

# DFO risk assessments: potential threat of green crab, mitten crab, and tunicates in Canada's waters

Chris McKindsey – Institut Maurice-Lamontagne  
Tom Therriault – Pacific Biological Station

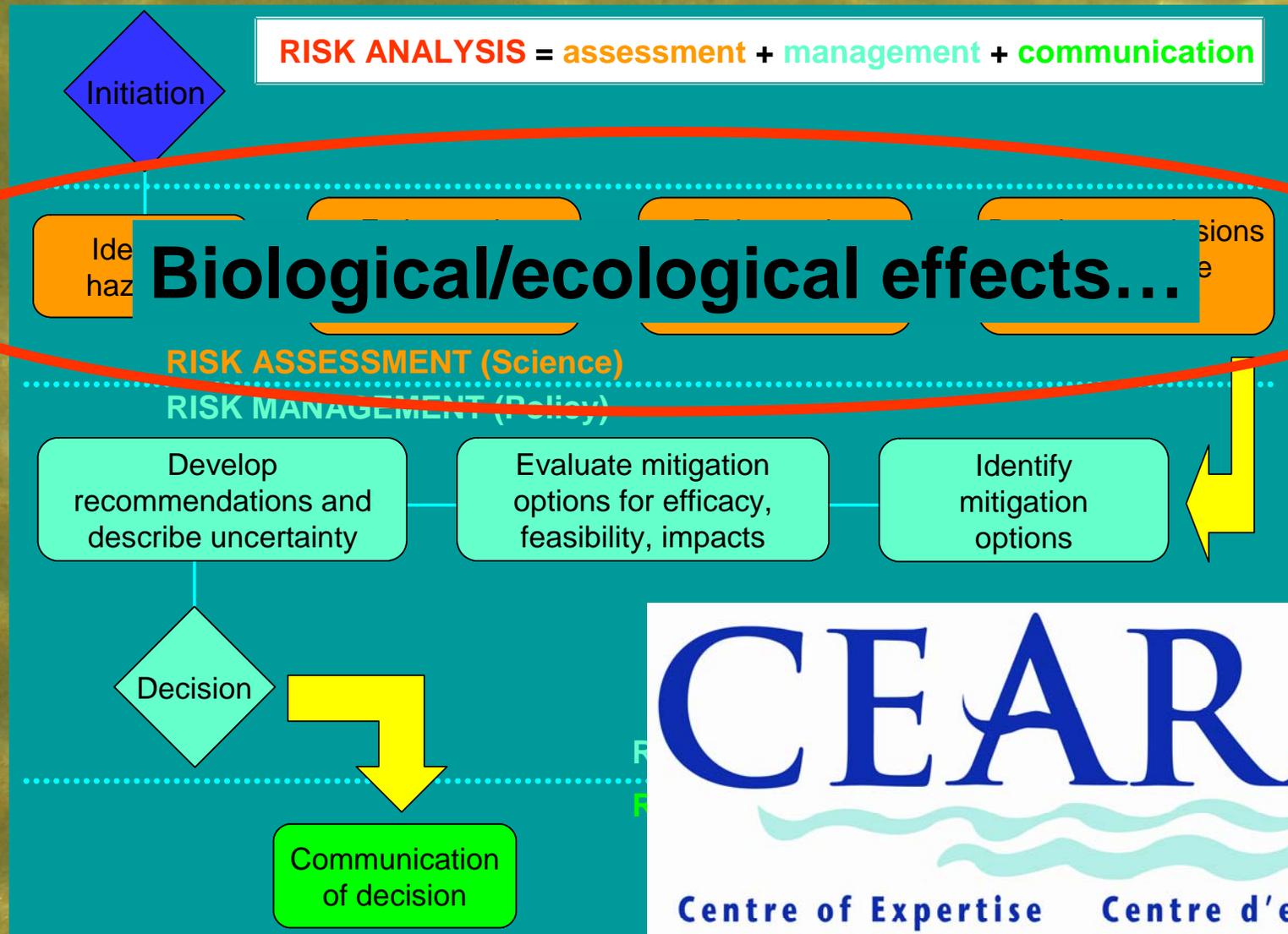


# Outline

- Risk analysis vs assessment: what and why?
- CEARA
- Invasion steps and RA process
- Tunicate RAs
- Crab RAs
- Current issues
- Upcoming...



# Risk analysis / assessment



**CEARA**

Centre of Expertise for Aquatic Risk Assessment

Centre d'expertise analyse des risques aquatiques

# Why a risk assessment?

## The purpose of a risk assessment is...

to use the best available scientific knowledge (both factual information and scientific theory) to provide technical support for decision making under uncertainty.

## The purpose of an ecological risk assessment is...

to assess risk to non-human organisms, populations, and ecosystems.



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## Centre of Expertise for Aquatic Risk Assessment (CEARA)

### [\\*Asian Carp Information\\*](#)

#### The objectives of CEARA:

**Risk Assessment Methods Guidelines (2006, 2008, 20??)**  
**Risk Assessment Tools (QBRAT + 5 species/groups)**  
**Biological Synopses (many species)**  
**Species Risk Assessments (plants, fish, invertebrates)**  
**Pathway Risk Assessments (e.g., aquarium, shipping)**  
**Products: Meeting proc, Tech reports, Primary pubs, etc.**

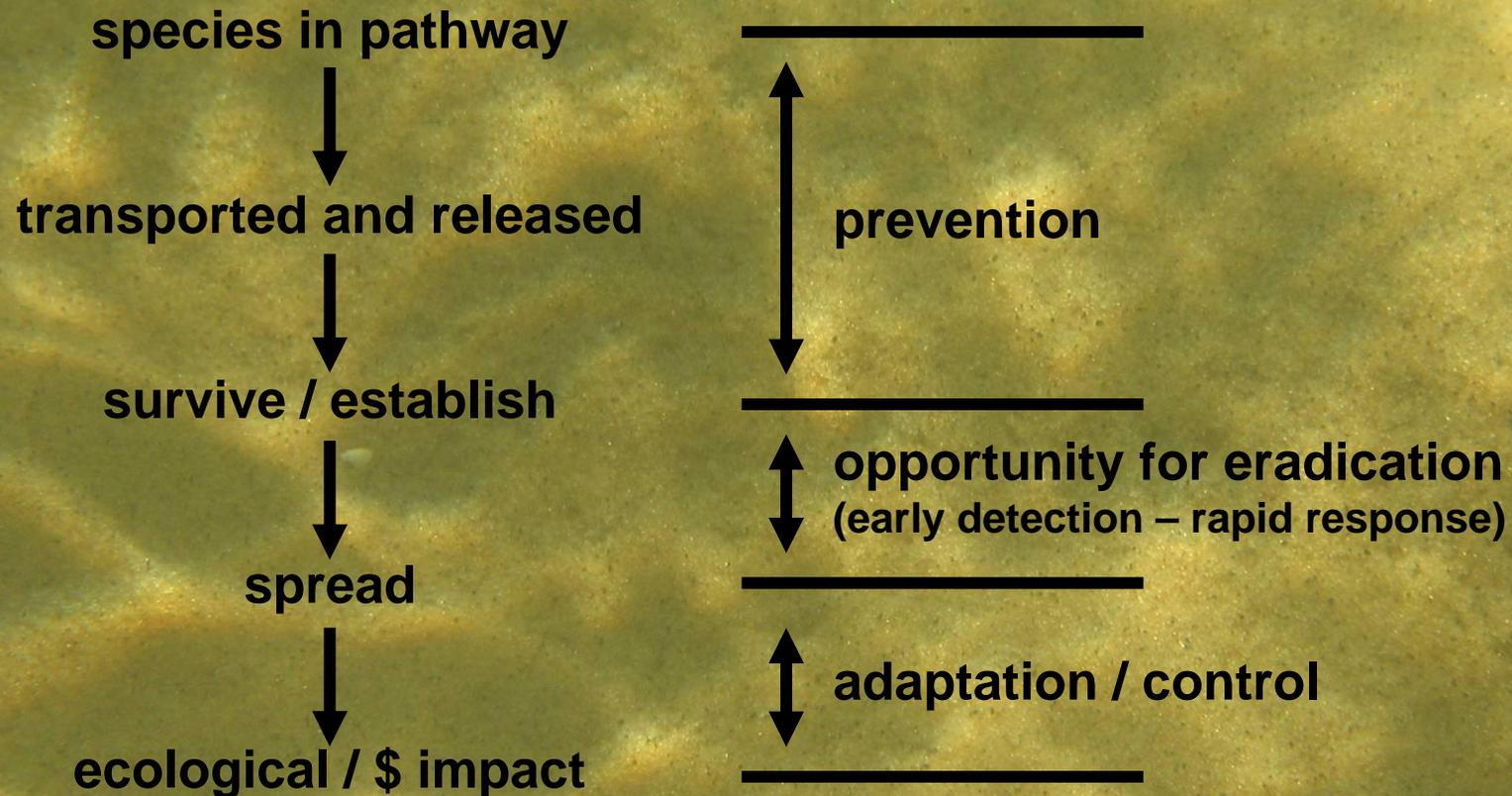
**Google: CEARA + DFO**

# Process of species invasion

nb: best to halt introductions rather than established population

## Invasion Process

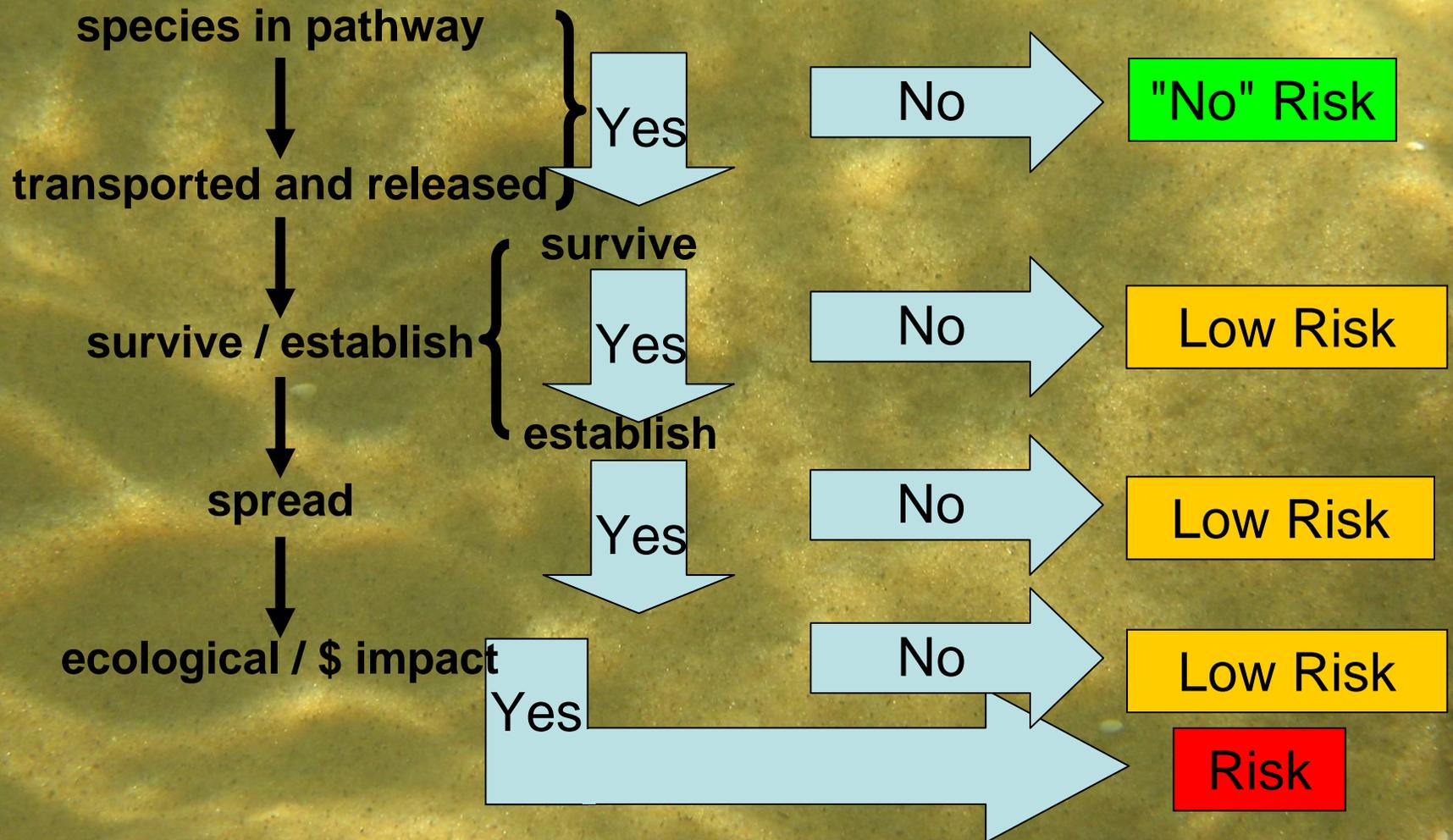
## Management



# Risk assessment process

## Invasion Process

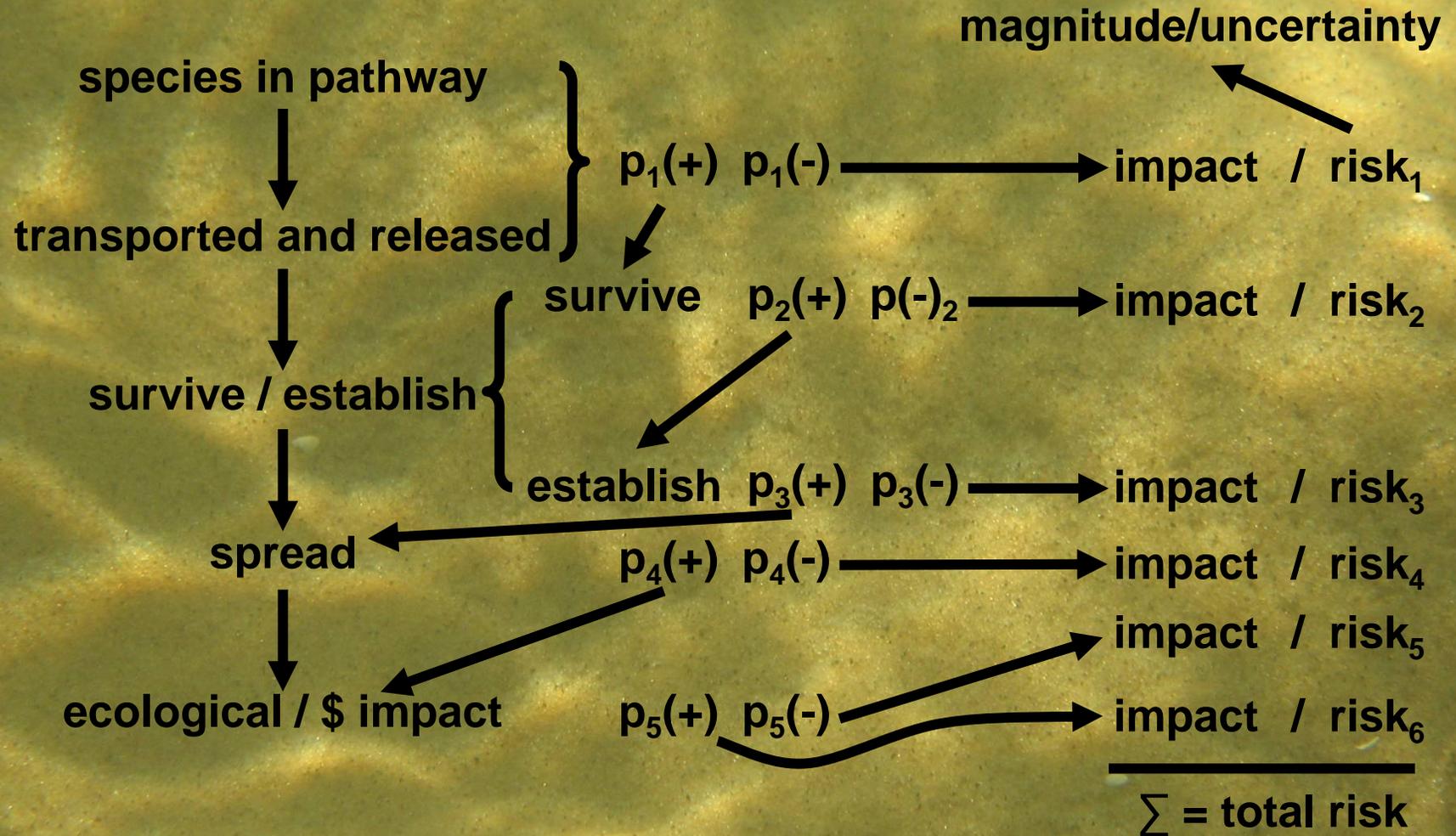
## RA (Basic example)



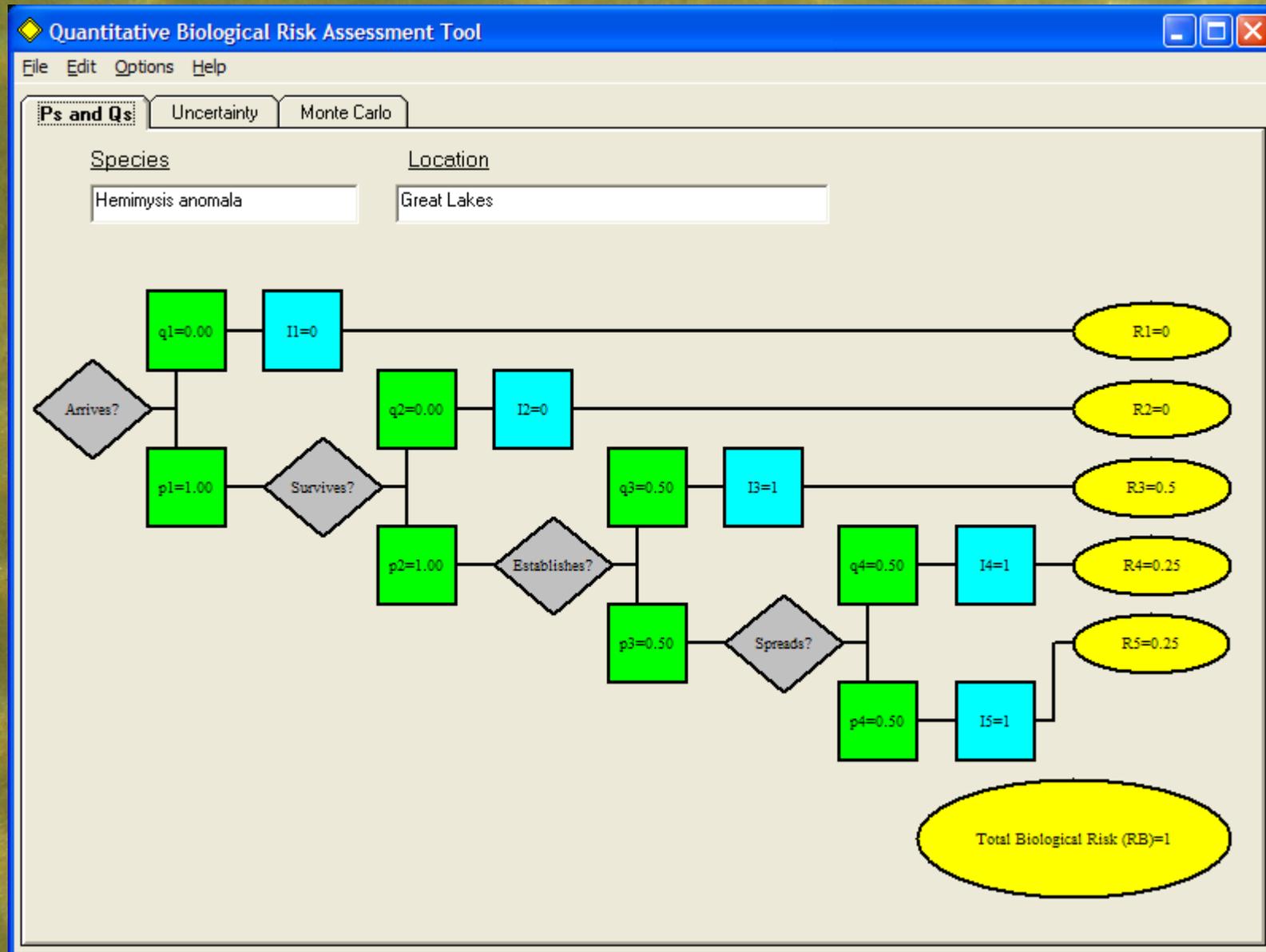
# Risk assessment process

## Invasion Process

## RA (QBRAT example)

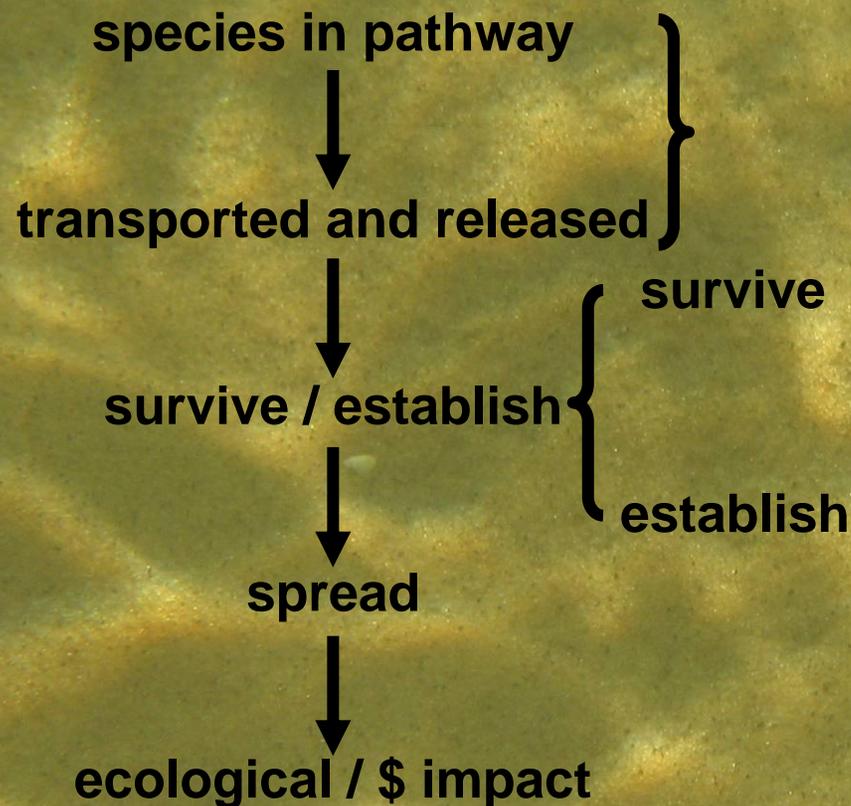


# Risk assessment process (QBRAT)



# Tools to assess risk

## Invasion Process

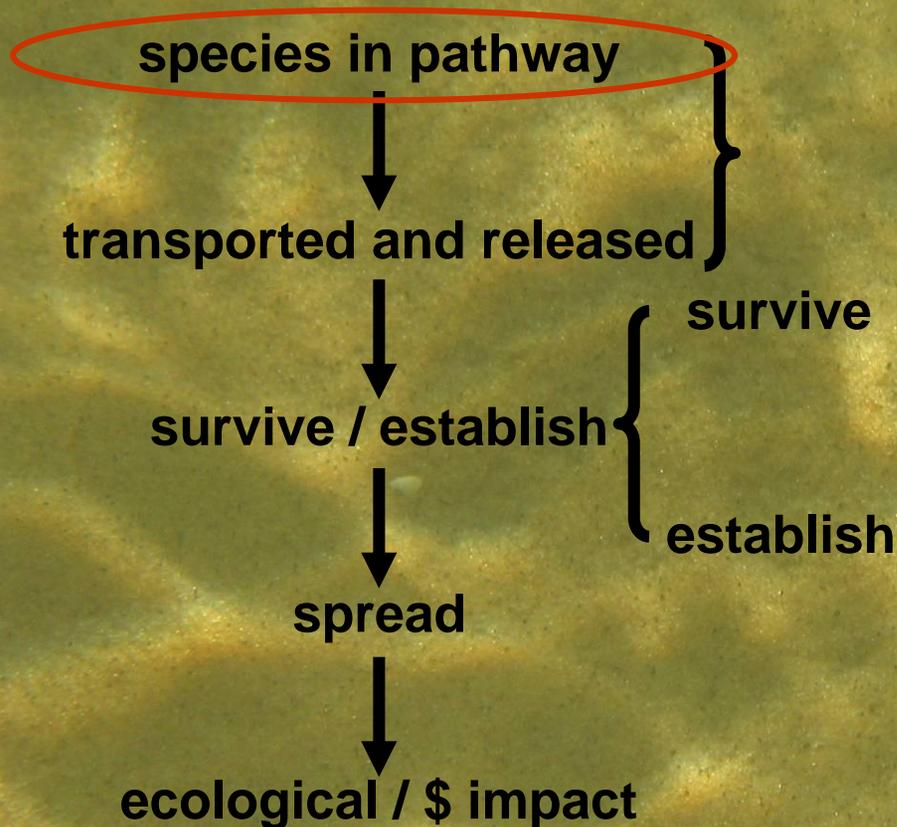


## Potential tools

- species distributions
- basic survey work
- theoretical possibility
- biological attributes
- environmental niche modelling
- spread modelling
- trait-based impact modelling

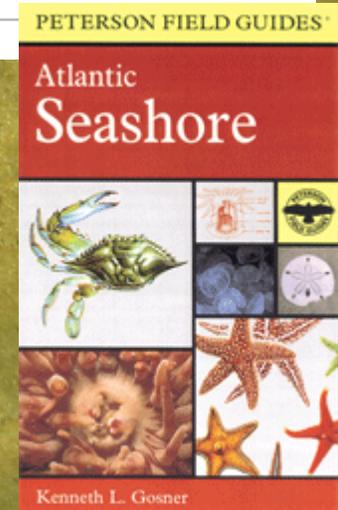
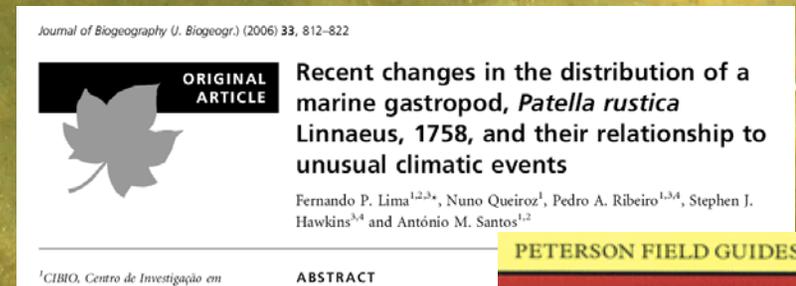
# Tools to assess risk

## Invasion Process



## Spp in pathway

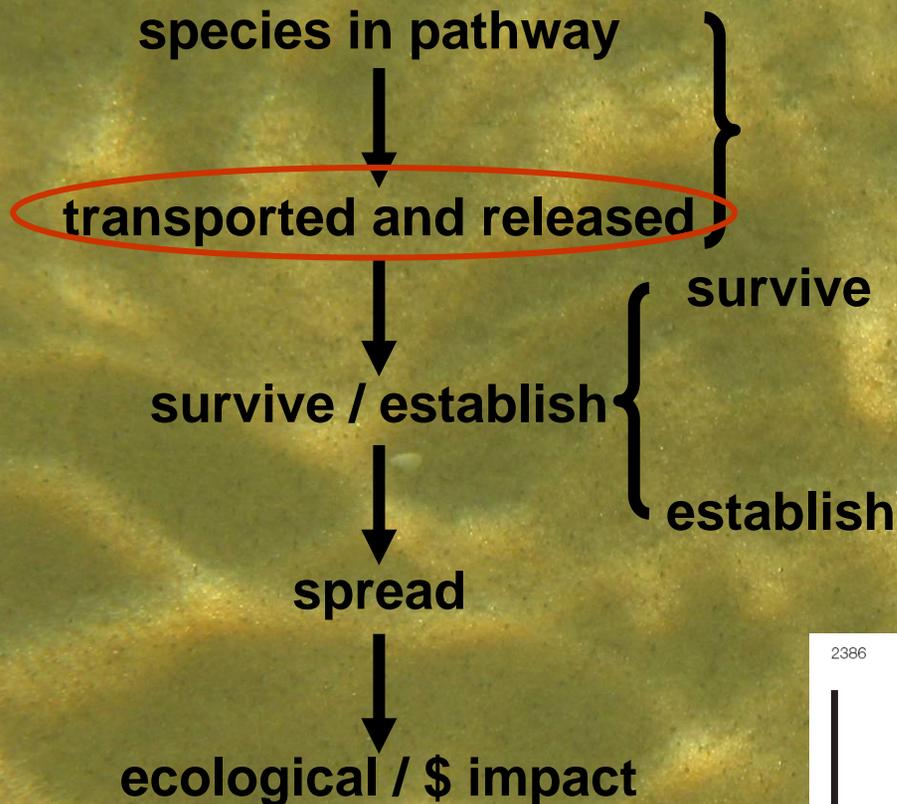
- species distributions



grey/personal information

# Tools to assess risk

## Invasion Process



## Transport / release

### - basic survey work

Journal of Plankton Research Vol.22 no.5 pp.923-937, 2000

#### Survival of tropical ballast water organisms during a cruise from the Indian Ocean to the North Sea

Stephan Gollasch, Jürgen Lenz<sup>2</sup>, Mark Dammer and Hans-Georg Andres<sup>1</sup>  
*Institut für Meereskunde, Düsterbrookweg 20, 24105 Kiel, Germany and*  
<sup>1</sup>*Taxonomische Arbeitsgruppe der Biologischen Anstalt Helgoland, Zoologisches Institut und Museum, Martin-Luther-King-Platz 3, 20146 Hamburg, Germany*

<sup>2</sup>To whom correspondence should be addressed

**Abstract.** In an assessment of non-indigenous species transported by international ship traffic to German waters, commissioned by the German Federal Environmental Agency, the survival of tropical plankton organisms in ballast water was studied by accompanying a container vessel on its 23-day voyage from Singapore to Bremerhaven in Germany. Two tanks, one filled off Singapore and

### - theoretical possibility

2386

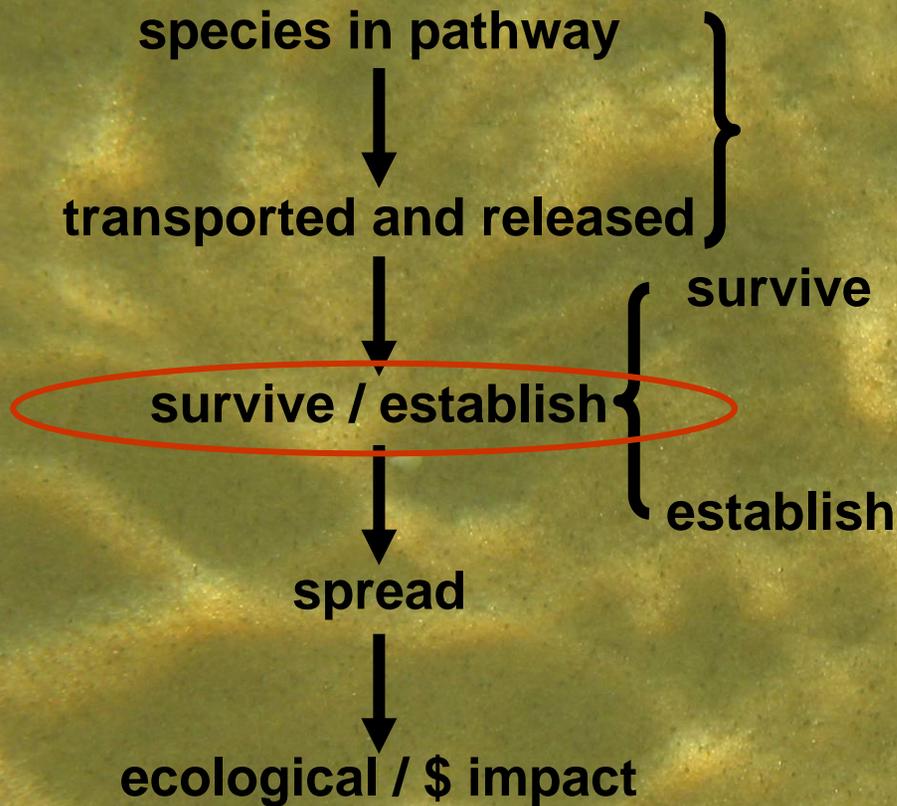
#### Modelling the invasion risk of diapausing organisms transported in ballast sediments

Marjorie J. Wonham, Sarah A. Bailey, Hugh J. MacIsaac, and Mark A. Lewis

**Abstract:** Biological invasions via ship ballast are a major driver of biodiversity change in aquatic systems. In the Laurentian Great Lakes basin, unique shipping operations pose a particular invasion risk. The majority (>90%) of in-

# Tools to assess risk

## Invasion Process



## Survive / establish

- biological attributes



- environmental niche modelling

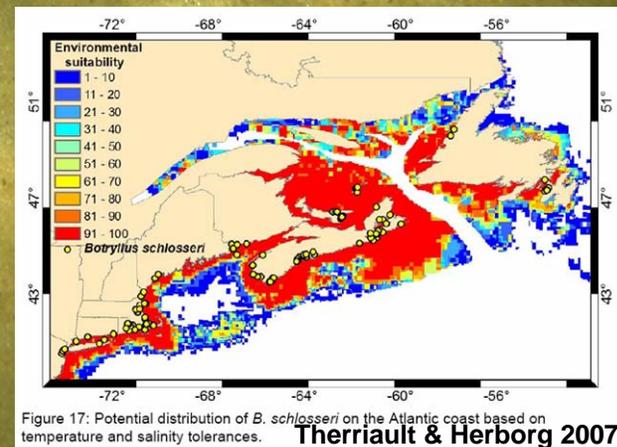
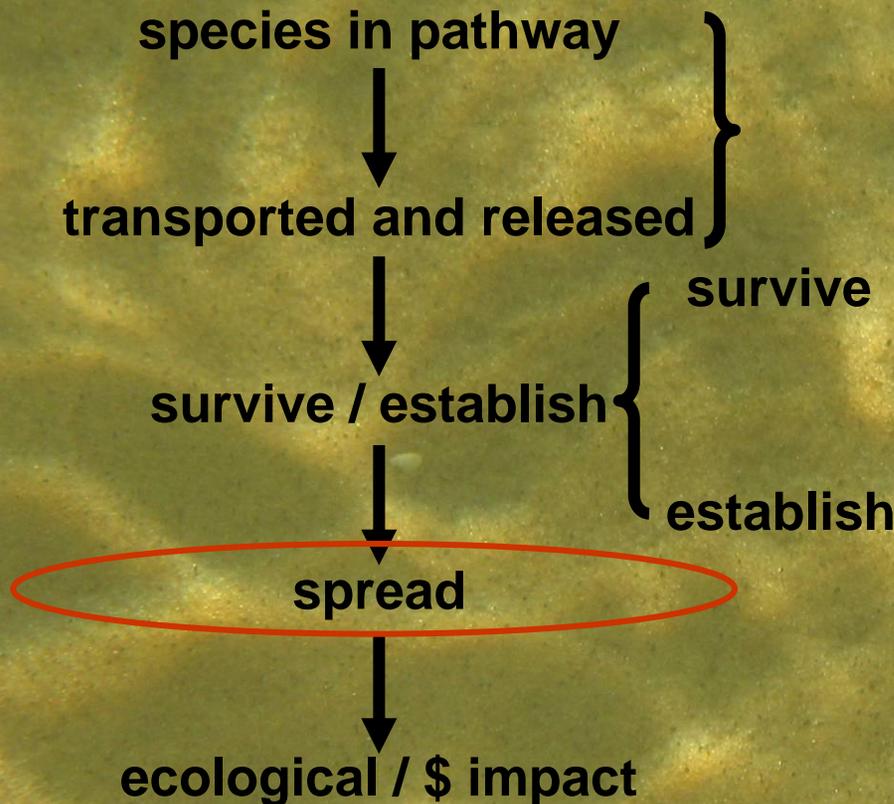


Figure 17: Potential distribution of *B. schlosseri* on the Atlantic coast based on temperature and salinity tolerances. Therriault & Herborg 2007

# Tools to assess risk

## Invasion Process



## Spread

### - spread modelling

*Ecological Applications*, 11(6), 2001, pp. 1789–1799  
© 2001 by the Ecological Society of America

#### OVERLAND DISPERSAL OF AQUATIC INVASIVE SPECIES: A RISK ASSESSMENT OF TRANSIENT RECREATIONAL BOATING

LADD E. JOHNSON,<sup>1,3</sup> ANTHONY RICCIARDI,<sup>2</sup> AND JAMES T. CARLTON<sup>1</sup>

<sup>1</sup>Maritime Studies Program, Williams College–Mystic Seaport, Mystic, Connecticut 06355 USA  
<sup>2</sup>Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1

*Abstract.* Predictions of the geographic spread of introduced species are often limited by a lack of data on their mechanisms of dispersal. We interviewed boaters and inspected boating equipment at public boat launches on Lake St. Clair (Michigan, USA) to assess the potential for the zebra mussel, an invasive bivalve, to be dispersed overland to inland waters by transient recreational boating activities. Several mechanisms associated with recreational boating were found to be capable of transporting either larval or adult life

*Ecology Letters*, (2005) 8: 91–101 doi: 10.1111/j.1461-0248.2004.00687.x

#### REVIEW

### The spatial spread of invasions: new developments in theory and evidence

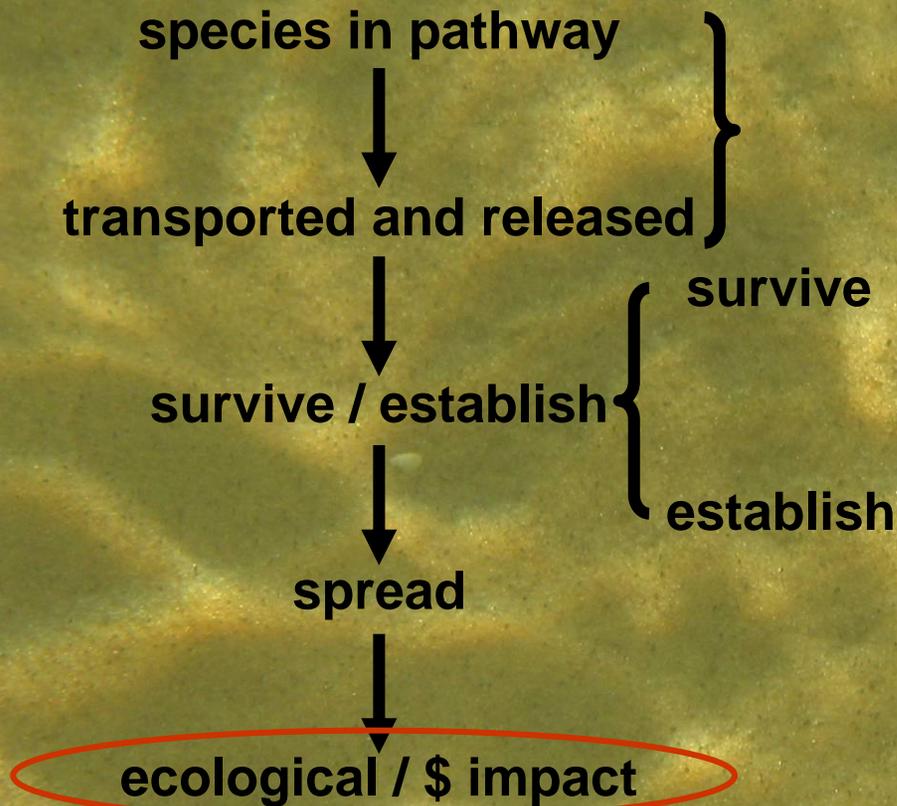
**Abstract**  
We review and synthesize recent developments in the study of the spread of invasive species, emphasizing both empirical and theoretical approaches. Recent theoretical work has shown that invasive species spread is a much more complex process than the classical models suggested, as long range dispersal events can have a large influence on the rate of range expansion through time. Empirical work goes even further, emphasizing the role of spatial heterogeneity, temporal variability, other species, and evolution. As in some of the classic work on spread, the study of range expansion of invasive species provides unique opportunities to use differences between theory and data to determine the important underlying processes that control spread rates.

**Keywords**  
Diffusion, dispersal, integro-difference equations, invasions, reaction-diffusion, spatial spread.

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Kara Moore,<sup>1</sup> Caz Taylor<sup>1</sup> and  
Diane Thomson<sup>1</sup>  
<sup>1</sup>Department of Environmental  
Science and Policy, University of

# Tools to assess risk

## Invasion Process



## Ecological impact

- observation/exp't studies
- trait-based impact modelling

Biological Invasions (2005) 7: 265-279

© Springer 2005

Can species traits be used to predict marine macroalgal introductions?

Cecilia D. Nyberg\* & Inger Wallentinus

Department of Marine Ecology, Marine Botany, Göteborg University, Box 461, SE 405 30 Göteborg, Sweden; \*Author for correspondence (e-mail: cecilia.nyberg@marbot.gu.se; fax: +46-31-7732727)

Received 17 July 2003; accepted in revised form 18 February 2004

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### PERSPECTIVES

**Predicting the identity and impact of future biological invaders: a priority for aquatic resource management**

Anthony Ricciardi and Joseph B. Rasmussen

# Problems: lack of data



## Solution: Use a Network of Experts

7. What is the importance (and associated uncertainty) of the following pathways for further spread of *Didemnum sp.*?

**vectors...**

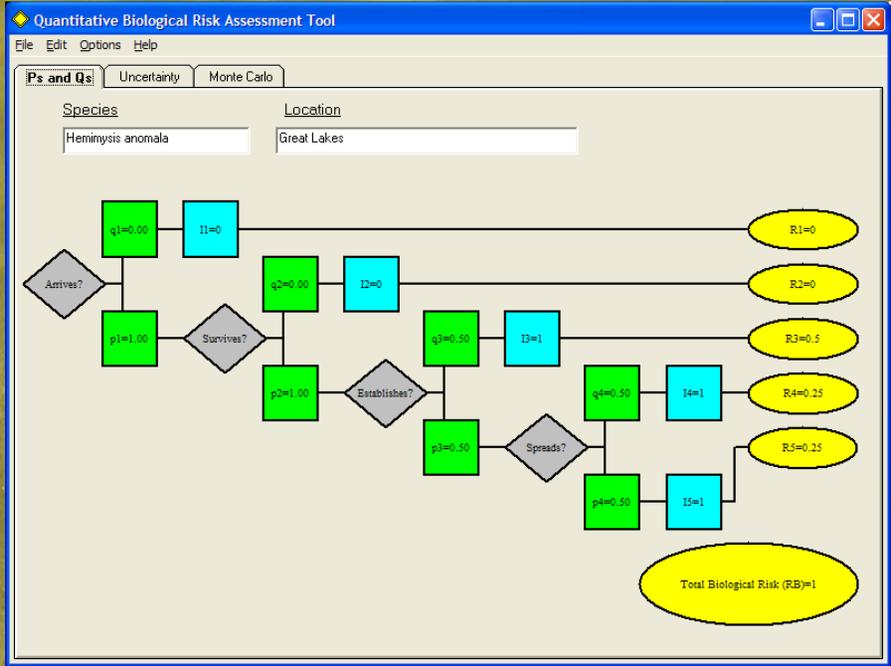
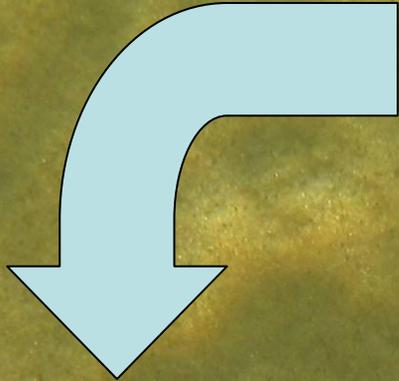
	vector importance	uncertainty
natural dispersal of larvae	<input type="text"/>	<input type="text"/>
natural dispersal when attached to floating materials	<input type="text"/>	<input type="text"/>
ballast water	<input type="text"/>	<input type="text"/>
hull fouling of large (>50m) commercial vessels	<input type="text"/>	<input type="text"/>
hull fouling of small (<50m) commercial/ recreational vessels	<input type="text"/>	<input type="text"/>
hull fouling on slow moving vessels (barges, drilling platforms, etc)	<input type="text"/>	<input type="text"/>

9. What is the level and probability of impact of further spread of *Didemnum sp.* on...

**impacts...**

	impact level	impact likelihood
Biodiversity	<input type="text"/>	<input type="text"/>
Marine protected areas	<input type="text"/>	<input type="text"/>
Shellfish aquaculture	<input type="text"/>	<input type="text"/>
Finfish aquaculture	<input type="text"/>	<input type="text"/>
Commercial fisheries	<input type="text"/>	<input type="text"/>
Vessels/ Moorings	<input type="text"/>	<input type="text"/>
Recreational activities: boating, fishing, diving, etc	<input type="text"/>	<input type="text"/>

# Wrap-up



### Step 3: Estimating Aquatic Organism Risk Potential

The following summary table was used to determine the overall risk potential by combining the probability of establishment estimate determined in Step 1 with the three consequences of establishment determined in Step 2. In the table Green = Low Risk, Yellow = Moderate Risk and Red = High Risk.

Ecological or Genetic Consequence	Very High					
	High					
	Moderate					
	Low					
	Very Low					
		Rare	Low	Moderate	High	Very High
Probability of Introduction						

## **Steps in a "typical" CEARA RA**

- 1. Meet to select most pressing candidates**
- 2. Form team**
- 3. Do/commission biological synopsis**
- 4. Create and post survey**
- 5. Meet to write RA**
- 6. Send to int'l experts and others**
- 7. Host peer review**
- 8. Rework manuscript**
- 9. Publish as CSAS paper**

# Components in a "typical" CEARA (sp) RA

## 1. Vectors (magnitude + uncertainty)

Natural (drift, movement, hitchhiking)

Ballast / hull fouling

Aquaculture / fishing

Etc...

- Expert surveys

## 2. Impacts

Ecological

Genetic

Pathogens and fellow travelers

- Biological synopses

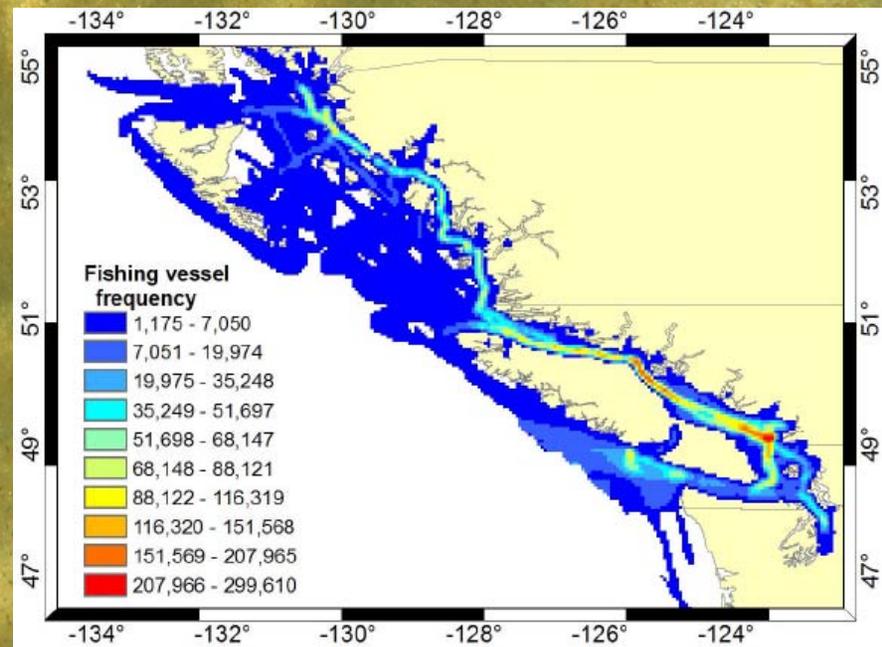
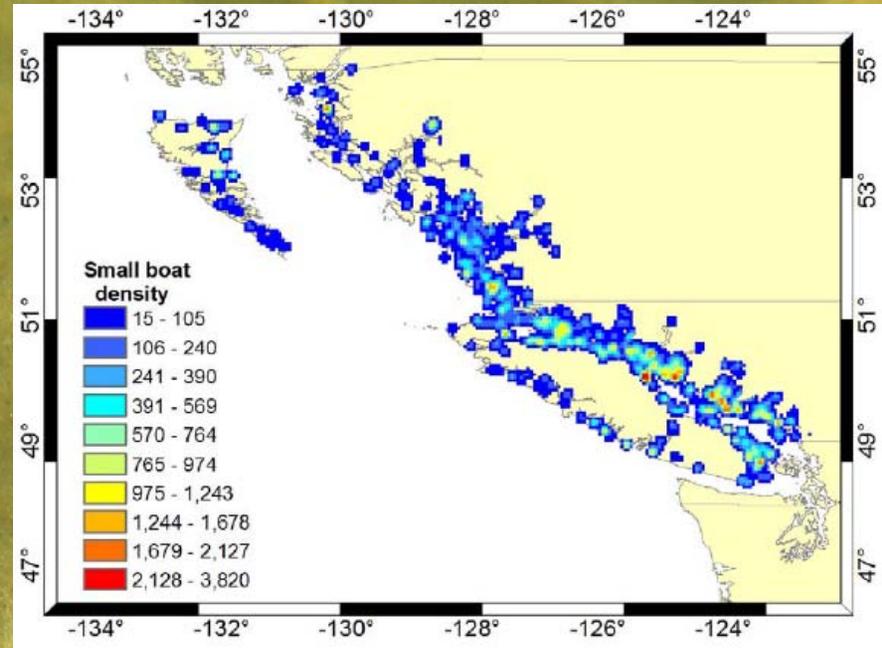
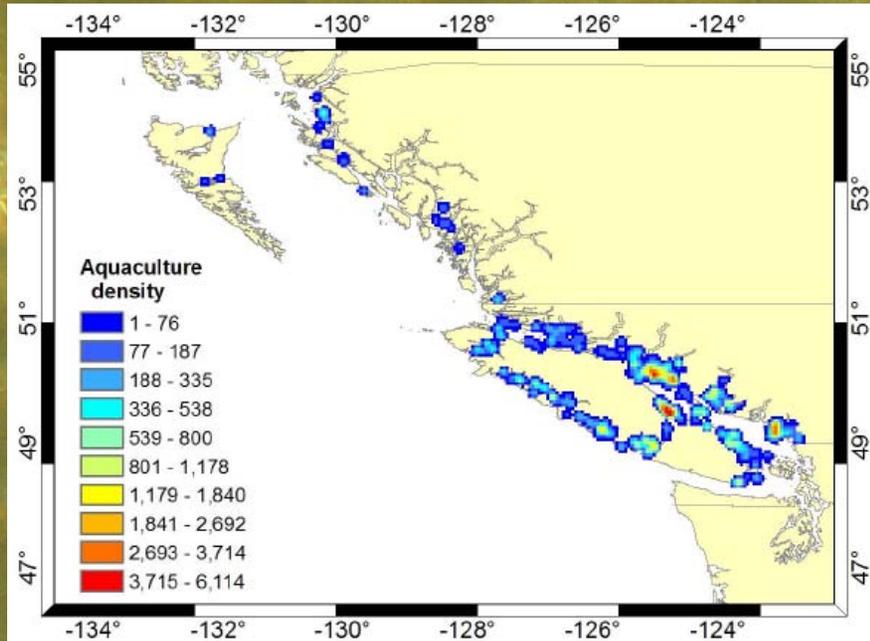
## 3. Potential distribution

Physiological tolerances

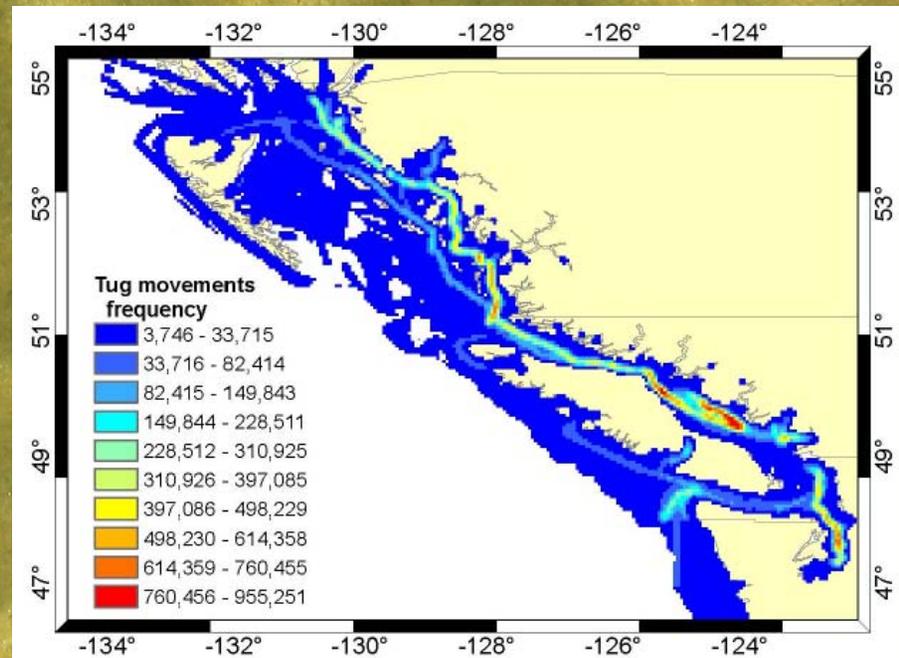
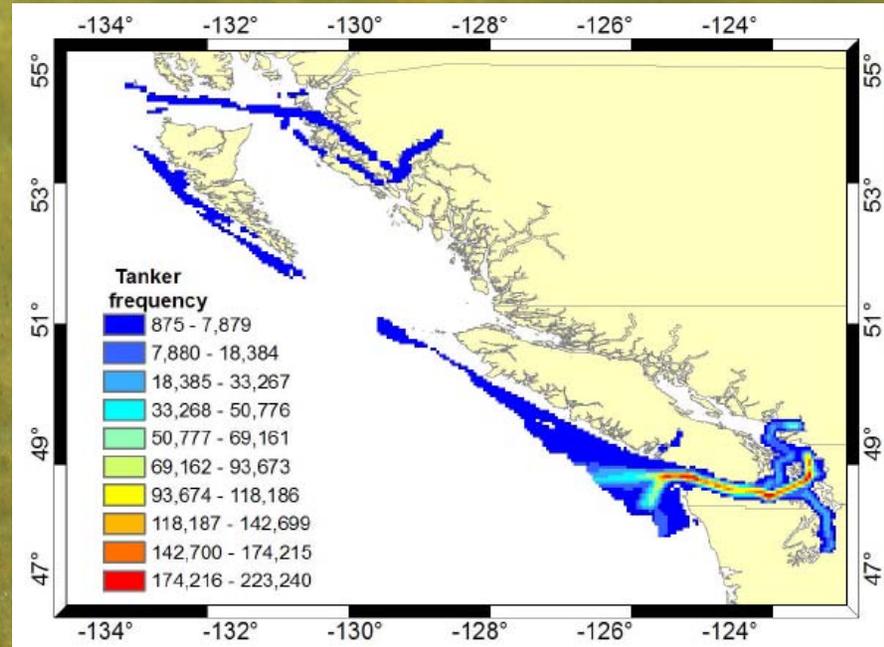
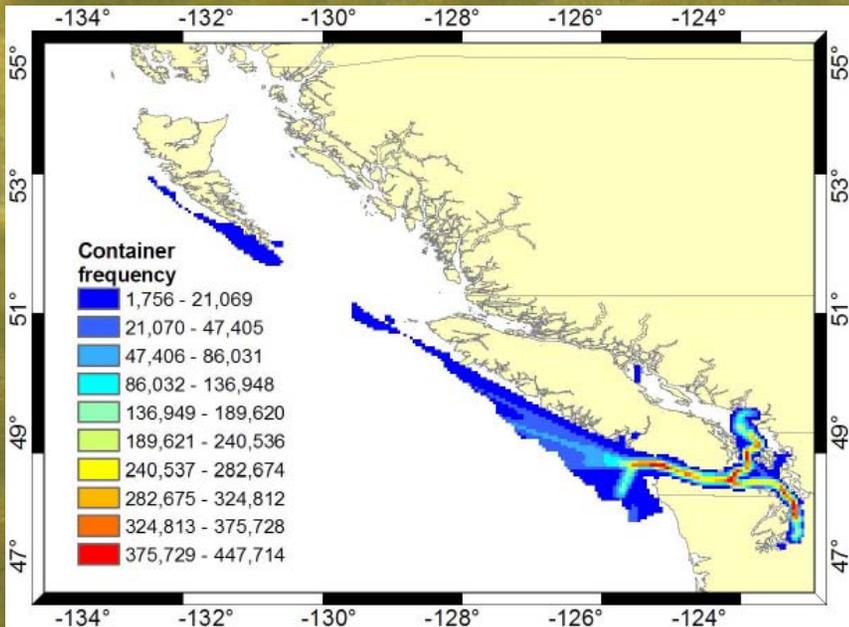
Ecological niche modeling

Ecological or Genetic Consequence	Very High					
	High					
	Moderate					
	Low					
	Very Low					
		Rare	Low	Moderate	High	Very High
Probability of Introduction						

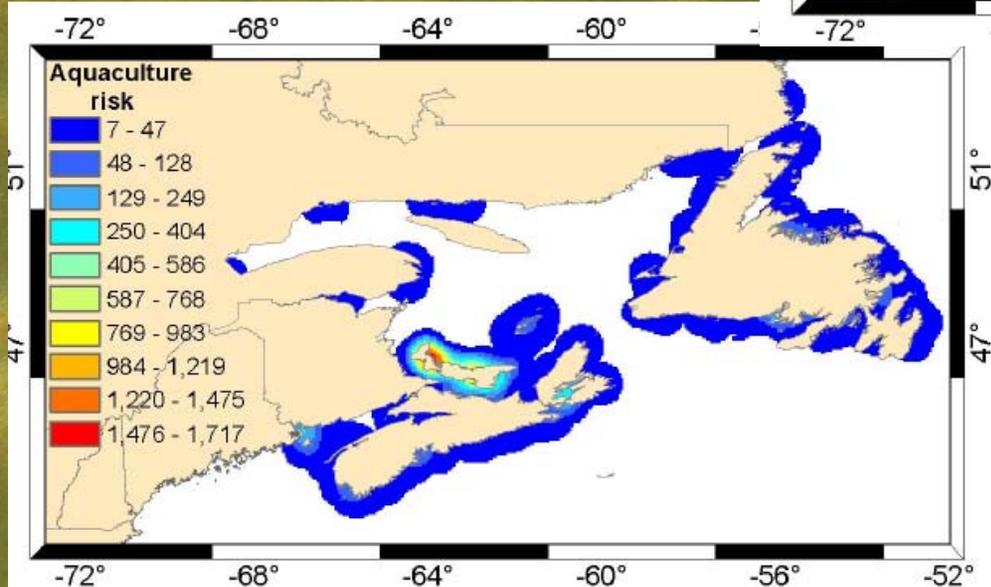
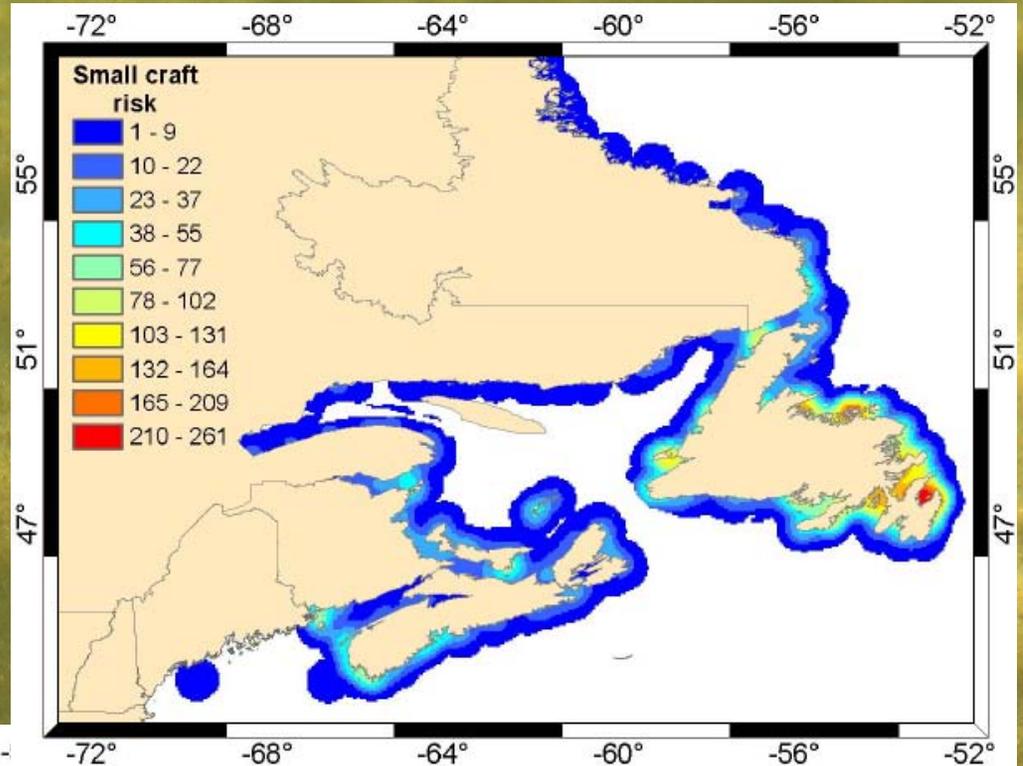
# Vectors



# Vectors



# Vectors



# Impacts (original format)

1. Ecological

2. Genetic

3. Pathogens and fellow travelers



# Potential distribution

1. Physiological tolerances

2. Ecological niche modelling



# Tunicates

*Styela clava*

*Ciona intestinalis*

*Botryllus schlosseri*

*Botrylloides violaceus*

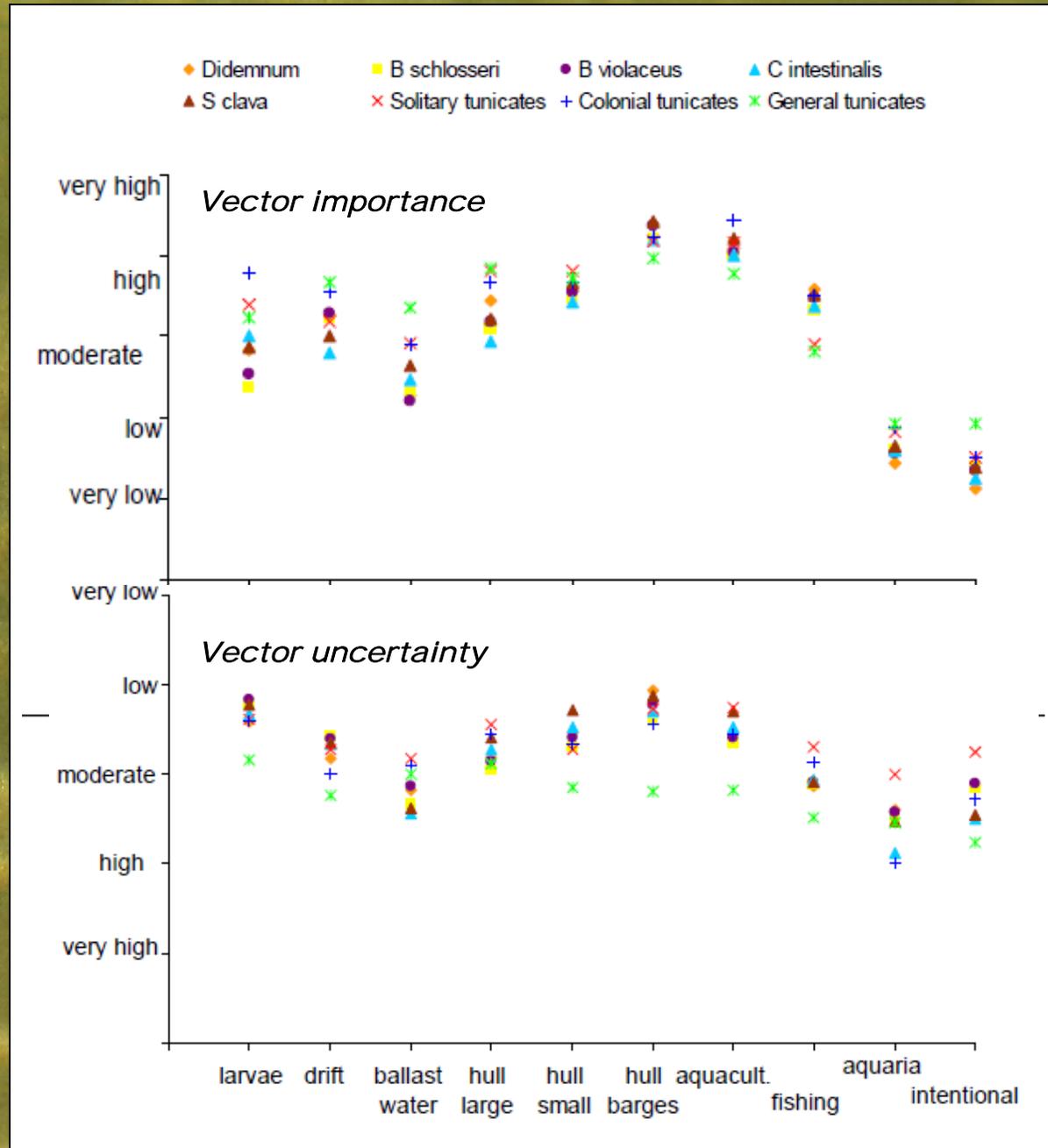
*Didemnum* sp. (*vexillum*)



Therriault, T.W., Herborg, L.-M., 2007. Risk assessment for two solitary and three colonial tunicates in both Atlantic and Pacific Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/063: pp. iv + 64.

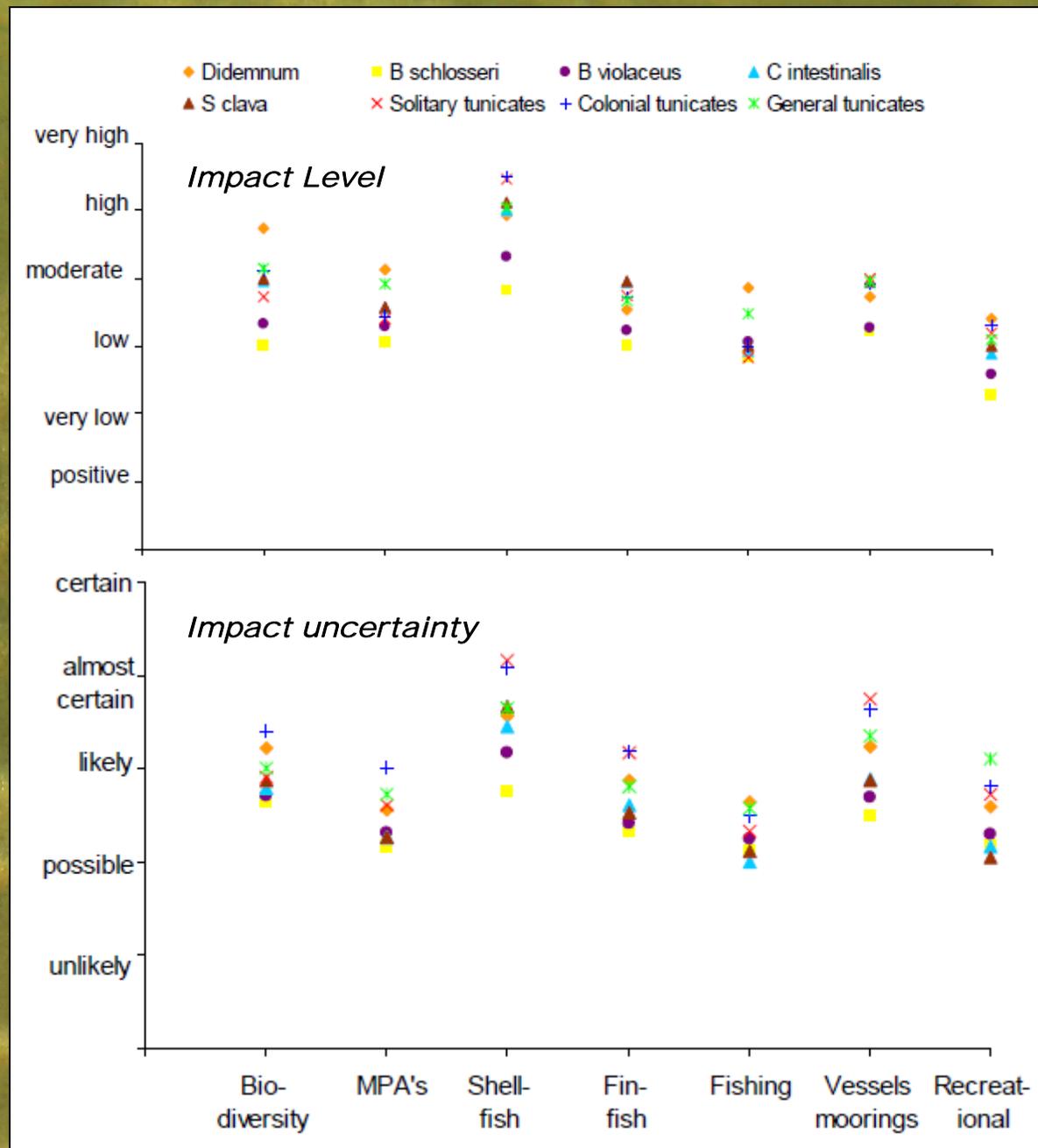
# Vectors

Expert survey results  
(Corroborated by BS)

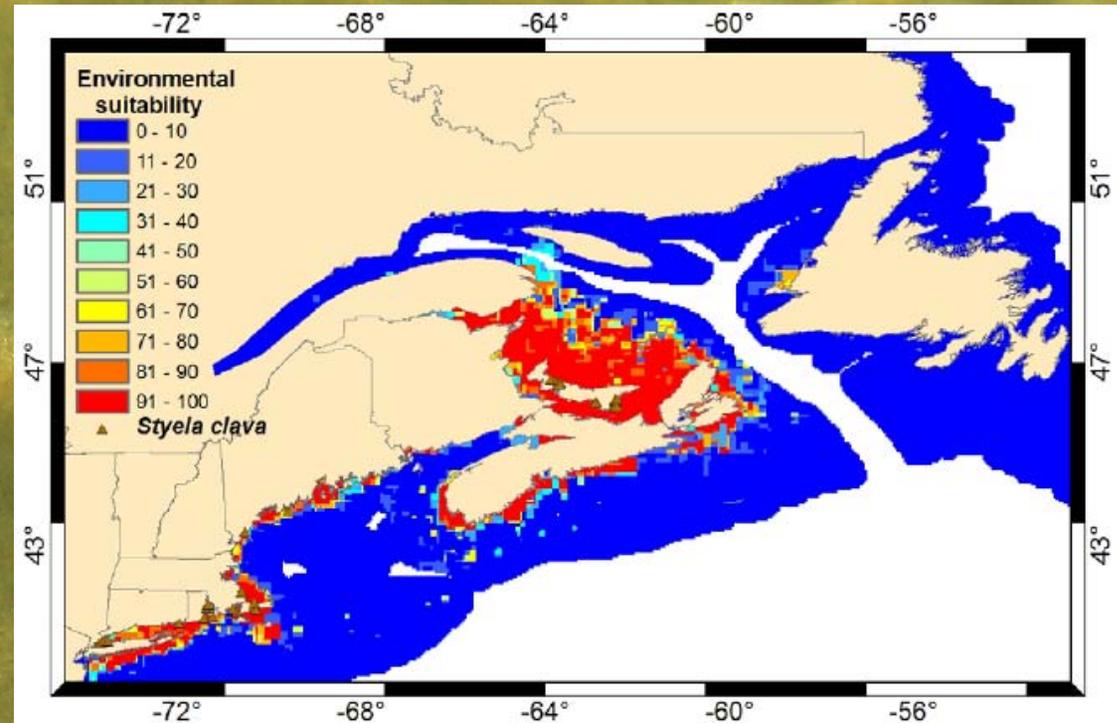
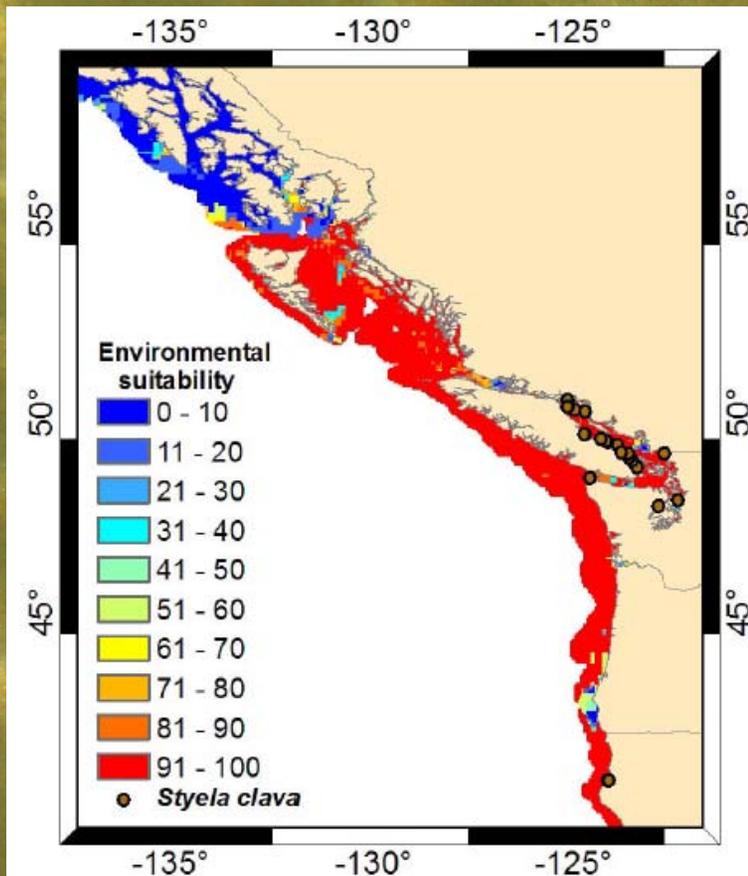


# Impacts

Expert survey results  
(Corroborated by BS)



# *Styela clava*



**Genetic Algorithm for Rule-set Prediction (GARP) to predict suitable environments based on current known distributions on coasts**

# Styela clava

## Tunicate

### Establishment

Element	Atlantic Coast		Pacific Coast	
	Rank	Uncertainty	Rank	Uncertainty
Arrival	Very High	Very Low	Very High	Very Low
Survival	Very High	Very Low	Very High	Very Low
Reproduction	Very High	Very Low	Very High	Very Low
Spread	Very High	Very Low	Very High	Very Low
Overall	<b>Very High</b>	Very Low	Very High	Very Low

## Pathogen or fellow traveler

Element	Atlantic Coast		Pacific Coast	
	Rank	Uncertainty	Rank	Uncertainty
Arrival	High	Very High	High	Very High
Survival	High	Very High	High	Very High
Reproduction	High	Very High	High	Very High
Spread	High	Very High	High	Very High
Overall	High	Very High	High	Very High

### Impact

Element	Atlantic Coast		Pacific Coast	
	Magnitude	Uncertainty	Magnitude	Uncertainty
Ecological Consequence	<b>Moderate</b>	Moderate	Moderate	Moderate
Genetic Consequence	Very Low	Low	Low	Low

Element	Atlantic Coast		Pacific Coast	
	Magnitude	Uncertainty	Magnitude	Uncertainty
Ecological Consequence	High	Low	High	Low
Genetic Consequence	Low	Low	Low	Low

### Final risk rating for tunicate

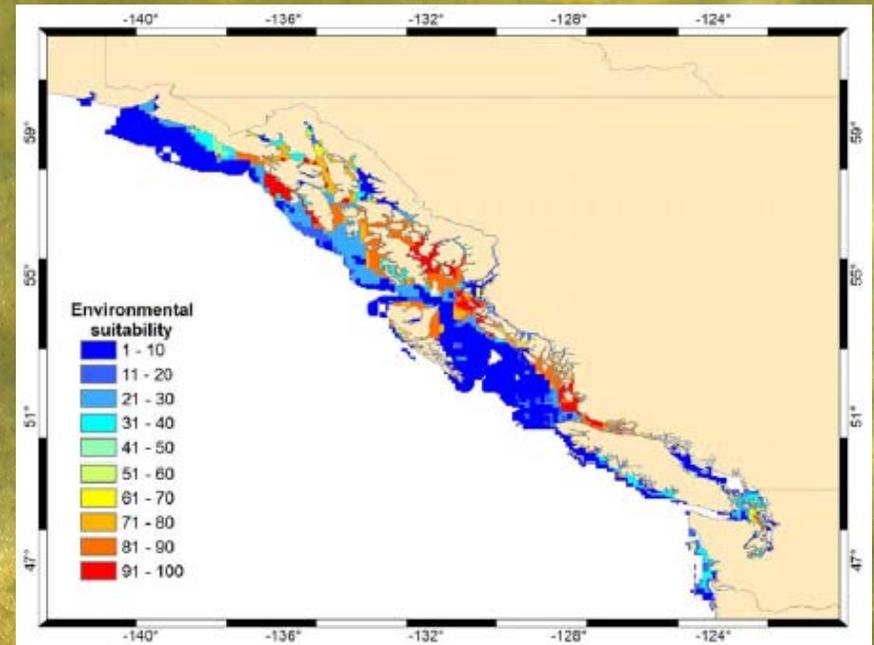
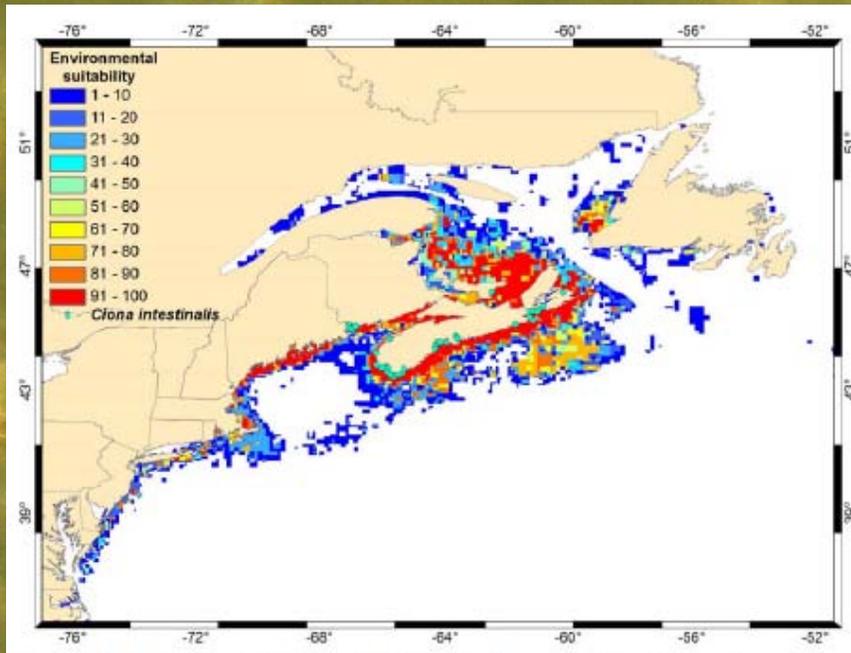
Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	<b>High</b>	Moderate	High	Moderate
Genetic	Moderate	Low	Moderate	Low

### Final risk rating for pathogen or fellow traveler

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	High	Very High	High	Very High
Genetic	Moderate	Very High	Moderate	Very High

Ecological or Genetic Consequence	Very High						
	High						
	Moderate						
	Low						
	Very Low						
	Rare	Low	Moderate	High	Very High		
Probability of Introduction							

# *Ciona intestinalis*



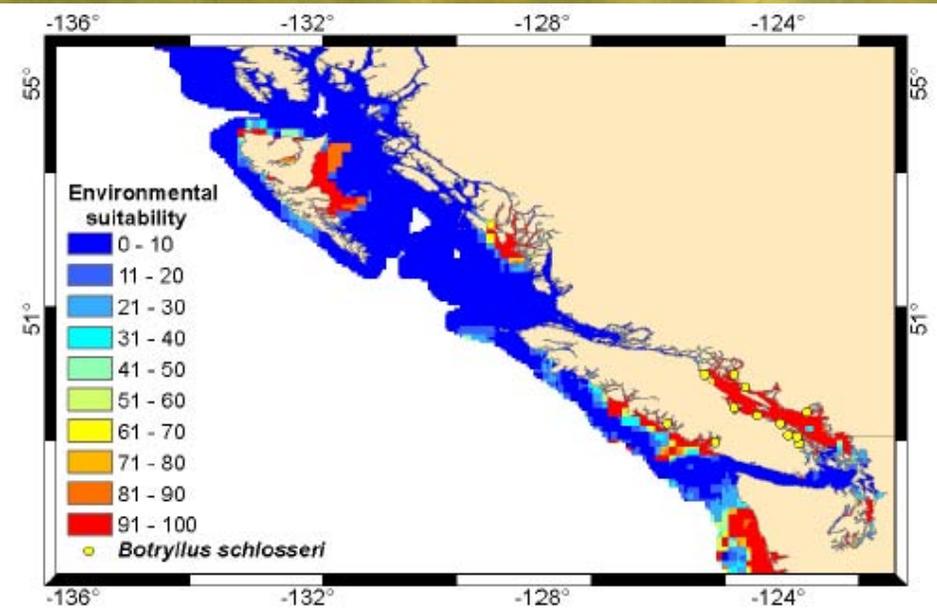
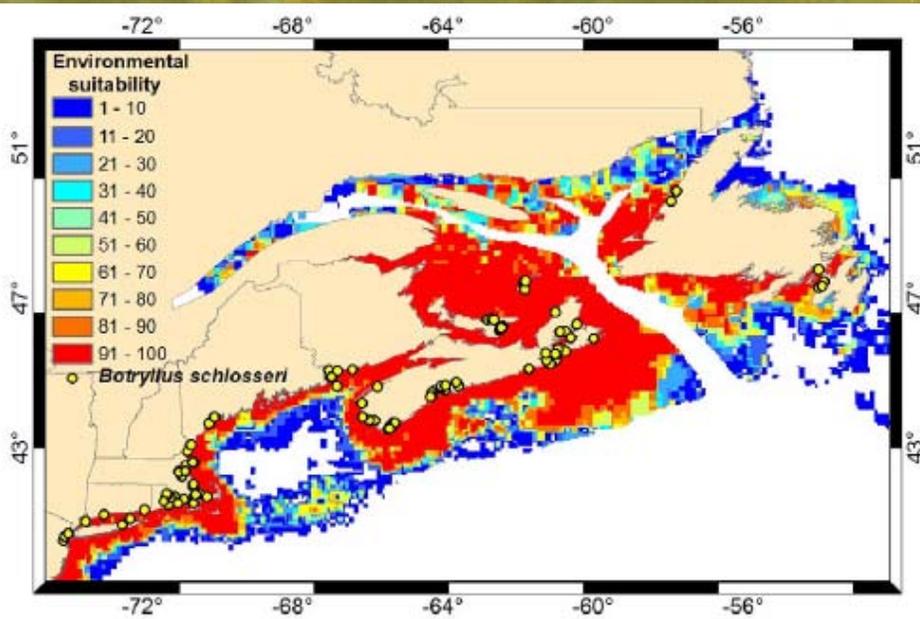
## Final risk rating for tunicate

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	High	Moderate	Moderate	High
Genetic	Moderate	Low	Moderate	High

## Final risk rating for pathogen or fellow traveler

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	Moderate	High	Moderate	High
Genetic	Low	High	Low	High

# Botryllus schlosseri



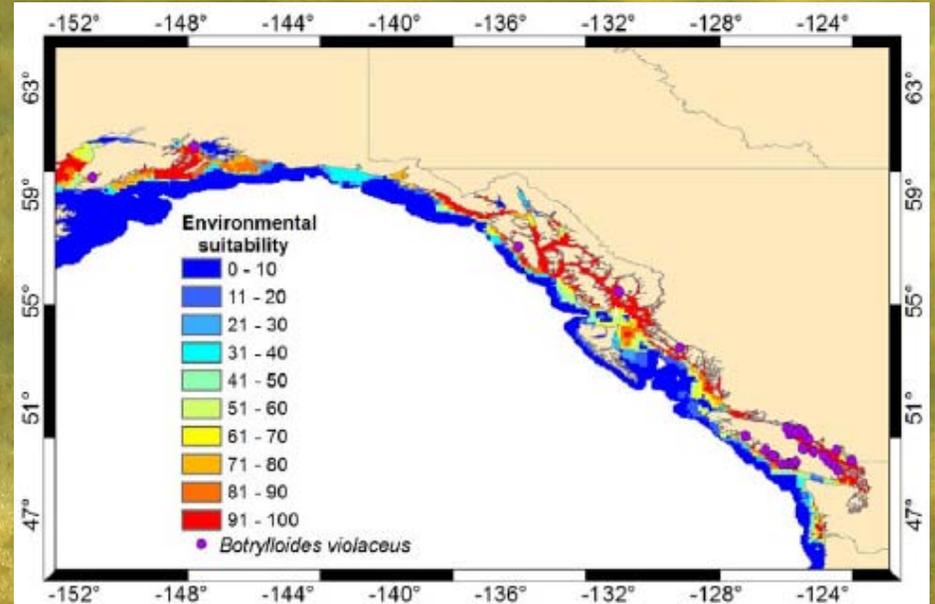
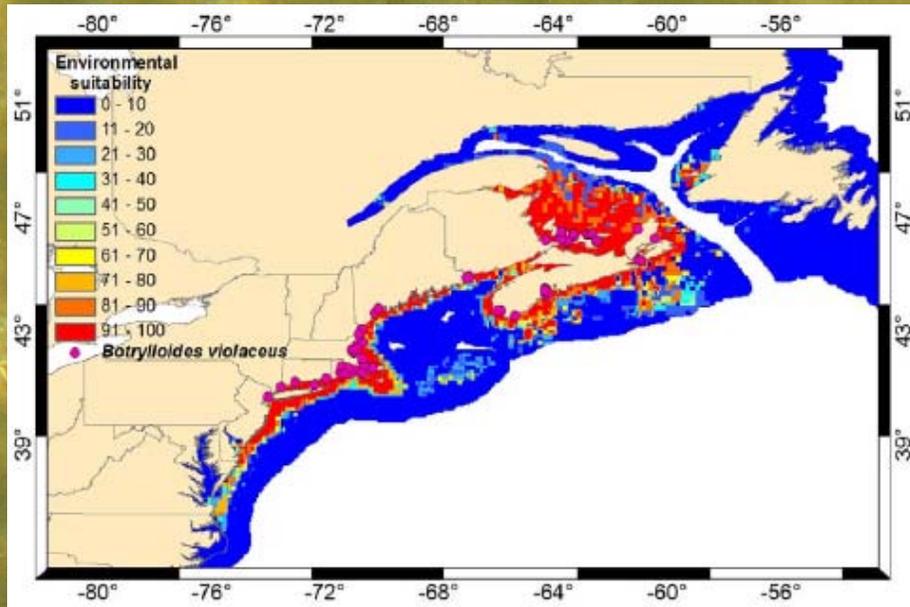
## Final risk rating for tunicate

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	High	Moderate	High	Moderate
Genetic	Moderate	Low	Moderate	Low

## Final risk rating for pathogen or fellow traveler

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	Low	High	Low	High
Genetic	Low	High	Low	High

# *Botrylloides violaceus*



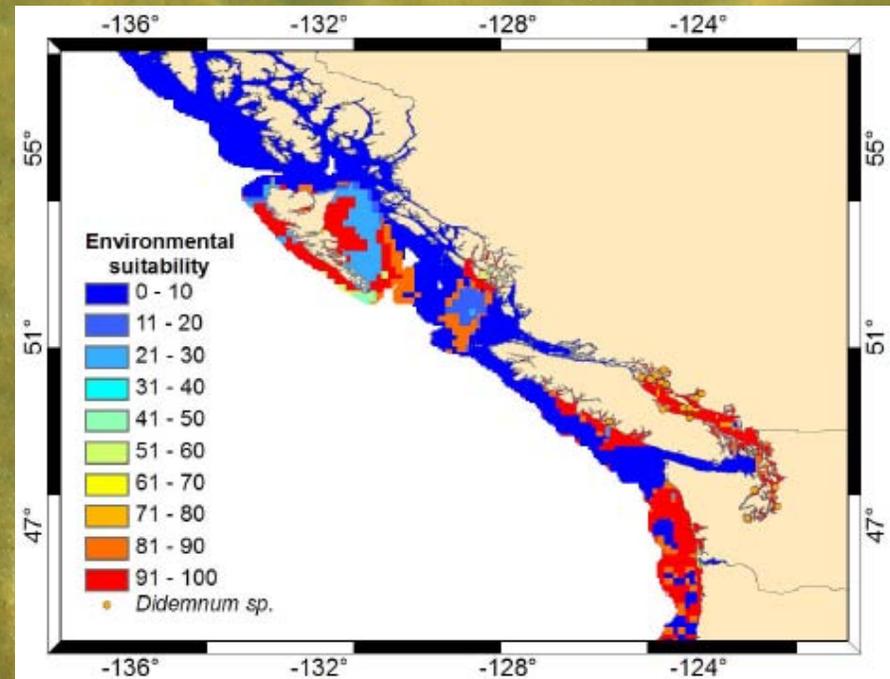
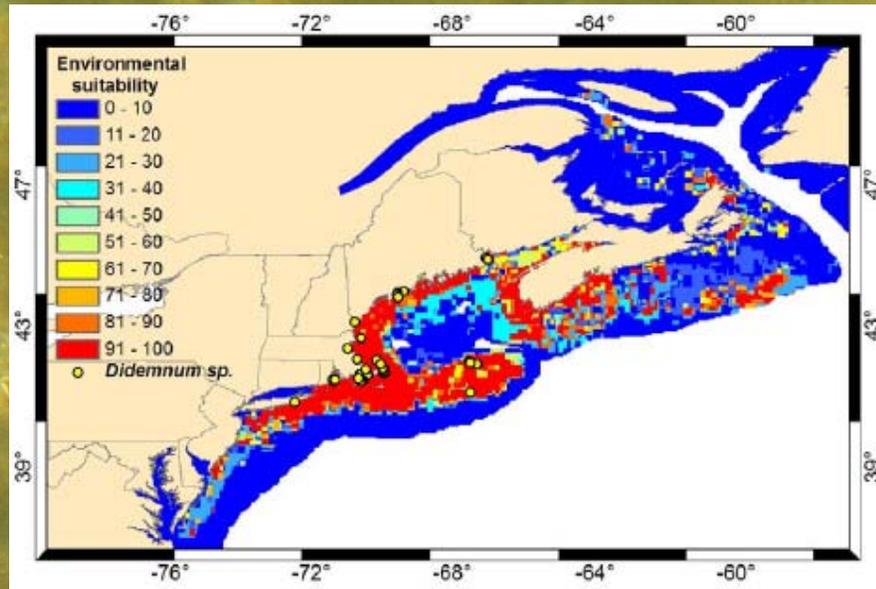
## Final risk rating for tunicate

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	High	Moderate	High	Moderate
Genetic	Moderate	Low	Moderate	Low

## Final risk rating for pathogen or fellow traveler

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	Low	Very High	Low	Very High
Genetic	Low	Very High	Low	Very High

# *Didemnum vexillum*



## Final risk rating for tunicate

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	High	Low	High	Low
Genetic	Moderate	Low	Moderate	Low

## Final risk rating for pathogen or fellow traveler

Risk Component	Atlantic Coast		Pacific Coast	
	Rating	Uncertainty	Rating	Uncertainty
Ecological	Low	Very High	Low	Very High
Genetic	Low	Very High	Low	Very High

# Crabs

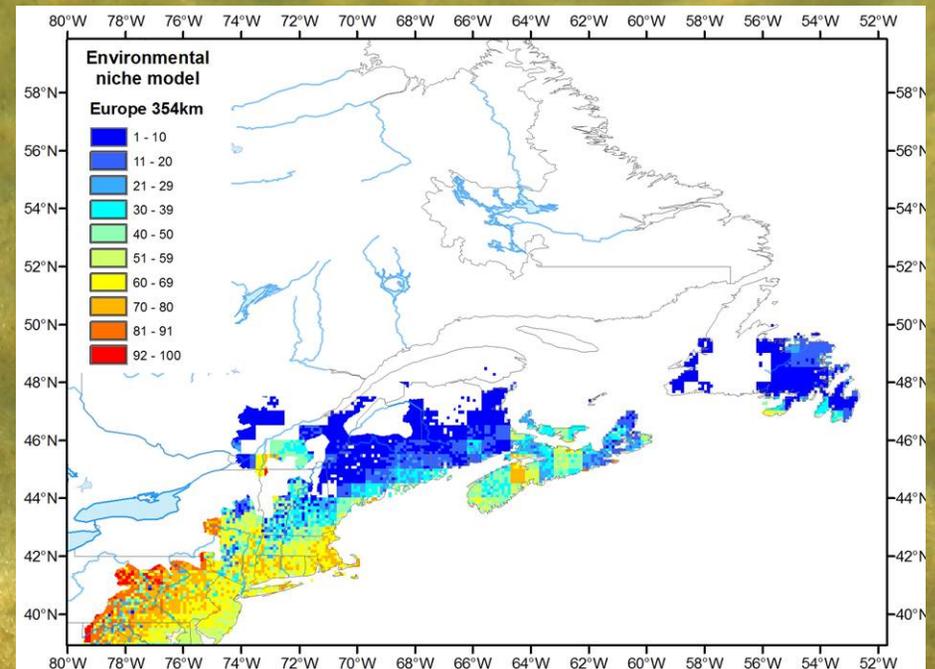
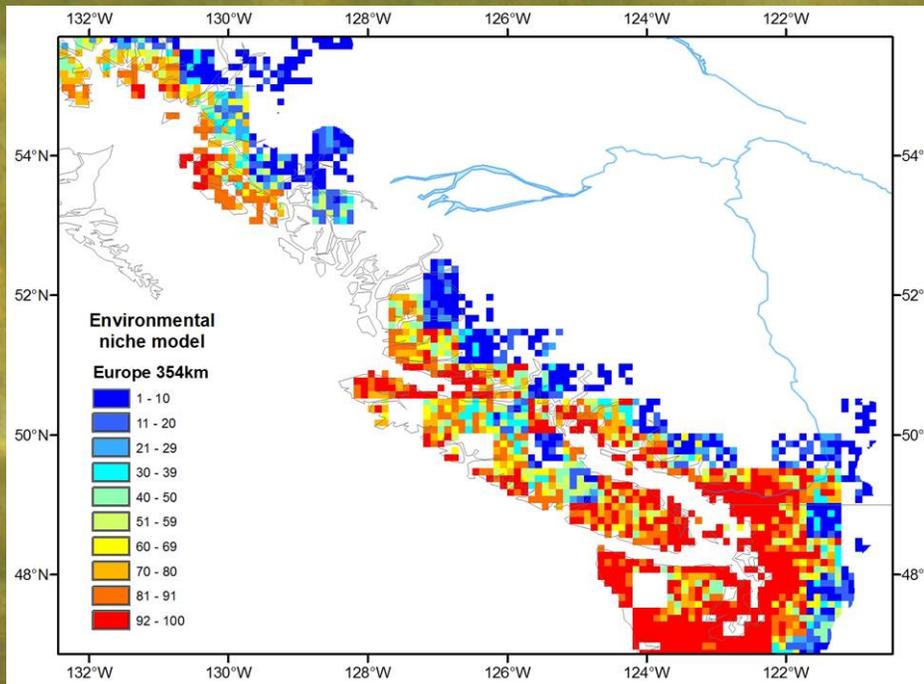
*Carcinus maenas*  
*Eriocheir sinensis*



Therriault, T.W., Herborg, L.-M., Locke, A., McKindsey, C.W., 2008. Risk assessment for Chinese mitten crab (*Eriocheir sinensis*) in Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/041: pp. iv + 33.

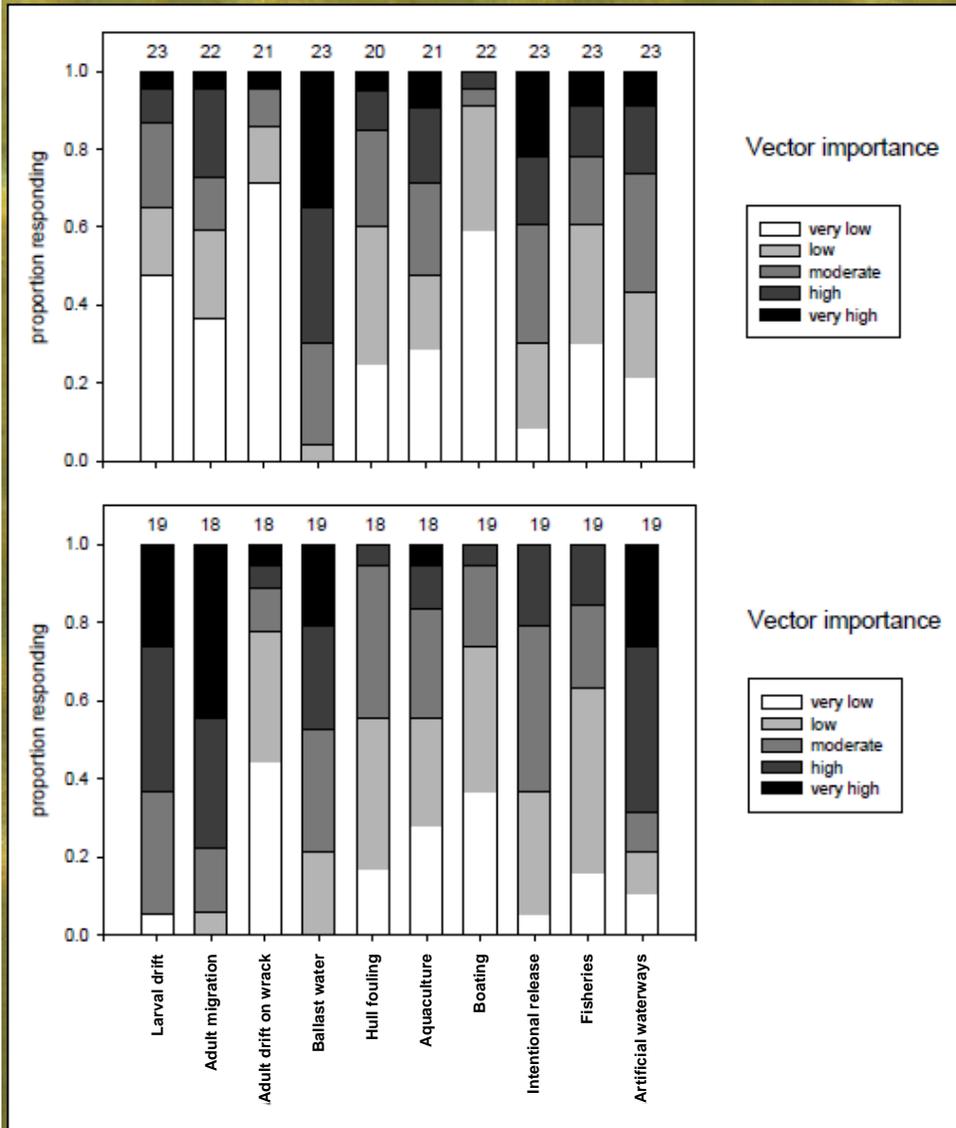
Therriault, T.W., Herborg, L.-M., Locke, A., McKindsey, C.W., 2008. Risk assessment for European green crab (*Carcinus maenas*) in Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/042: pp. iv + 40.

# ***Eriocheir sinensis* (ecological niche modelling)**



+ based on Asian distb'n  
+ ballast water discharge

# *Eriocheir sinensis* (survey results)

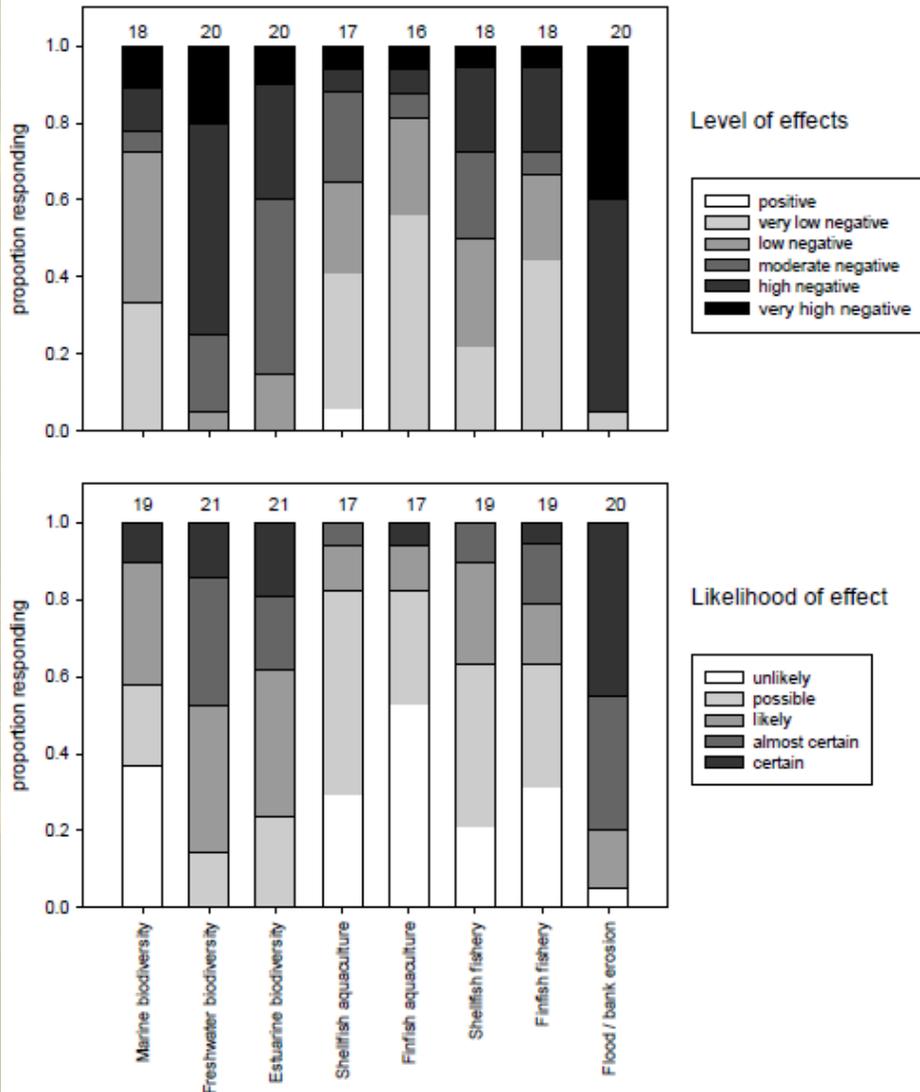


Primary introduction

Secondary spread

# Eriocheir sinensis

## Impacts (survey results)



Element	Atlantic Coast		Pacific Coast	
	Rank	Uncertainty	Rank	Uncertainty
Arrival	Very High	Very Low	High	Low
Survival	Very High	Very Low	High	Low
Reproduction	Moderate	High	Moderate	High
Overall Establishment	Moderate	High	Moderate	High
Spread	Very High	High	High	High

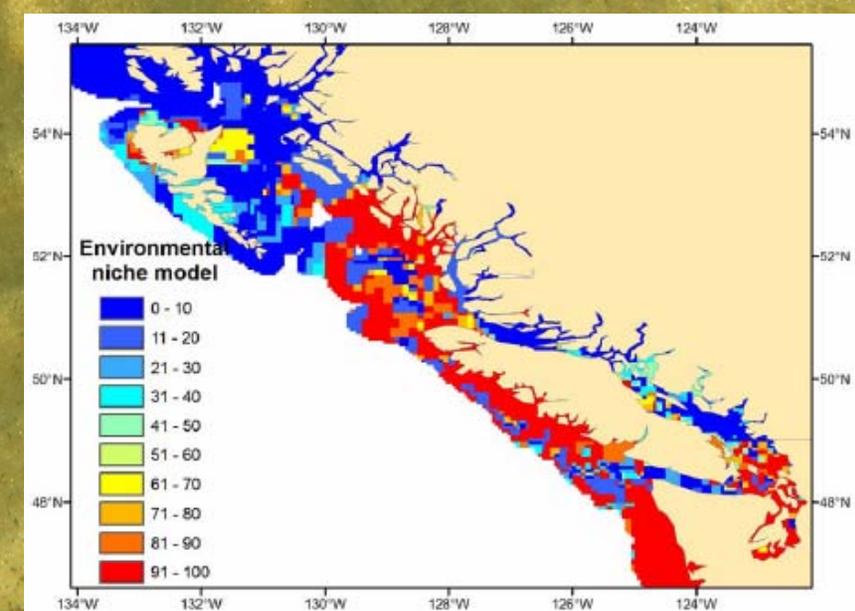
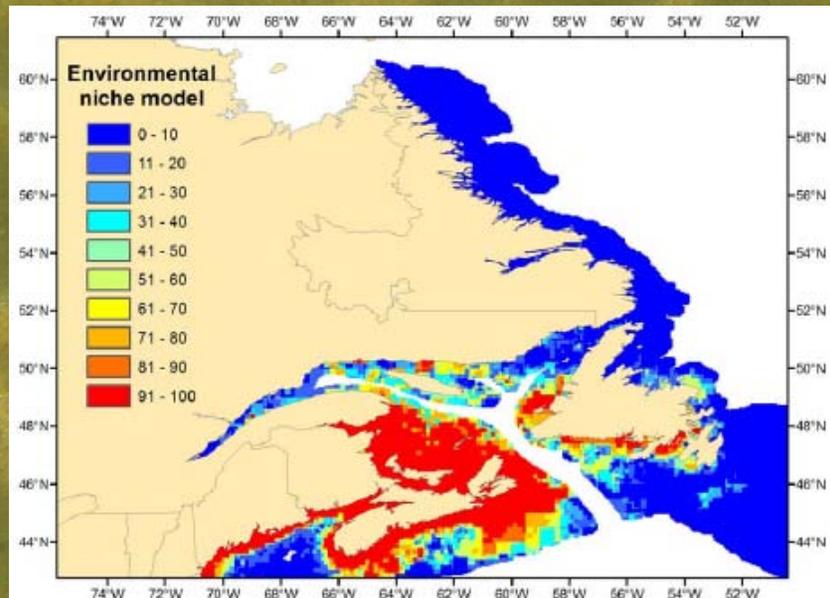
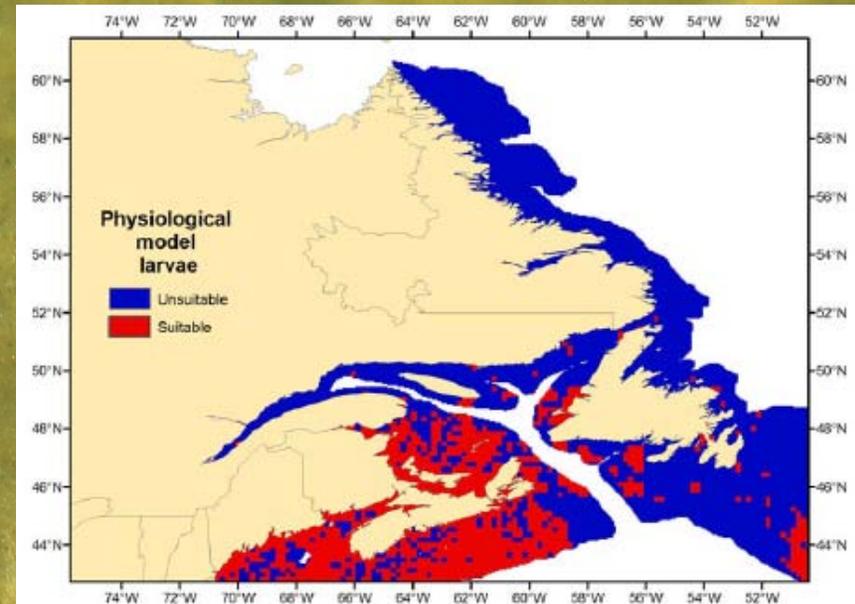
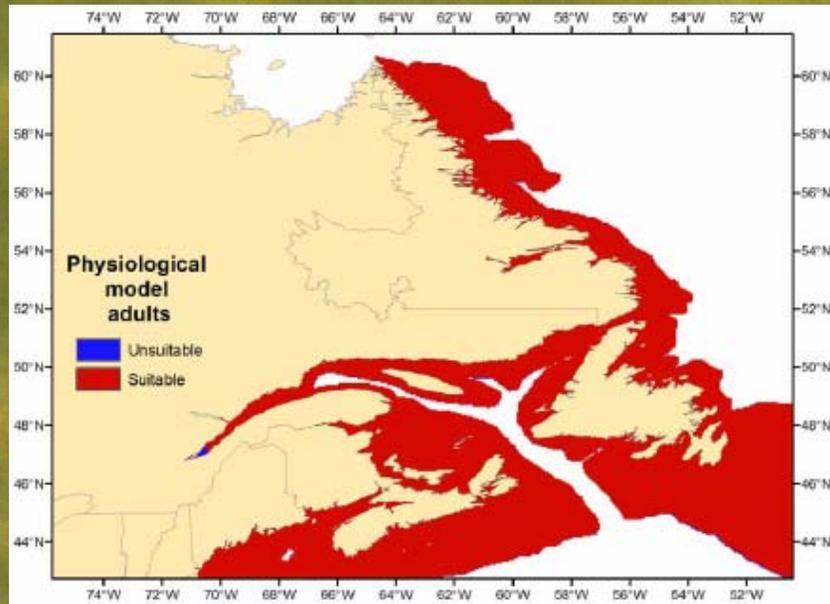
Element	Survey/Literature Results		Peer-review Results	
	Magnitude	Likelihood	Magnitude	Uncertainty
Biodiversity Consequences	<b>Impacts</b>			
Marine	Low	Possible	Very Low	Very High
Freshwater	High	Not Certain	High	Low
Estuarine	High	Likely	High	High
Shellfish Aquaculture	Low	Possible	Low	High
Finfish Aquaculture	Low	Unlikely	N/A	
Shellfish Fishery	Low (Moderate)	Possible	Low	High
Finfish Fishery	Low	Possible	Moderate	High
Wildlife/Human Health Consequences	Low	Likely	Moderate	High
Habitat Consequences	Moderate	Likely	Moderate	High
Flood Protection /River Bank	Very High	Likely	Very High	High
Genetic Consequences	Very Low	Unlikely	Very Low	Very Low

**subdivided impacts**

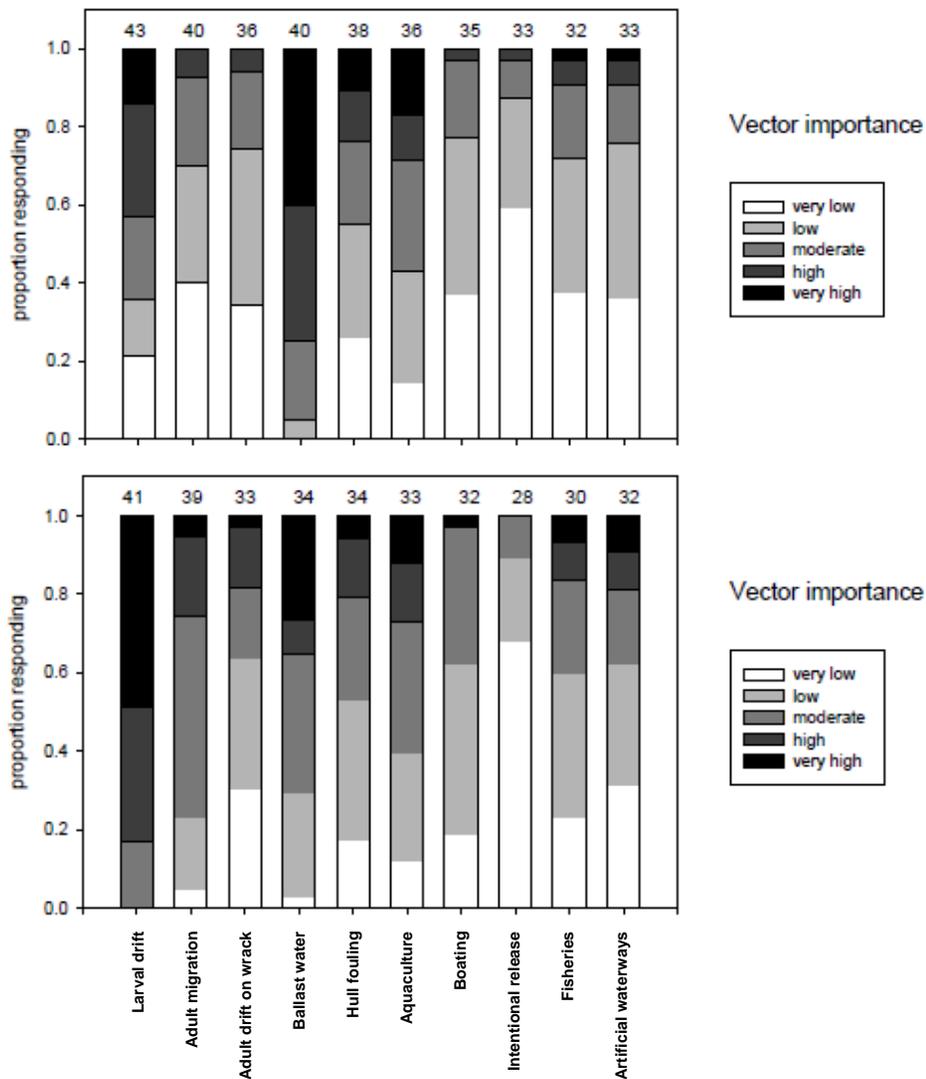
**Modified ratings**

Element	Atlantic Canada		Pacific Canada	
	Rating	Uncertainty	Rating	Uncertainty
Biodiversity Consequences	<b>Risk</b>			
Marine	Low	Very High	Low	Very High
Freshwater	Moderate	High	Moderate	High
Estuarine	Moderate	High	Moderate	High
Shellfish Aquaculture	Moderate	Very High	Moderate	Very High
Finfish Aquaculture	N/A	N/A	N/A	N/A
Shellfish	Moderate	High	Moderate	High

# *Carcinus maenas*



# *Carcinus maenas*

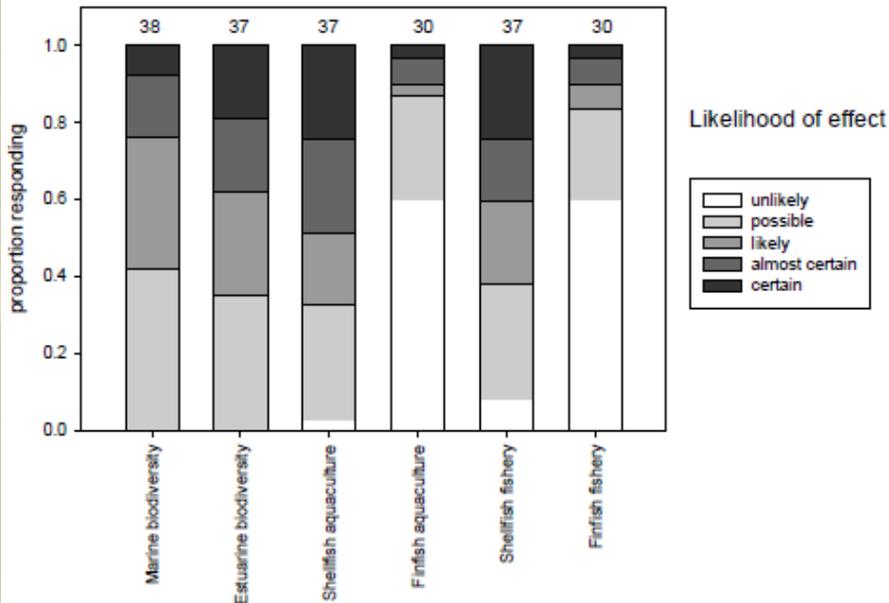
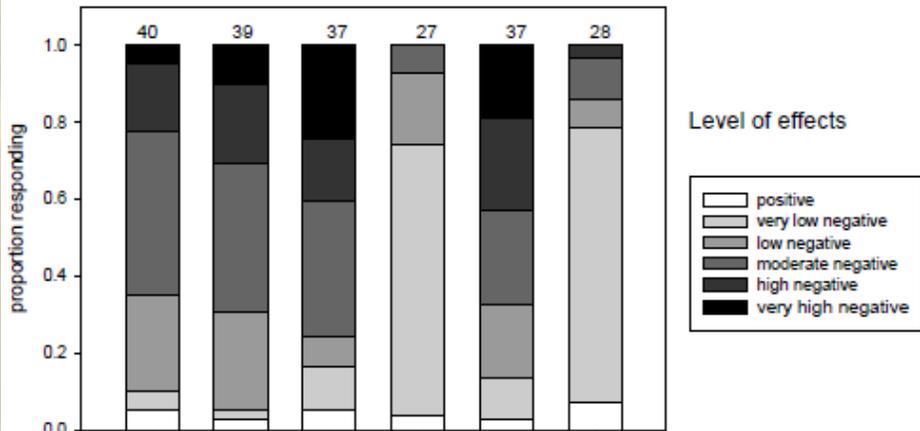


Primary introduction

Secondary spread

# Carcinus maenas

## Impacts (survey results)



Element	Atlantic Coast		Pacific Coast	
	Rank	Uncertainty	Rank	Uncertainty
Arrival	Very High	Very Low	Very High	Very Low
Survival	Very High	Very Low	Very High	Very Low
Reproduction	Very High	Very Low	Very High	Very Low
Overall Establishment	Very High	Very Low	Very High	Very Low
Spread	Very High	Low	Very High	Low

Element	Survey/Literature Results		Peer-review Results					
	Magnitude	Likelihood	Magnitude	Uncertainty				
Biodiversity Consequences	<b>Impacts</b>							
Marine					Moderate	Likely	High	Low
Estuarine					Moderate	Likely	High	Low
Shellfish Aquaculture					Moderate	Likely	Very High	Moderate
Finfish Aquaculture					Very Low	Unlikely	Very Low	Very Low
Shellfish Fishery					Moderate	Likely	Very High	Moderate
Finfish Fishery	Very Low	Unlikely	Low	Moderate				
Wildlife Health Consequences	Low	Possible	Low	Moderate				
Habitat Consequences	High	Likely	High	Low				
Genetic Consequences	Very Low	Unlikely	Very Low	Low				

Element	Atlantic Coast		Pacific Coast					
	Rating	Uncertainty	Rating	Uncertainty				
Biodiversity Consequences	<b>Risk</b>							
Marine					High	Low	High	Low
Estuarine					High	Low	High	Low
Shellfish Aquaculture					High	Moderate	High	Moderate
Finfish Aquaculture					Moderate	Very Low	Moderate	Very Low
Shellfish Fishery					High	Moderate	High	Moderate
Finfish Fishery	Moderate	Moderate	Moderate	Moderate				
Wildlife Health Consequences	Moderate	Moderate	Moderate	Moderate				
Habitat Consequences	High	Low	High	Low				
Genetic Consequences	Moderate	Low	Moderate	Low				

# Summary of RA for tunicates and crabs

Ecological Consequence	Very High					<i>Dv</i> (E-W)
	High					<i>Es</i> (fw) <i>Cm</i> (hab)
	Moderate				<i>Ci</i> (W)	<i>Sc</i> (E-W) <i>Ci</i> (E) <i>Bs</i> (E-W) <i>Bv</i> (E-W) <i>Dv</i> (E-W) <i>Cm</i> (biod)
	Low					<i>Es</i> (mar)
	Very Low					
		Rare	Low	Moderate	High	Very High
	Probability of Introduction → spread					

***Styela clava* (Sc) – clubbed tunicate**

***Ciona intestinalis* (Ci) – vase tunicate**

***Botryllus schlosseri* (Bs) – golden star tunicate**

***Botrylloides violaceus* (Bv) – violet tunicate**

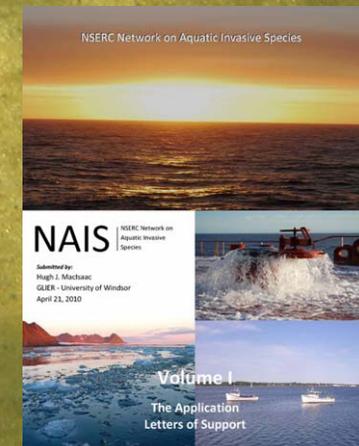
***Didemnum* sp. (*vexillum*) (Dv) – pancake batter tunicate**

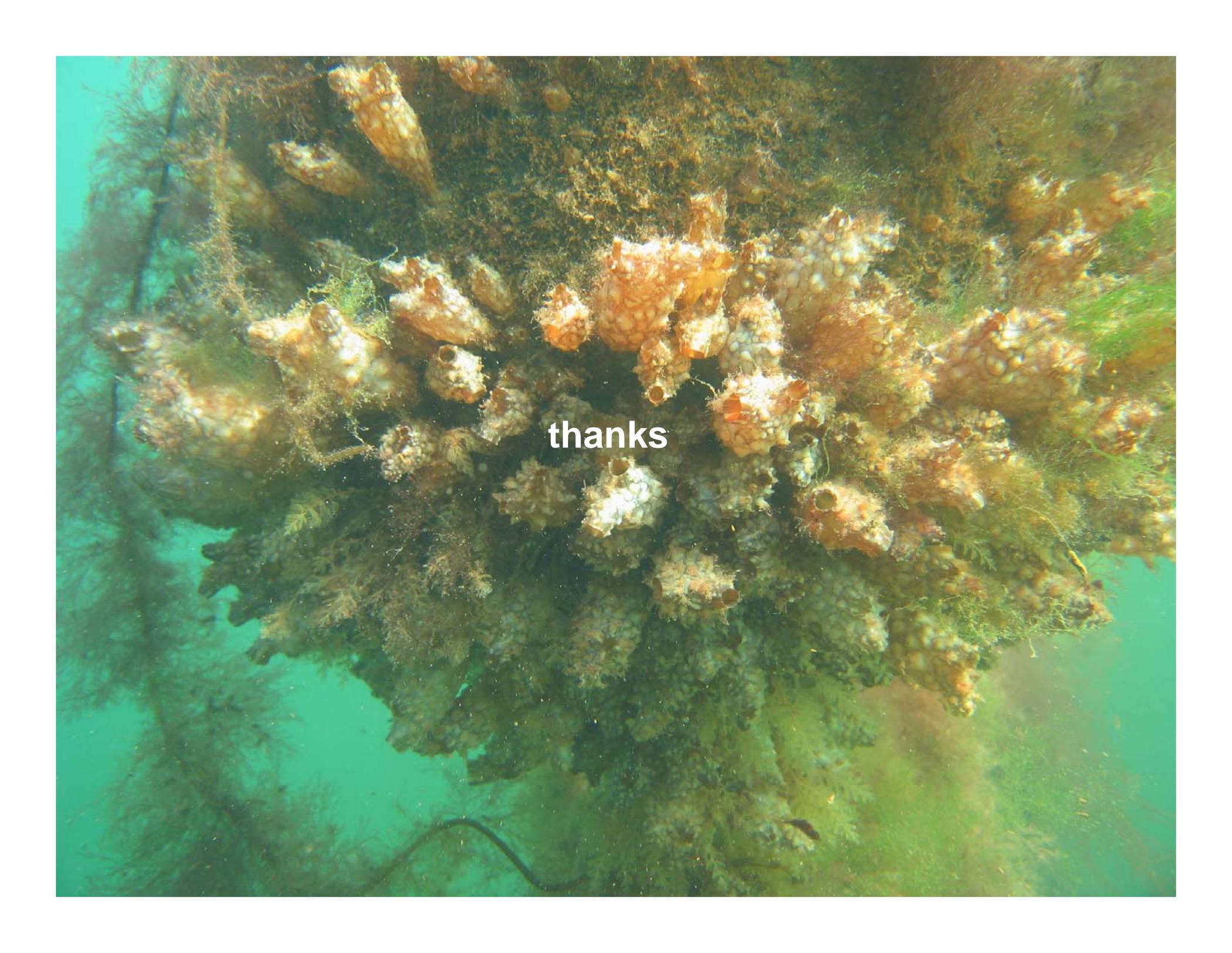
***Carcinus maenas* (Cm) – green crab**

***Eriocheir sinensis* (Es) – Chinese mitten crab**

# Issues / next steps

1. Impact often based on studies on unnatural habitat → who cares? (i.e., what of natural communities?)
2. Update methods based on Parksville...
3. Involve policy and socio-economic people
4. Standardize methods for vectors
5. Upcoming: east/west coasts for shipping  
smallcraft
6. CAISN II: Niche modelling  
Uncertainty



An underwater photograph of a coral reef. The scene is dominated by various types of coral, including large, branching structures and smaller, more intricate forms. The water is a clear, vibrant blue-green, and the lighting is bright, highlighting the textures and colors of the marine life. The word "thanks" is overlaid in the center of the image in a white, sans-serif font.

thanks

### ***Vector Importance***

**Very low:** European green crabs have not been demonstrated or believed to utilize this vector. Does not require management action.

**Low:** European green crabs are unlikely to spread by this vector. May require efforts to minimize spread.

**Moderate:** European green crabs can spread by this vector in favorable circumstances. Management could provide a reduction of spread.

**High:** European green crabs have extensively used this vector. Management would be important for a reduction of spread, but none has been attempted.

**Very high:** European green crabs have extensively used this vector despite extensive management efforts.

### ***Vector Uncertainty Levels***

**Very high uncertainty:** Little to no information; expert opinion based on general species knowledge.

**High uncertainty:** Limited information; third party observational information or circumstantial evidence.

**Moderate uncertainty:** Moderate level of information; first hand, unsystematic observations.

**Low uncertainty:** Substantial scientific information; non peer-reviewed information.

**Very low uncertainty:** Extensive scientific information; peer-reviewed information.

### ***Impact Level***

**Positive** A positive impact. Improvement of the factor in question.

**Very low negative** No measurable impact. Consequences can be absorbed without additional management action.

**Low negative** A measurable limited impact. Disruption to the factor in question, but reversible or limited in time, space, or severity. May require management effort to minimize.

**Moderate negative** A measurable widespread impact. A widespread disruption to the factor in question, but reversible, or of limited severity, or duration. Can be managed under normal circumstances.

**High negative** A significant impact. A widespread disruption to the factor in question that persists over time, or is likely not reversible. Will require effective management or adaptation of procedures.

**Very high negative** A critical impact. Extensive disruption to the factor in question, that is irreversible. May already be unmanageable or will become so unless effective management is immediately put in place.

### ***Estimated Probability if Impact***

**Unlikely** Impact will only occur in exceptions or is not expected

**Possible** Impact could occur in some circumstances

**Likely** Impact will probably occur in most circumstances

**Almost certain** Impact is expected to occur in most circumstances

**Certain** Impact has been observed to occur

