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Canadian national ballast water risk assessment

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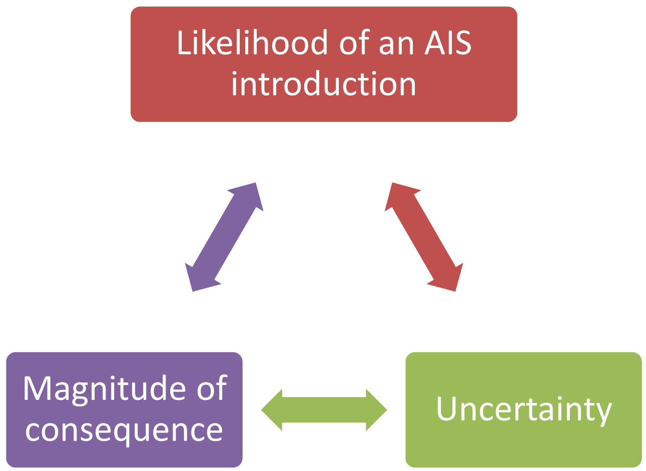
General Objectives

- To conduct an analysis of the relative risk among different ballast water pathways in Canada
- Consider the potential for arrival and survival of zooplankton and phytoplankton NIS (microbes are not considered) as well as the magnitude of consequences of these aquatic NIS
- Consider risk posed by ballast water from commercial ships under current regulatory requirements, as well as future requirements for International Maritime Organization (IMO) D-2 performance standards

Why Use a Risk Approach?

Simple	To facilitate the description, understanding and management of complex systems
Dynamic	Allows evidence & information to be objectively collected and combined
Predictive	Give the basis for science-based decision-making



(Fazil, 2005)

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Shipping Pathways in Canada

International Exempt vessels
Vessels operating outside the Canadian EEZ, but within the exchange exemption zone

Coastal Domestic vessels
Vessels operating between Great Lakes, Canadian Atlantic & Arctic ports

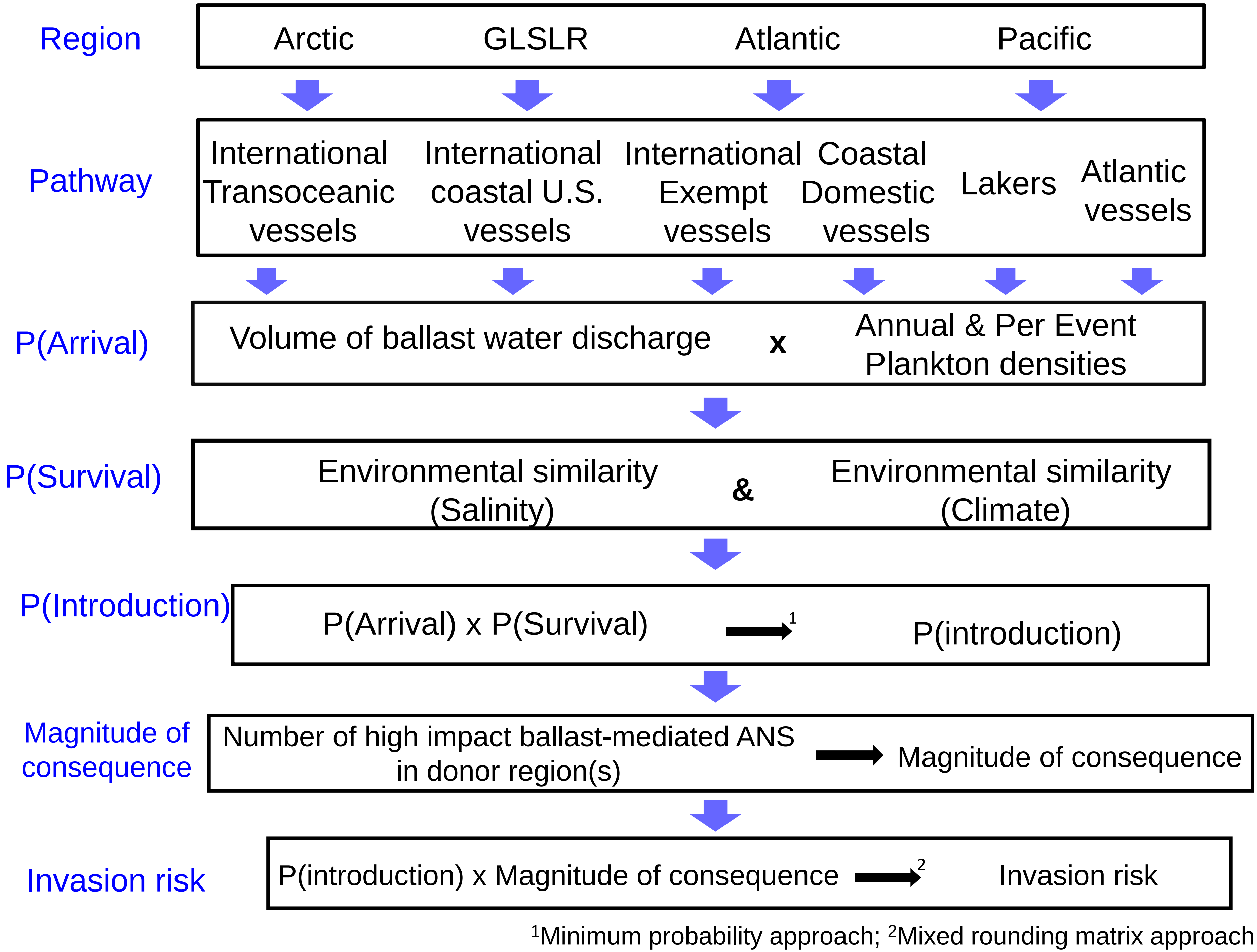
International Coastal U.S. vessels
Vessels operating outside the Canadian EEZ and the exchange exemption zone on a coastal U.S. route

Atlantic vessels
Vessels that operated exclusively between Atlantic ports inside the Canadian EEZ

International Transoceanic vessels
Vessels operating outside the Canadian Exclusive Economic Zone (EEZ) on a transoceanic route

Lakers
Vessels that operated exclusively within the Great Lakes and the St. Lawrence Estuary

Canada



Region
Arctic
GLSLR
Atlantic
Pacific
Pathway
International Transoceanic vessels
International coastal U.S. vessels
International Exempt vessels
Coastal Domestic vessels
Lakers
Atlantic vessels
P(Arrival)
Volume of ballast water discharge
x
Annual & Per Event Plankton densities
P(Survival)
Environmental similarity (Salinity)
&
Environmental similarity (Climate)
P(Introduction)
P(Arrival) x P(Survival)
1
P(introduction)
Magnitude of consequence
Number of high impact ballast-mediated ANS in donor region(s)
Magnitude of consequence
Invasion risk
P(introduction) x Magnitude of consequence
2
Invasion risk
¹Minimum probability approach; ²Mixed rounding matrix approach

Step 1A

Estimating p(arrival)

-Probability that a non-indigenous species (NIS) will arrive

-For each pathway in all the regions:

Abiotic

•Obtain shipping data from government agencies

•Vol. of ballast water discharged as proxy for arrival potential

•# of discharge events

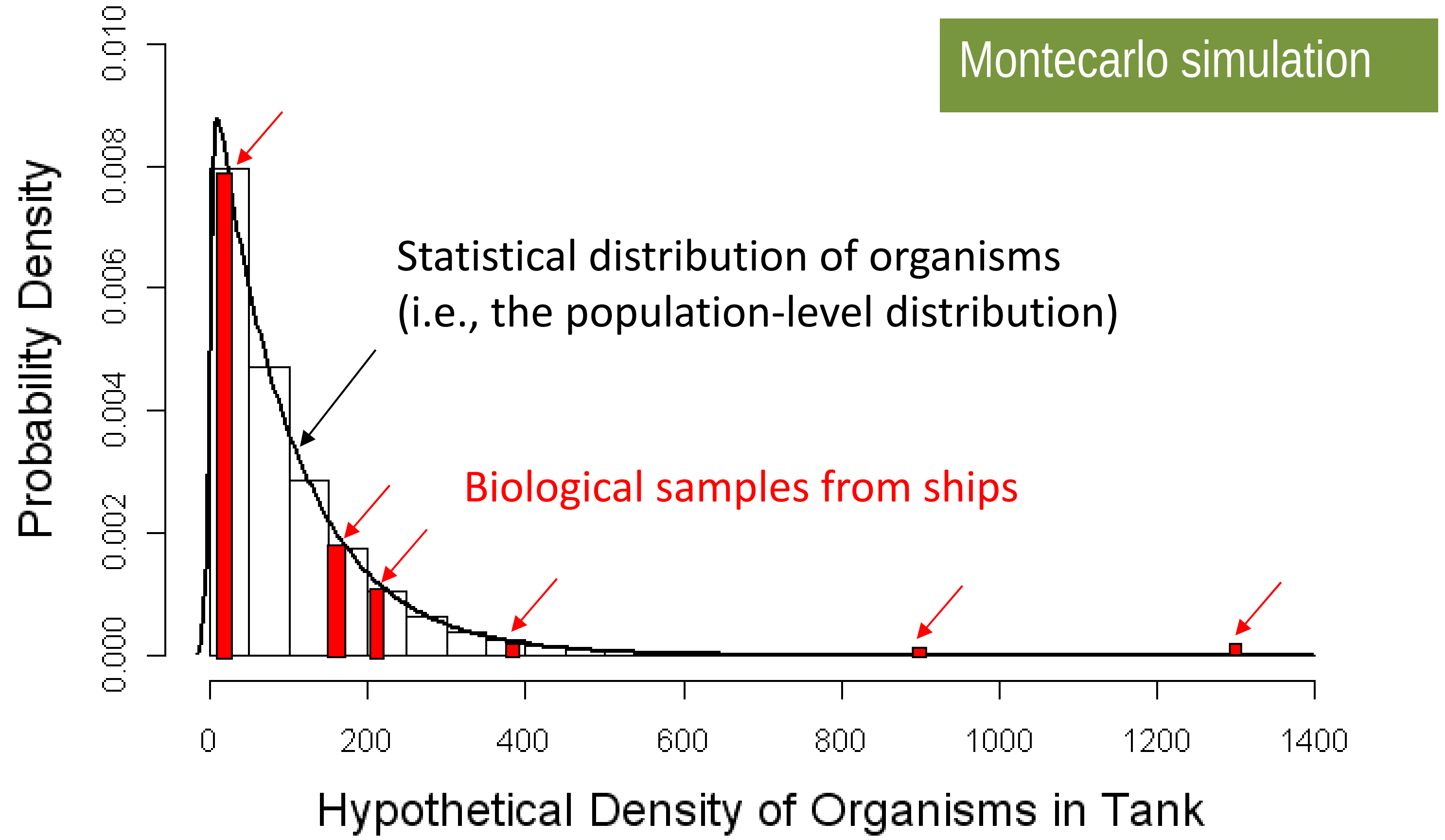
Biological

•Obtain abundances zooplankton/phytoplankton from recent studies

[Canadian Aquatic Invasive Species Network – CAISN; Fisheries and Oceans Canada:

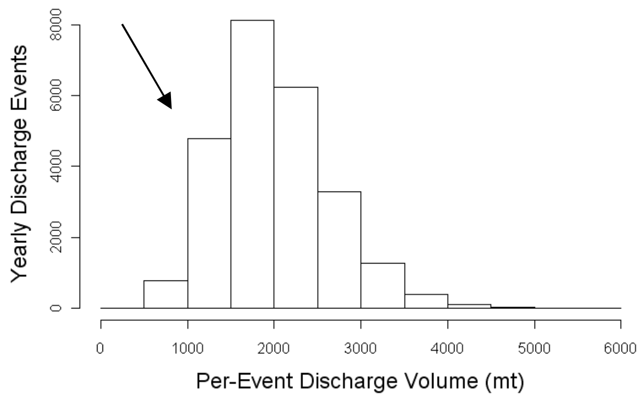
Bailey et al. 2011; Briski et al. 2012a,b; Dibaccio et al. 2012; Humphrey et al. 2008; Klein et al. 2009; Roy et al. 2012]

Step 1A

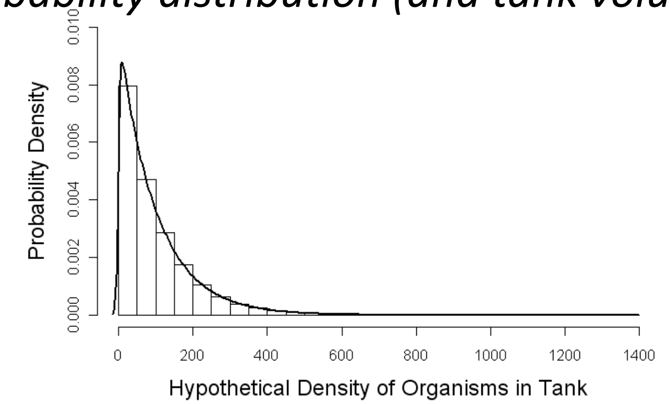

Montecarlo simulation
Statistical distribution of organisms
(i.e., the population-level distribution)
Biological samples from ships
Probability Density
0.000
0.002
0.004
0.006
0.008
0.010
0
200
400
600
800
1000
1200
1400
Hypothetical Density of Organisms in Tank

Montecarlo simulation

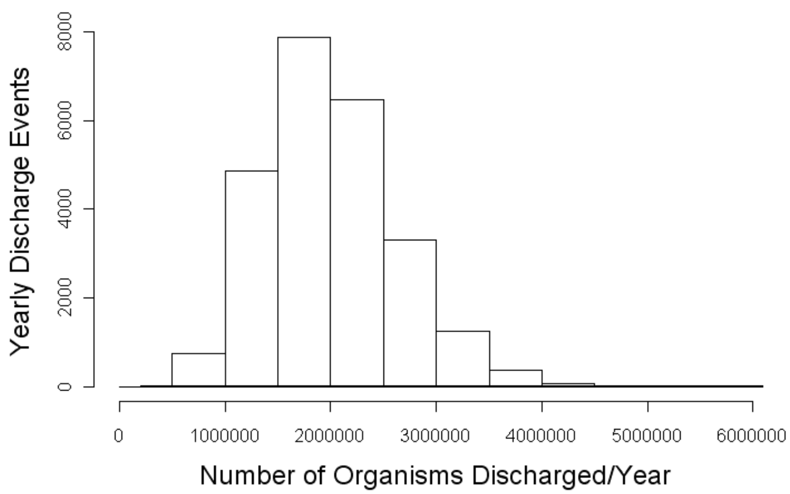
1) For each discharge event



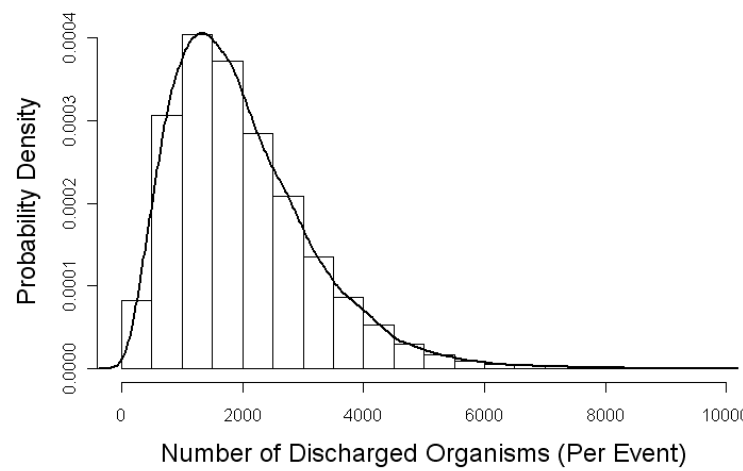
2) Randomly assign an organism density based on the probability distribution (and tank volume)



Result: Annual Propagule Pressure
(num organisms discharged/pathway/year)



Result: Propagule Pressure per event
(num organisms discharged/pathway/event)



Step 1B Estimating p(survival)

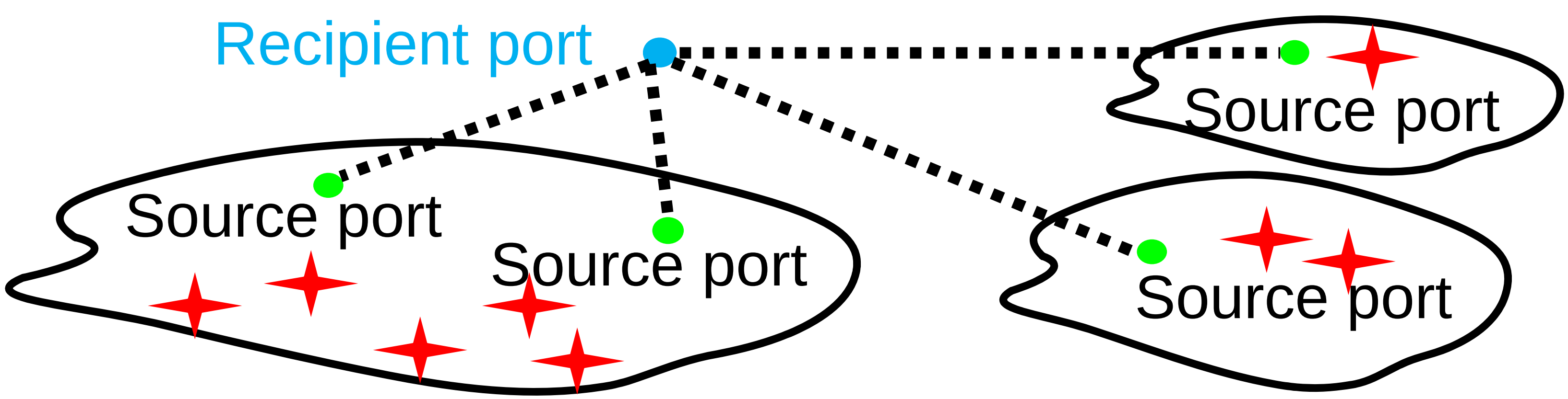
Salinity classification
Freshwater = 0.0 - 5.0‰
Brackish = 5.1 -15.9‰
Marine = >16‰

Climate classification
Polar = > 60° N
Cold-Temperate = 40° - 60°
Warm-Temperate =20° - 40°
Tropic = 0° - 20° N

- Matrix approach will be used to assess similarity between source-recipient ports
- Combine salinity and climate similarities => single environmental measure
- Assign p(survival) rating based on the percentage of “High” suitability scores within each pathway using breakpoint analysis

Step 2 Estimating magnitude of consequences

- Tabulate the # of high impact NIS (AIS) in connected ecoregions
- Assume each connected port may be a donor of all AIS in the ecoregion



- Summarize cumulative # of AIS by each pathway within regions
- Comparisons for each pair of pathways based on statistical differences to assign the rating of magnitude of consequence

Step 3 Estimating invasion risk

- Combine p(introduction) and magnitude of consequences using a mixed rounding matrix approach (Orr 2003; DFO 2009)
- Uses the GLSLR International transoceanic vessels as a bench mark.

		P (Introduction)				
		Lowest	Lower	Intermediate	Higher	Highest
Consequence	Highest					
	Higher					
	Intermediate		GLSLR International			
	Lower					
	Lowest					

Results: Current Risk

	Current Risk under BWE	
Pathway	Annual	Per Discharge Event
Arctic Coastal Domestic	Lowest	Lowest
Arctic International Transoceanic	Lowest/Intermediate	Highest
Eastern Coastal Domestic	Lowest/Intermediate	Highest
GLSLR International Transoceanic	Lowest	Lowest
Lakers	Highest/Lowest	Highest/Lowest
Atlantic International Coastal U.S.	Intermediate/Highest	Highest
Atlantic International Exempt	Intermediate/Highest	Highest
Atlantic International Transoceanic	Highest	Highest
Pacific International Coastal U.S.	Highest	Highest
Pacific International Exempt	Highest	Highest
Pacific International Transoceanic	Highest	Highest

Note that risk differed for some pathways depending on taxonomic group being considered (reported as zooplankton/phytoplankton)

Canada

Results: Future Risk

	Future Risk under IMO D-2	
Pathway	Annual	Per Discharge Event
Arctic Coastal Domestic	Lowest	Lowest
Arctic International Transoceanic	Lowest/Intermediate	Lowest/Highest
Eastern Coastal Domestic	Lowest	Lowest
GLSLR International Transoceanic	Lowest	Lowest
Lakers	Lowest	Lowest
Atlantic International Coastal U.S.	Lowest/Highest	Lowest/Highest
Atlantic International Exempt	Lowest/Highest	Lowest/Highest
Atlantic International Transoceanic	Lowest/Highest	Lowest/Highest
Pacific International Coastal U.S.	Lowest/Highest	Lowest/Highest
Pacific International Exempt	Lowest/Highest	Lowest/Highest
Pacific International Transoceanic	Lowest/Highest	Lowest/Highest

Note that risk differed for some pathways depending on taxonomic group being considered (reported as zooplankton/phytoplankton)

Conclusions

- Current requirements for BWE reduce the risk of invasions for freshwater ecosystems (Great Lakes), but are less effective for marine ecosystems
- Future projections indicate D-2 discharge standard will dramatically reduce arrival potential of zooplankton for all pathways, but will have lesser effect for phytoplankton
- The risk of domestic vessels for introduction of aquatic NIS is variable across regions, taxa and timescales. Lakers pose a relatively high risk for zooplankton NIS at both timescales

Considerations

- Analyses are based on 2006-08 shipping patterns and environmental conditions - reanalysis may be required with climate change and/or changes in shipping traffic
- Biological data was not available for all shipping pathways – uncertainty is greater for pathways where assumptions were used
- Enforcement levels are a potentially confounding factor, being greater in the GLSLR than other regions
- National risk assessment considers only ballast water discharges by merchant vessels – additional work is required to assess risk of hull fouling by merchant and non-merchant vessels

Fisheries and Oceans Canada / Pêches et Océans Canada

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NSERC CRSNG

CAISN Canadian Aquatic Invasive Species Network

Downloads:

DFO Research Document: http://www.dfo-mpo.gc.ca/Library/352598.pdf

PLoS ONE: http://dx.doi.org/10.1371/journal.pone.0118267

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