Evaluating Ballast Water Treatment Standards: Testing Relationships Between Propagule Pressure and Colonization Success of *Daphnia magna*, a Surrogate Invader.

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Participation

- Dissertation committee members: Dr. Mary Balcer (UWS), Dr. Stephanie Guildford (UMD), Dr. Ray Newman (UMTC), and Dr. John Pastor.
- UWS In kind services – Testing laboratory
- Great Ships Initiative – Monetary support for laboratory infrastructure
- Graduate and undergraduate student support – 10 students

Rationale

- Freshwater ecosystems are vulnerable to invasions by nonindigenous species (NIS)
  1) Municipal and industrial water supplies
  2) Natural resources development
  3) Recreation
  4) <u>Commercial navigation</u>
- NIS are causing environmental changes and imposing higher economic costs
  1) Zebra and quagga mussels altering food web structure
  2) Zebra and quagga mussels adding increased costs to raw water users of the Great Lakes

Rationale cont.

- Laurentian Great Lakes have received an increasing number of NIS
    1) Since the 1800s 139 NIS have established
    2) 1959-1989 establishment rate = 0.6 species per year
    3) 1989-2001 establishment rate = 1.8 species per year
    4) Many of the NIS are believed to have entered via ballast water of ships

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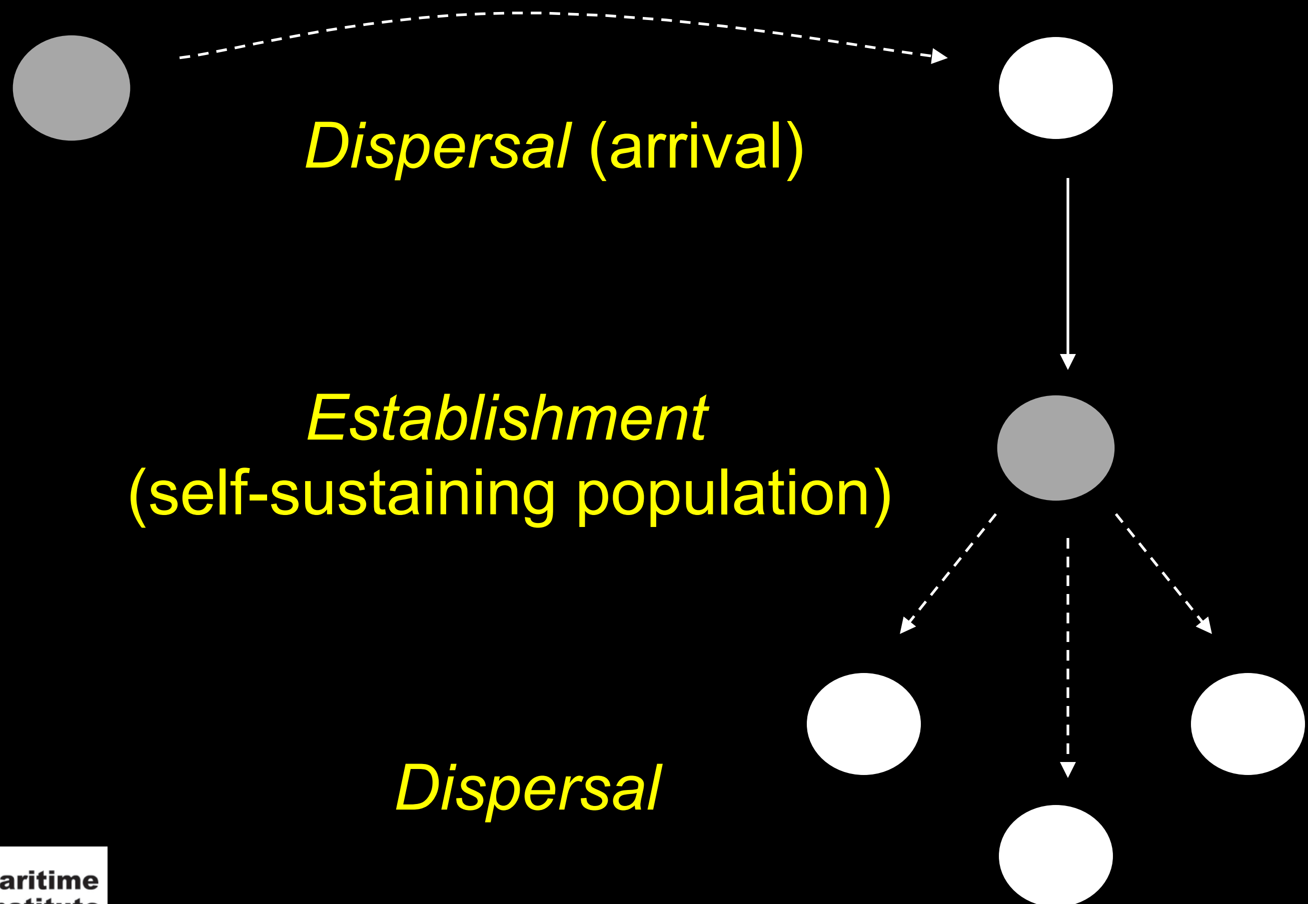
Rationale cont.

Biological invasions require a pair of steps -



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Rationale cont.

- A goal of invasion ecology is to determine what factor(s) lead to establishment

- Propagule pressure – number of organisms introduced per event and the number of events
    1) Large introduced populations are less likely to become extinct
    2) Large populations more likely to tolerate environmental extremes
    3) Declining populations are sustained through addition of propagules

- General theory based predictions suggest that higher propagule pressure increases probability of establishment success.

- Few experimental studies have quantified explicitly how much propagule pressure is required to overcome establishment barriers.

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Rationale cont.

- U. S. Congress passed and reauthorized legislation in the 1990s that requires vessels to manage their ballast water in one of two ways to reduce dispersal and establishment:

1) Ballast Water Exchange (BWE) by flushing ballast tanks in the open ocean

2) Ballast Water Treatment (BWT) by proactive decontamination

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Rationale cont.

- International Maritime Organization (IMO) standards
  1) Less than 10 viable organisms per cubic meter greater than 50 microns in min. dimension
  2) Less than 10 viable organisims per mL between 10-50 microns in min. dimension

- Federal Standard–Coast Guard Authorization Act of 2008
  1) 100 times more strict than IMO

- California's standard
  1) No detectable living organisms that are greater than 50 microns in min. dimension
  2) Less than 0.01 living organisms per mL between 10-50 microns in min. dimension

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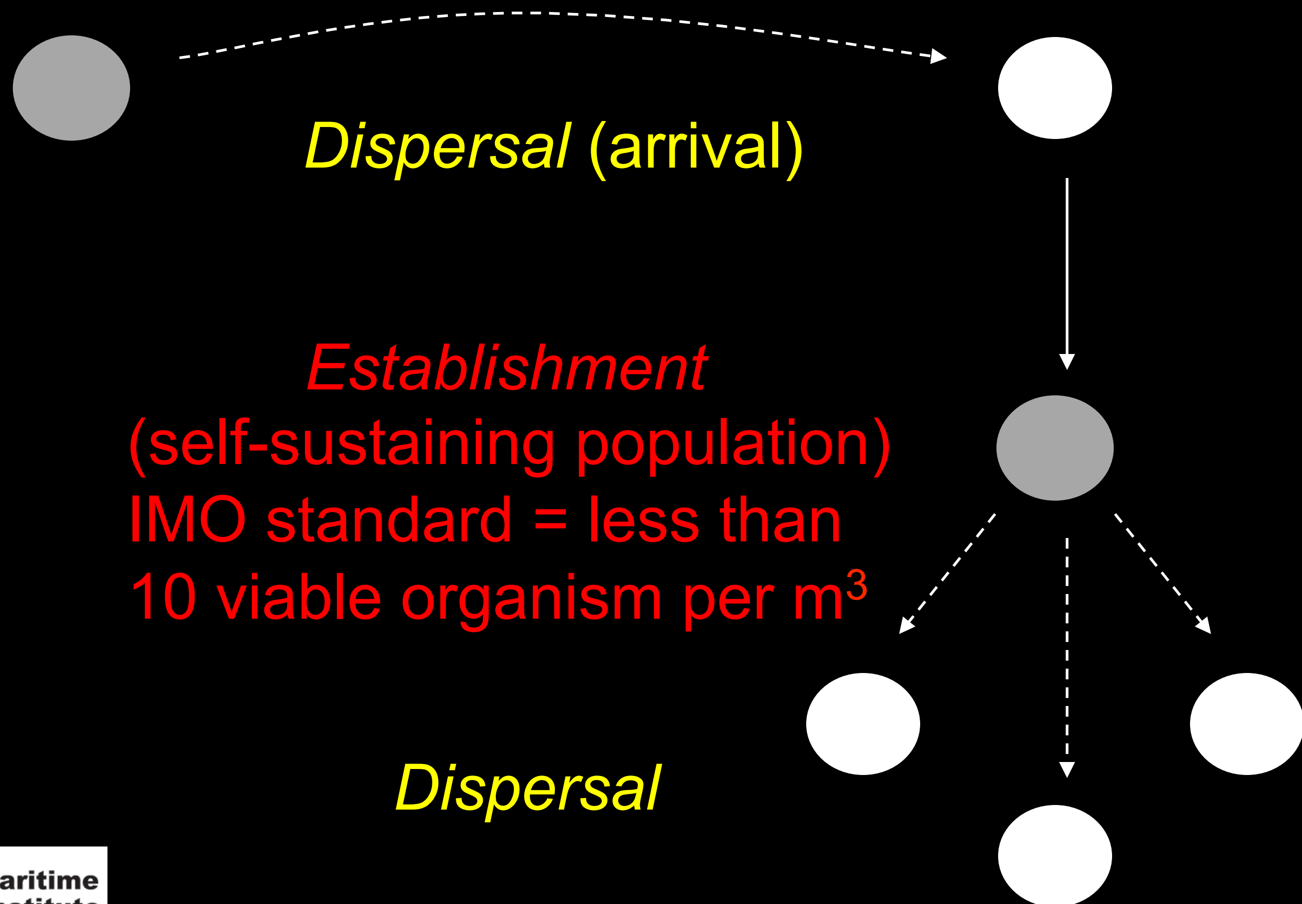
Rationale cont.

Biological invasions require a pair of steps -



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Methods

- Objective: Conduct dose-gradient experiments to quantify how a model non-native species (*Daphnia magna*) establishes in response to different levels of propagule pressure and in response to different recipient communities

- Hypothesis: Current IMO ballast water treatment standards prevent establishment of *D. magna*, a surrogate invader.

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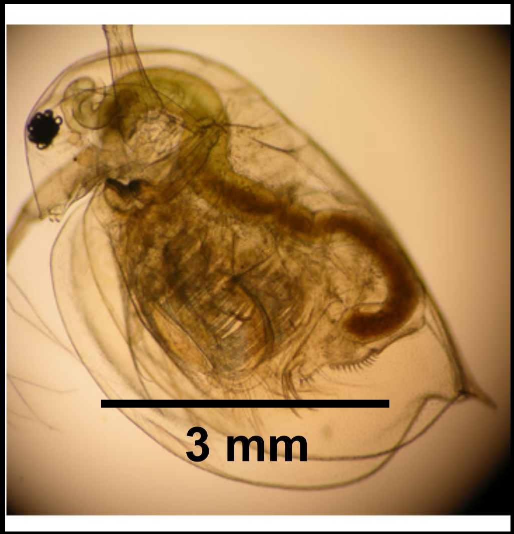
Methods cont.

- *Daphnia magna* served as the surrogate invader
- 230-L mesocosm tanks
- 16:8 h light:dark cycle
- Temperature, Light, pH, Dissolved Oxygen, Chlorophyll measured weekly
- Experiment length: 8 weeks
  1) Nov-Dec 2009
  2) May-June 2010
  3) Aug-Sep 2010
  4) Oct-Nov 2010



Methods cont.

- Tanks were stocked with starting densities of *D. magna* that straddled IMO standards.

- Doses = 0, 5, 10, 15, 20 *D. magna* per m^3 randomly assigned to tanks (n=3)

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Methods cont.

- During the 8 week experiment, weekly estimates of *D. magna* are made by subsampling 1.0 L of water
  1) All *D. magna* will be returned to respective tank
  2) Background community concentrated and preserved
  3) On day 56 the entire 200 L is searched for *D. magna*

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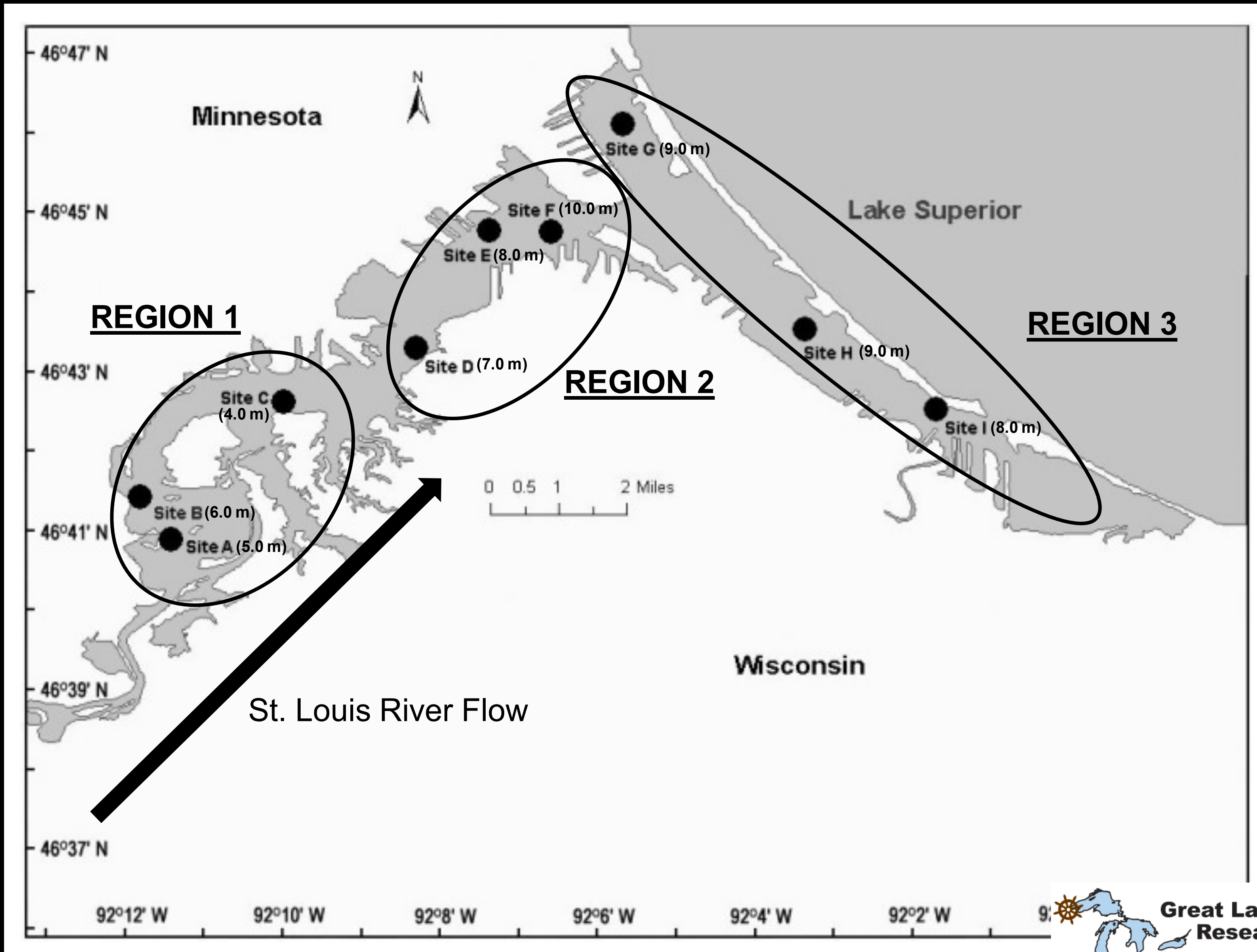
Schematic of the 9 sampling sites A-I (maximum depth) in the Duluth-Superior Harbor and St. Louis Estuary.



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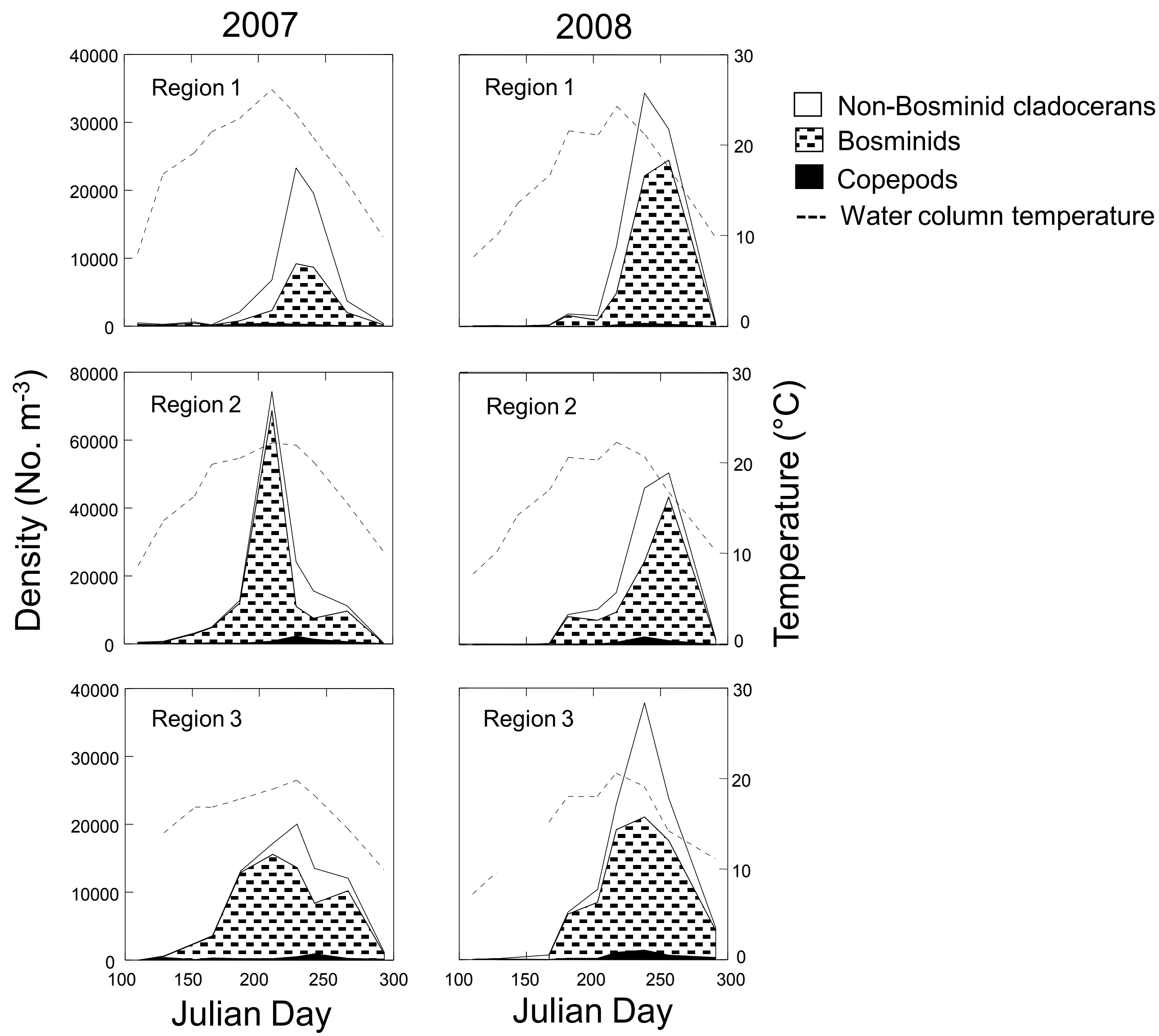
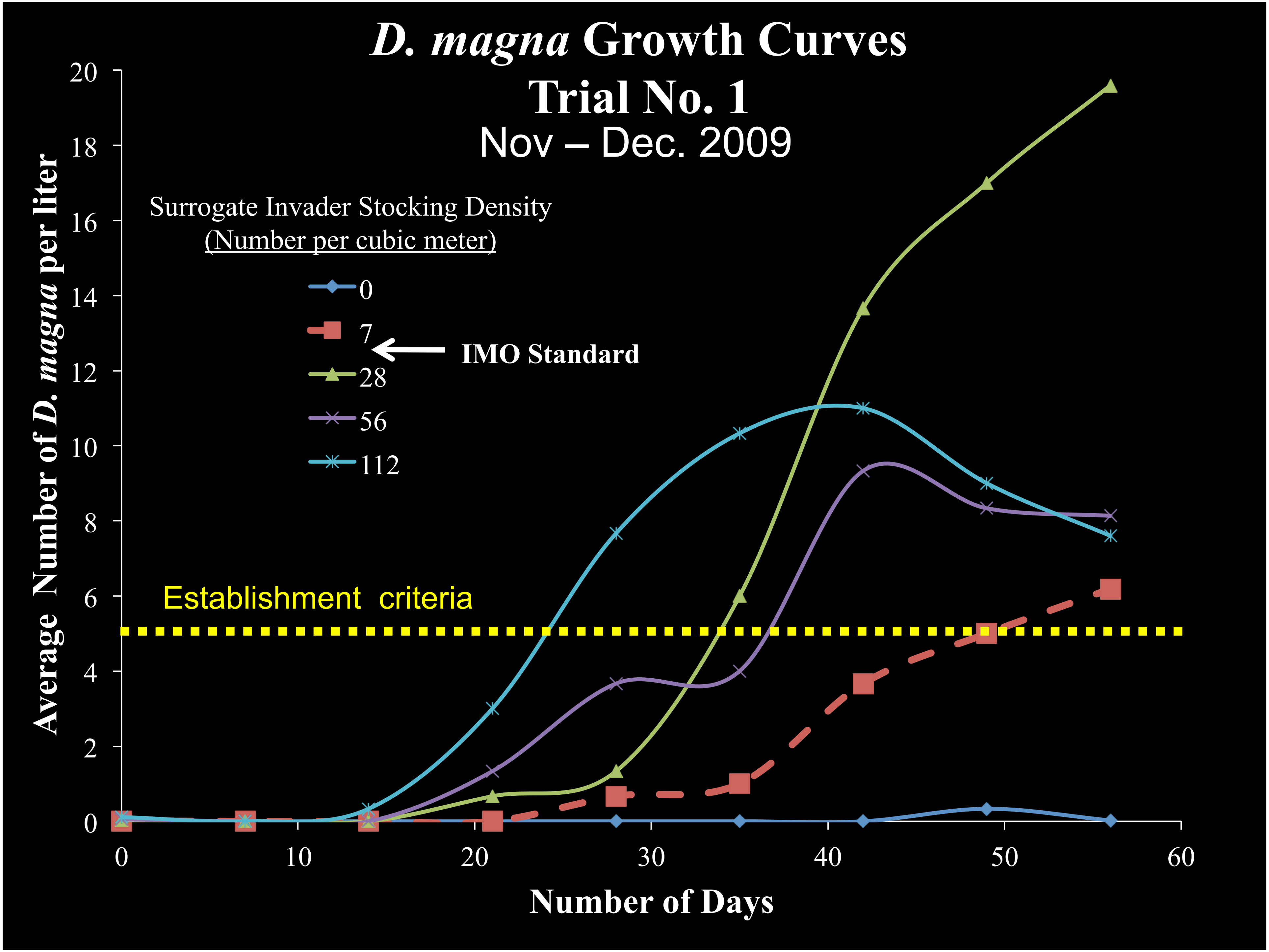
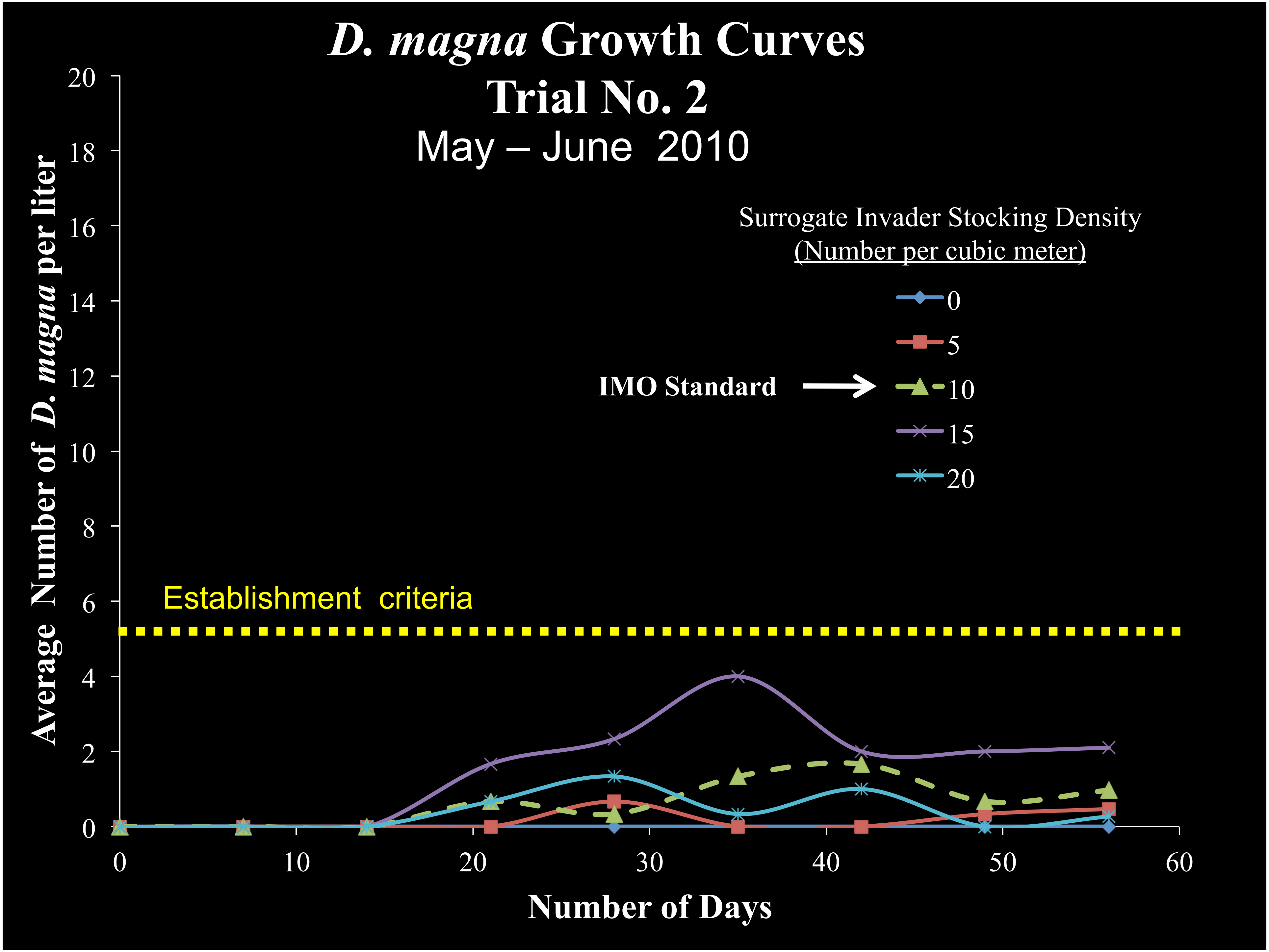
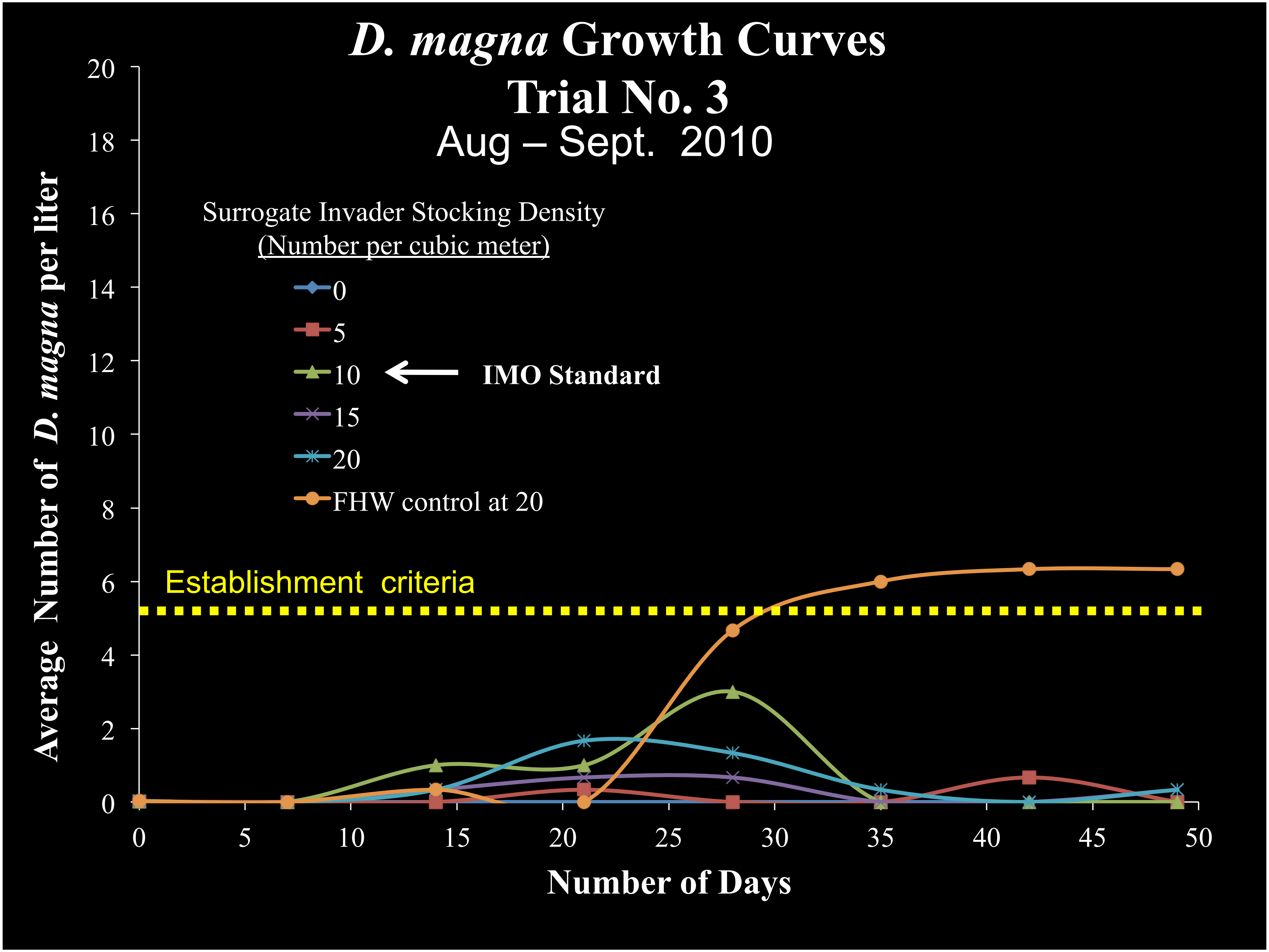
Average water column densities of crustacean zooplankton and average integrated water column temperatures as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region.





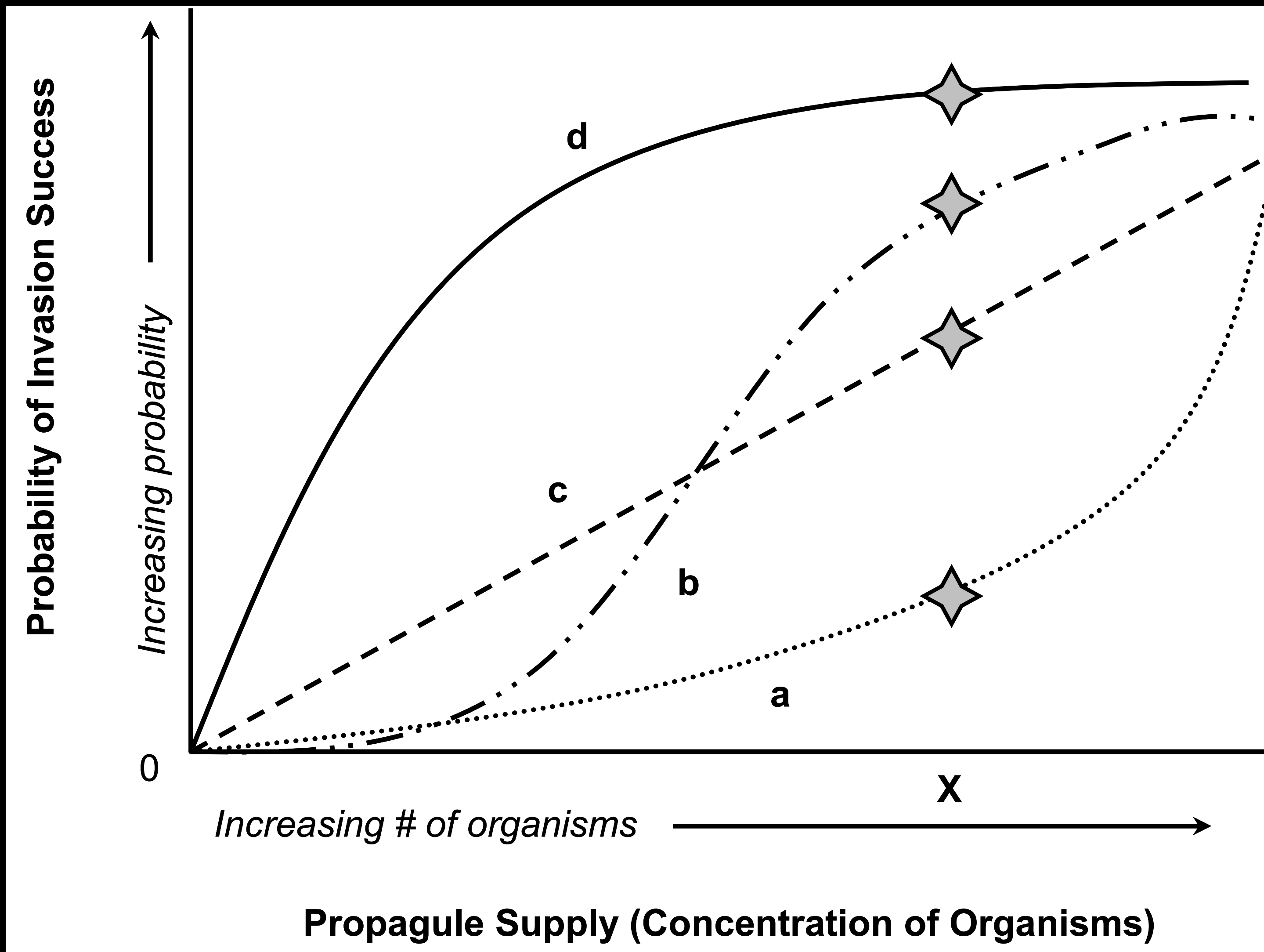
D. magna Growth Curves
Trial No. 1
Nov – Dec. 2009
Surrogate Invader Stocking Density
(Number per cubic meter)
0
7
28
56
112
IMO Standard
Establishment criteria
Average Number of D. magna per liter
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
Number of Days


D. magna Growth Curves
Trial No. 2
May – June 2010
Surrogate Invader Stocking Density
(Number per cubic meter)
0
5
IMO Standard
10
15
20
Establishment criteria
Average Number of D. magna per liter
Number of Days
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60



D. magna Growth Curves
Trial No. 3
Aug – Sept. 2010
Surrogate Invader Stocking Density
(Number per cubic meter)
0
5
10
IMO Standard
15
20
FHW control at 20
Establishment criteria
Average Number of *D. magna* per liter
Number of Days
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
40
45
50

Model Development

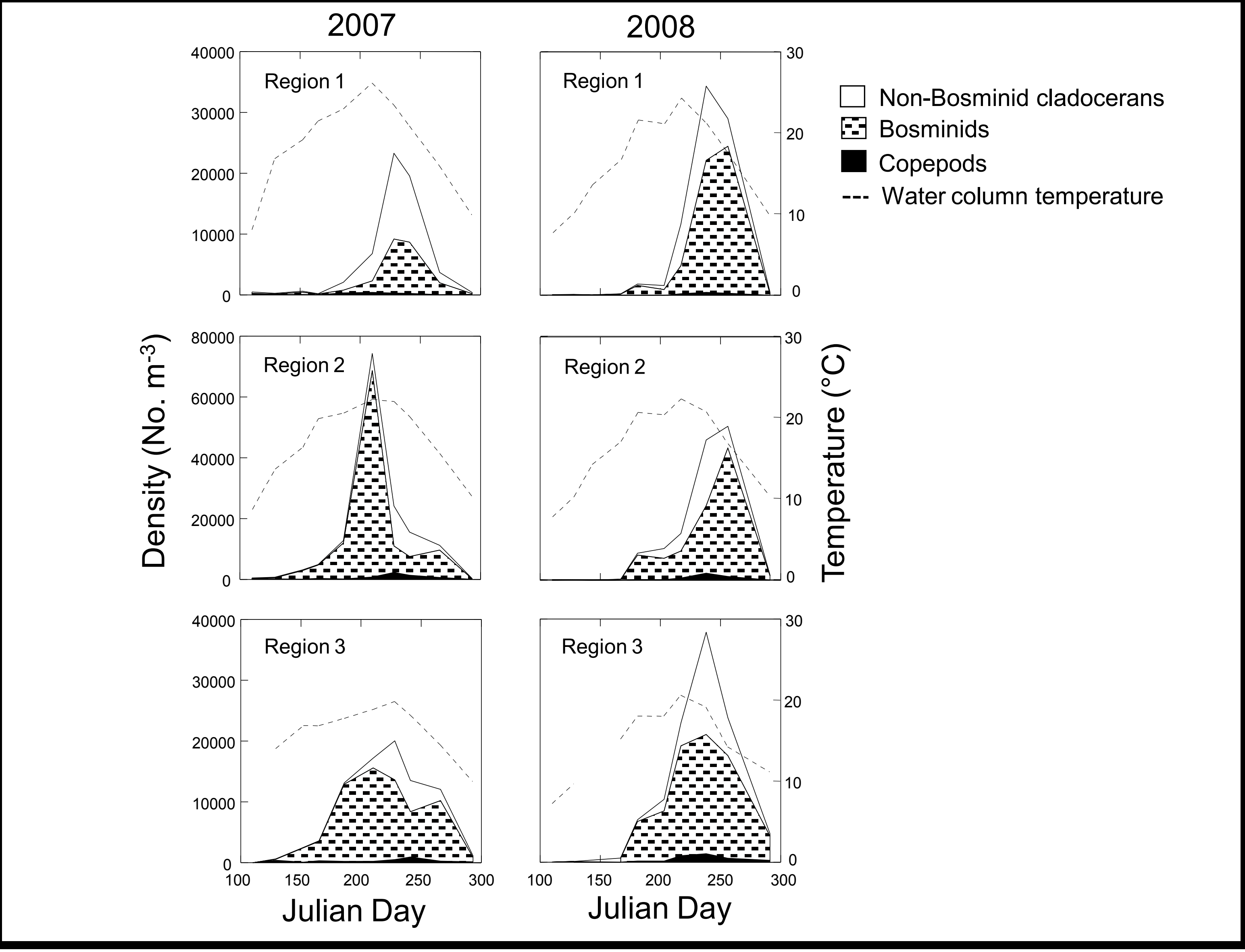


Modified from Ruiz G.M. and J.T. Carlton 2003. Invasion vectors: a conceptual framework for management. In: Invasive Species, Vectors and Management Strategies. Ruiz G.M. and J.T. Carlton (Eds). Washington D.C.: Island Press. 459-504.

Preliminary Conclusions

- Natural densities of crustacean zooplankton in the Duluth-Superior Harbor are seasonally variable.
- Experimental evidence indicates that establishment success of a surrogate invader introduced at IMO standards is non-zero.
- Data not shown - establishment success may be related to the density and or composition of the recipient community.

Average water column densities of crustacean zooplankton and average integrated water column temperatures as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region.



Future Work

- Conduct 4th trial in Oct-Nov 2010
- Conduct 5th, 6th, and 7th trials in 2011
- Develop a model of ballast water based invasion that relates establishment risk to propagule pressure.

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Thank You

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