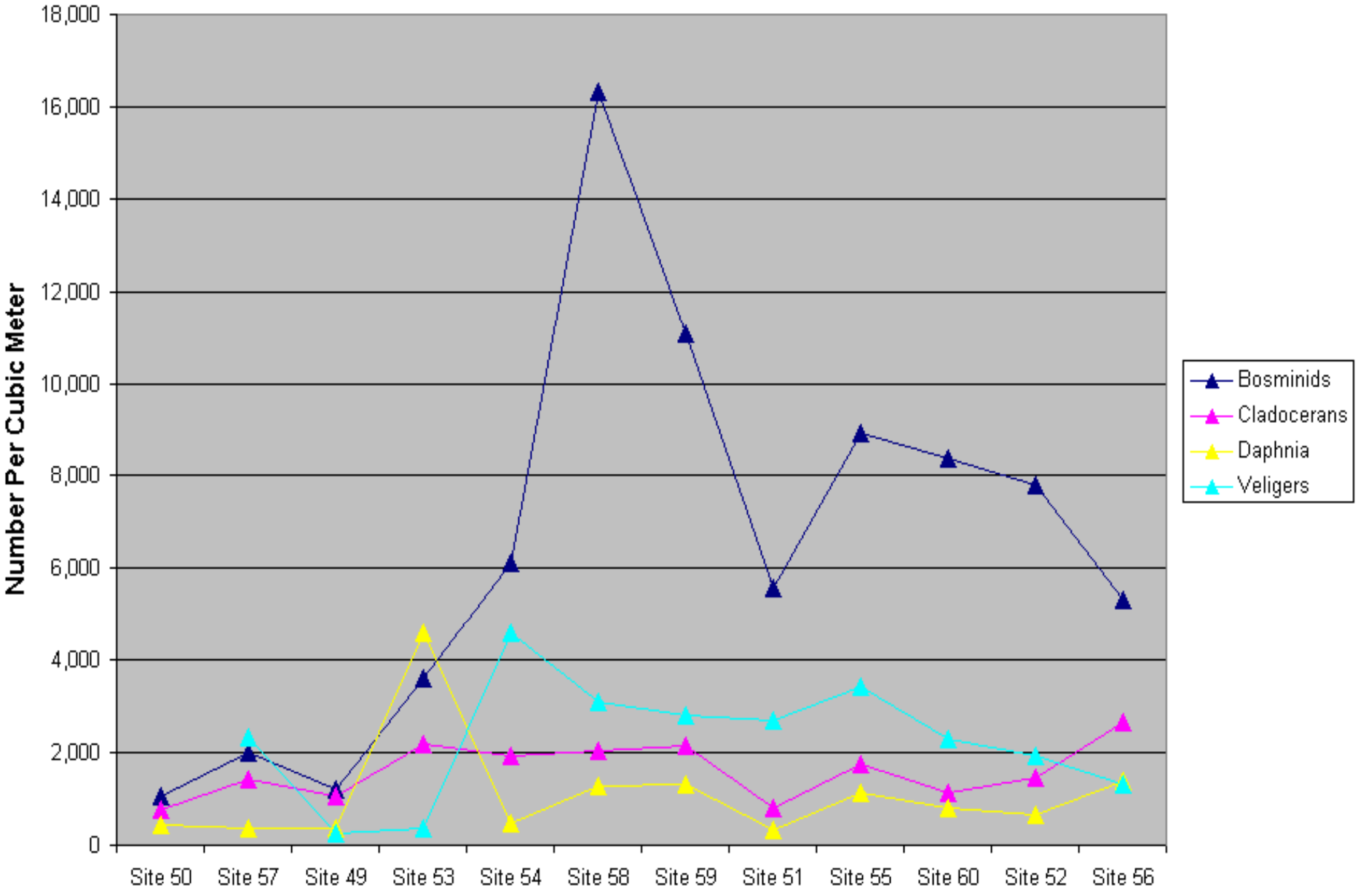
- *D. magna* as surrogate herbivore, parthenogenesis reproduction

- The Great Ships Initiative (GSI) is funding the construction of an on-site laboratory building at the RDTE facility
  - Will house 32 independently plumbed, grow-out mesocosms (each 1 m^{-3} capacity)
  - Assess the long-term viability of organisms post-treatment (FALL and WINTER 2008-2009)

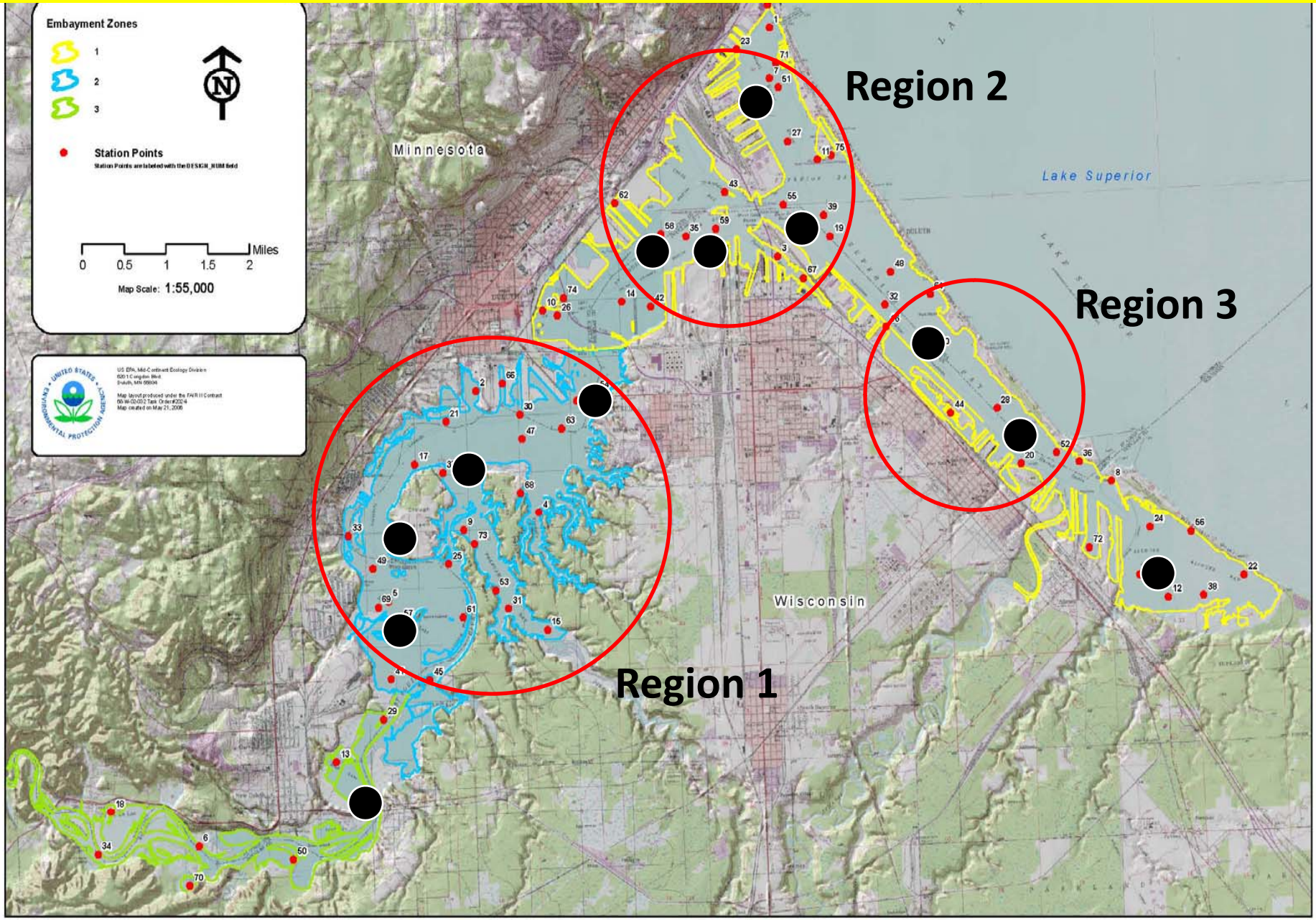
Results for Objective 2 and 3


Embayment Zones
1
2
3
Station Points
Station Points are labeled with the DESIGN_RUM field
0 0.5 1 1.5 2 Miles
Map Scale: 1:55,000
US EPA, Mid-Continent Ecology Division
6201 Congdon Blvd
Duluth, MN 55804
Map layout produced under the FAR II Contract
68-W-02-032 Task Order #232-4
Map created on May 21, 2006
Minnesota
Wisconsin
Lake Superior
LAKE SUPERIOR
DULUTH

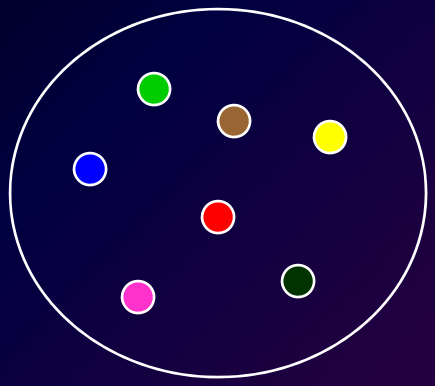
2007 Average Zooplankton Density (May – October)



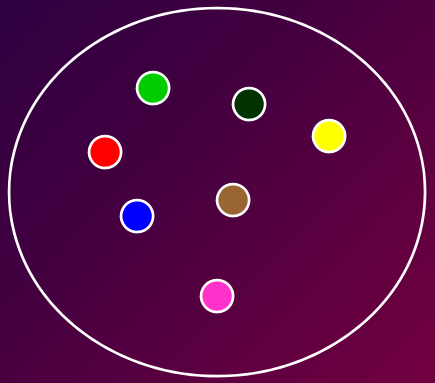
Jaccard Coefficient of Similarity = $c / (s_1 + s_2 - c)$

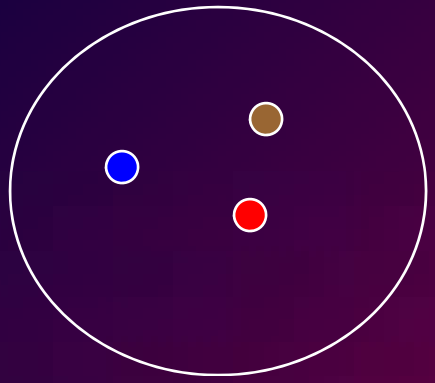


Jaccard Coefficient of Similarity

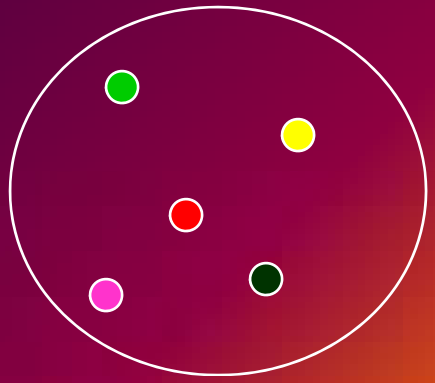


100% similar – all 7 species present in each community.





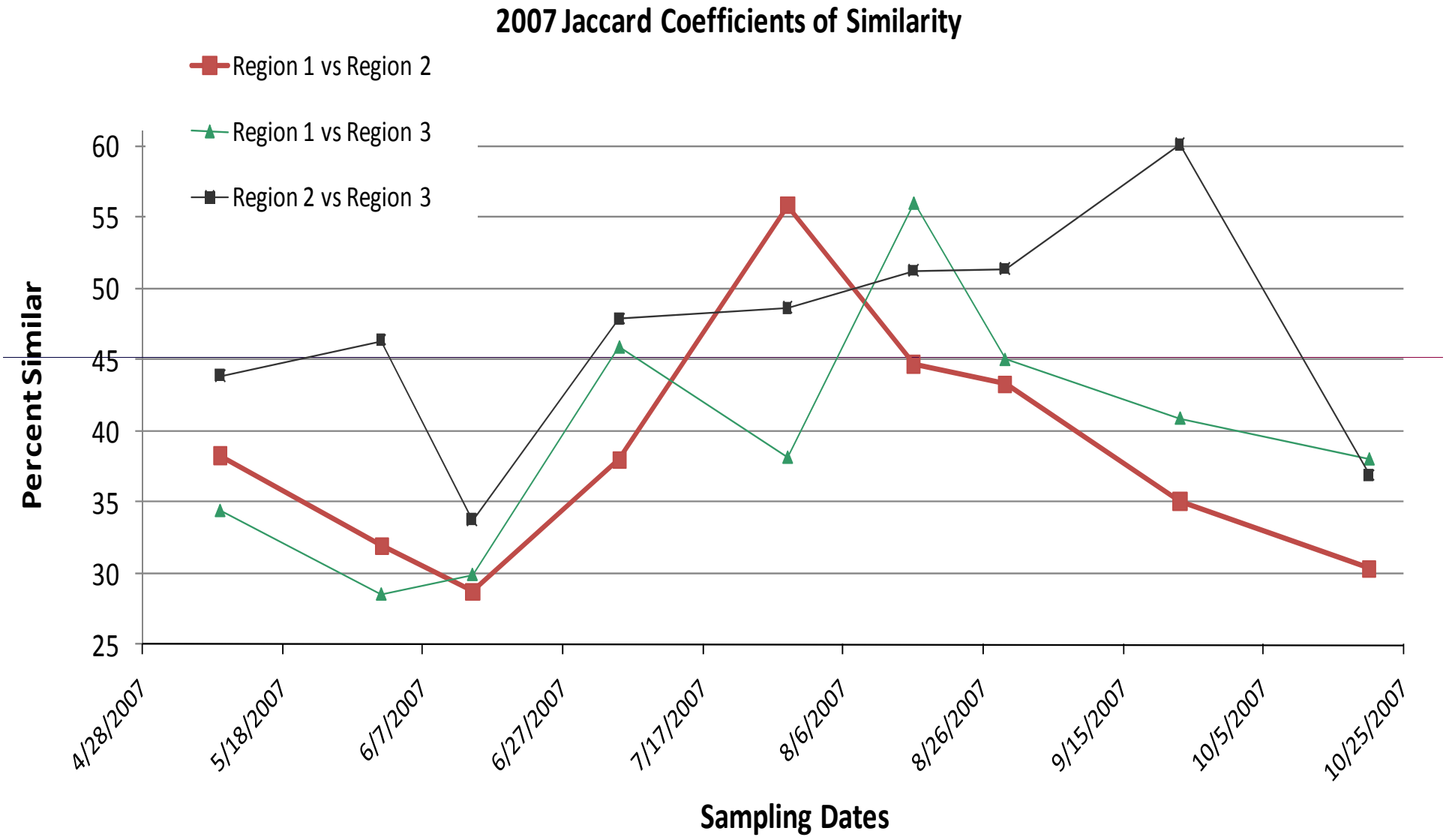
14% similar – only 1 of 7 species present in each community.



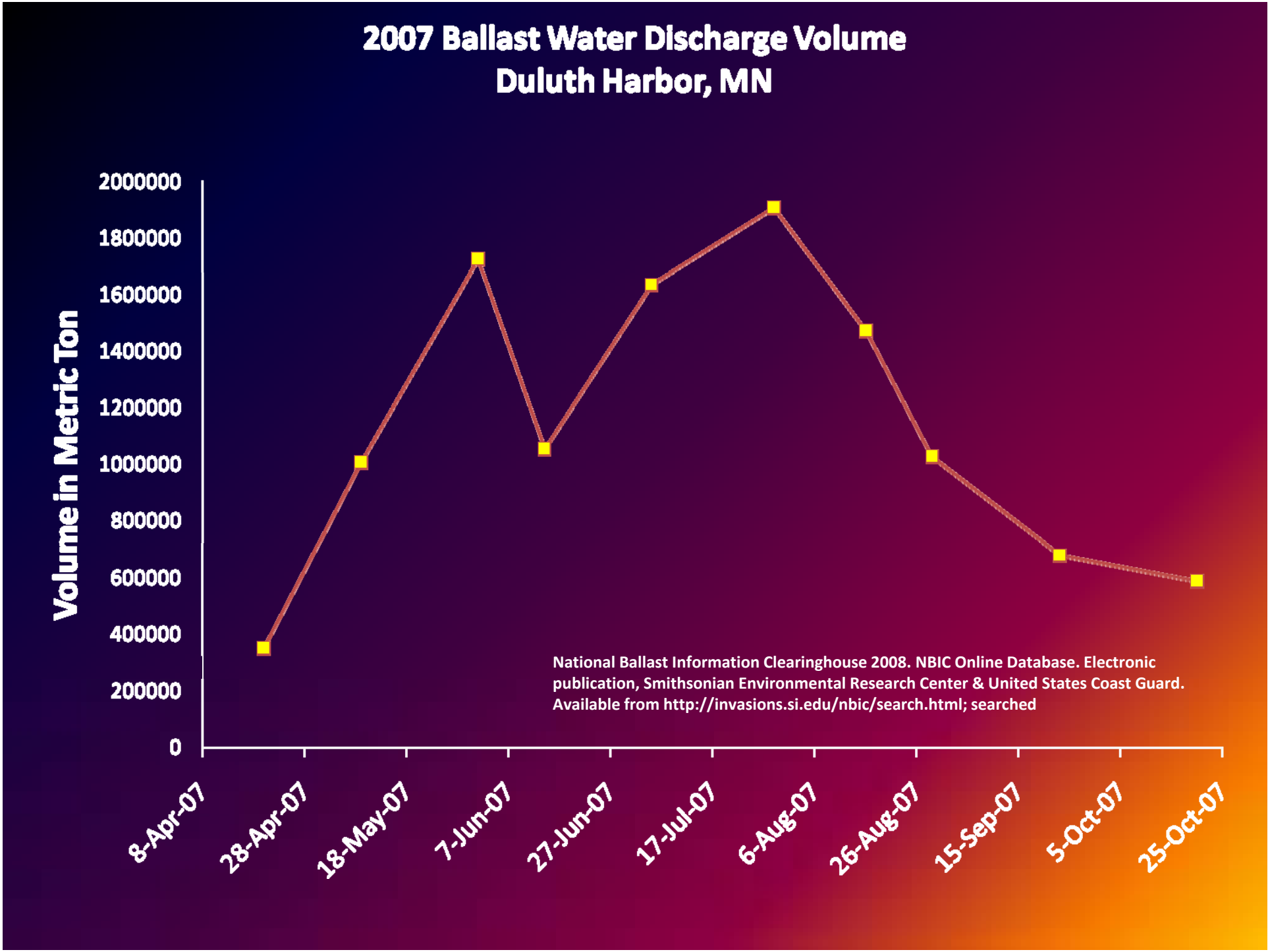
Species List for Duluth-Superior Harbor

Diaphansoma sp. Latona sp Latona setifera Sida crystallina Chydorus sp. Alona sp. Alona quadrangularis Alonella sp Camptocercus sp Camptocercus recterostra Eurycercus sp. Graptoliberis sp. Pleuroxus sp. Leydigea quadrularis Leydigea sp Monospilus sp. Pleuroxus striatus Pleuroxis denticulatus Eubosmina sp. Bosmina longirostrus Ilyocryptus sp. Macrothrix sp Macrothrix laticornis Ceriodaphnia sp Simocephalus sp Daphnia sp. Daphnia pulex D. retrocurva D. g. mendota D. parvula D. ambigua Harpacticoid male Harpacticoid female Eurytemora male Eurytemora female Epischura male Epischura female D. sicillodies male D. sicillodies female D. sicilis male D. sicilis female D. ashlandi male D. ashlandi female D. orgenensis male D. orgenensis female D. minutus male D. minutus female M. albidus male M. albidus female M. edax male M. edax female Paracyclops poppei male Paracyclops poppei female Paracyclops chiltoni male Paracyclops chiltoni female T. mexicanus male T. mexicanus female Eucyclops sp male Eucyclops sp female E. agilis male E. agilis female E. prionophorus male E. prionophorus female E. elegans male E. elegans female A. vernalis male A. vernalis female D. thomasi male D. thomasi female Leptodora Holopedium N auplii Cyclop copepidids Mesocyclop copepidids Tropocyclop copepidids Diaptomus copepidids Harpactacoid copepidids Eury copepidids Epischura copepidids Ostracod sp. Veligers

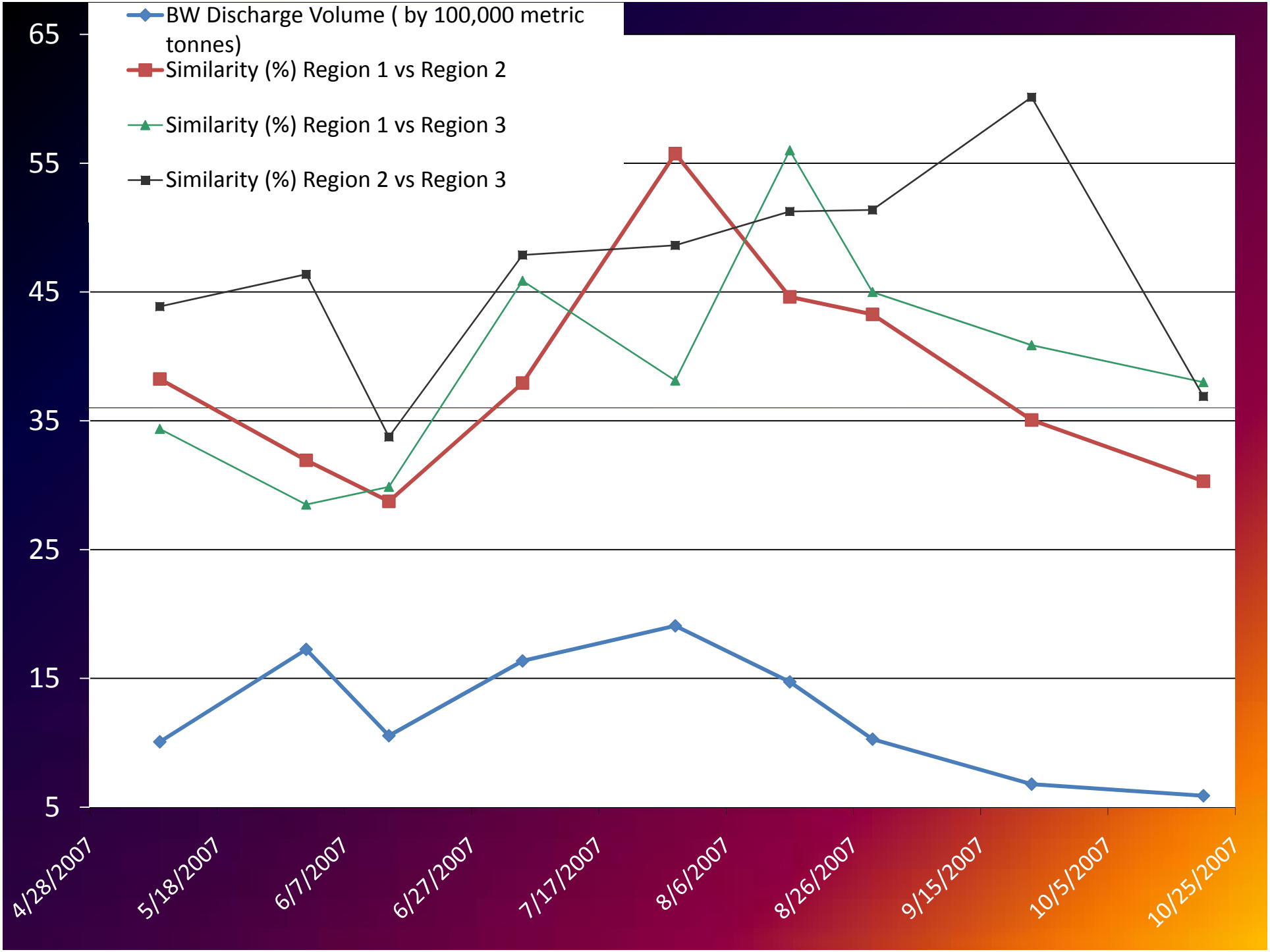
Total Species Count = 62

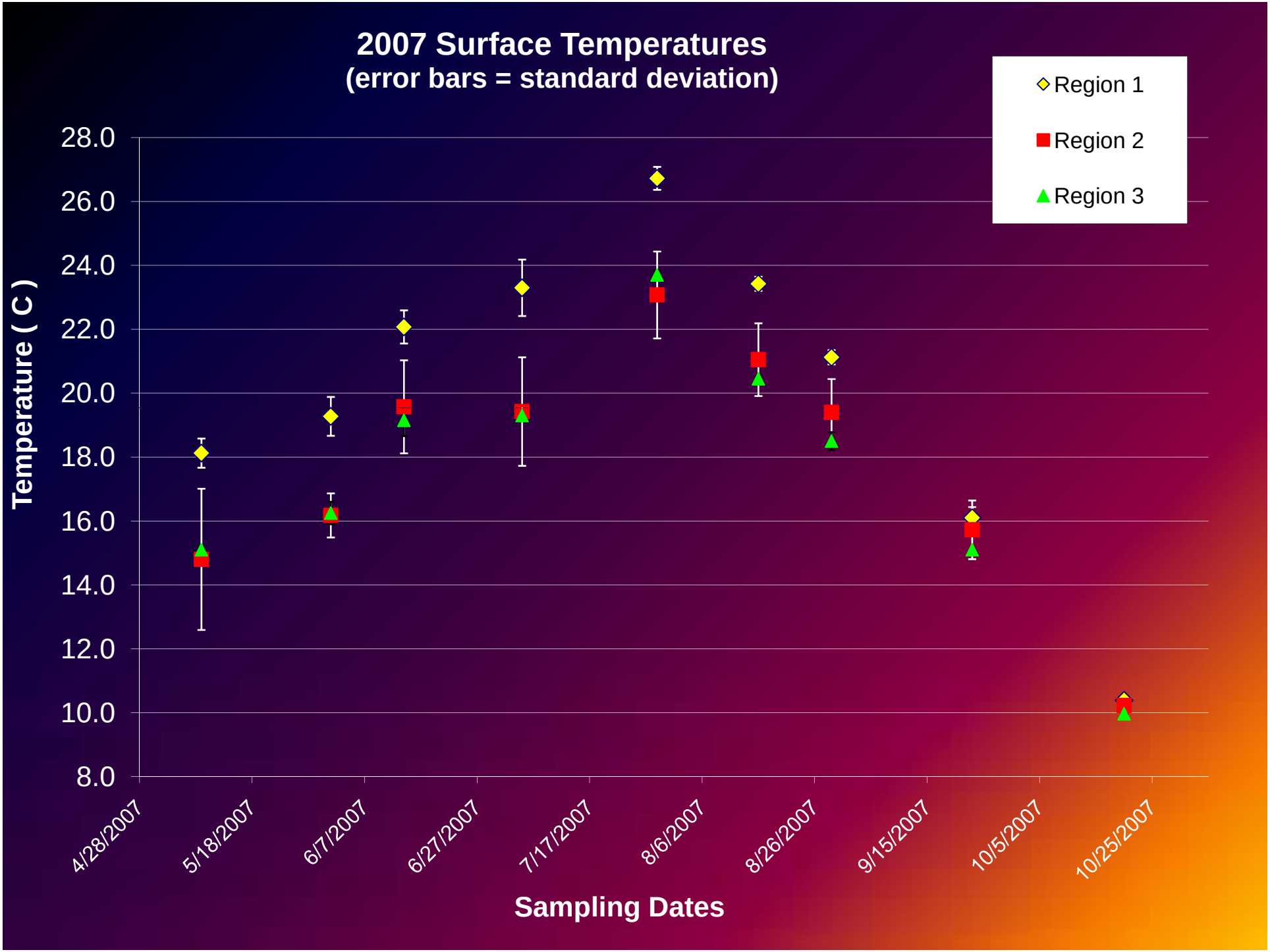

2007 Jaccard Coefficients of Similarity
Region 1 vs Region 2
Region 1 vs Region 3
Region 2 vs Region 3
Percent Similar
60
55
50
45
40
35
30
25
4/28/2007
5/18/2007
6/7/2007
6/27/2007
7/17/2007
8/6/2007
8/26/2007
9/15/2007
10/5/2007
10/25/2007
Sampling Dates

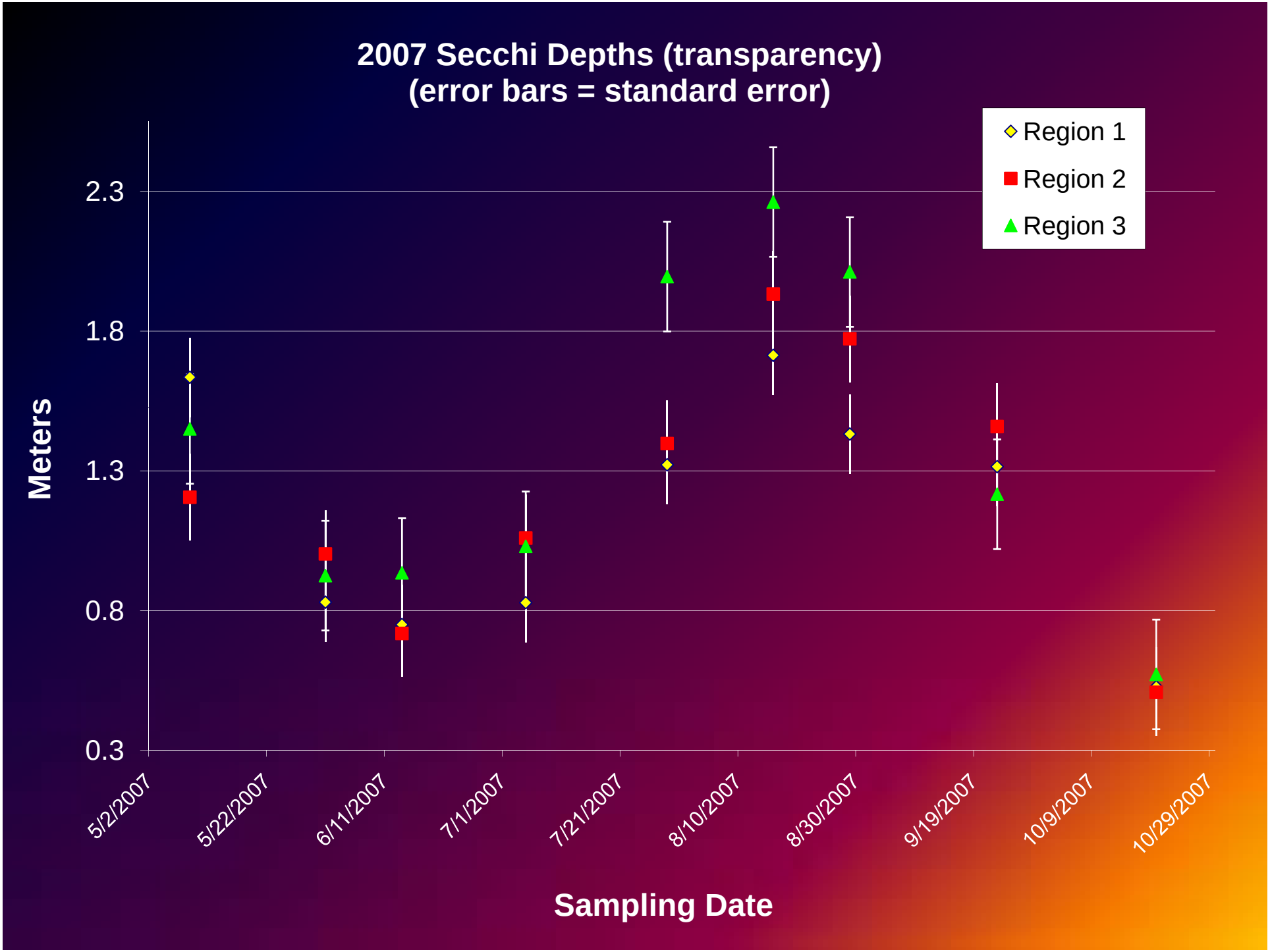
2007 Ballast Water Discharge Volume
Duluth Harbor, MN

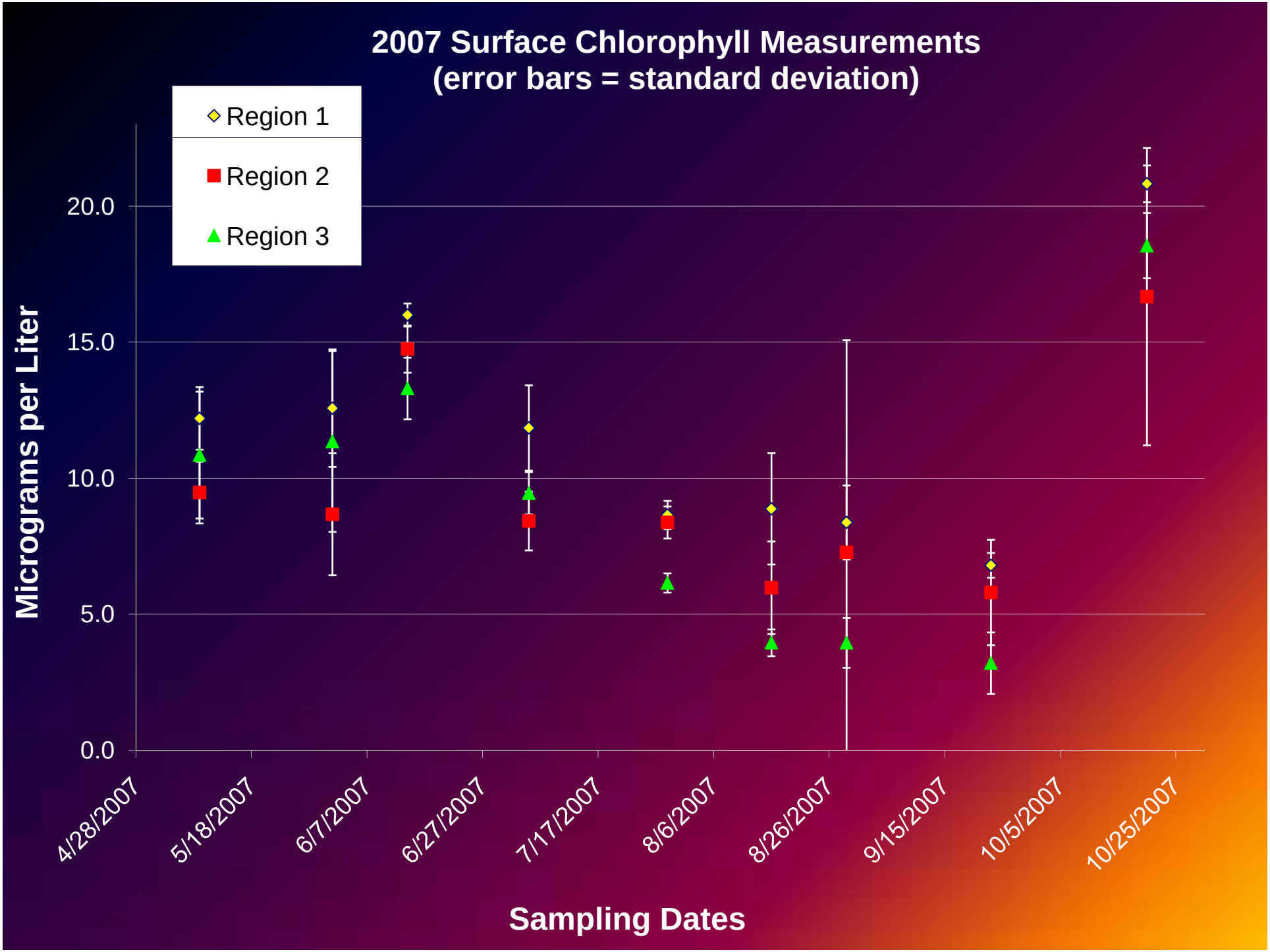


National Ballast Information Clearinghouse 2008. NBIC Online Database. Electronic publication, Smithsonian Environmental Research Center & United States Coast Guard. Available from http://invasions.si.edu/nbic/search.html; searched


BW Discharge Volume (by 100,000 metric tonnes)
Similarity (%) Region 1 vs Region 2
Similarity (%) Region 1 vs Region 3
Similarity (%) Region 2 vs Region 3
65
55
45
35
25
15
5
4/28/2007
5/18/2007
6/7/2007
6/27/2007
7/17/2007
8/6/2007
8/26/2007
9/15/2007
10/5/2007
10/25/2007


2007 Surface Temperatures
(error bars = standard deviation)
Region 1
Region 2
Region 3
Temperature (C)
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
4/28/2007
5/18/2007
6/7/2007
6/27/2007
7/17/2007
8/6/2007
8/26/2007
9/15/2007
10/5/2007
10/25/2007
Sampling Dates


2007 Secchi Depths (transparency)
(error bars = standard error)
Region 1
Region 2
Region 3
Meters
2.3
1.8
1.3
0.8
0.3
5/2/2007
5/22/2007
6/11/2007
7/1/2007
7/21/2007
8/10/2007
8/30/2007
9/19/2007
10/9/2007
10/29/2007
Sampling Date


2007 Surface Chlorophyll Measurements
(error bars = standard deviation)
Region 1
Region 2
Region 3
Micrograms per Liter
20.0
15.0
10.0
5.0
0.0
4/28/2007
5/18/2007
6/7/2007
6/27/2007
7/17/2007
8/6/2007
8/26/2007
9/15/2007
10/5/2007
10/25/2007
Sampling Dates

Summary of Results

- Patterns in similarity among regional zooplankton assemblages appear to correlate with increased ballast water discharge volumes in the Duluth Harbor.
- Habitat characteristics (temperature, clarity, chlorophyll) do not appear to converge during periods of increased regional similarity in zooplankton assemblages.