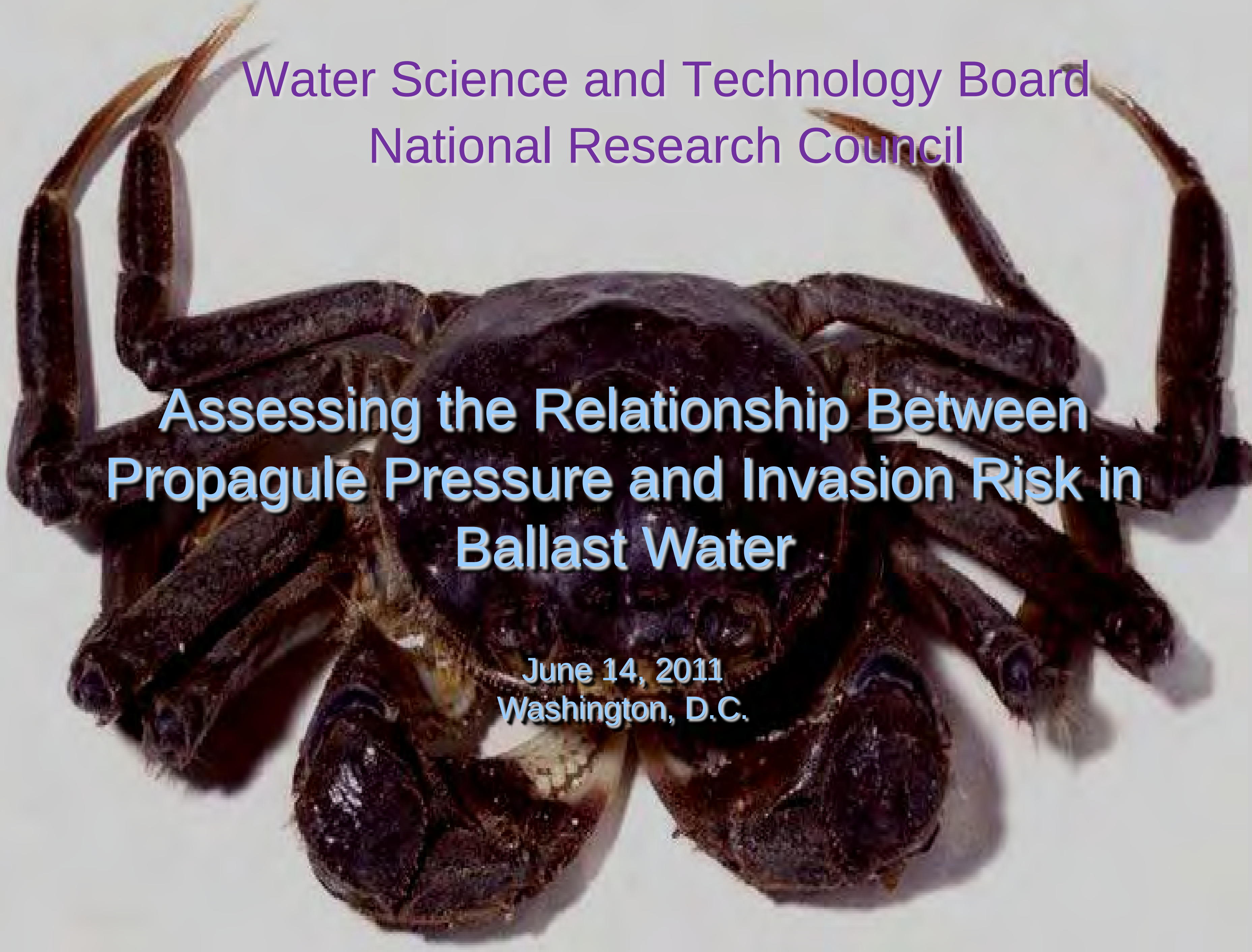
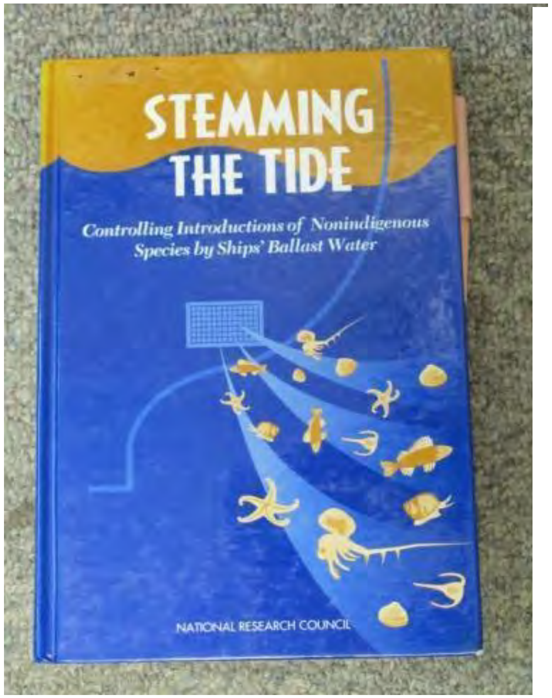
Water Science and Technology Board
National Research Council



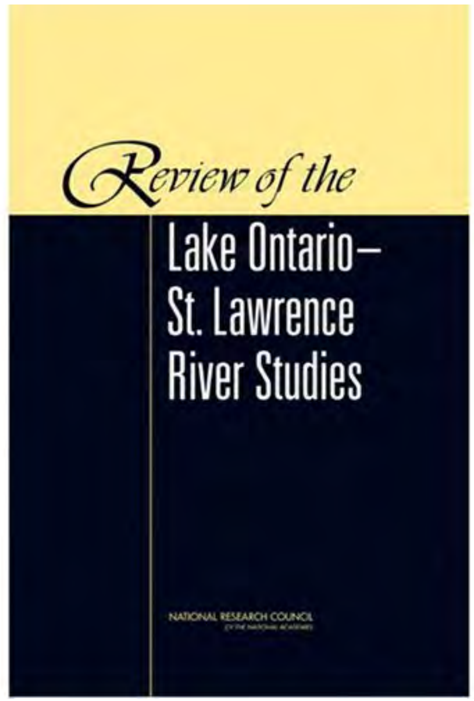
Assessing the Relationship Between Propagule Pressure and Invasion Risk in Ballast Water

June 14, 2011
Washington, D.C.

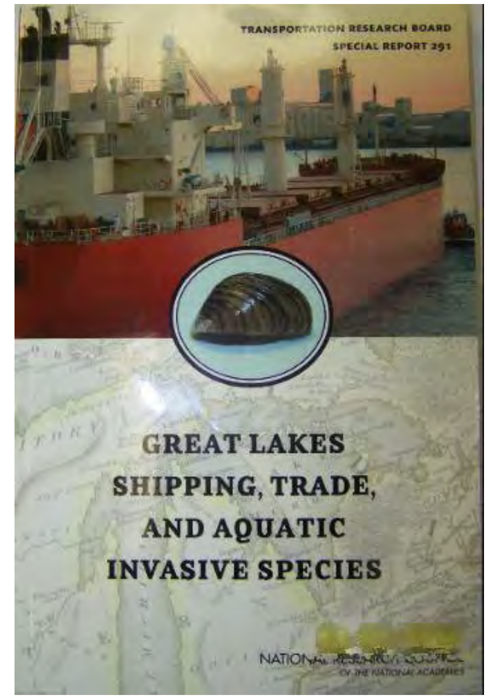
Previous NRC Reports Dealing with Ballast Water



Stemming the Tide
1996



Review of the Lake Ontario - St. Lawrence River Studies
2006



Great Lakes Shipping, Trade, and Aquatic Invasive Species
2008

Statement of Task

1. Evaluate the state of the science of various approaches that assess the risk of establishment of aquatic nonindigenous species given certain concentrations of living organisms in ballast water discharges.

- What are the advantages and disadvantages of the available approaches?
- Identify and discuss the merits and practical utility of other additional approaches of which the National Academy of Sciences is aware.
- How can the various approaches be combined or synthesized to form a model or otherwise more powerful approach?
- What are the data gaps or other shortcomings of the various approaches and how can they be addressed within the near and long term?
- Can a "natural invasion rate" (invasion rates based on historic invasion rates), or other "natural" baselines, be reliably established, and if so, how? What utility might such baselines have in informing EPA's derivation of allowable numeric limits for living organisms in ballast water discharges? Can such baselines be established on a national basis, or would this need to be done on a regional or ecosystem basis?

Statement of Task

2. Recommend how these approaches can be used by regulatory agencies to best inform risk management decisions on the allowable concentrations of living organisms in discharged ballast water in order to safeguard against the establishment of new aquatic NIS and to protect and preserve existing indigenous populations of fish, shellfish, and wildlife and other beneficial uses of the nation’s waters.

3. Evaluate the risk of successful establishment of new aquatic NIS associated with a variety of ballast water discharge limits that have been used or suggested by the international community and/or domestic regulatory agencies.

Not the Committee's Tasks:

- Assess ballast water treatment technologies
- Recommend specific numeric standards

Committee on Assessing Numeric Limits for Living Organisms in Ballast Water

Sponsors:

U.S. Environmental Protection Agency

U.S. Coast Guard

JAMES T. CARLTON, *Chair*	Williams College/Mystic Seaport, Mystic CT
GREGORY M. RUIZ, *Vice-Chair*	Smithsonian Environmental Research Center, Edgewater MD
JAMES E. BYERS	University of Georgia, Athens
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EDWIN D. GROSHOLZ	University of California, Davis
BRIAN LEUNG	McGill University, Montreal, Quebec
HUGH J. MACISAAC	University of Windsor, Ontario
MARJORIE J. WONHAM	Quest University, Squamish, British Columbia

Committee Meetings/Presenters

MEETINGS: Three committee meetings plus one virtual meeting

PRESENTERS

- Henry Lee — EPA Office of Research & Development
- Jim Hanlon, Ryan Albert — EPA Office of Wastewater Management
- Richard Everett, Greg Kirkbride — U.S. Coast Guard
- Andrew Cohen — Center for Research on Aquatic Bioinvasions
- Maurya Falkner — California State Lands Commission
- John Drake — University of Georgia
- Miriam Tepper, Andrew Langridge
  Kellina Higgins, Cassandra Elliott — Students at Quest University, Canada

Ballast Water Facts

- Over 90,000 arrivals per year in U.S. coastal waters
- About half of arrivals are from overseas, half are coastal
- Significant variation in the volume of ballast discharged and the number of arrivals per port
- Ballast water can contain almost anything < 30 cm
- Densities of different organism types range from 10^3 to 10^{10} individuals per liter
- Ballast Water Exchange (BWE) and salt water flushing significantly reduce organism concentration and change the diversity of organisms in ballast
- No new invasions detected in the Great Lakes or San Francisco Bay between 2006 and 2010

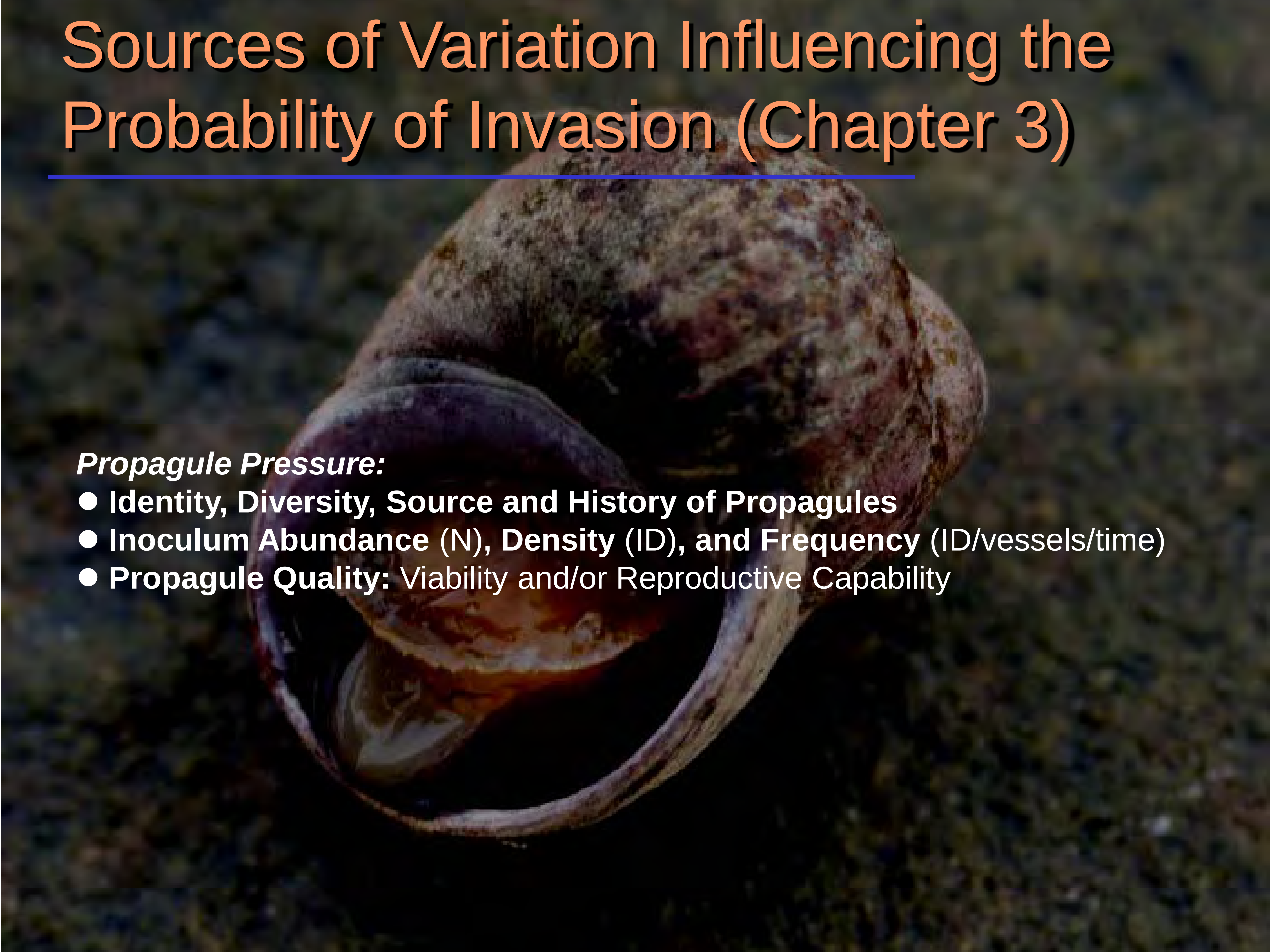
Policy Context for Regulating Ballast Discharge (Chapter 2)

- EPA CWA Vessel General Permit (VGP)
- NANPCA, NISA (USCG administered)
- State Variations
- IMO standard, Other Countries
- Limitations of the Current Programs
  - Gaps in coverage (e.g., transoceanic vs. coastal routes)
  - Currently no inspection program for the VGP
  - Alaska (oil tankers) variously covered
  - Statutory exemptions in both programs
  - Considerable variation due to state certification and other requirements

Conclusions—Regulatory Issues

- The statutes that guide the EPA and USCG regulatory programs appear to provide the essential considerations and scope needed to develop scientifically based numeric standards
- Both EPA and USCG programs authorize rigorous enforcement of reporting and implementation actions, which will facilitate data gathering on organism density and diversity
- USCG regulations will require equipping ships with sampling ports
- Future regulations assume there is a quantifiable relationship between organism density in ballast water and invasion risk

Sources of Variation Influencing the Probability of Invasion (Chapter 3)



Propagule Pressure:

- **Identity, Diversity, Source and History of Propagules**
- **Inoculum Abundance** (N)**, Density** (ID)**, and Frequency** (ID/vessels/time)
- **Propagule Quality:** Viability and/or Reproductive Capability

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Species Traits:

- **Genetics**: Bottlenecks, Quality, Variability, Enhancement, and Novelty
- **Life History Characteristics**
- **Population Density and Abundance**
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- **Dispersal and Mobility**
- **Environmental Matching**

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Environmental Traits:

- **Habitat Landscape:** habitat fragmentation or connectivity
- **Retention** of Propagules in Habitable Environment
- **Biological Interactions** with Resident Species (native and nonindigenous)
- **Disturbance Regimes**

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Temporal Variation
cuts across all of these processes:
Source, transit conditions,
and recipient region
all vary with time

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Best Case Scenario for an Invasion

- High-quality propagules
- Released in a retentive environment that closely matches that of the species' origin
- Inocula with high genetic variability
- Being physiologically plastic and having trophic breadth
- Life history characteristics such as direct development, asexual reproduction, and/or the ability to form resting stages
- Efficient dispersal capabilities combined with habitat connectivity
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Chapter 3 Conclusion:

While inoculum density is a key component, it is but one of scores of variables that can and do influence invasion outcome. Any method that attempts to predict invasion outcomes based upon only one factor of the invasion process is likely to suffer from a high level of uncertainty.

Propagule Pressure and Establishment Risk (Chapter 4)

- Models ranging from descriptive (simple empirical regressions) to mechanistic (probabilistic and dynamic demographic)

- Single-species and multiple species models

- Models considered, among many others:
  - Population Viability Analysis (PVA)
  - Reaction/Diffusion (R/D) models
  - risk-release portion of Natural Invasion Rates (NIR)
  - Per Capita Invasion Probabilities (PCIP)

Propagule Pressure and Establishment Risk (Chapter 4)

For both invasion risk and organism density in ballast, the existing data (historical invasion records, recent ballast surveys) are substantially mismatched in time and patchy in time, space, and taxonomic resolution. Statistical modeling has been applied to these data, but the data are not sufficient to characterize a biologically meaningful relationship.

The analyses that do exist have attempted to use ***proxy variables****; for example, several studies have used the number of ship arrivals as a proxy for organism density. However, even if a relationship is found between vessel arrivals and invasions, this relationship may be spurious and not causal.*

Chapter 4 Conclusions

Shorter term: mechanistic *single-species* models are recommended for best-case-scenario species

best-case for an invasion: fast growth, parthenogenetic or other asexual reproductive abilities, lecithotrophic larvae

Longer term: a robust *statistical model* of the risk-release relationship is recommended

more fruitful at a local scale than a nationwide scale

There is no evidence that any proxy variable used thus far is a reliable stand-in for organism density

Other Approaches to Setting a Ballast Water Discharge Standard (Chapter 5)

- Expert Opinion-based Approaches
  - IMO
  - Zero-detectable discharge standard
  - Natural Invasion Rates

- While each of these approaches has some merits, each is compromised by assumptions, data limitations, or operational difficulties

- Expert opinion can provide a standard as a benchmark (baseline) for management, while scientific models can be used to quantitatively derive standards

The Path Forward (Chapter 6)

- Available methods for determining a numeric standard for ballast water discharge are limited by a *profound lack of data and information* to develop and validate models of the risk–release relationship.
- Yet it is clear that significantly reducing ID will reduce the probability of invasions, when controlling for all other variables.
- As a first step, a benchmark discharge standard should be established that clearly reduces concentrations of coastal organisms below levels resulting from BWE (such as IMO D-2).
- Following the setting of an initial benchmark, a risk–release model or models should be selected as the foundation for the data gathering and analysis effort.

The Path Forward

A two-track approach (experimental and field) should be pursued to obtain data. Research should be coordinated and focused to assure that key aspects are addressed, especially if multiple research groups and locations are involved.

Experiments:

- Large-scale mesocosms
- Diverse range of taxa and different types of environments
- *Focus on a best-case-for-invasion scenario*
- Should deliver results over the next three to five years
- Could base an interim ballast water discharge standard on experimental results
- Would also have direct application to other vectors

The Path Forward

Field Studies

- There is no program in place to detect new invasions across sites
- Ship-based ballast sampling just beginning
- Data should be collected and analyzed to parameterize the models and provide real-world validation of experimental data
- Selected sentinel estuaries (San Francisco Bay, Chesapeake, Tampa)
- Study design is critical
- Results could be expected in about 10 years