Maritime Environmental Resource Center

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www.maritime-enviro.org

Maritime Environmental Resource Center

Foci

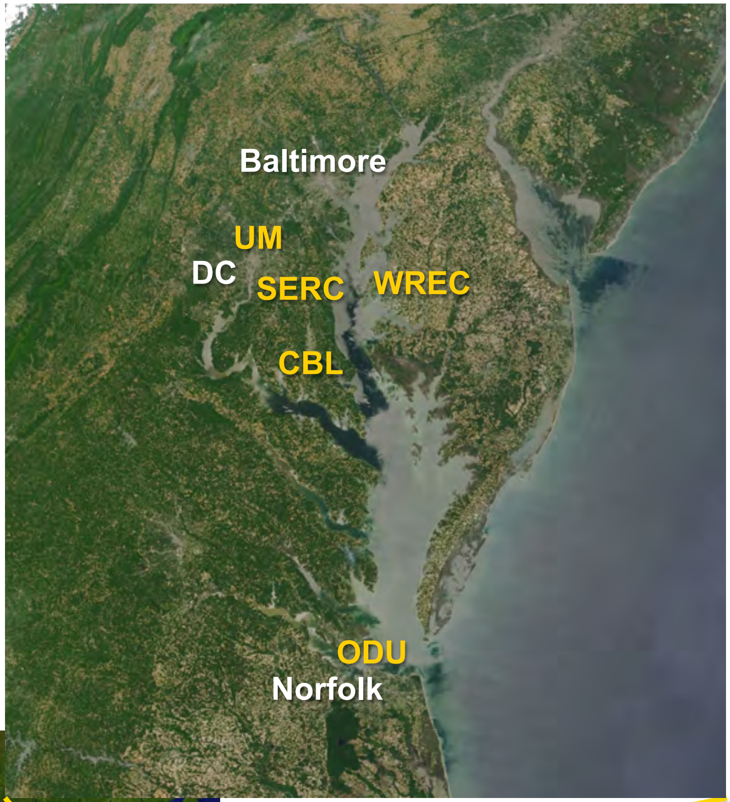
- Evaluating the mechanical and biological efficacy of ballast water management systems - laboratory, land-based and shipboard
- Facilitating the development and adoption of green ship technologies
- Assessing the economics of ballast water regulations, management and green shipping

Partners

Independent Laboratory

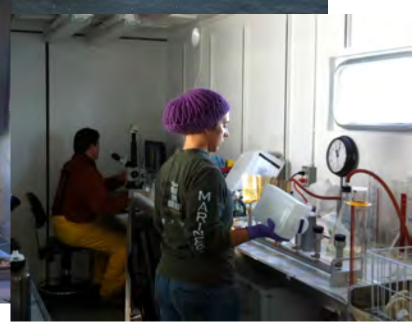
MERC Centered on the Chesapeake Bay

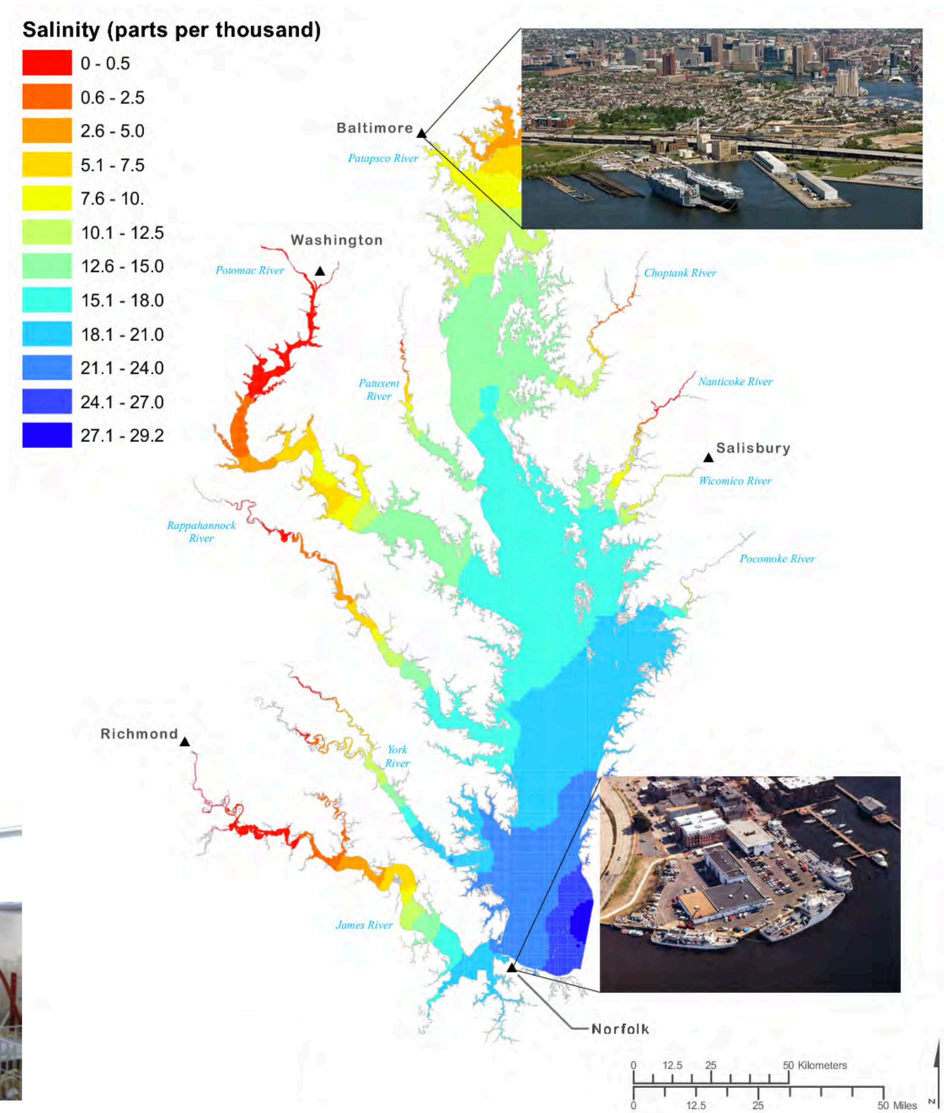
- Diverse physical conditions for system testing
- Abundant and taxonomically diverse plankton
- Expertise and experience
- More than 150 known aquatic invasive species in the Bay
- Economically and politically important region



MERC Mobile Test Platform

- Port of Baltimore, 5 – 12 psu
- Port of Norfolk, 21 – 28 psu
- Washington DC, 0 psu





Sampling Approach and Volumes

Environmental Science & Technology

ARTICLE

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Enumerating Sparse Organisms in Ships' Ballast Water: Why Counting to 10 Is Not So Easy

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Supporting Information

ABSTRACT: To reduce ballast water-borne aquatic invasions worldwide, the International Maritime Organization and United States Coast Guard have each proposed discharge standards specifying maximum concentrations of living biota that may be released in ships' ballast water (BW), but these regulations still lack guidance for standardized type approval and compliance testing of treatment systems. Verifying whether BW meets a discharge standard poses significant challenges. Properly treated BW will contain extremely sparse numbers of live organisms, and robust estimates of rare events require extensive sampling efforts. A balance of analytical rigor and practicality is essential to determine the volume of BW that can be reasonably sampled and processed, yet yield accurate live counts. We applied statistical modeling to a range of sample volumes, plankton concentrations, and regulatory scenarios (i.e., levels of type I and type II errors), and calculated the statistical power of each combination to detect noncompliant discharge concentrations. The model expressly addresses the roles of sampling error, BW volume, and burden of proof on the detection of noncompliant discharges in order to establish a rigorous lower limit of sampling volume. The potential effects of recovery errors (i.e., incomplete recovery and detection of live biota) in relation to sample volume are also discussed.

INTRODUCTION

Maritime transportation is a foundation of the global market. There are well over 50,000 commercial ships which move goods around the world among over 300 major ports.[1,2] However, the ballast water associated with merchant vessel traffic is also responsible for the transfer and introduction of aquatic invasive species to coastal waters where they can cause enormous ecological and economic damage.[3−5]

In an attempt to minimize the risk of BW introductions, the International Maritime Organization (IMO[6]) and U.S. Coast Guard (USCG[7]) have each proposed discharge standards limiting maximum concentrations of living organisms that can be released with BW, including new regulations requiring ship operators to meet those limits. The USCG has proposed to implement regulations in two phases: phase 1 proposes to set standards similar to current IMO standards and phase 2 proposes standards up to 1,000 times stricter. The IMO and USCG phase 1 standards require BW discharged by ships to contain:

1. Fewer than 10 viable organisms $\cdot m^{-3} \geq 50$ μm in minimum dimension or smallest measure among length, width, and height excluding fine appendages such as sensory antenna and setae (the majority of organisms in this size class are zooplankton).
2. Fewer than 10 viable organisms $\cdot mL^{-1} < 50$ μm and ≥ 10 μm in minimum dimension. (The majority of organisms in this size class are protozoa, including zooplankton).
3. Fewer than the following concentrations of indicator microbes, as a human health standard: (a) toxicogenic *Vibrio cholerae* (serotypes O1 and O139) with <1 colony forming unit $\cdot$ 100 mL^{-1}; (b) *Escherichia coli* <250 cfu $\cdot$ 100 mL^{-1}; and (c) intestinal *Enterococci* <100 cfu $\cdot$ 100 mL^{-1}.

To achieve the above discharge standards, technology developers and manufacturers around the world are advancing onboard BW treatment systems[8,9] that use methods such as filtration + UV radiation, deoxygenation, ozonation, and chlorination.[9]

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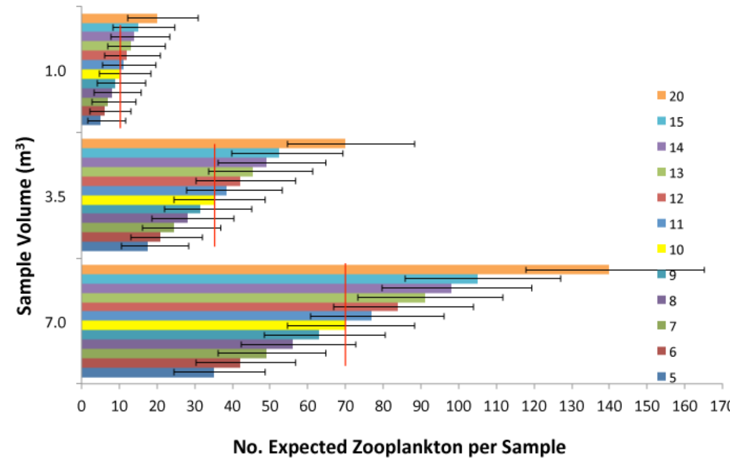

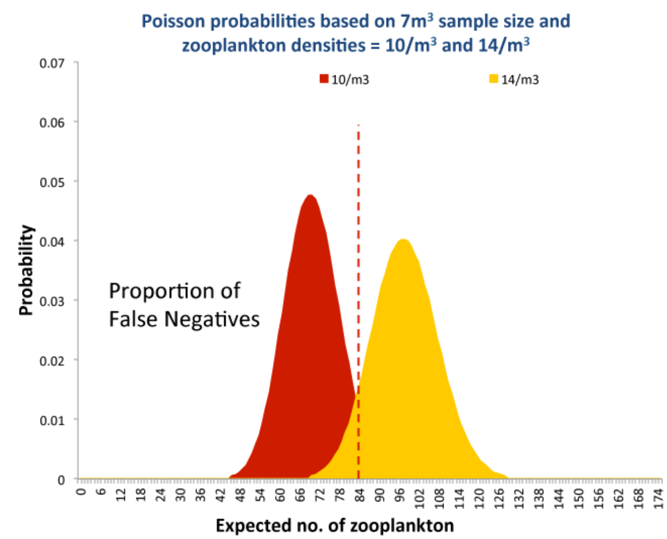

Phased Approach to Compliance Monitoring

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Verifying Compliance with Ballast Water Discharge Regulations

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U.S. and international rules have been proposed to reduce the risks associated with invasive aquatic organisms by requiring that ships' ballast water be treated to kill or remove living organisms and achieve certain standards before being discharged. Enforcing these rules requires verifying when a discharge violates these standards. A preliminary comparison of verification systems indicates that mandatory reporting and inspecting treatment equipment do not provide an acceptable level of confidence and that sampling and analyzing enough ballast water to achieve acceptable confidence is prohibitively costly. The most cost-effective alternative that achieves an acceptable level of confidence involves indirect measures of ballast water using sensors that indicate whether discharge standards are met.

Keywords ballast water regulations, enforcement, invasive species

Introduction

The international maritime industry, with more than 70,000 merchant vessels, is responsible for transporting more than 80% of the goods traded in world markets, and is a foundation for the global economy.[1] However, commercial shipping is also responsible for transporting ballast water and introducing aquatic invasive species to coastal waters where they can cause enormous ecological and economic damage.[2]

The 1990 U.S. Non-indigenous Aquatic Nuisance Prevention and Control Act (NANPCA) was the first federal law to address the problem of aquatic invasive species.[3] It focused mainly on ballast water introductions. The NANPCA contained provisions that required ships headed for the Great Lakes to exchange their ballast water at sea. The law was reauthorized in 1996, renamed the National Invasive Species Act (NISA) and expanded to encourage, but not require, ballast water exchange for all ships arriving from outside the 200-mile U.S. exclusive economic zone (EEZ).[4] NISA also made reporting of ballast water management to a national registry mandatory for all ships entering U.S. ports. In 2004, the U.S. Coast Guard (USCG) published regulations requiring vessels to maintain a ballast water management plan that involves mid-ocean exchange of ballast water, retention of

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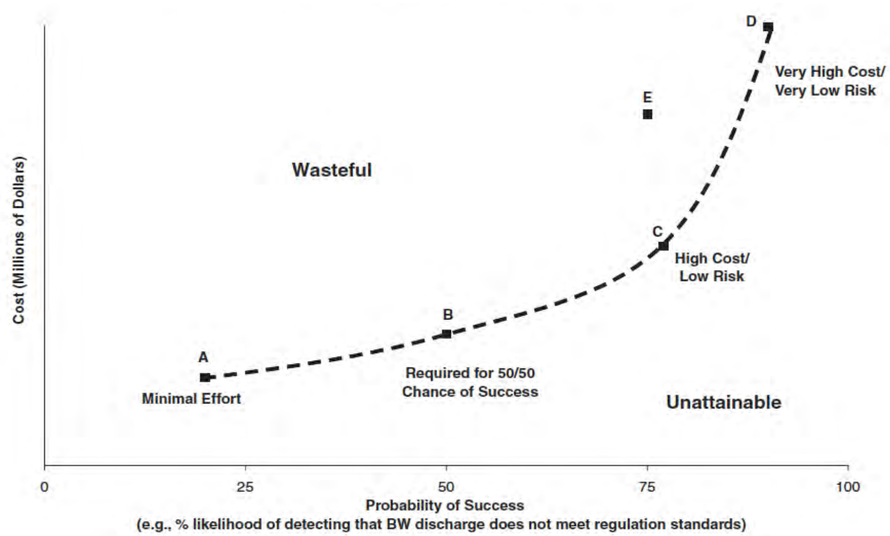
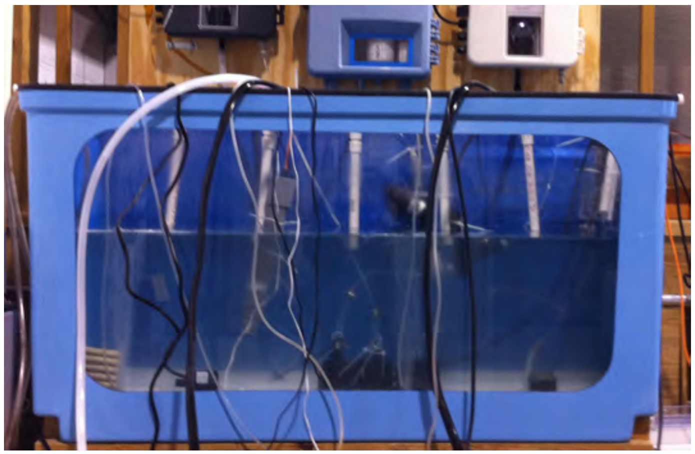
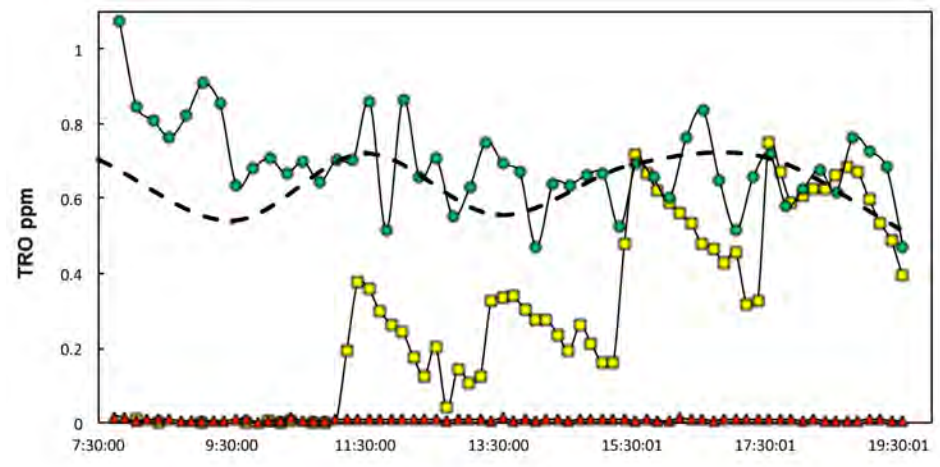
- Reporting
- Inspections
- Measures of system performance
- Indirect measures of exceedance
- Direct measures of discharge standards



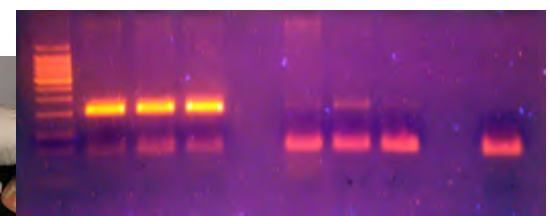
Indirect Measures for Compliance Monitoring

- **TRO/TRC sensor and analyzer evaluations**





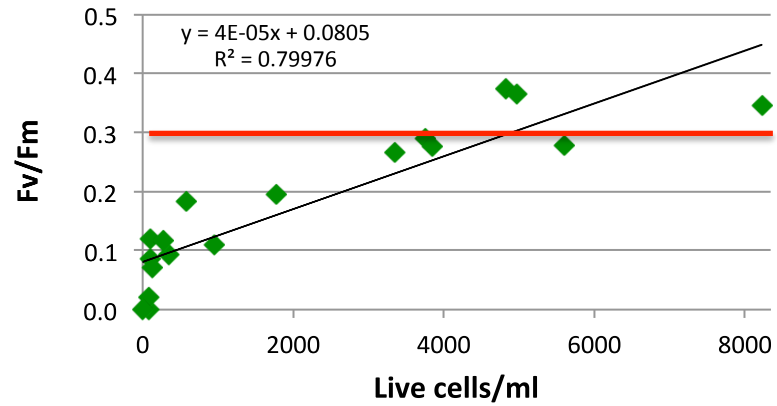
- **Fluorometers, ATP, DNA and genetic probes as indicators**

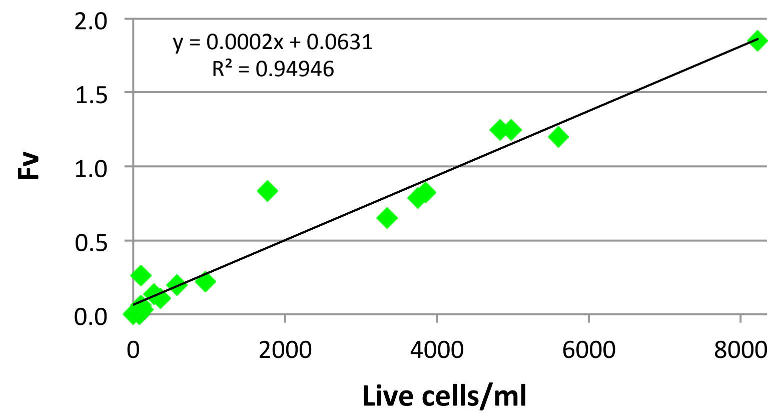


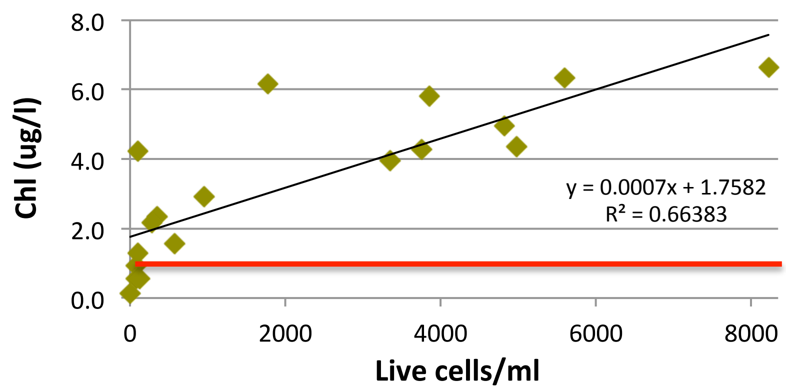
Fluorometry for Compliance Monitoring

- Photosynthetic Quantum Efficiency reflects 'viability' of phytoplankton
  - Live/healthy $\phi_p \approx 0.7$
  - Dead $\phi_p \approx 0$

- In situ fluorometers are:
  - Fast (instantaneous)
  - Optical (reagent-free)
  - Sensitive (near standards)







Economics of Ballast Water & Green Shipping

sustainableshipping

December 17, 2010

Available online at SustainableShipping.com, an online news and information resource dedicated to marine transportation and the environment.

Kick-starting Ballast Water Treatment Markets

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Maritime Environmental Resource Center

Let's assume International Maritime Organization (IMO) ballast water discharge regulations are ratified and similar U.S. Coast Guard (USCG) rules are established in 2011 or 2012, and governments make commitments to implement and enforce them a year later. Then what? Does it make sense to trust fledgling ballast water treatment system (BWT) markets to mature fast enough with enough supply capacity to allow widespread compliance and significant reductions in harmful ballast water discharges? If not, what interventions in BWT markets will be required to kick-start them, so they have a chance of doing what will be expected of them?

Based on planned IMO compliance deadlines, over 50,000 merchant ships will need to install certified BWT systems by 2016 or 2017; that's about 10,000 ships per year for five or so years after ratification. Since many larger ships may need to install multiple BWT units to meet IMO discharge standards, the number of actual BWT units that will need to be manufactured and installed during those years to achieve widespread compliance may be closer to 20,000 or 30,000 per year. If these numbers are off a bit, or the IMO and USCG compliance schedules are relaxed by a year or two, the overall situation is still the same - for ballast water regulations to succeed, BWT supplies will need to grow very large, very fast.

In business, however, there is usually a multiyear lag between when decisions are made to invest in manufacturing capacity and when large-scale production can take place. This means significant investments in BWT manufacturing capacity will need to be made very soon for BWT markets to provide what ballast water regulations need to succeed. Fifty or so BWT vendors, mostly small start-ups, are flirting with entering the market, some large shipping companies are dabbling with ship-board demonstrations, and a few actual transactions have taken place. However, no serious investments are being made in BWT supply capacity, and none can be expected until there is more certainty about the size and timing of global demand for BWT systems. That certainty of demand, of course, will not exist until nations make credible commitments to enforce ballast water regulations with certain and meaningful penalties. Unfortunately, it will be politically and practically impossible for nations to commit to enforce these regulations as long as inadequate BWT supplies make it impossible for many ship owners to comply with them. This

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"Gaming" Ballast Water Treatment Markets

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During September, 2010 two London-based meetings will address ways to resolve global ballast water (BW) problems. One, a well-publicized industry conference, will focus on emerging global markets for ballast water treatment (BWT) systems.[1] The other, a less publicized meeting at the International Maritime Organization (IMO), will focus on intergovernmental strategies for implementing and enforcing IMO ballast water regulations.[2] Although different in focus, the two meetings could hardly be more interrelated. The emergence of markets for BWT systems will depend on when and how BW regulations are implemented and enforced. Conversely, the willingness and ability of IMO member countries to implement and enforce BW regulations will, out of necessity, depend on whether BWT markets evolve with enough supply capacity to allow widespread compliance.

The topics of the two meetings are also intertwined because in regulation-driven markets buyers are only as quality-conscious as regulators require them to be. Whether the IMO sets weak or strict standards for determining compliance, in other words, will have an enormous effect on supply and demand and on who wins and loses in BWT markets. If complying with BW regulations merely requires having a "certified" BWT system on board, for example, the lowest cost "certified" BWT system will dominate the market, perhaps to the exclusion of higher cost and more effective and reliable systems. If compliance requires installing and properly maintaining and using a certified BWT system with the capacity to treat BW during all of a ship's ballasting operations, and if BW discharge standards are enforced using direct or indirect treatment performance measures, on the other hand, providers of higher quality, more reliable, and more appropriately engineered BWT systems and global maintenance and support services will have markets and be able to survive.

Of course, the cost of any BWT system will always need to compete fairly directly with the cost of not complying, which depends on the likelihood of violations being detected and prosecuted and whether penalties for violations are

[1] http://www.rivieramm.com/events/Ballast-Water-Treatment-Technology-Conference-29/Event-Home-395

[2] http://www.imo.org/includes/blastDataOnly.asp/data_id%3D28894/1.pdf

sustainableshipping

July 8, 2011

Available online at SustainableShipping.com, an online news and information resource dedicated to marine transportation and the environment.

"MEPC 62 special: The world can afford sustainable shipping"

Dennis King
University of Maryland Center for Environmental Science
Maritime Environmental Resource Center

It is always worth considering the potential costs and related economic impacts of new environmental regulations affecting global shipping. However, claims by some shipping industry groups that pending IMO ballast water regulations or a proposed carbon levy on bunker fuel will impose unbearable economic hardships on businesses and households around the world seem far-fetched. Let's take a look at the basic numbers.

It is estimated that widespread compliance with IMO ballast water regulations will require more than 50,000 merchant ships to install on-board ballast water treatment (BWT) systems at a cost of about $1 million each.

For a few years after implementation the IMO's tiered schedule of compliance deadlines could result in as many as 15,000 merchant ships per year installing BWT systems so the annual cost to the shipping industry during those peak years will be about $15 billion.

Once the existing global fleet is in compliance, of course, compliance costs will decline significantly to around $3 billion or so annually and be associated primarily with installation of treatment systems on newly built ships.

At the same time as these IMO ballast water regulations are in the works, the World Bank, UNEP and other groups are proposing a carbon levy on bunker fuel with most talk about a levy of perhaps US$50 per tonne.

In 2009 the global merchant fleet purchased 341.5 million tonnes of bunker fuel at an average price of about $600 per tonne (total value = $204.9 billion).

In that year a $50 per tonne carbon levy on bunker fuel would have increased industry-wide fuel costs by about $17.1 billion. Coincidently, this increase in annual shipping costs is about the same as the $15 billion increase in annual shipping costs associated with ships complying with IMO ballast water regulations during peak years.

To put the potential economic impacts of either environmental initiative in perspective, let's round annual costs of each to $15 billion and examine what that could mean to the shipping industry and to the exporters, importers, and businesses and households that rely on global trade.

According to the Organization for Economic Cooperation and Development (OECD), global earnings by the world shipping industry in 2009 were about $380 billion. This means that if a $15 billion increase in annual shipping costs associated with either compliance with ballast water regulations or a $50 per ton carbon levy on bunker fuel were absorbed fully by the shipping industry as reduced earnings, shipping industry earnings would decline by 4.5%.

However, let's assume instead that ship owners and carriers pass all of these costs on to their customers (exporters) in the form of higher shipping costs, and that exporters pass them forward to their customers (importers) in the form of higher priced imported goods. And finally, let's assume that importers pass the higher cost of imported goods along to their customers (the world's businesses and consumers) in

MERC Beyond Ballast

- **Ship Biofouling and Invasive Species**

  Tolerance of fouling organisms to conditions found during common ocean voyages

  Methods for quantifying effectiveness of ship biofouling management guidelines

- **Ship Alternative Fuels**

  Analysis of alternative fuels for coastal support vessels

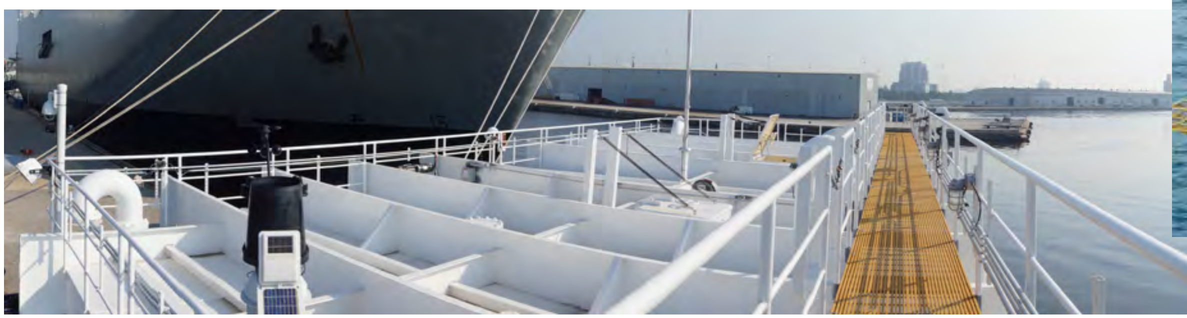
  Alternative fuels and exhaust emissions

Solar and Wind Power for Ports

- **MERC Mobile Test Platform**

  Need for uninterrupted power

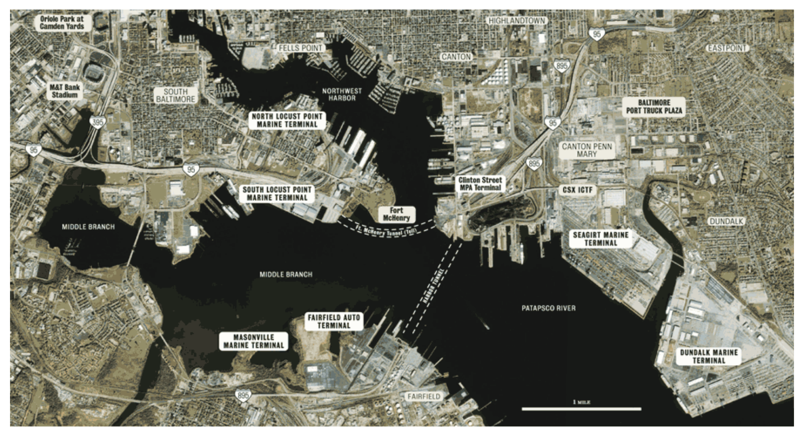
  Need for power when not connected to shore



- **Provide estimate of power potential in Port of Baltimore**

  Estimates of daily, monthly and seasonal potentials per unit area

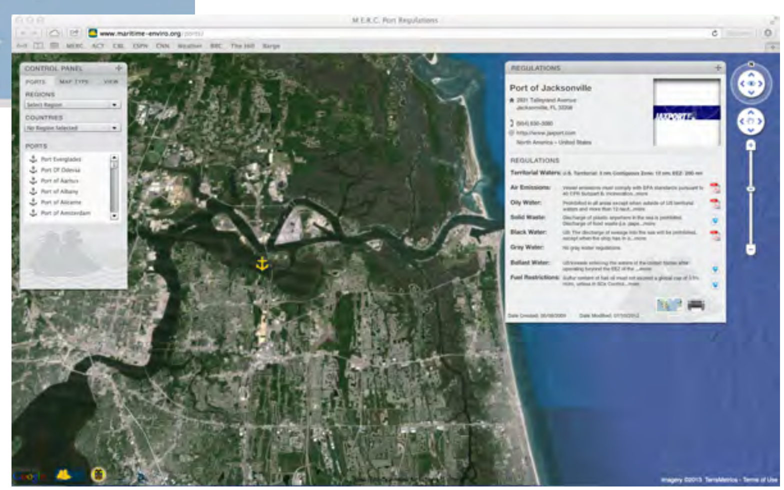
  Extrapolated to port-wide potential



MERC Port Discharge Database

- A resource for vessel operators, crew and ports
- Up-to-date, searchable and map-based regulatory information
- Prevent unnecessary and unintentional infractions and environmental degradation

Oily / Bilge Water	Incinerator Operation
Ballast Water	Incinerator Ash
Grey Water	Hazardous Waste
Black Water / Treated Wastewater	Cargo Residual / Deck Wash / Hull Cleaning / Paint Chips
Sewage Sludge	Air Emissions / Fuel Restrictions
Food Waste	Ozone Depleting Compounds
General Garbage	Other



MARAD Office of Environment

- **Ballast Water/Invasive Species**
  - **Test platforms and demonstration projects**
  - **Policy/reg development (Domestic/IMO/ISO)**
- **Air Emissions/Energy**
  - **Alt fuels & vessel repowering demonstrations**
  - **Modeling**
  - **Policy/reg development (Domestic/IMO)**

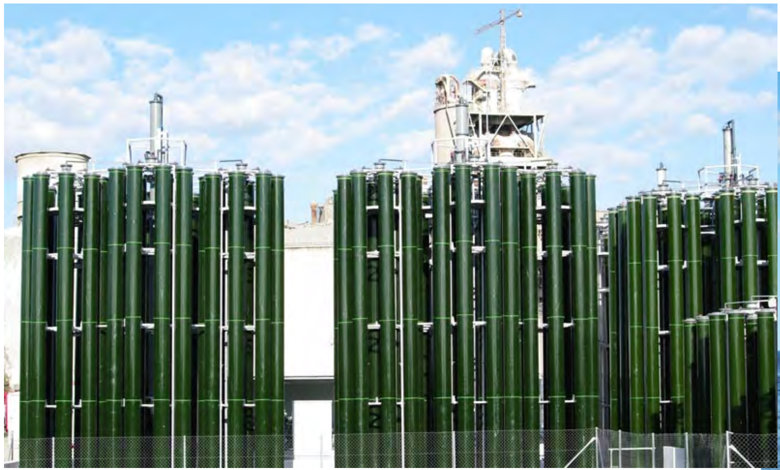
- **Vessel Recycling**
- **Environmental Management Systems & Green Objectives**
- **Environmental Planning (port infrastructure projects)**
- **NEPA**
- **Other Agency Support**

MARAD Office of Environment

- **Port and vessel air emissions and energy**
- **Two fuels show promise for maritime application**

  LNG – Feasibility Study identifying challenges (engineering, infrastructure, cost, public perception) and public benefits

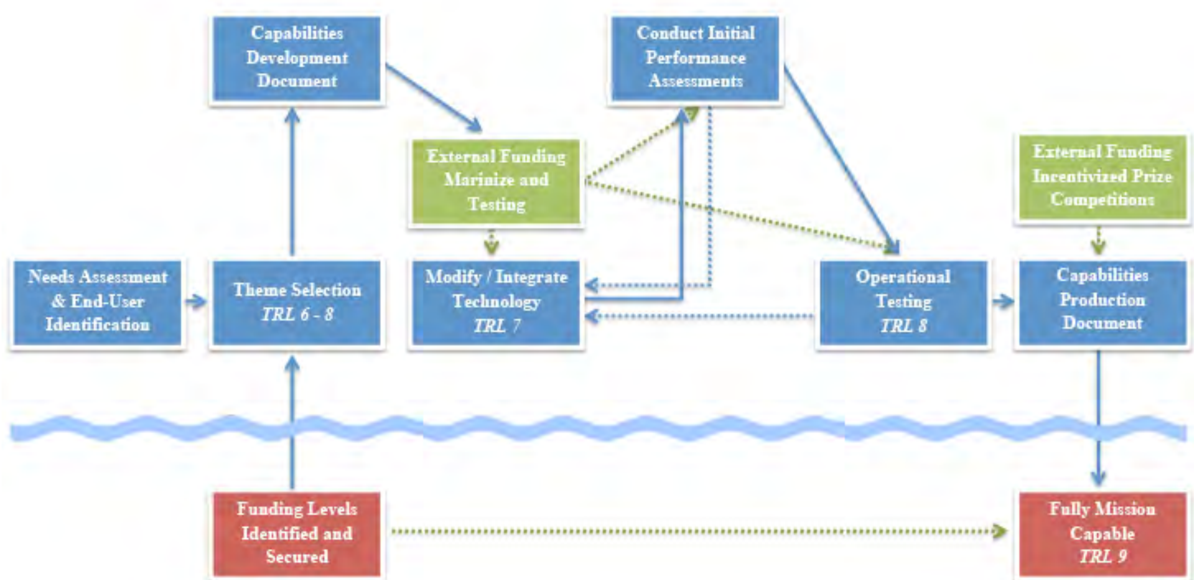
  Biofuels – Algal-based "Drop-in Fuels" evaluations aboard MARAD school ship found significant reduction on SOx, NOx and CO_2 when compared with pure ultra low sulfur diesel



MARAD Environmental Innovation Program

- **A developing approach to better address maritime community needs**
- **Stakeholder driven: ports, lines, technology developers/ providers, and regulatory agencies**
- **Focus on the transition of priority innovations into operations**

TRL	Description
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and 'flight qualified' through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system 'flight proven' through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.



MERC and MARAD

- As we formulate our research priorities, we would like your input.
- What are your current and most pressing environmental concerns?
- What do you perceive as emerging issues?
- Where can we help?
- How can we best to engage ports?

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