United States Environmental Protection Agency

Developing a coordinated research strategy to inform setting of protective ballast water discharge standards

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US Coast Guard 2012 Ballast Water Discharge Standards (IMO D2/US EPA 2013 Vessel General Permit)

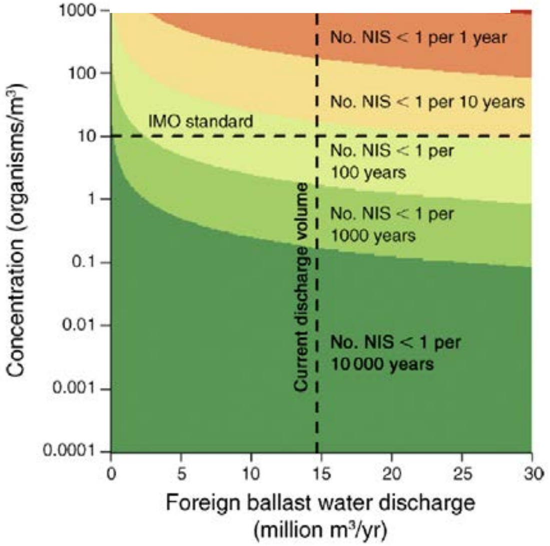
Phase	> 50 µm	10 µm to 50 µm	Microbial (≤ 10 µm)			
			Total	*V. cholerae**	*E. coli*	enterococci
1	< 10/ m^3	< 10/ml	NA	<1 CFU /100 ml	<250 CFU /100 ml	<100 CFU /100 ml
2	< 1/100m^3	< 1/100 ml	< 1,000 bacterial cells AND <10,000 viruses per 100 ml	<1 CFU /100 ml	<126 CFU /100 ml	<33 CFU /100 ml

*Toxicogenic *V. cholerae* O1 and O139

THE CHALLENGE

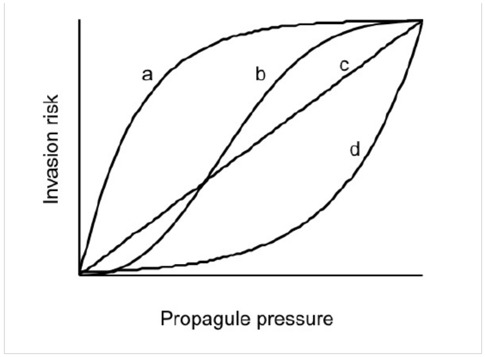
$$N_P = \frac{N_h}{\sum_1^n D_i C_i} O_P$$

What level of organismal discharge constitutes “acceptable risk” of ballast water borne invasions?



$$P_S = 1 - \prod_{s=1}^{S} \prod_{r=1}^{R} (1 - p_{r,s})^{N_{r,s}^{c_{r,s}}}$$

What is the nature of the relationship between propagule pressure and invasion risk?



OBSERVATIONS FROM THE NRC REPORT

“Assessing the Relationship Between Propagule Pressure and Invasion Risk in Ballast Water”

- “The available methods for determining a numeric discharge standard for ballast water are limited by a profound lack of data and information to develop and validate models for the risk-release relationship. Therefore, it was not possible with any certainty to determine the risk of nonindigenous species establishment under existing discharge limits.”

- “To date, there has been no concerted effort to collect and integrate the data necessary to provide a robust analysis of the risk-release relationship needed to evaluate invasion probability associated with particular ballast water discharge standards.”

RECOMMENDATIONS FROM THE NRC REPORT

"Assessing the Relationship Between Propagule Pressure and Invasion Risk in Ballast Water"

- Replicated experiments across a range of taxonomic groups, conducted using large-scale mesocosms with closed quarantine facilities or local biota in multiple systems (e.g. fresh, marine)
- A well-designed ship discharge sampling program to measure propagule supply involved stratified random samples across ship type, source regions, and seasons across [a minimum of 10] years.
- Standardized field surveys for the same estuaries, repeated over time, to estimate the occurrence of new invasions for the same taxa or species found in arriving ballast.
- A highly directed and coordinated effort, with explicit sampling design, standardized methods and analyses, and data integration across multiple sites and times.

United States Environmental Protection Agency

2012 Workshop, Washington DC

hosted by US EPA and ANSTF

NAME	AFFILIATION
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Mike Hoff	US Fish and Wildlife Service
Carolyn Junemann	US Department of Transportation
Erin Grey	University of Notre Dame
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RECOMMENDATIONS FOR PRELIMINARY DATA ANALYSIS

- Identified nearly 70 studies that assess biodiversity being conveyed in ships' ballast
- To our knowledge, no comprehensive meta-analysis of this data has been attempted
  - Differences in sampling methodology make comparisons of studies difficult
  - Different studies capture different aspects of the variation in propagule supply
- Recommend development of a unified database for ballast water propagule supply, based initially on existing data
- Recommend rapid commencement of rigorous meta-analysis of existing data to derive a clearer picture of propagule supply and its variation

RECOMMENDATIONS FOR EXPERIMENTAL STUDIES

- Focus on taxa that represent worst case scenarios for invasion (e.g. facultative parthenogens, high intrinsic rates of population increase, wide environmental tolerances)
- Experimental systems must be capable of supporting establishment of target species at some relevant inoculum level, within an experimentally tractable time frame
- Data collection should focus on temporal sampling of population density as well as experimental endpoints (success/failure to establish)
- Whenever possible, experiments should be conducted at multiple scales (e.g. micro- and meso-cosm)

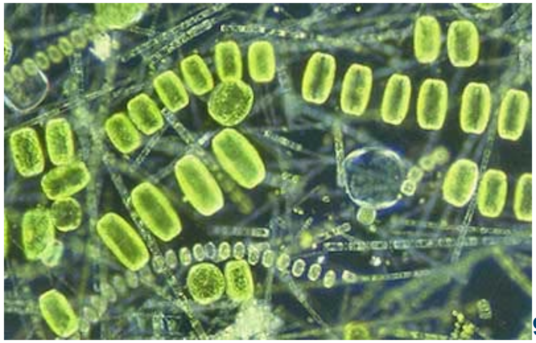
CHOOSING TARGET ORGANISMS

- Life history and biology represent worst case scenarios for invasion

- Establishment can be, with some confidence, attributed to BW exchange (esp. important for ship and port surveillance)

- Easily collectible/recognizable

- Amenable to laboratory manipulation (known conditions for rearing in micro- or meso-cosm)



- Molecular probes for detection have been or could rapidly be developed

RECOMMENDATIONS FOR SHIP SURVEYS

- The goal of ship surveys should be
  - To quantify, as best as possible, the propagule input to the recipient system
  - To define the functional relationship between BW volume and propagule supply
- Requires *intensive* sampling of one to three target ports
- In-line sampling should be the standard
- Need to initiate the effort rapidly, to allow assessment of the impacts of numerical discharge standards on propagule supply

RECOMMENDATIONS FOR PORT SURVEILLANCE

- Surveillance efforts should be designed based on accepted guidelines for coastal AIS surveillance and sampling principles developed to optimize detection of rare taxa
- Should focus on a subset of target taxa (5-10), as well as overall community profiling
- Stratified (by likelihood of target and other invasive species presence, e.g. habitat suitability and propagule discharge “hotspots”) random sampling designs
- Surveillance efforts should be designed based on both direct and ancillary benefits (see below)

RECOMMENDATIONS FOR PORT SURVEILLANCE

Survey evaluations to assess marine bioinvasions

Marnie L. Campbell [a,*], Brendan Gould [b], Chad L. Hewitt [a]

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Sensitivity and cost considerations for the detection and eradication of marine pests in ports

Keith R. Hayes [a,*], Rob Cannon [b], Kerry Neil [c], Graeme Inglis [d]

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[c] Queensland Department of Primary Industries and Fisheries, P.O. Box 5396, Cairns, Qld 4870, Australia
[d] National Centre for Aquatic Biodiversity and Biosecurity, P.O. Box 8602, Christchurch, New Zealand

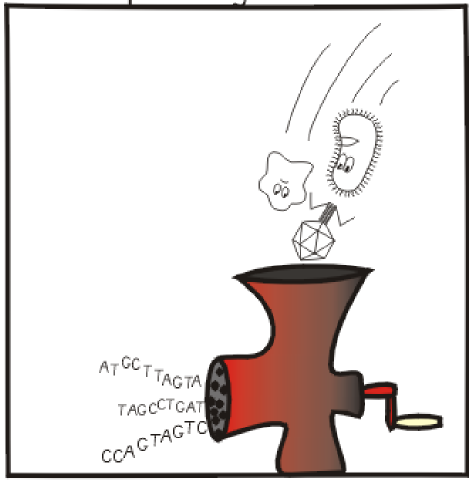
Effort and potential efficiencies for aquatic non-native species early detection

Joel C. Hoffman, John R. Kelly, Anett S. Trebitz, Greg S. Peterson, and Corlis W. West

INCORPORATION OF NOVEL TECHNOLOGIES IN SURVEILLANCE EFFORTS

- Species-specific genetic detection methods should be adopted for target species—qPCR or dPCR approaches should be developed to enable estimation of target propagule abundance
- Community profiling approaches such as meta-genetic next-generation sequencing should be adopted to assess overall biodiversity
- Approaches should be applied to both ship and port surveillance

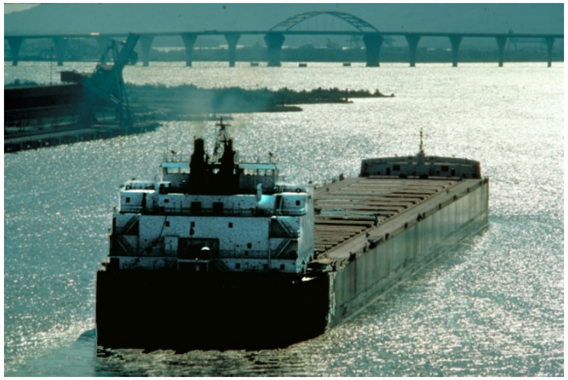
Mass sequencing



by Viktor S. Poór

CHOOSING TARGET PORTS

- Well-described invasion histories and patterns (current and historical) of BW discharge (i.e. adequate baseline knowledge)
- Substantial logistical support for ship and harbor sampling (history of sampling, collaboration, cooperation and/or compliance of locals)
- Ship and port sampling should be conducted at the same place for at least some subset of targets
- Targets should be chosen considering both direct and ancillary benefits (see below)



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PROPOSED TIMELINE

VGP 2018

2013 2023 2033

Data mining & meta-analysis

Assist in design of sampling strategies by identifying most important sources of variation, improve estimates of propagule supply

Conduct mesocosm experiments

Parameterize biological and demographic models of RRR, provide estimates of worst case RR scenarios in target species for ground-truthing in the field

Design intensive ship sampling strategy

Rapid incorporation of existing knowledge, simulation studies to assess likely effectiveness of different strategies, to inform most cost-effective practices

Identify funding for intensive ship sampling

Get a clear picture of PS and determine the functional relationship between BW volume and PS for at least one recipient port; provide rigorous comparison of PS before and after implementation of numerical standards

Intensive ship sampling for 1-3 target ports

Design intensive recipient port sampling strategy

Rapid incorporation of existing knowledge, development of strategies for cost-effective incorporation of molecular tools

Identify funding for intensive recipient port sampling

Intensive ship sampling for multiple target ports

Assess establishment patterns, monitor changes in invasion rate with implementation of numerical standards, adaptive re-design of sampling approaches, provide early detection of target and high risk species, etc.

RECOMMENDATIONS FOR COORDINATION

- Experimental and surveillance efforts need be only loosely coordinated; ideally surveillance efforts will target at least some of the sentinel taxa being studied in experimental efforts
  - Experimental studies could potentially be funded through basic science grants (e.g. NSF, unlike surveillance efforts)
  - Experimental studies can be geographically detached from surveillance efforts

- Ship and port surveillance efforts need to be tightly coordinated
  - Standardization required within ship sampling and port sampling efforts; shared sampling training and teams can be leveraged
  - Biodiversity assessments should be standardized between efforts (e.g. to the extent possible, the same identification protocols, including genetic approaches, should be utilized in both ship and port samples)
  - In at least some cases, ship and port surveillance should be geographically linked
  - Will require standardization of data collection and archiving, ideally through coordination of centralized databases
  - Will require substantial, coordinated, long-term funding (multiple millions of US dollars committed over at least 10 years of study)

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ANCILLARY BENEFITS OF A LONG-TERM BALLAST WATER RESEARCH STRATEGY

- **Ship surveillance** will provide a means to assess reductions in organism discharges associated with establishment of discharge standards (assessing efficacy of policy changes)
- **Port surveillance** will establish a system capable of registering changes in invasion rate associated with management and policy changes
- **Port surveillance** will help to establish a standardized, coordinated coastal biodiversity monitoring network that will have general value for understanding coastal biodiversity and its response to global change
- **Port surveillance** will foster development of technologies (e.g. genetic methods, sampling strategies) that will enhance cost-effective biodiversity monitoring in aquatic systems
- **Port and ship surveillance** will establish a model for a nationally standardized early detection and monitoring system for new aquatic invasions
- **Lessons learned about the risk-release relationship for ballast water** will inform efforts to understand that relationship for other vectors (e.g. hull fouling)
- **Lessons learned about the risk-release relationship for ballast water** will teach us about mechanisms and patterns of establishment in aquatic systems, with broad applicability to conservation, restoration and resource management

GOALS FOR DEVELOPING THE RESEARCH STRATEGY

- Develop a report from the 2012 workshop, slated for completion summer 2013
- Deliver that report through the Aquatic Nuisance Species Task Force and EPA to other federal, state, and international partners with potential future involvement in the issue
- Develop a streamlined version of the report for peer-review publication