Risk assessment for ship-mediated introductions of aquatic non-indigenous species to the Canadian Arctic

F. Chan[1], J.E. Bronnenhuber[2], J.N. Bradie[2], K.L. Howland[3], N. Simard[4] and S.A. Bailey[2]

[1]Great Lakes Institute for Environmental Research (GLIER), University of Windsor
[2]Bayfield Institute, Fisheries and Oceans Canada, Burlington, ON
[3]Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, MB
[4]Institut Maurice-Lamontagne, Fisheries and Oceans Canada, Mont-Joli, QC

Non-Indigenous Species

- Species that live outside of their native distributional range
- Introduced to new environment by human activities, either deliberate or accidental
- Also known as introduced, alien, exotic, non-native or invasive species



Ship-Mediated Invasions

Source Population

Transportation

Survival

Establishment

Spread

(Blackburn *et al*. 2011)

Ballast water discharge

Hull fouling

At least 237 aquatic and marine NIS have been introduced worldwide via ship vectors

(Molnar *et al.* 2008)

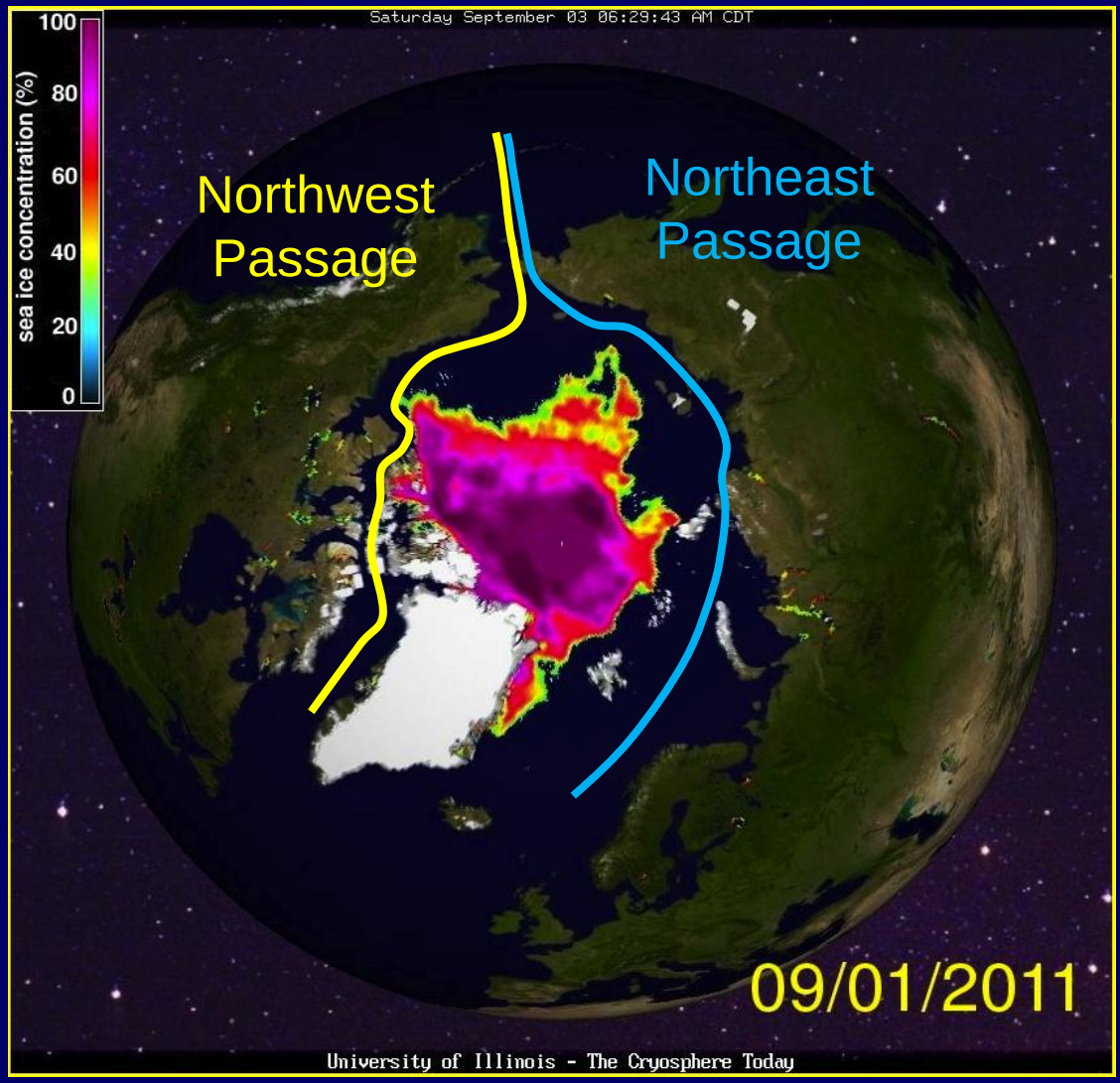
Increased Arctic Shipping

↑ Propagule pressure

- number of introduction events
- number of propagules per introduction
- condition of propagules

↑ Colonization pressure

- number of species

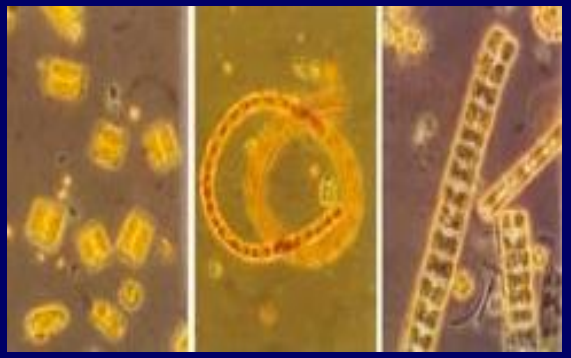


Invasions in High Latitudes

NIS may benefit from enhanced survival associated with warmer climate and increased food supply (Vermeij and Roopnarine 2008; Cheung *et al.* 2009)

Examples:

- A Pacific diatom was found in the northern Atlantic after a warm summer (Reid *et al.* 2007)



Neodenticula seminae

- Rainbow smelt is reported from Hudson Bay and is expanding its northern range (Rooney and Paterson 2009)

Osmerus mordax

Study Goal

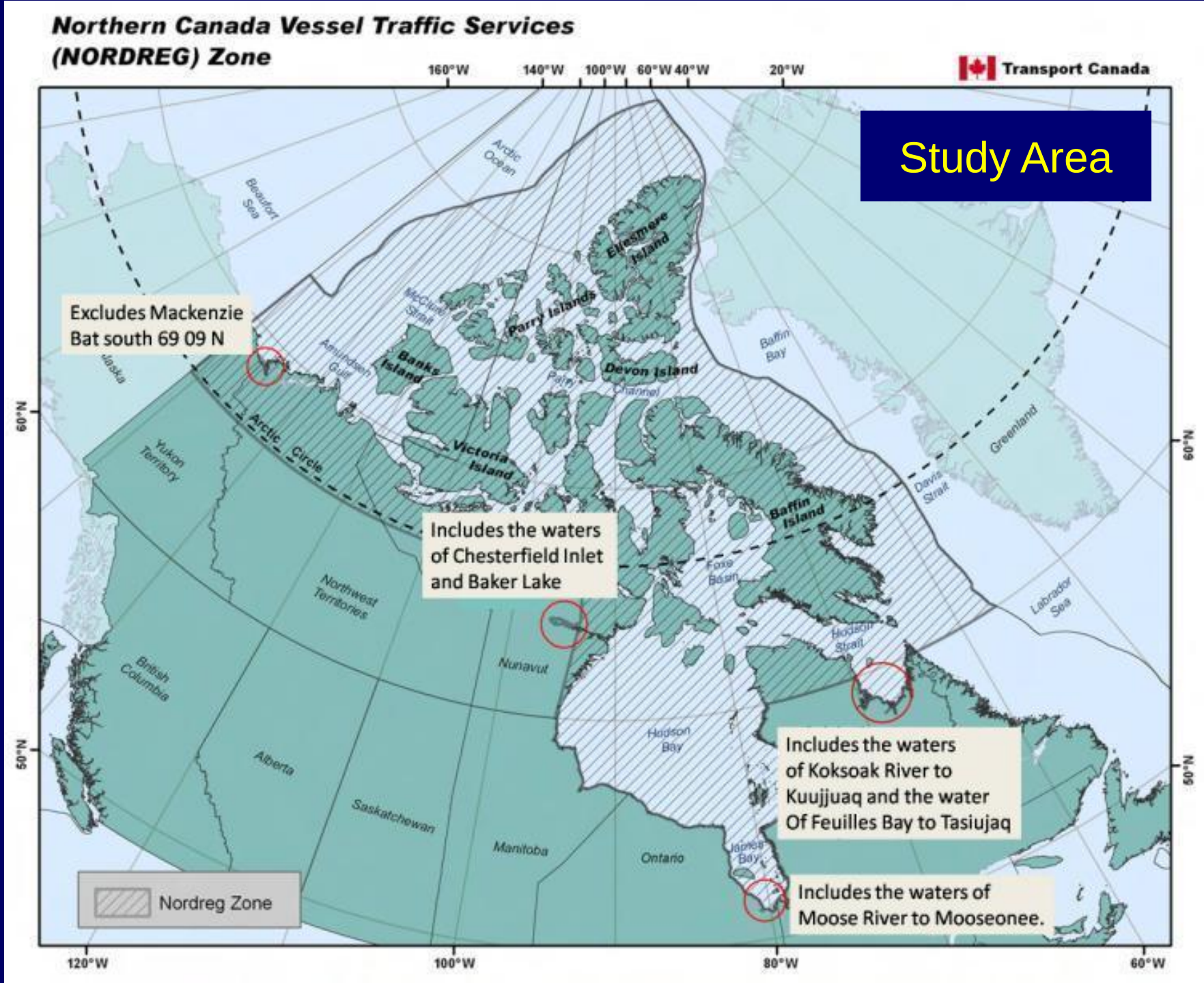
Assess current invasion risk of hull fouling and ballast water to ports in the Canadian Arctic

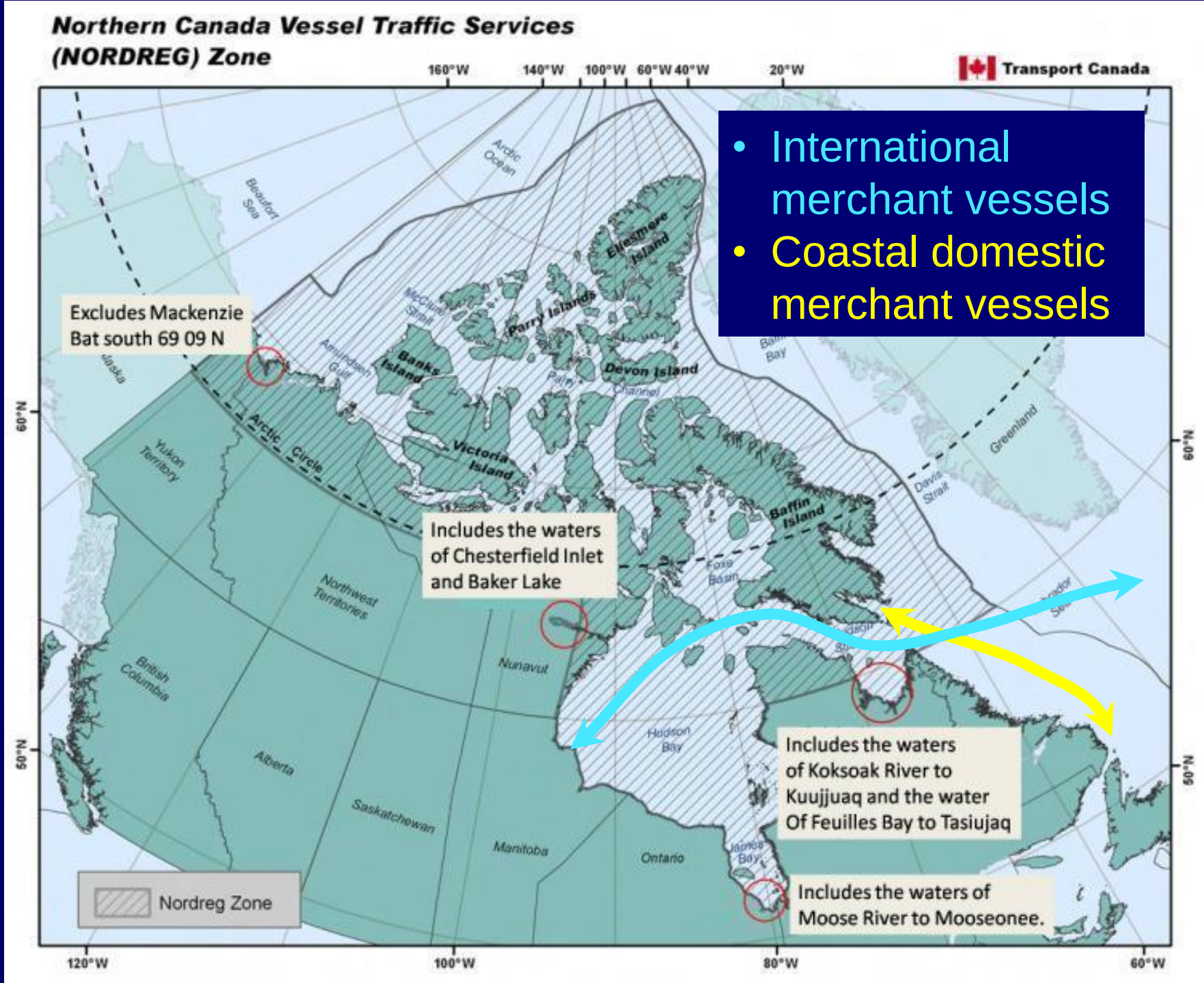
Risk = P(Introduction) x Consequence

(NRC 2001; Orr 2003)

Objectives:

1. Conduct a semi-quantitative, relative risk assessment for each ship vector by vessel pathway
2. Identify ports at relatively high risk of hull- and/or ballast-mediated invasions and the responsible pathway(s)


Northern Canada Vessel Traffic Services
(NORDREG) Zone
Transport Canada
Study Area
Excludes Mackenzie
Bat south 69 09 N
Includes the waters
of Chesterfield Inlet
and Baker Lake
Includes the waters
of Koksoak River to
Kuujjuaq and the water
Of Feuilles Bay to Tasiujaq
Includes the waters of
Moose River to Mooseonee.
Nordreg Zone
160°W
140°W
100°W
60°W
40°W
20°W
120°W
100°W
80°W
60°W
60°N
50°N
Arctic Ocean
Beaufort Sea
Alaska
Yukon Territory
Northwest Territories
Nunavut
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Hudson Bay
James Bay
Foxe Basin
Baffin Bay
Davis Strait
Labrador Sea
Greenland
Hudson Strait
Ellesmere Island
Parry Islands
Banks Island
Victoria Island
Devon Island
Baffin Island
Arctic Circle


Northern Canada Vessel Traffic Services
(NORDREG) Zone
Transport Canada
160°W
140°W
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• International merchant vessels
• Coastal domestic merchant vessels
Excludes Mackenzie Bat south 69 09 N
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Includes the waters of Koksoak River to Kuujjuaq and the water Of Feuilles Bay to Tasiujaq
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Nordreg Zone
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Nunavut
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
James Bay
Alaska
69°N
50°N
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80°W
60°W

Risk Assessment Framework

International merchant vessels

Top 3 ports

Coastal domestic merchant vessels

Top 3 ports

Ballast water analysis

Environmental similarity analysis

P(Arrival)

P(Survival)

P(Establishment)

P(Introduction)

\+

Impact analysis

Magnitude of potential consequence

= Invasion risk

Estimating P(Arrival)

Data sources:

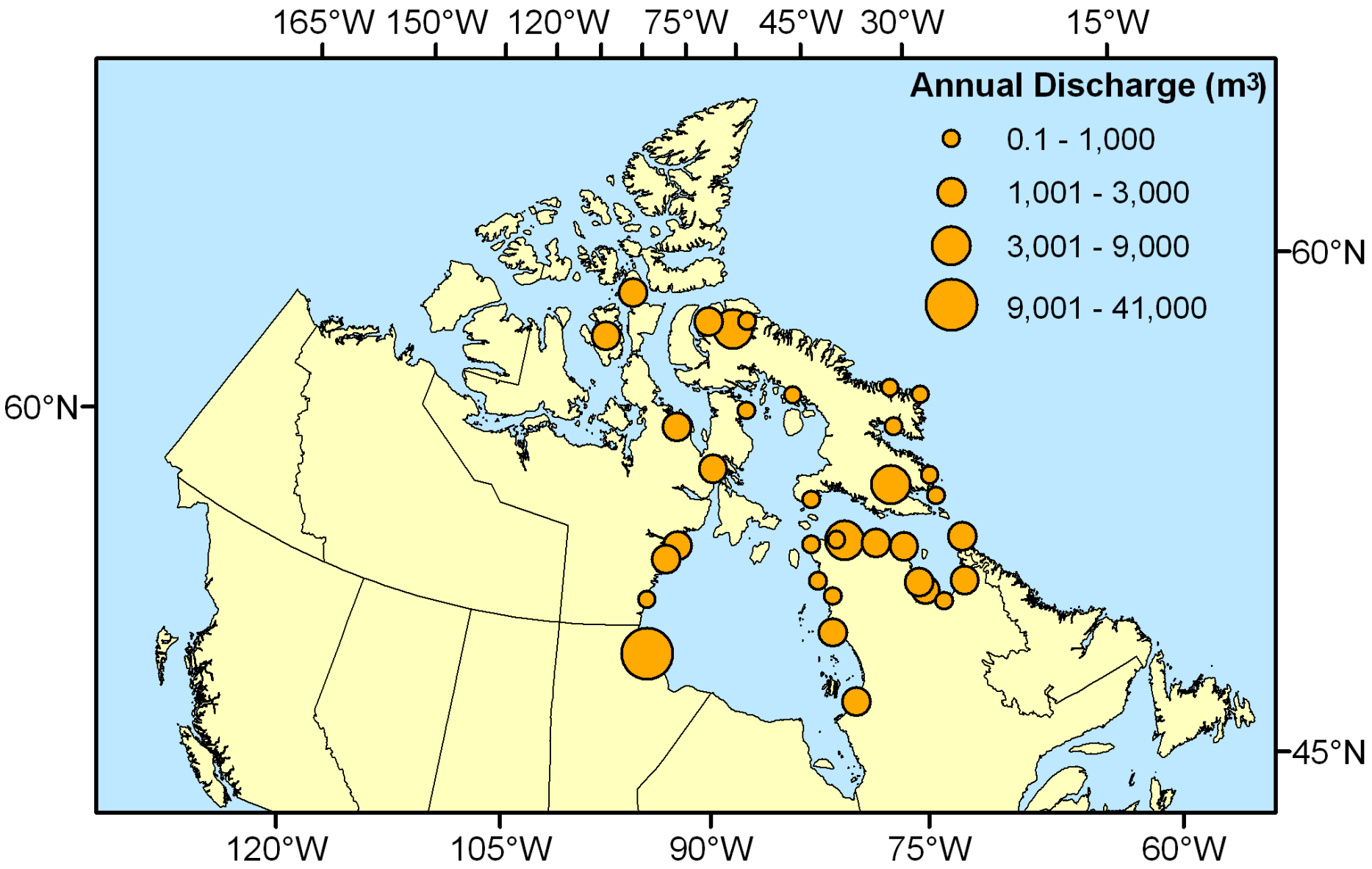
- Ballast water data from Canadian Coast Guard and Transport Canada

Methods:

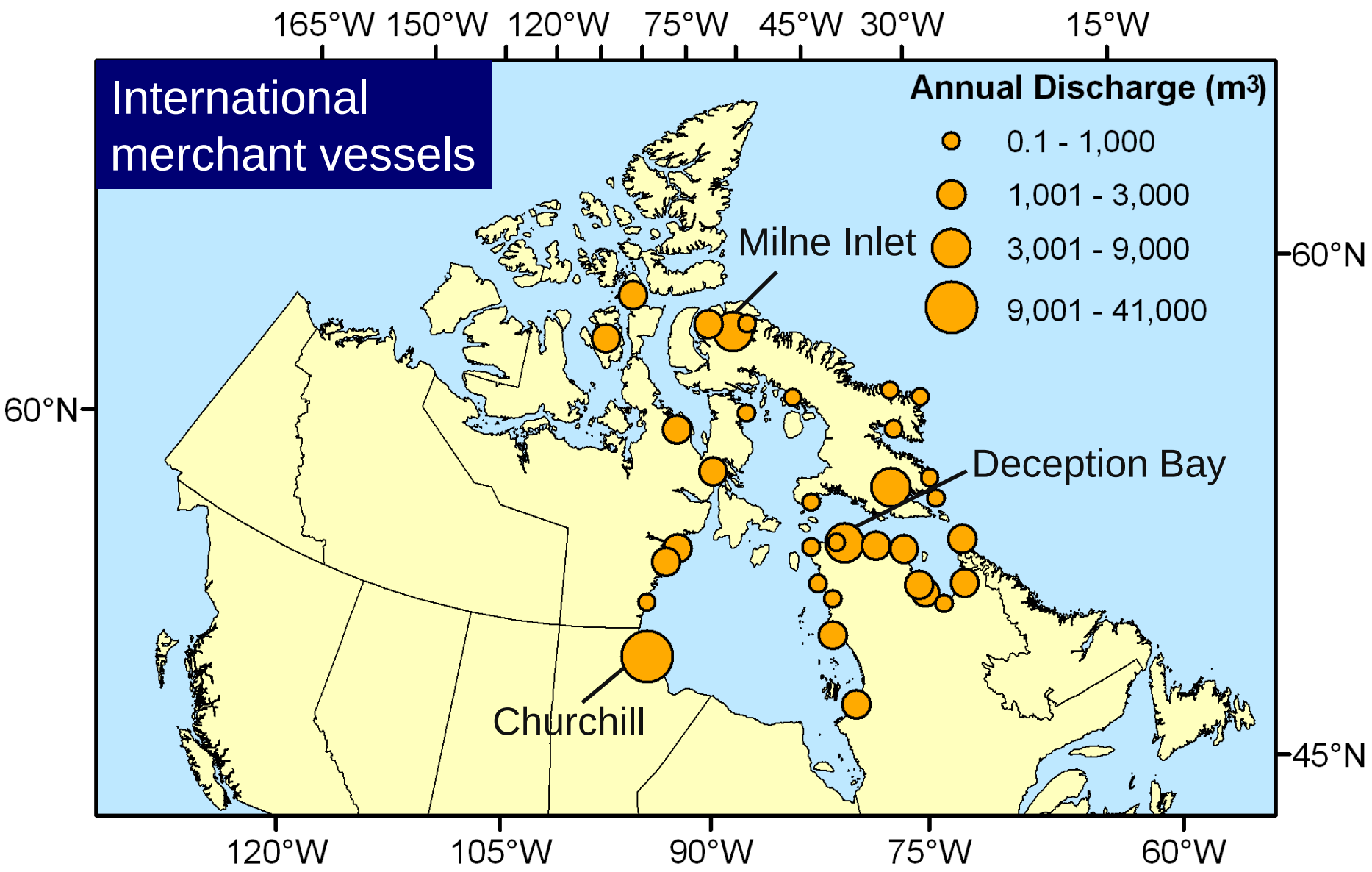
- Track ballast water activities at all Canadian Arctic ports for 2005-2008
- Apply correction factors to account for ballast water exchange efficacy

  (Ruiz and Smith 2005; Gray *et al.* 2007)

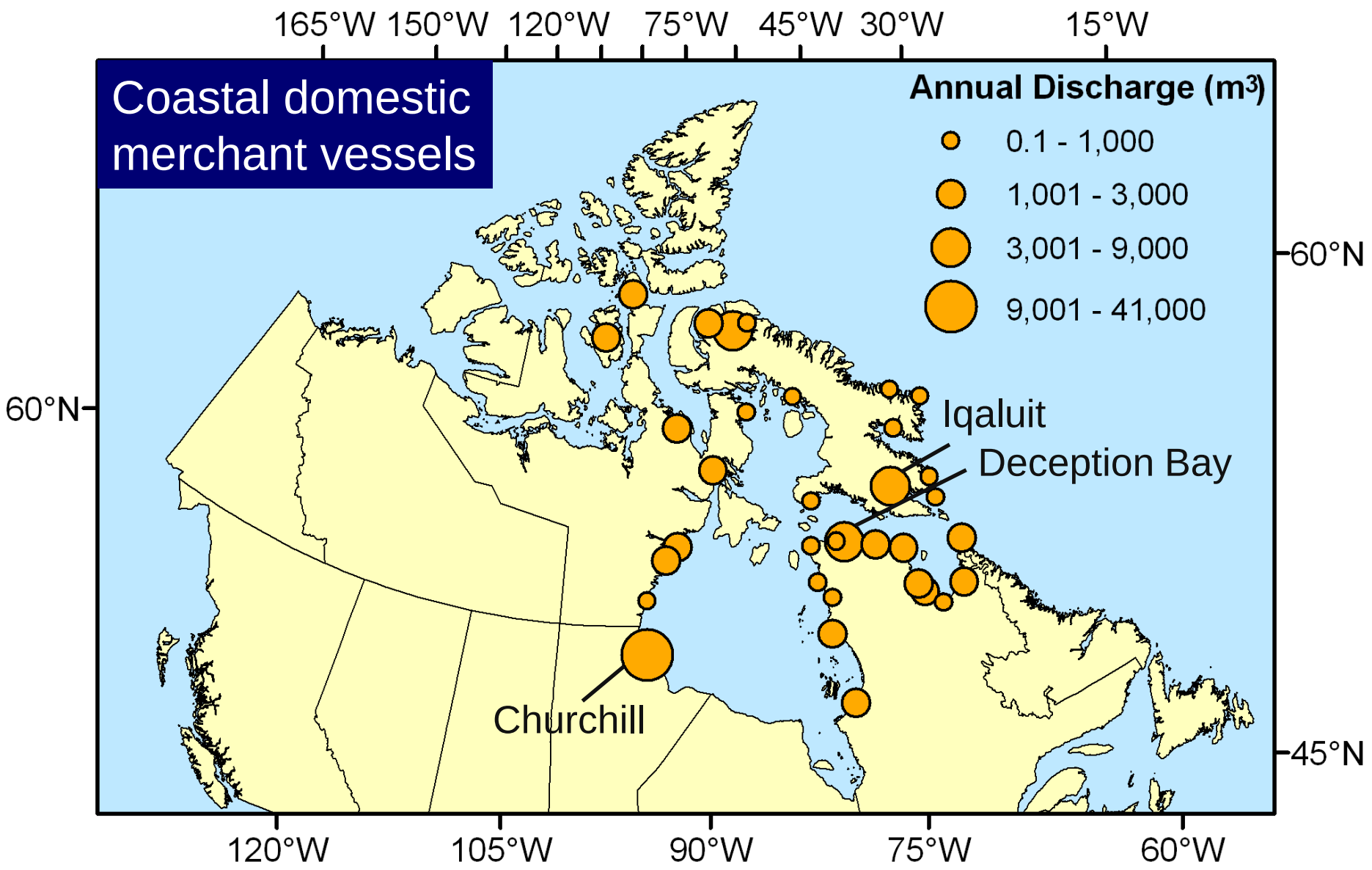
Ballast Water Discharges



Ballast Water Discharges



Ballast Water Discharges



Estimating P(Arrival)

- Use ballast water volume as proxy for propagule supply
- Assign P(Arrival) ratings for ports based on volume of ballast water discharged

Mean annual corrected volume of ballast water discharged (m^3)	P (Arrival)
27,735 – 34,667	Highest
20,801 – 27,734	Higher
13,868 – 20,800	Intermediate
6,934 – 13,867	Lower
0 – 6,933	Lowest

(National Research Council 2011)

Estimating P(Establishment)

Data source:

- Global port environmental data (Keller *et al.* 2011)

Methods:

- Obtain water temperature and salinity data for each port
- Estimate environmental similarity using Euclidean distance
- Calculation is driven evenly by temperature and salinity (Keller *et al.* 2011)

Environmental Similarity Analysis

- Assign P(Establishment) ratings based on environmental distance
- P(Establishment) is directly proportional to the degree of environmental similarity (Hewitt and Hayes 2002)

Environmental distance		P (Establishment)
0.00 – 1.40	Most similar	Highest
1.41 – 2.80		Higher
2.81 – 4.20		Intermediate
4.21 – 5.60		Lower
5.61 – 7.00	Least similar	Lowest

Estimating Potential Impact

Data sources:

- Nature Conservancy's Marine Invasive Database (Molnar *et al.* 2008)

Methods:

- Tabulate number of high impact ballast-mediated NIS at connected source ports
- Assume each connected source port may be a donor of all high impact NIS in the ecoregion

Cercopagis pengoi

Dreissena polymorpha

Estimating Potential Impact

- Use number of high impact NIS as proxy for magnitude of potential consequence
- Assign magnitude of potential consequence for ports based on number of high impact NIS

Number of high impact ballast-mediated NIS	Magnitude of potential consequence
701 - 875	Highest
526 - 700	Higher
351 - 525	Intermediate
176 - 350	Lower
0 - 175	Lowest

Combining Risk Ratings

- Combine P(Arrival) and P(Establishment) using the minimum probability approach (Orr 2003)
- Use the mixed rounding symmetrical matrix to combine P(Introduction) and consequence

Consequence \ P(Introduction)	Lowest	Lower	Intermediate	Higher	Highest
Highest					
Higher					
Intermediate					
Lower					
Lowest					

(Modified from Koops and Cudmore 2009)

Ballast-Mediated Invasion Risk

Top 3 ports	Probability of introduction	Magnitude of consequence	Invasion risk
Top ports for international merchant ballast water discharges			
Churchill	Intermediate	Highest	Higher
Milne Inlet	Lower	Lowest	Lower
Deception Bay	Lowest	Lowest	Lower
Top ports for coastal domestic merchant ballast water discharges			
Churchill	Lowest	Lowest	Lower
Deception Bay	Lowest	Lowest	Lower
Iqaluit	Lowest	Lowest	Lower

Ballast-Mediated Invasion Risk

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Conclusions

- Churchill is at relatively high risk of NIS introductions from ballast water discharged by international merchant vessels
- International merchant vessels appear to be a higher risk pathway than coastal domestic vessels
  - Discharge both managed foreign and unmanaged domestic ballast water

Port of Churchill:
Major seaport for grain export

Next Steps

- Conduct biological surveys to identify NIS
- Incorporate biological data to calibrate risk rating system
- Include results from other regional risk assessments (Pacific, Atlantic and Great Lakes regions) to evaluate relative invasion risk at the national level

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