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Risk Assessment as a means to predict and prevent aquatic invasions

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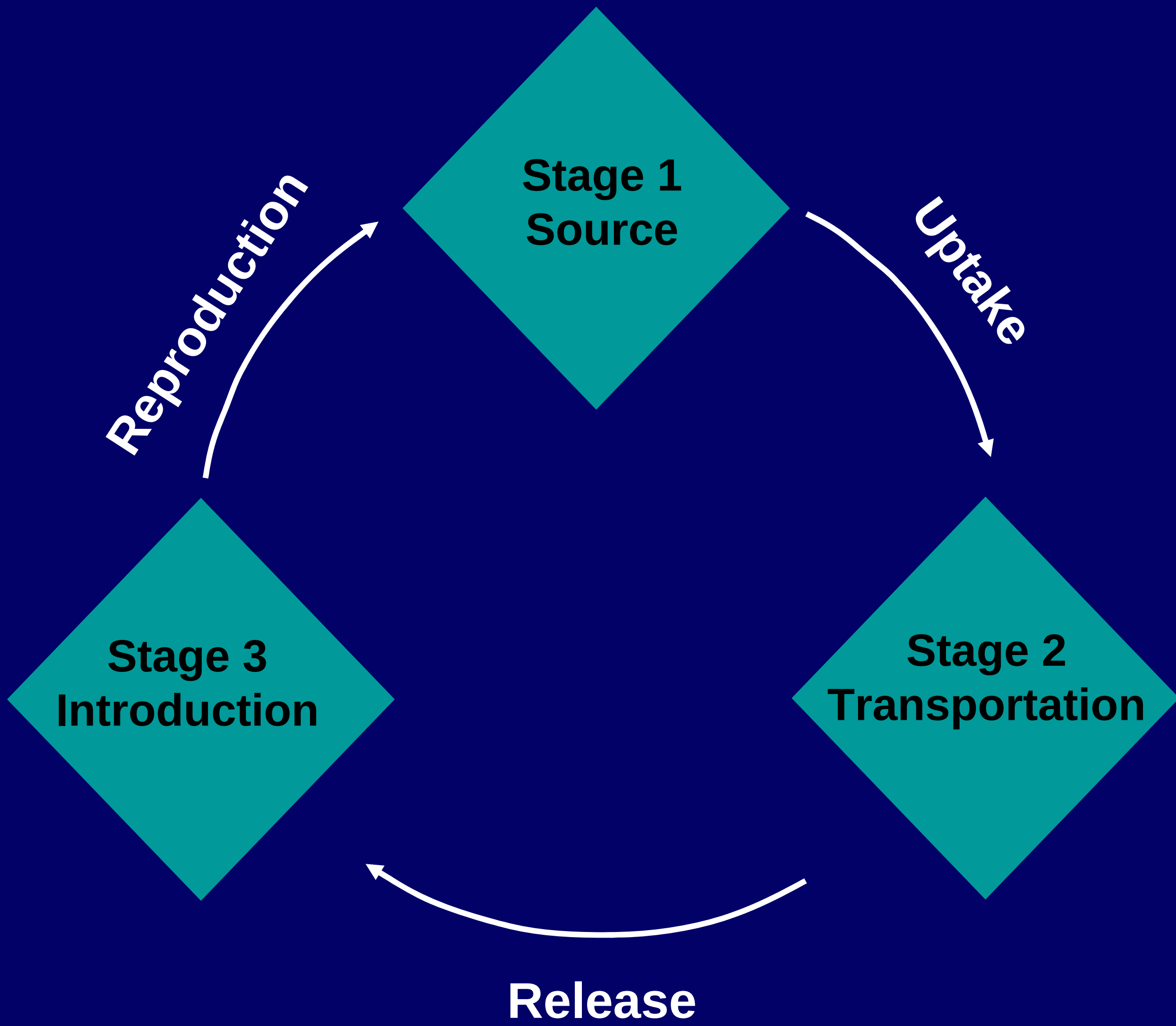
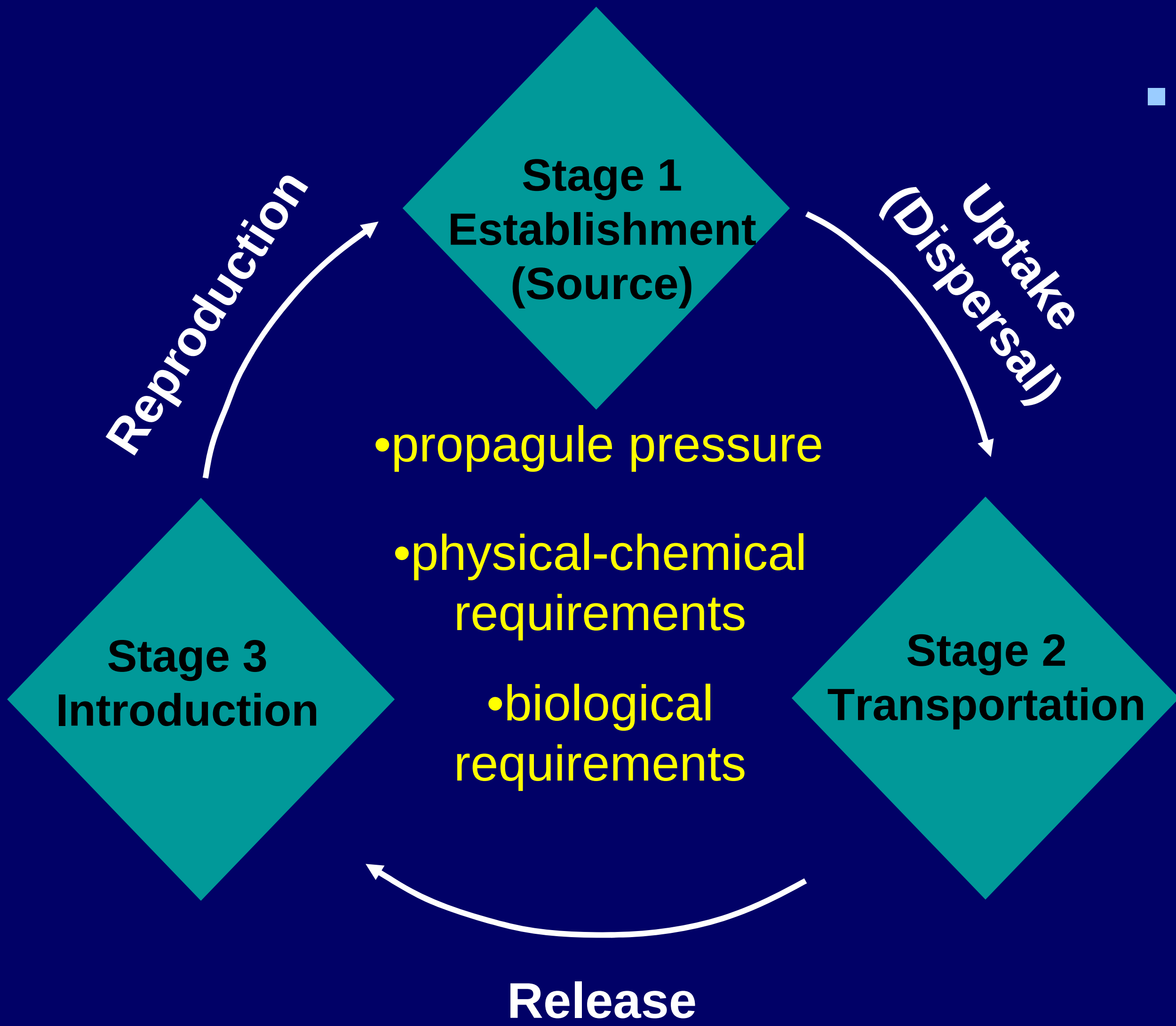
A Brief History of Invasion Theory

- Elton (1958) identified species-poor, disturbed, and island habitats as being more vulnerable to invasion
- Lodge (1993) and numerous others assembled lists of ‘characteristics’ of invaders and invasible habitats
- Williamson (1996) and others began to formulate a framework for the stages of the invasion process

Biological Invasion Framework



Biological Invasion Framework



- 3 key factors affect the transition between stages

Current Invasion Research

- Consider alternative hypotheses sequentially:
  - Propagule Pressure
  - Environmental Suitability
  - Ecological Suitability
- Prediction/Prevention through assessment of vectors and pathways
- Risk Assessment, Early Detection and (Rapid) Response

Definitions

- Propagule Pressure: described by the # of introduction events, # of propagules introduced per event, and the condition of those propagules
- Vector: the physical means by which a species is transported from one area to another (e.g. ballast water)
- Pathway: the route by which an invasive species is transferred from one ecosystem to another (e.g. transoceanic shipping)

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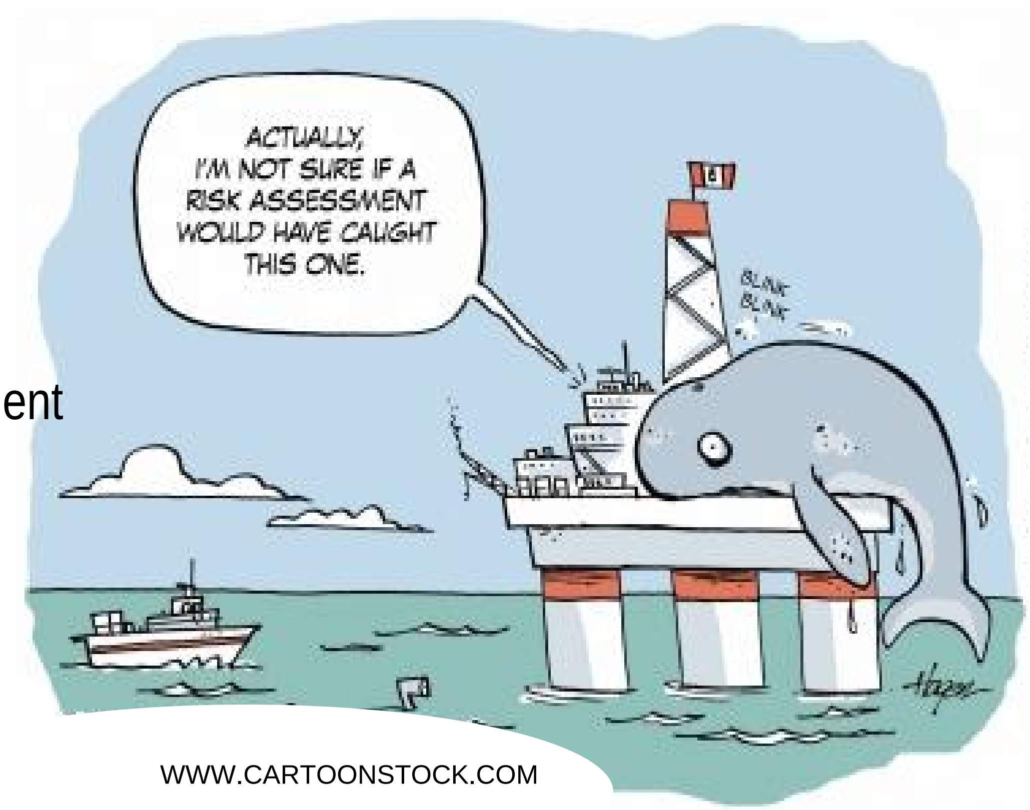
RISK ASSESSMENT 101

CEARA

Centre of Expertise for Aquatic Risk Assessment
Centre d'expertise analyse des risques aquatiques

Centre of Expertise for Aquatic Risk Assessment
Fisheries and Oceans Canada
Burlington, Ontario



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Risk Analysis

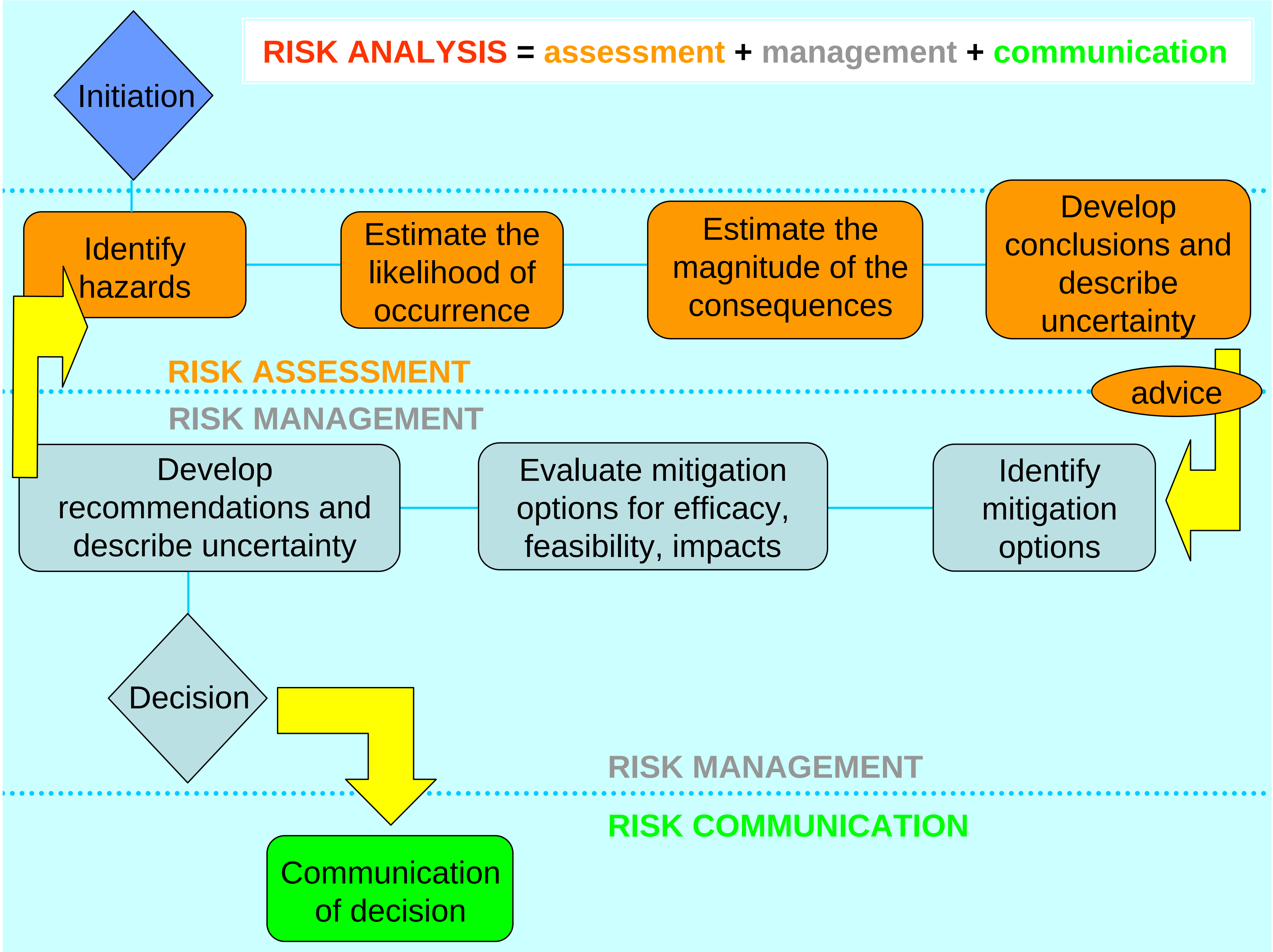
A procedure to identify threats & vulnerabilities, analyze them to ascertain the exposures, highlight how the impact can be eliminated or reduced, and communicate the results.

Risk Analysis = risk assessment + risk management + risk communication

Risk Assessment

A procedure to identify likelihood of threats & vulnerabilities, and analyze them to ascertain the magnitude of exposures.

Objective: "…to evaluate, order, and structure incomplete knowledge so as to allow decisions to be made with as complete an understanding as possible of the current state of knowledge, its limitations, and its implications." (Morgan, 1978)


RISK ANALYSIS = assessment + management + communication
Initiation
Identify hazards
Estimate the likelihood of occurrence
Estimate the magnitude of the consequences
Develop conclusions and describe uncertainty
RISK ASSESSMENT
advice
RISK MANAGEMENT
Develop recommendations and describe uncertainty
Evaluate mitigation options for efficacy, feasibility, impacts
Identify mitigation options
Decision
RISK MANAGEMENT
RISK COMMUNICATION
Communication of decision

Why Use a Risk Approach?

- Risk = likelihood, and severity, of an undesirable event
- Uses a probability to describe the chance that an event will occur, when the outcome of the event is unknown (i.e., many risks not deterministic)
- RAs incorporate (un)certainty of risk estimate:
  - Scientific (e.g., statistical, modeling, physical variability)
  - Human-based (bias, human error)

Biological Risk Assessment for Aquatic Invasive Species (AIS)

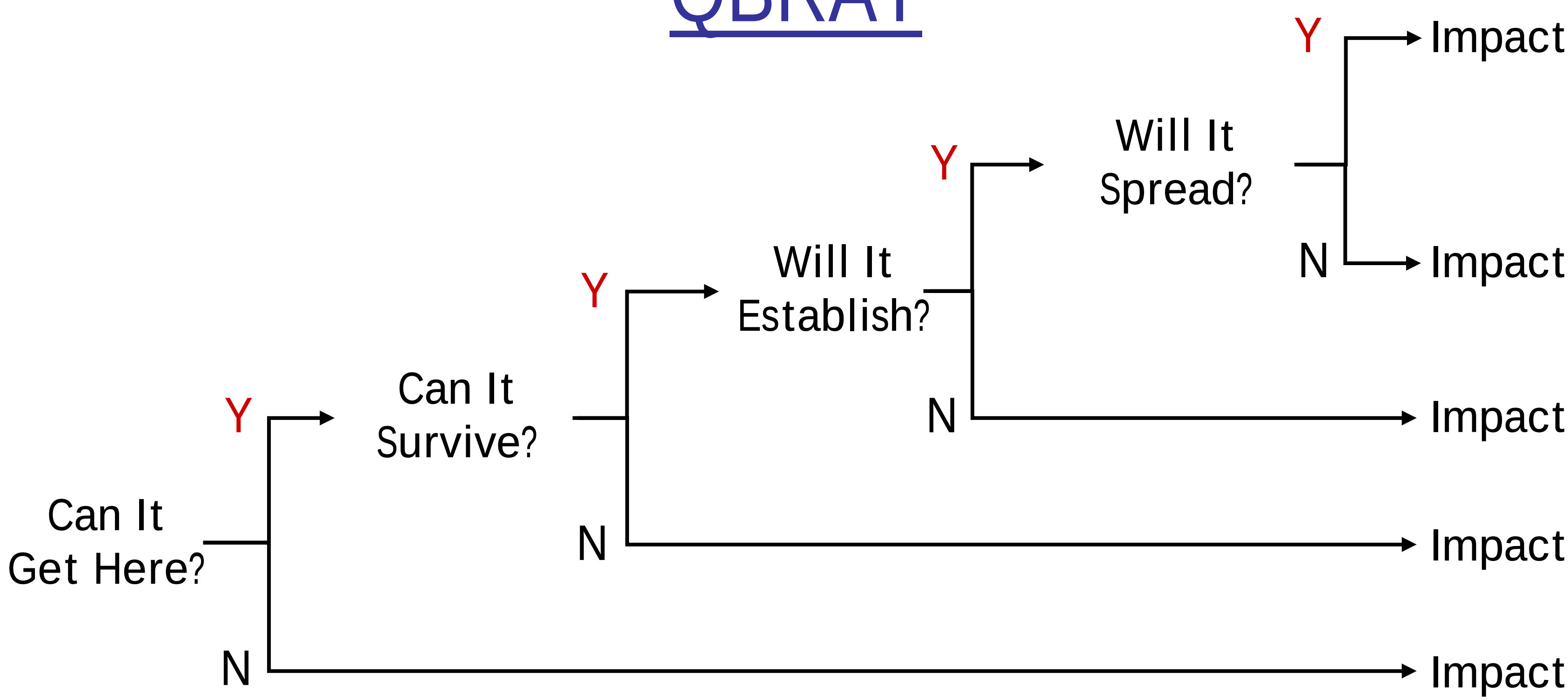
- Likelihood of an AIS introduction
  - probabilities of arrival, survival, establishment, and spread
- Magnitude of consequences (ecological impacts)
- Uncertainty
  - considers quality and quantity of data available to rank likelihood and magnitude
  - provides risk managers with indication of the inherent strengths and weaknesses in the risk assessment

Risk Assessment (RA) = P(Introduction) x Impact

where

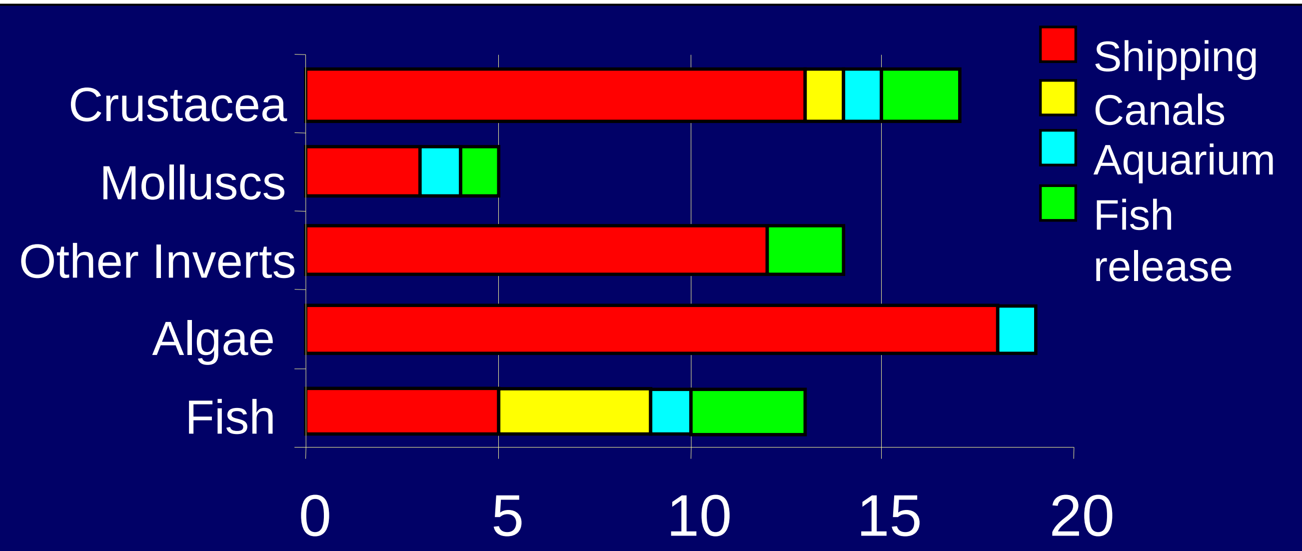
P(Introduction) = P(Arrival) x P(Survival) x
P(Establishment) x P(Spread)

A Quantitative Biological Risk Assessment Tool: QBRAT



P(Arrival)

- Evaluate vectors and pathways
- Measure propagule pressure

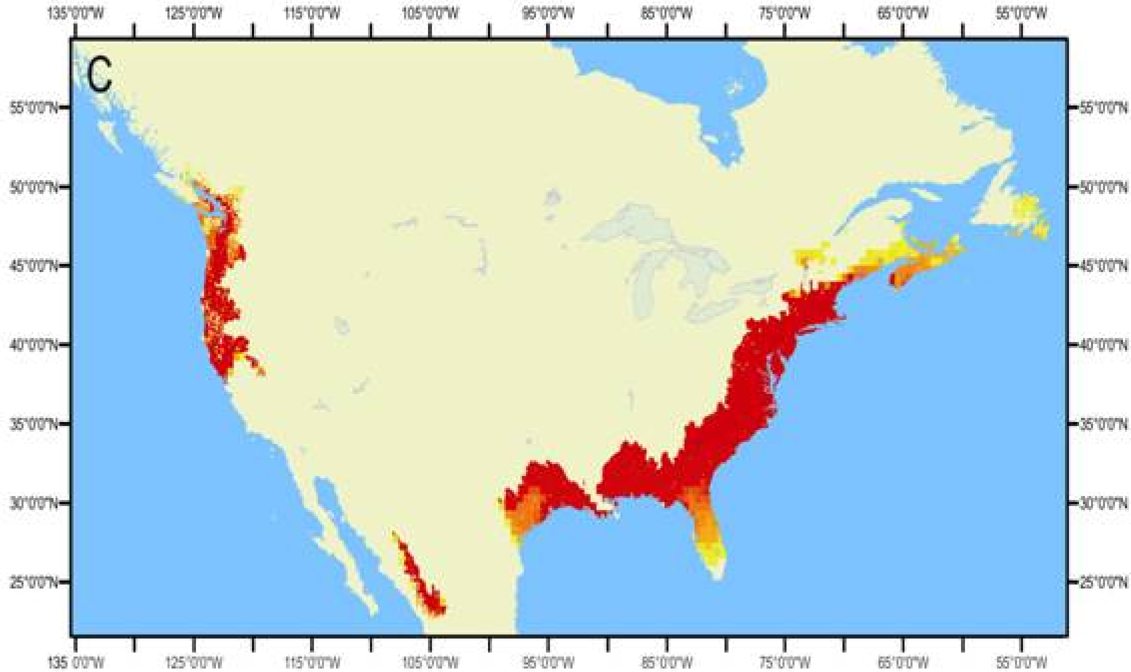


Summary of Great Lakes' AIS pathways

Grigorovich *et al*. 2003; Ricciardi 2006

P(Survival)

- Environmental Similarity Analysis
  - Biological tolerances of species
  - Habitat similarity of connected regions

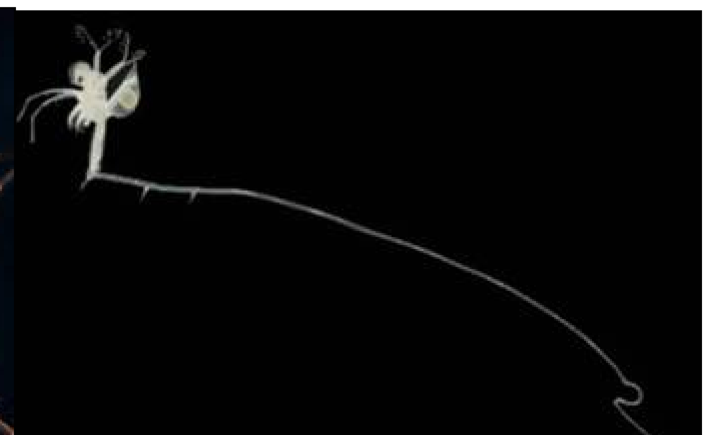


Chinese mitten crab, GARP-predicted distribution

Herborg et al. (2007)

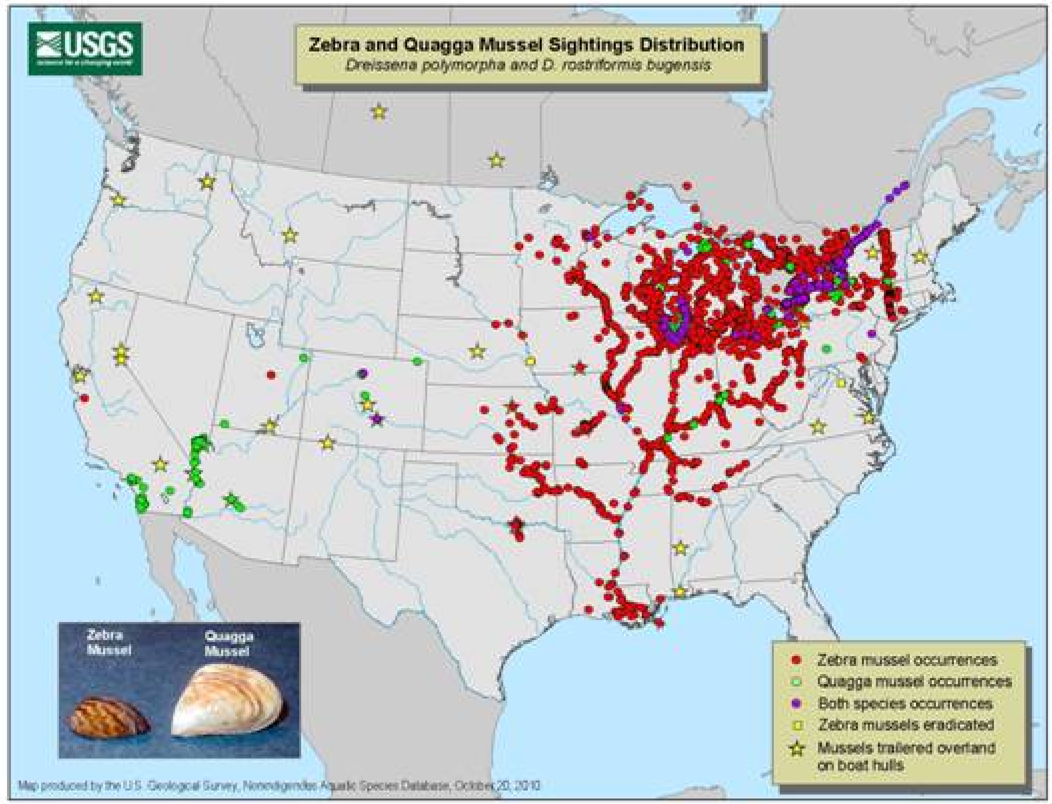
P(Establishment)

- Consider long-term population establishment needs
- (e.g. anadromous species, ability to survive winter)



P(Spread)

- Evaluate connectivity between habitats
- Re-assess vectors and pathways



Impact

- Assign impact ranking for all possible outcomes:
- I1 = impact of an AIS that does not arrive
- I2 = impact of an AIS that arrives but does not survive
- I3 = impact of an AIS that arrives, survives, but does not establish a reproductive population
- I4 = impact of an AIS that only establishes a local population
- I5 = impact of an AIS that establishes a wide-spread population

Uncertainty

Relative

- Very High Certainty
- High Certainty
- Moderate Certainty
- Low Uncertainty
- Very Low Uncertainty

Absolute

- Uniform Distribution
- Normal Distribution
- Lognormal Distribution
- Beta Distribution

Species RA vs. Pathway RA

- Species RA – driven by biology:
  - measure propagule pressure by vector(s) / pathway(s)
  - niche models used to predict new range based on native range
  - Impact predicted from biological studies and/or past history

- Pathway RA – driven by vector analysis:
  - multiple species involved
  - identity/native range/impacts may be unknown

Challenges – Pathway RAs

- Environmental and Impact measures plausible only at coarse scale
- Incorporation of current species knowledge
- Need biological data to calibrate risk levels
- Need data to inform mathematics of components



How are Risk Assessments Useful?

- Provide science advice well beyond answering the question:

"Is there a risk?"

How are Risk Assessments Useful?

- Prioritize future research needs
- Direct monitoring, early detection and rapid response activities
- Identify risky species and pathways for regulation
- Development and implementation of prohibition lists
- Analyze effectiveness of regulations – *did they decrease risk?*
- Identification of secondary pathways to prevent spread

Canada's National Risk Assessment for Ship-Mediated Invasions

Co-PIs: F. Chan, J. Bradie, N. Simard, C. McKenzie, K. Howland, J. Martin and T. Sutherland.

See also: Rup, Bailey et al. 2010. CJFAS 67: 256-268.

Main Objective

- Provide advice about the level of risk of ship-mediated invasions to different areas of Canada
- Identify gaps in current regulatory program

Ship Pathways in the Great Lakes

- Lakers
- Coastal
- Transoceanic

Defining the Role of Lakers

Two studies to characterize the role of Lakers in ANS introduction and/or spread in the Great Lakes:

1. Laker Transit Study
- Quantifies ballast water volume moved between inland ports
- Potential Propagule Pressure

2. Biological Sampling Study
- Identifies taxa being transported in domestic ballast water
- Effective Propagule Pressure

Laker Transit Study

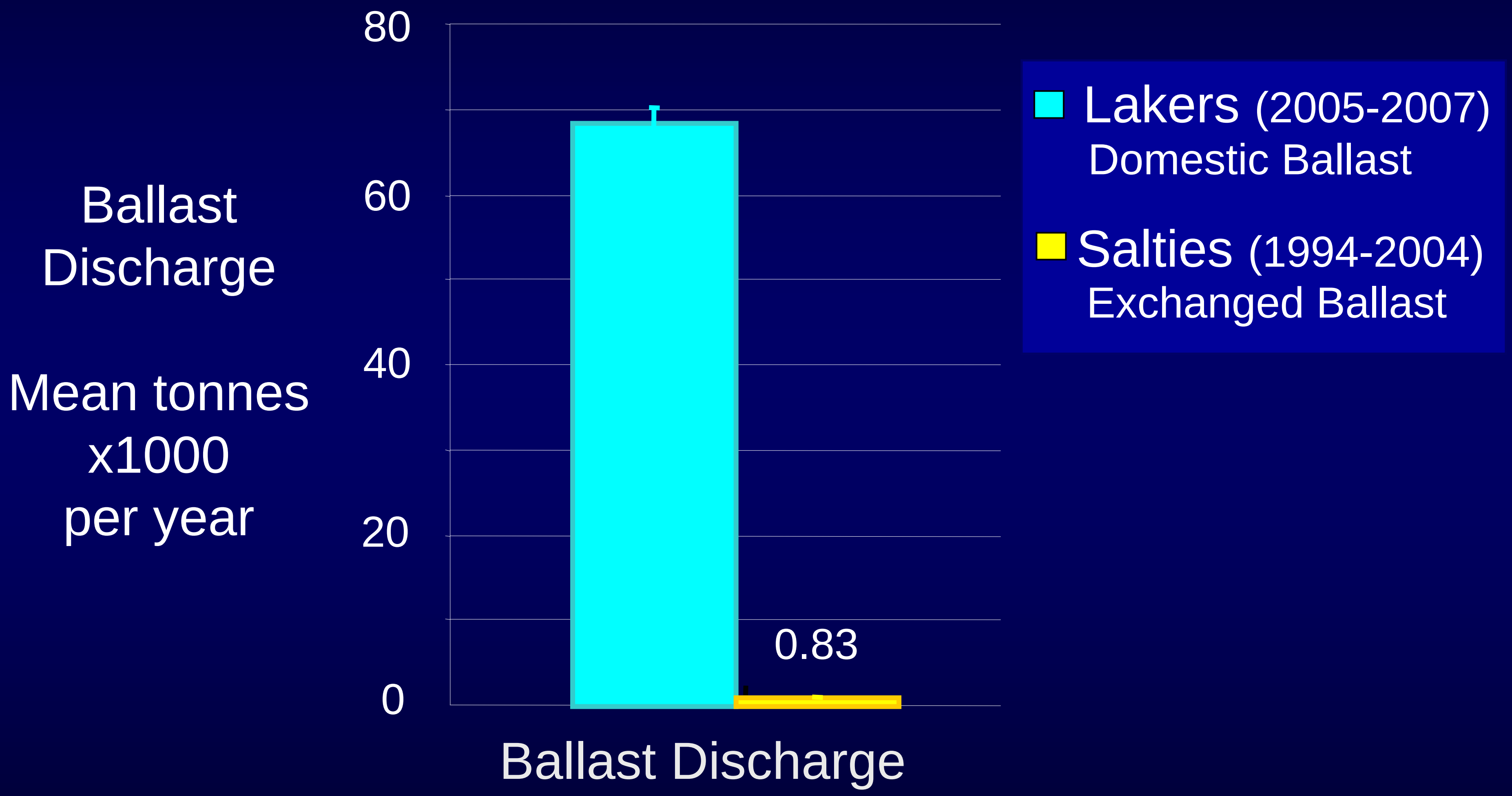
Methods:

- Vessel transits tracked for three year period (2005-2007)
- Primary data sources include:
  - INNAV (CDN Coast Guard)
  - NBIC (US Coast Guard, SERC; accessed 04/08)

Analysis includes:

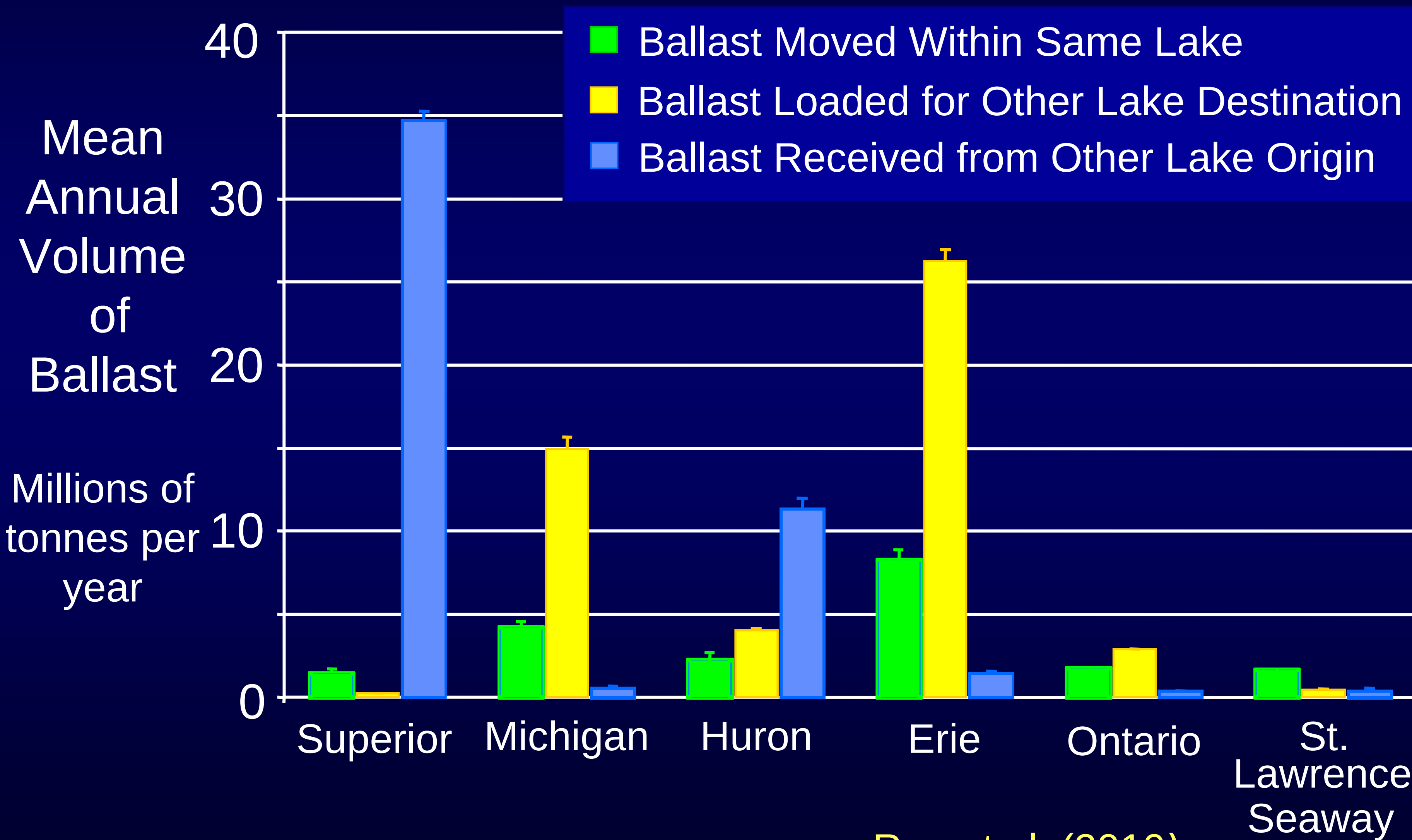
- 90 vessels: CDN and US fleet, including 8 tug/barges
- Over 28,000 transits to 137 ports

Relative Discharges in the Great Lakes



Sturtevant et al. (2007); Rup et al. (2010)

Laker Ballast Transfers by Lake



Rup et al. (2010)

Top Laker Ballast Donor Ports

Port	Ballast Tonnage Mt/yr Mean (S.E.)	Ballast Uptakes No./yr Mean (S.E.)
Detroit, MI	6.91 (0.45)	483 (36)
Nanticoke, ON	5.69 (0.17)	242 (10)
Gary, IN	4.80 (0.38)	145 (12)
Indiana Harbor, IN	4.62 (0.49)	218 (21)
St. Clair, MI	4.13 (0.12)	104 (3)
Cleveland, OH	3.20 (0.26)	317 (29)
Sault Ste-Marie, ON	2.26 (0.17)	233 (14)

If an ANS gets introduced to one of these ports (by any vector), it will likely spread to other locations very rapidly. These ports will be important for early detection/rapid response.

Rup et al. (2010)

Top Laker Ballast Recipient Ports

Port	Ballast Tonnage Mt/yr Mean (S.E.)	Ballast Discharges No./yr Mean (S.E.)
Superior, WI-Duluth, MN	20.31 (0.21)	704 (9)
Two Harbors, MN	7.94 (0.45)	233 (17)
Calcite, MI	3.41 (0.18)	286 (16)
Stoneport, MI	2.97 (0.30)	244 (22)
Port Inland, MI	2.39 (0.18)	201 (16)
Meldrum Bay-Bruce Mines, ON	2.12 (0.33)	222 (36)

These ports are at highest risk for introduction/spread of AIS by domestic ballast water. These ports will be important for monitoring/inspection efforts.

Rup et al. (2010)

Biological Study

Methods:

- Sample vessels in ballast only (no sediments)
- Ballast sampled through tank hatches or sounding tubes
- Samples collected May through November
- Includes CDN and US fleet
- Focus on ‘Lakers’ (vs. Coastal)

Preliminary Results

- 97 zooplankton taxa identified in Laker ballast
  - 7 ANS already reported from all 5 lakes
  - 2 ANS already reported from some lakes
    - both moved to lake not reported from (Superior)
  - 1 ANS not reported from Great Lakes
    - marine species (low probability for survival)
    - likely source: Les Mechins, PQ

Summary

- Data on transit patterns and biology of Laker ballast water will feed into National Risk Assessment - p(Arrival)
- Similar work is being conducted for all shipping pathways, for all Canadian ports, enabling uniform comparisons
- Estimated completion dates:
  - Great Lakes' RA: June 2011
  - National RA: December 2011

Limitations

- Due to breadth of National RA, only top three ports for each pathway/region will be completed
- p(Arrival) based on data from secondary sources
- ‘Snapshot’ study (1-3 years shipping data)
- Does not evaluate potential management strategies

Questions?

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http://www.dfo-mpo.gc.ca/science/coe-cde/ceara/index-eng.htm

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CAISN