Development of an AIS 'Monitoring' Program: Past, Present & Next Steps




Claudio DiBacco, J. Ben Lowen

Bedford Institute of Oceanography
Fisheries & Oceans Canada, Dartmouth, NS

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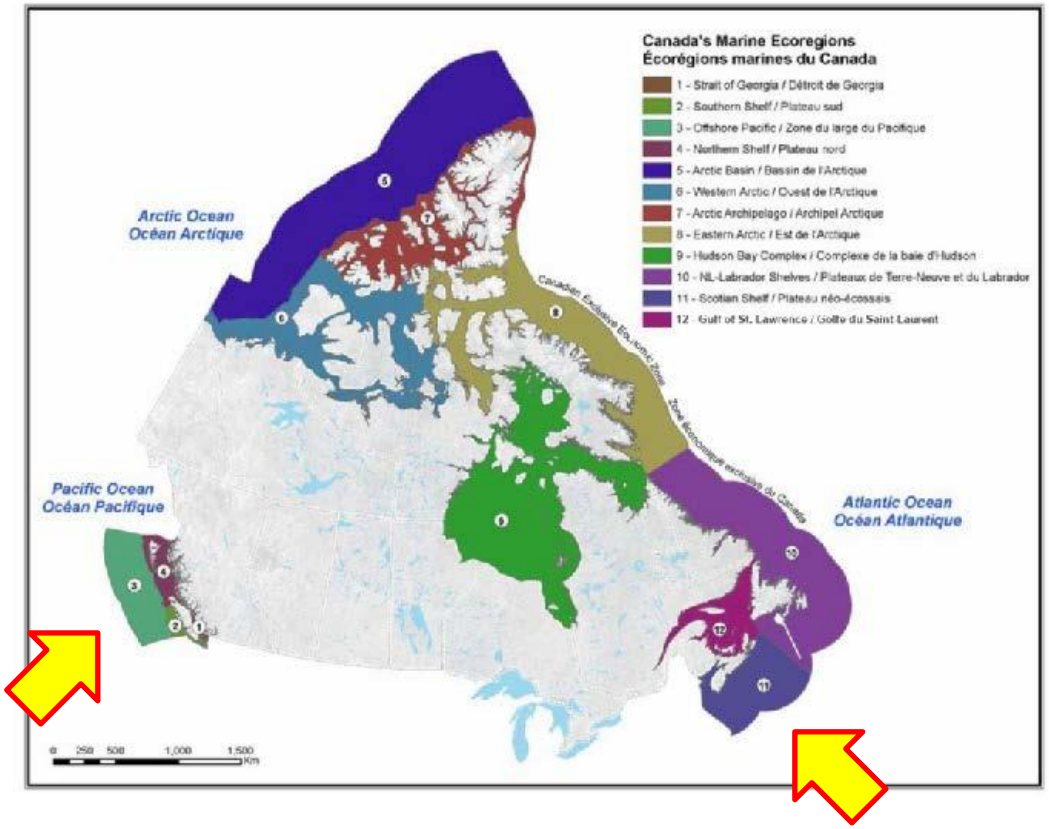
Outline

- ***Past***: Core DFO AIS Monitoring Program
  - Objectives & Program Components
  - Protocols, Common AIS, Monitoring Products
- ***Present***: Environmental Monitoring & Prediction
  - Physiological Tolerance, genetics (population structure)
  - Environmental Variability & Climate Change Projections
- ***Next steps…***
  - Hotspot analysis …
  - Vectors for dispersal …
  - Biogeographic barriers …

Fisheries & Oceans Canada (DFO) National AIS Program



Canadian Marine Ecoregions (DFO 2009)

- **DFO AIS Monitoring Program**
  - **National Program**
- **Of 12 Canadian Marine Ecoregions…**
  - **Regions 1-4 & 10-12 have been monitored since 2006**
  - **Regions 8 & 9 are monitored more sporadically …**
  - **Others (5 – 7) not at all ☹**

Regional Program Objectives

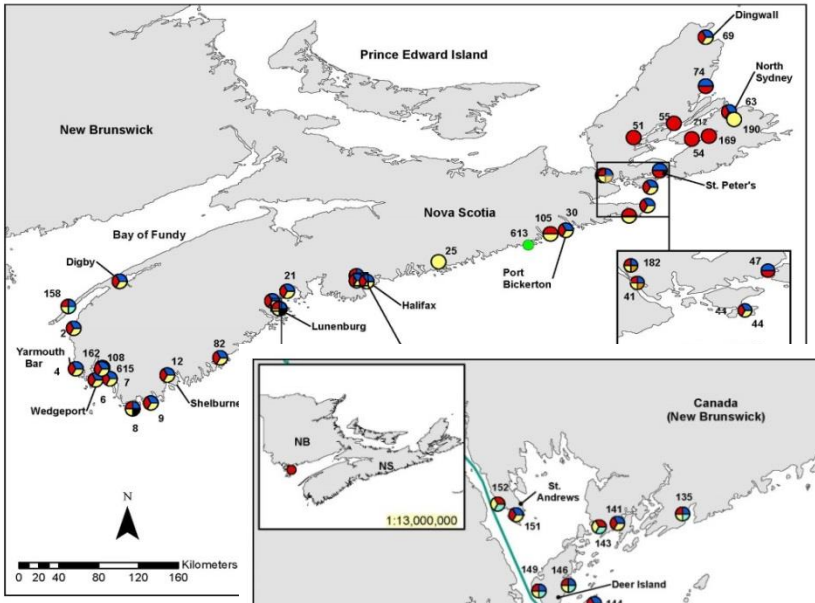
- **Overarching**
  - To protect the health and productivity of Canada's aquatic ecosystems through the ***identification of high risk AIS and their pathways***, & ***reducing the risk of their introduction and spread***

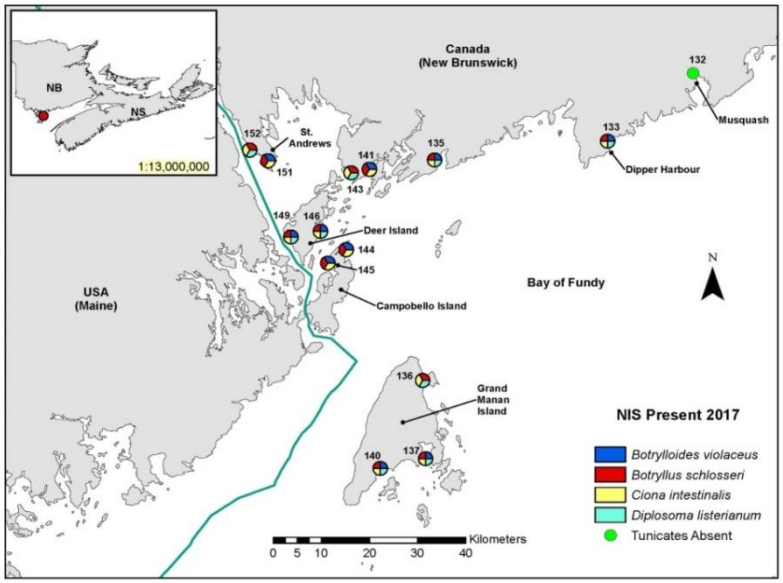
- **Specific**
  - prevention of new invasions
  - early detection of new invaders
  - rapid response to new invaders
  - management of established and spreading invaders
    - *containment, eradication, control*

AIS Program Components

- **Annual Monitoring**
  - Field assessment (e.g., collector plates, rapid assessment, eDNA)
- **Research & Development**
  - Experimental Field & Laboratory (e.g., physiological tolerance)
  - Population Structure (e.g., genomics, environmental responses)
  - Modelling (e.g., suitable habitat & connectivity modelling)
  - Climate Projection (i.e., environmental variability & climate change)
- **Risk Analysis & Assessment**
  - Rapid Response & delineation, SLRAs, DLRAs
- **Data Management & Sharing**

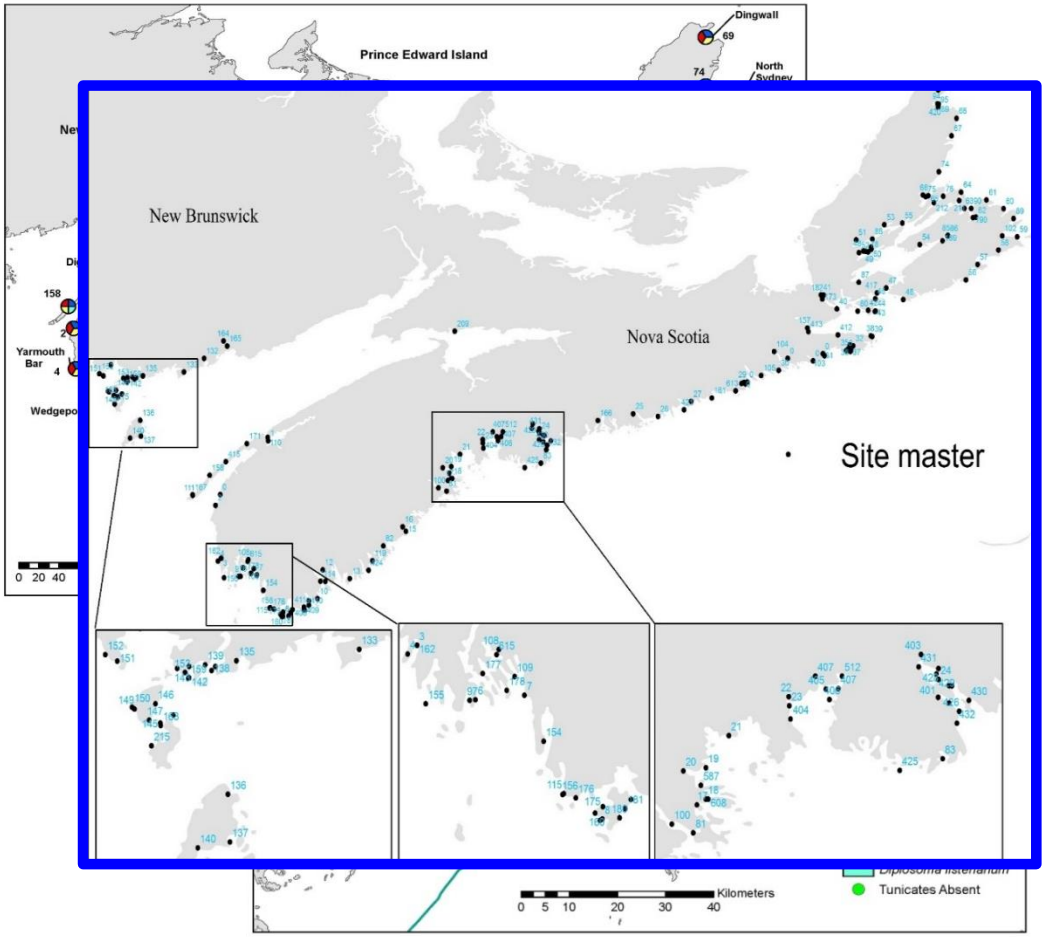
AIS Monitoring Protocols





- DFO Maritime's Protocols
  - ~50-60 sites yr^{-1}
  - Sentinel & Targeted Sites
  - Spring to Fall Deployment
- Monitor
  - Introduction & Establishment
  - Presence / Absence
  - Range Expansion (Inter-annual)
  - Relative Abundance (% Cover)
  - Environmental Drivers
  - Species Interactions & Impacts

AIS Monitoring Protocols



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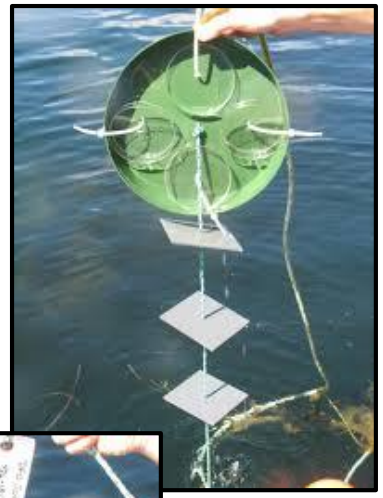
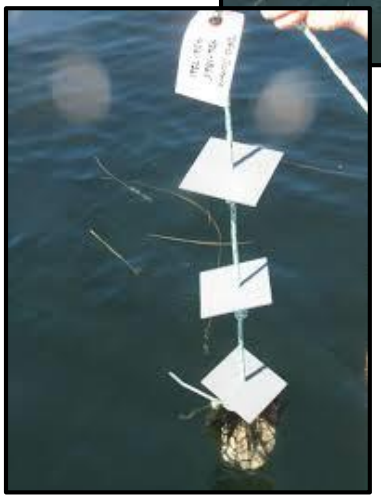
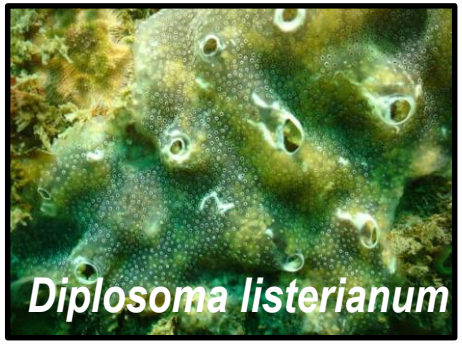
AIS Monitoring Protocols

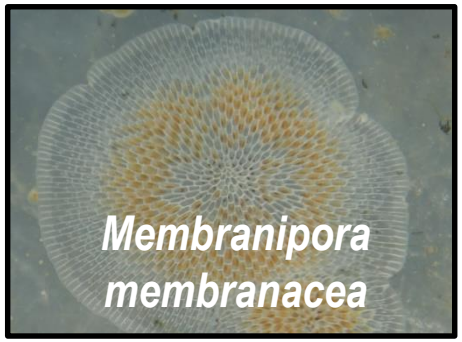
- Target at-risk sites
  - Best available information
  - Spring Deployment / Fall Recovery to assess recruitment, growth season
- 10 settlement collectors site^{-1}
  - ~1m depth; 5 - 10 m apart
- Fall Assessment
  - Presence/Absence
  - Species Richness
    - AIS & Native species
  - % Cover



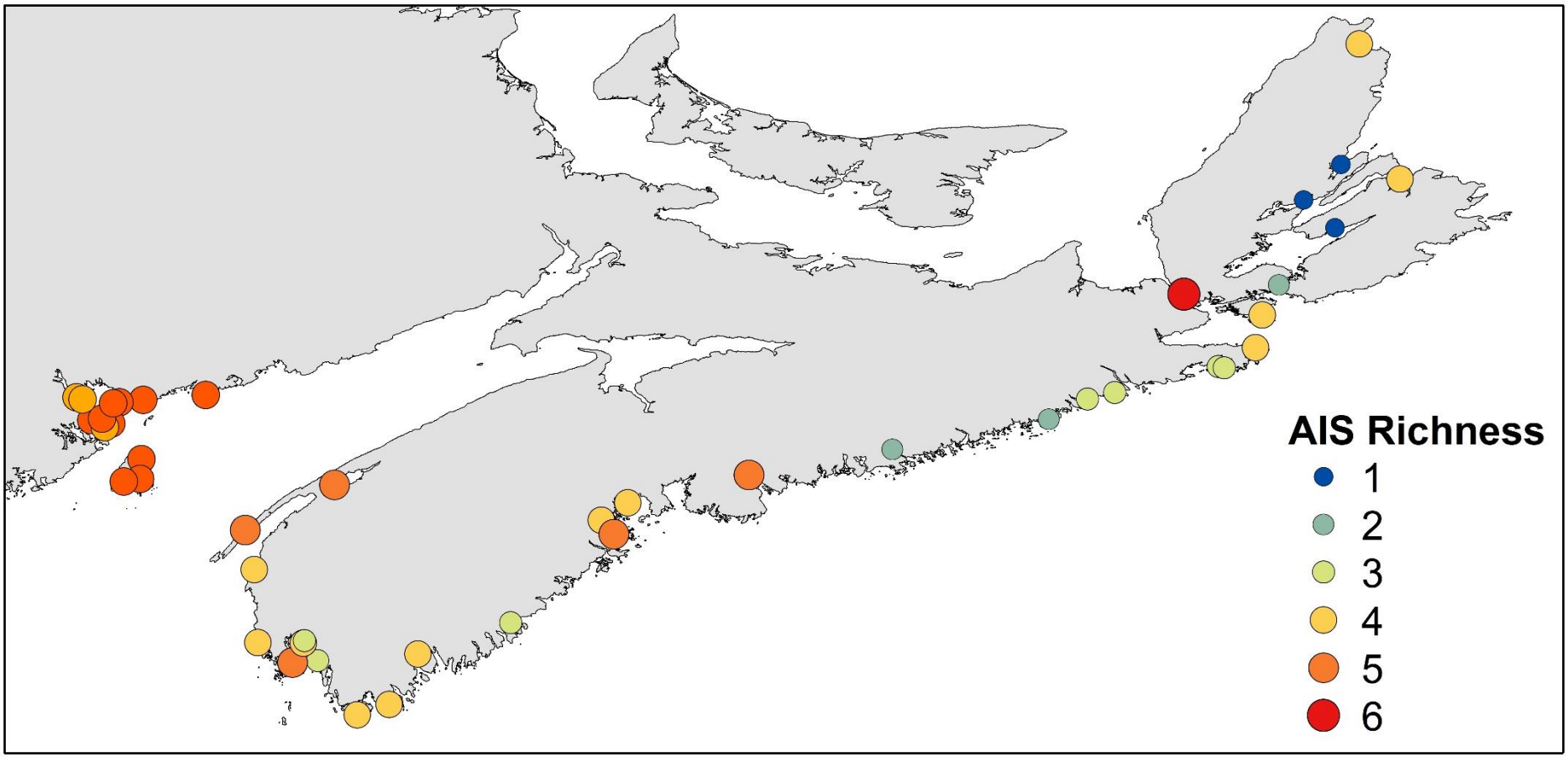




Common Western Atlantic AIS



AIS Presence/Absence & Richness



AIS Abundance (% Cover)

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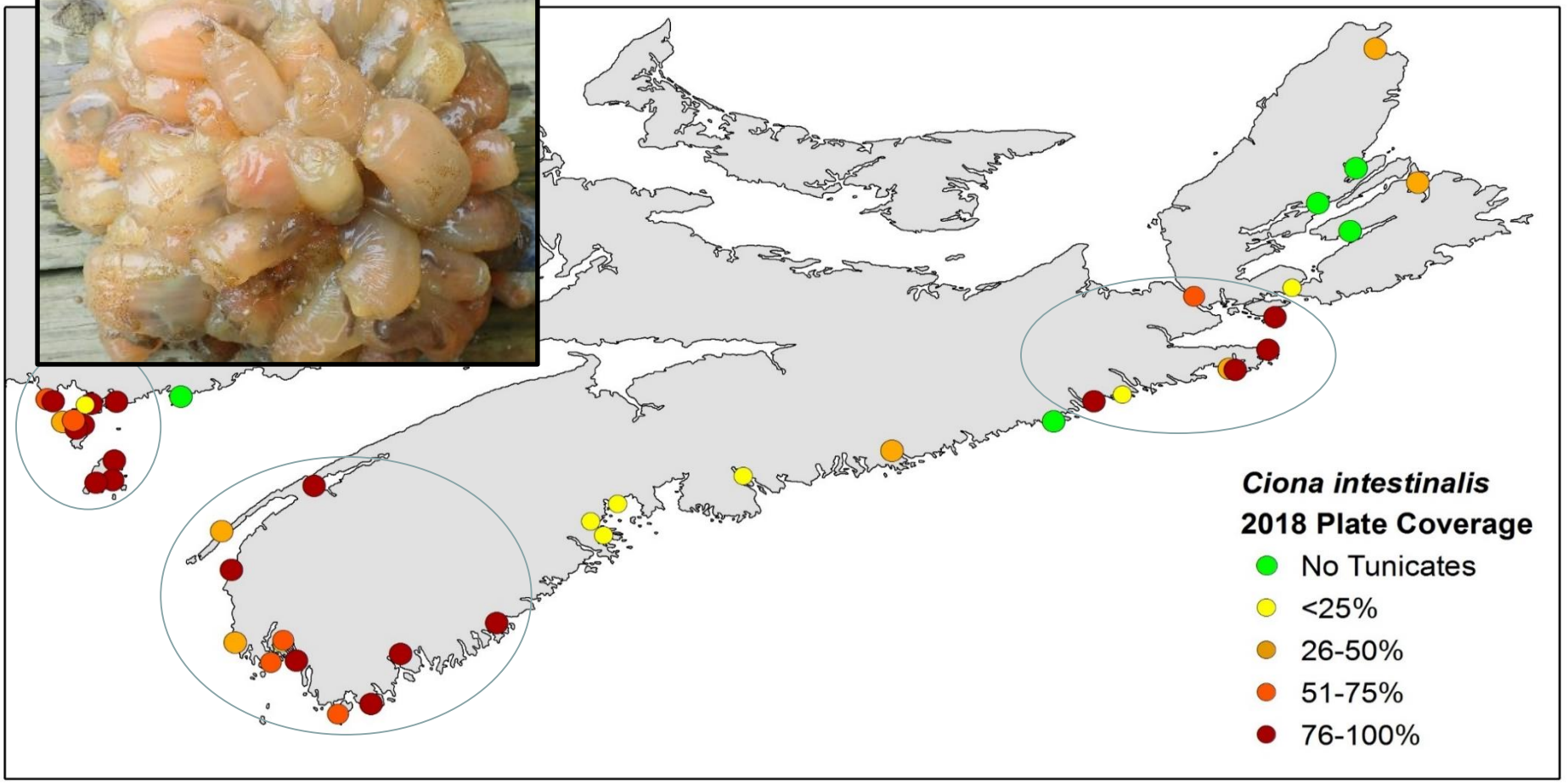
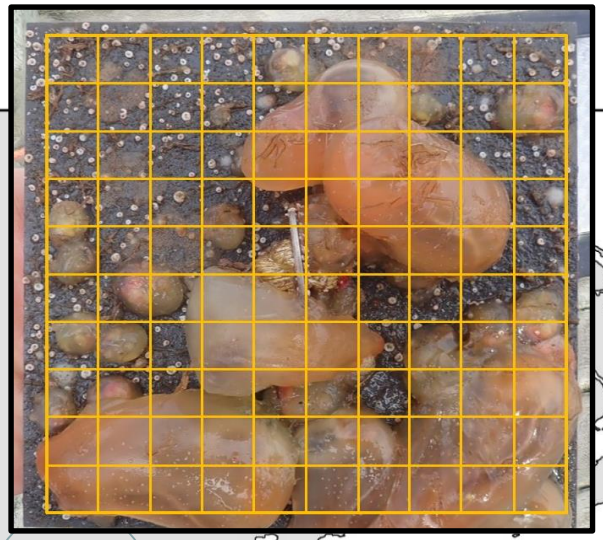
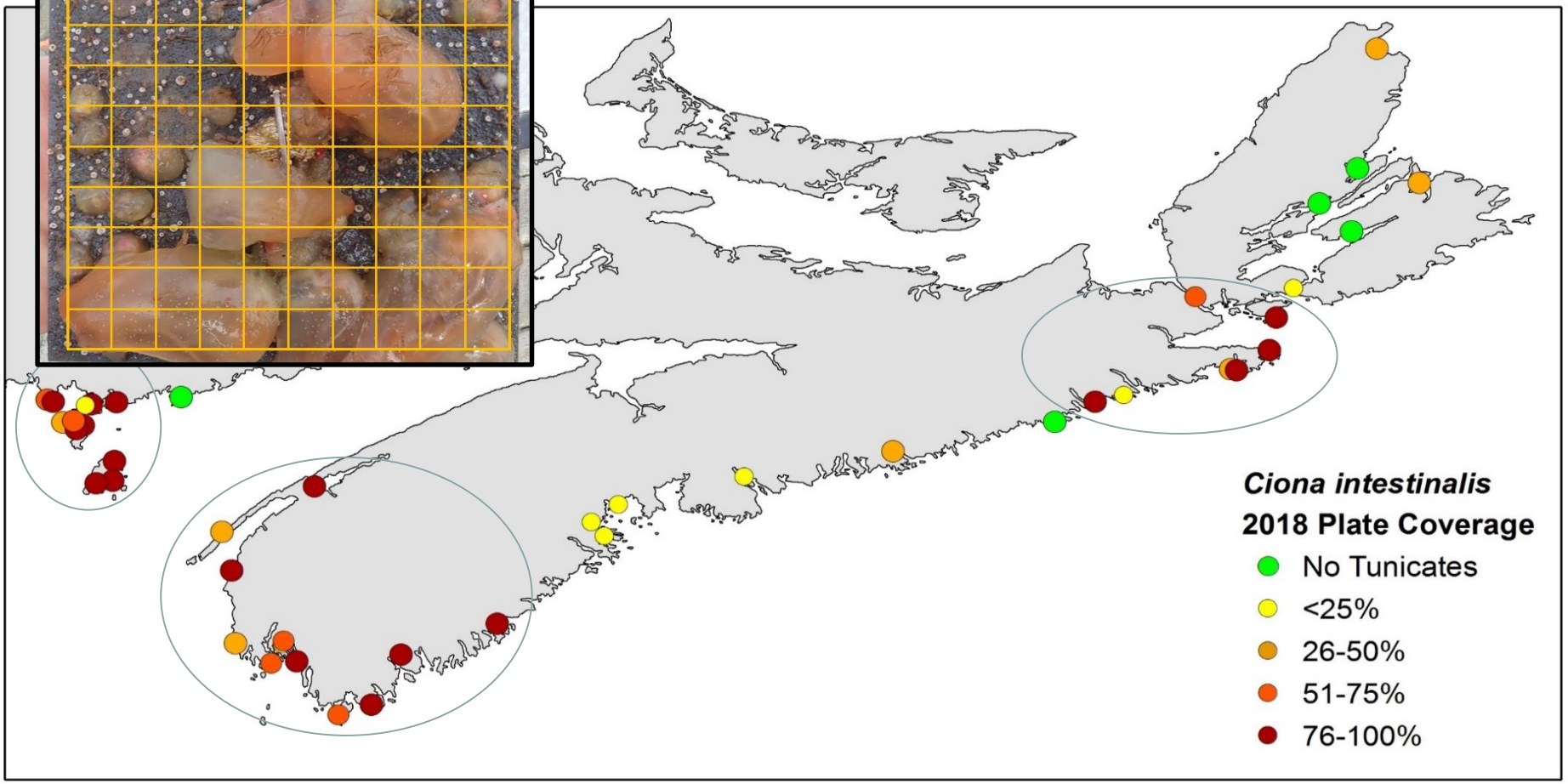


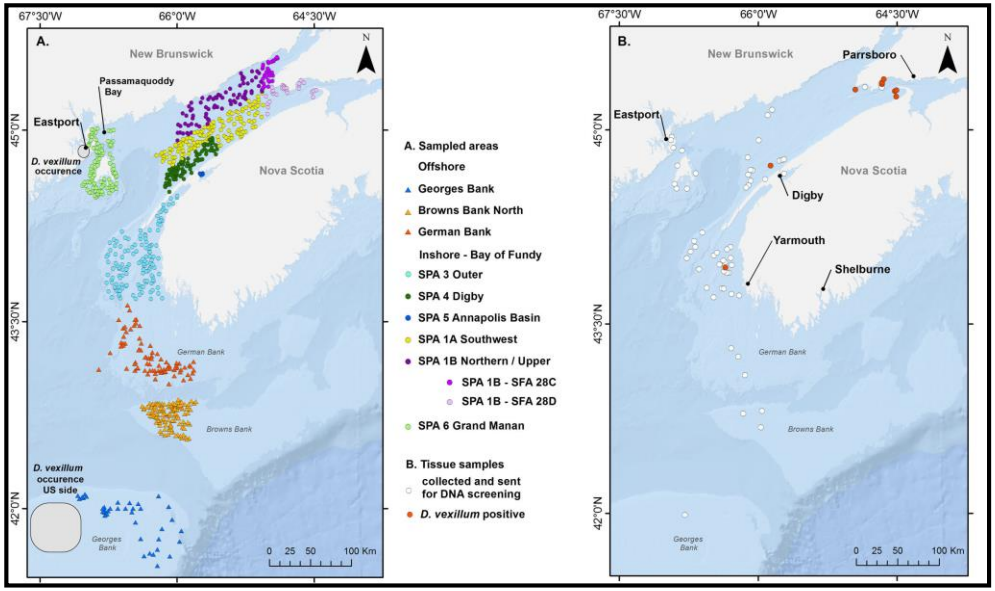
AIS Abundance (% Cover)





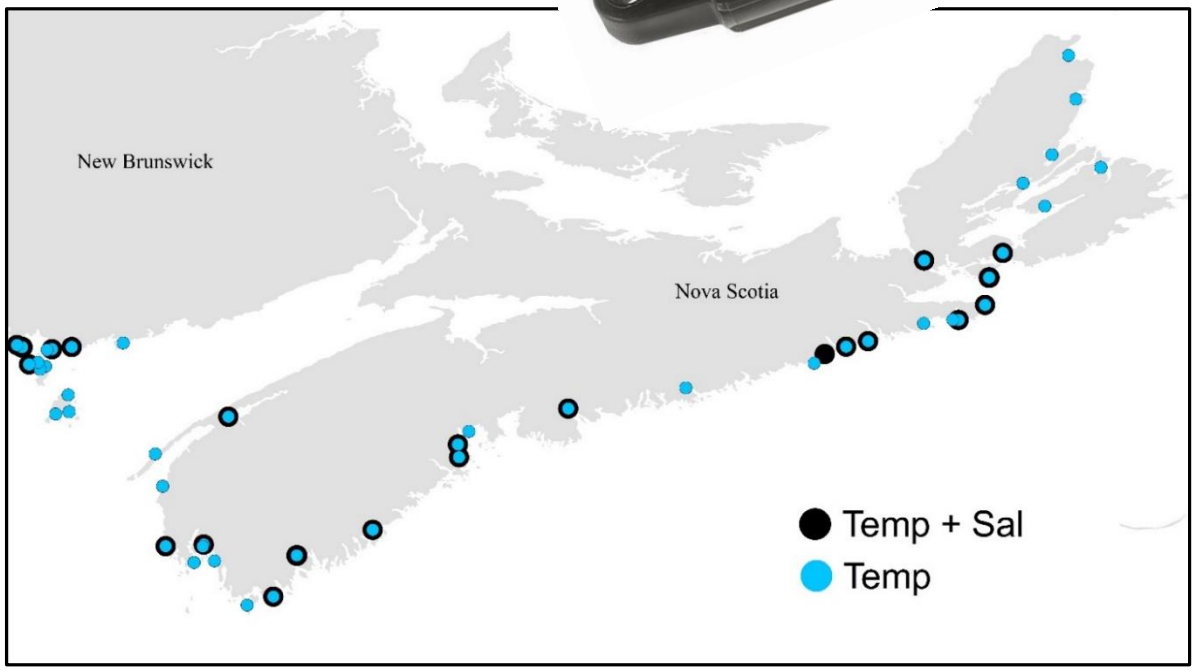
Additional Monitoring Tools

1. Rapid Assessments & Responses
2. Monitoring surveys
3. Subtidal ground lines

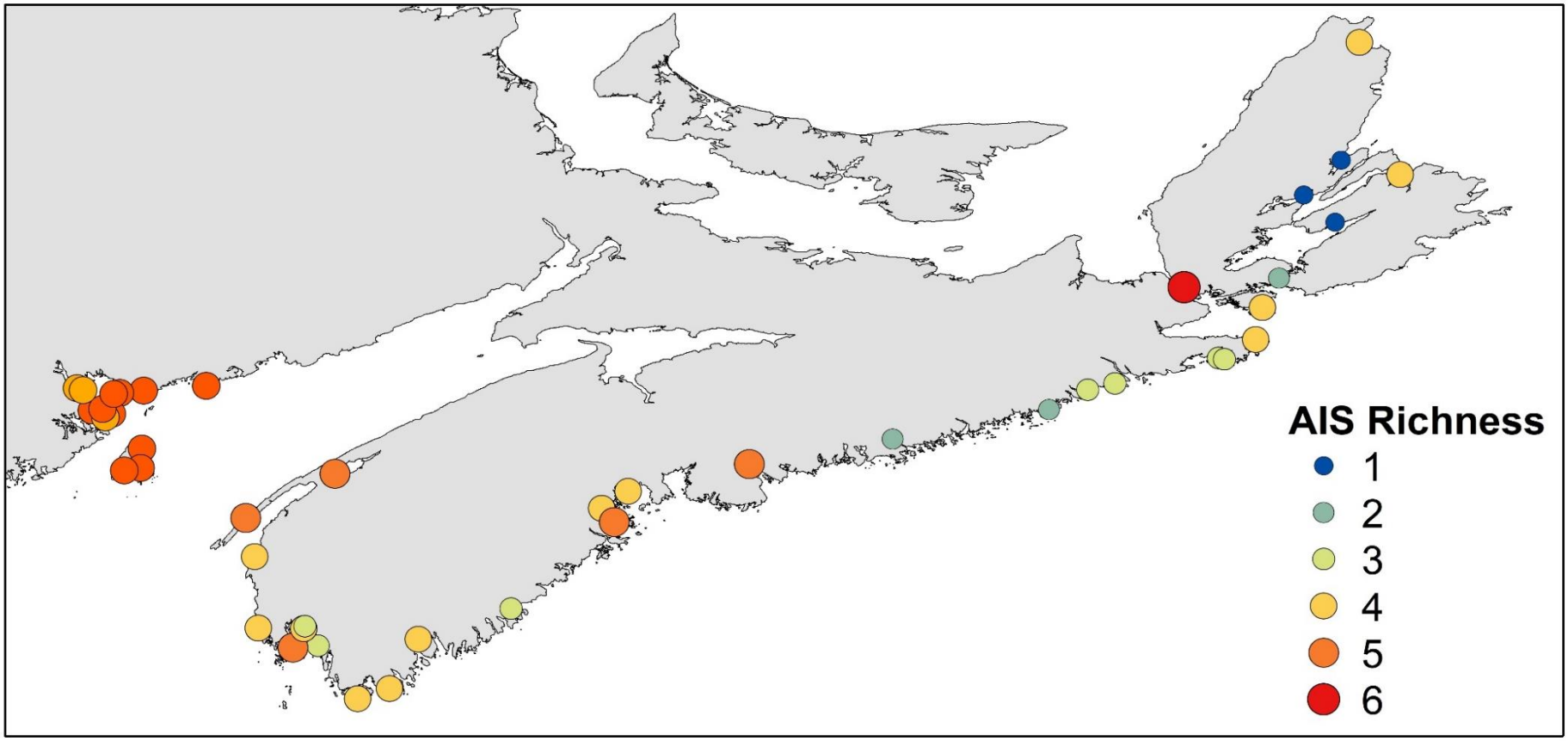


Environmental Monitoring

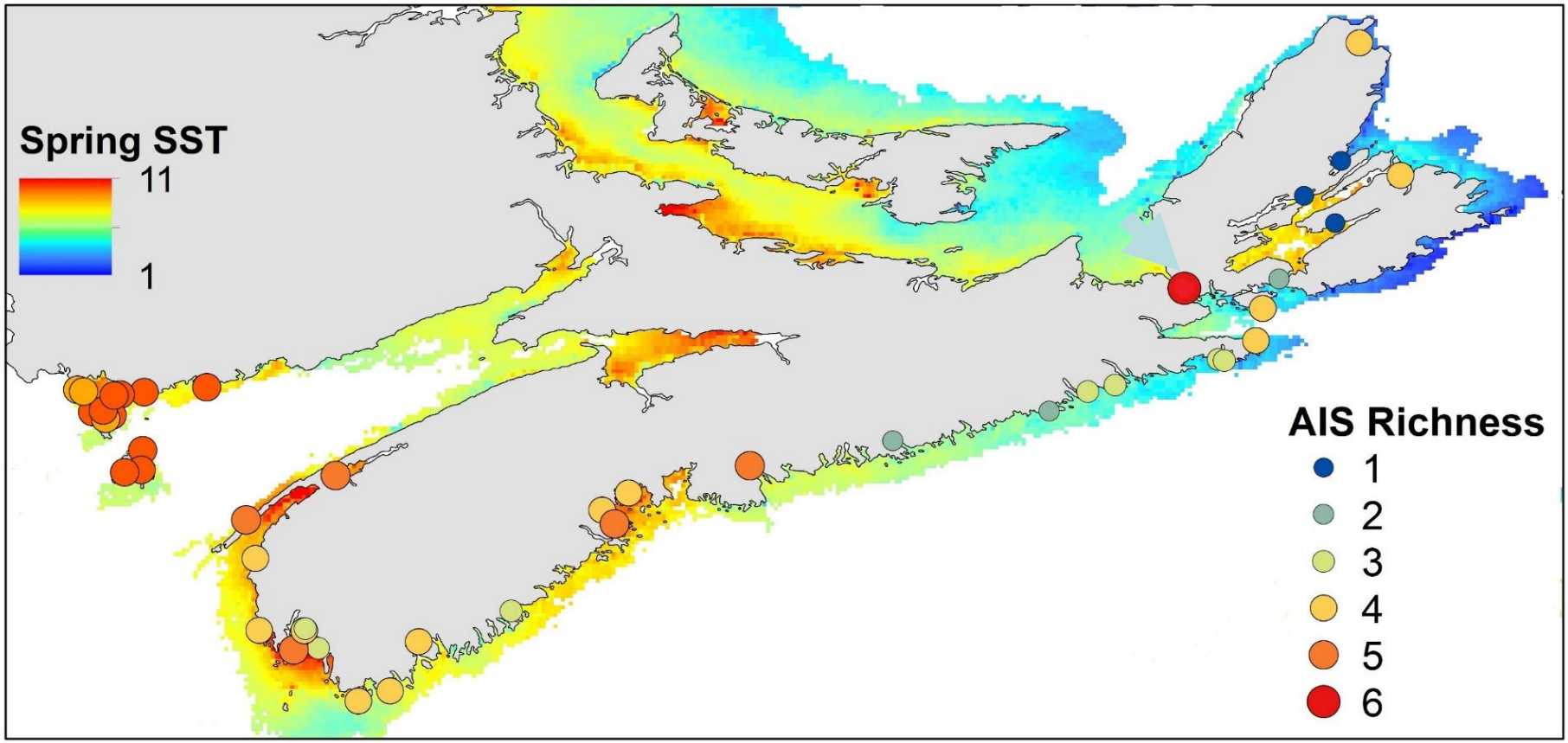
- **Environmental Monitoring**
  - Temperature @ all sites
  - Temp. & Salinity @ select sites



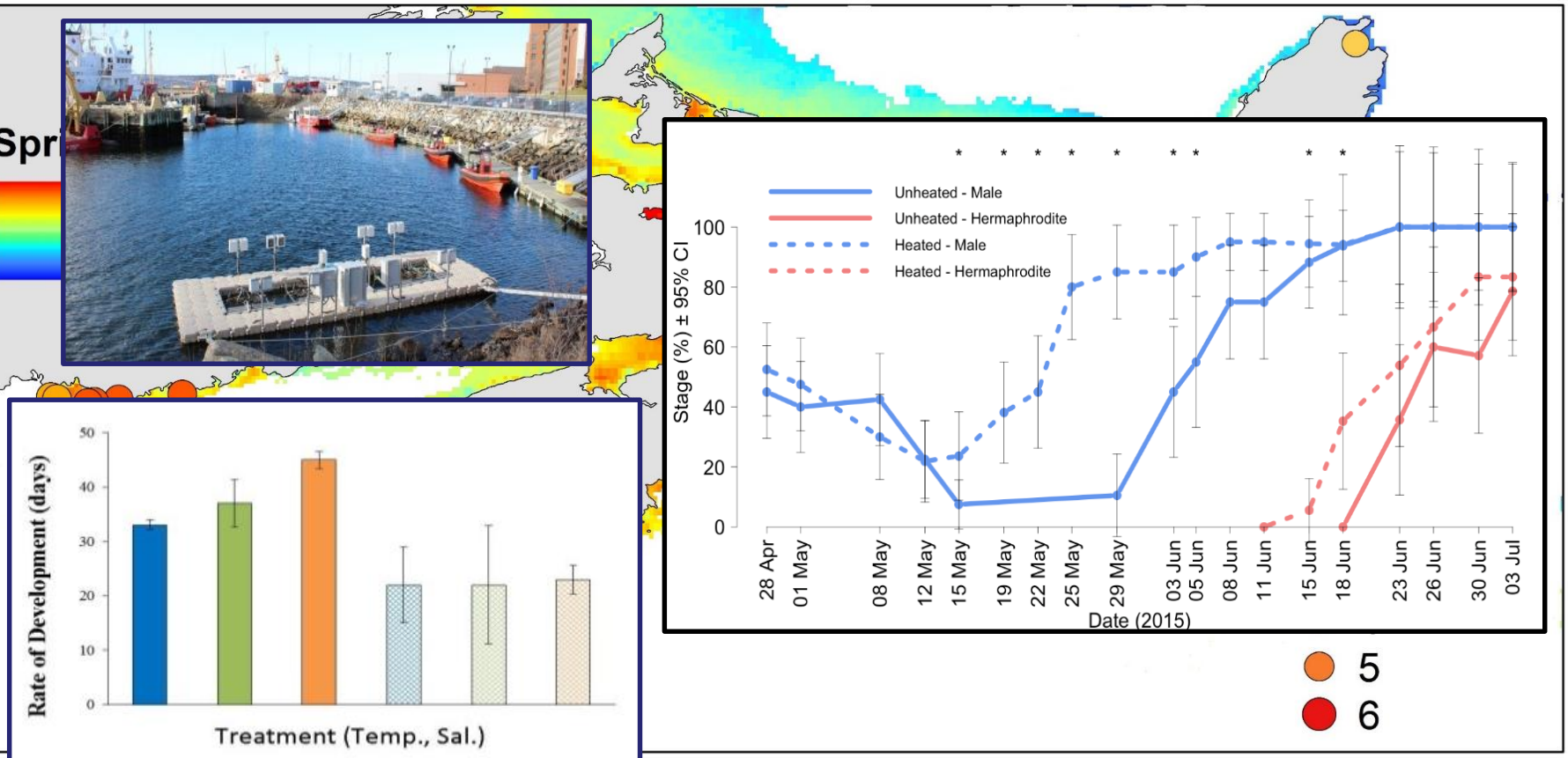
AIS Richness



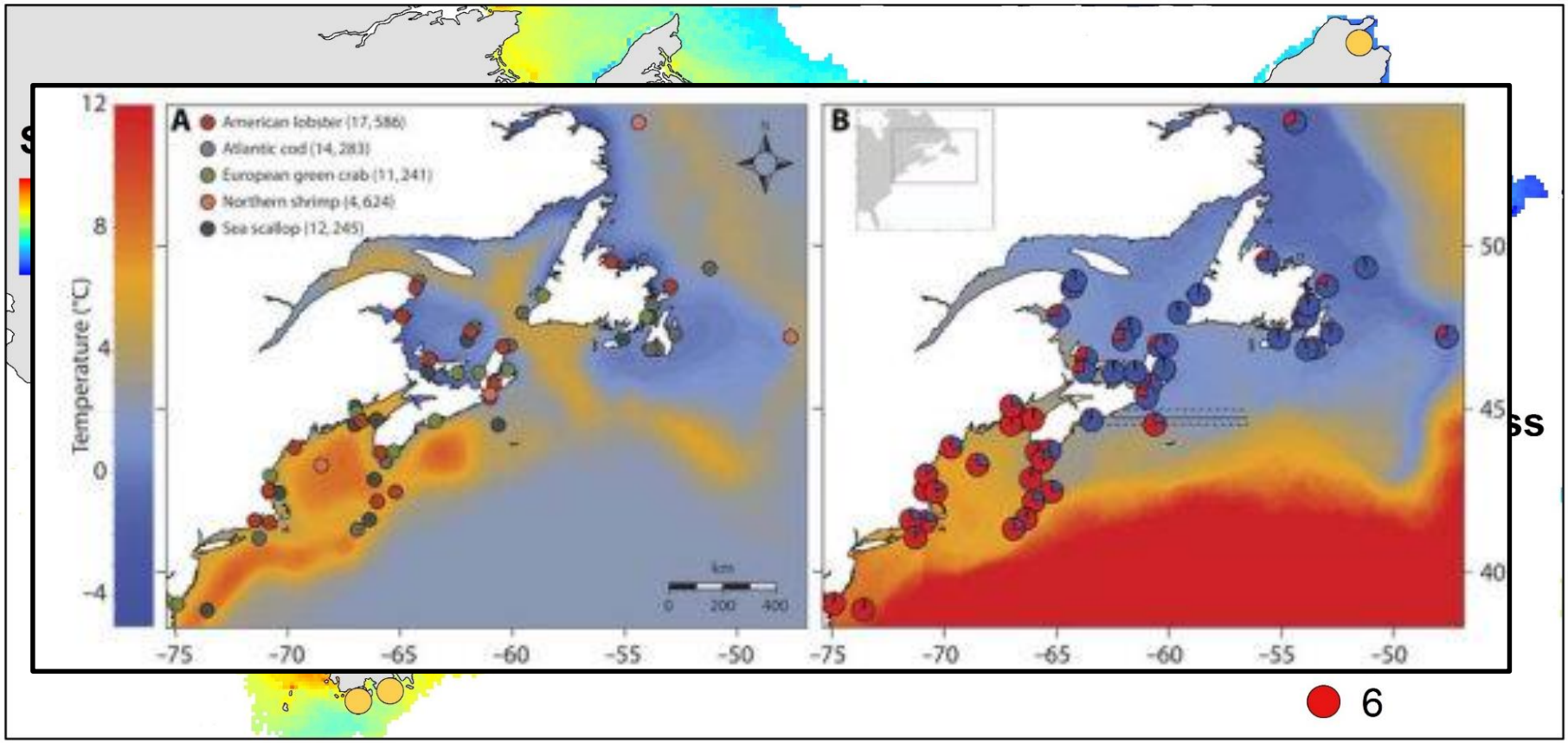
AIS Environmental Monitoring



AIS Physiological Tolerances



AIS Genetic Structure



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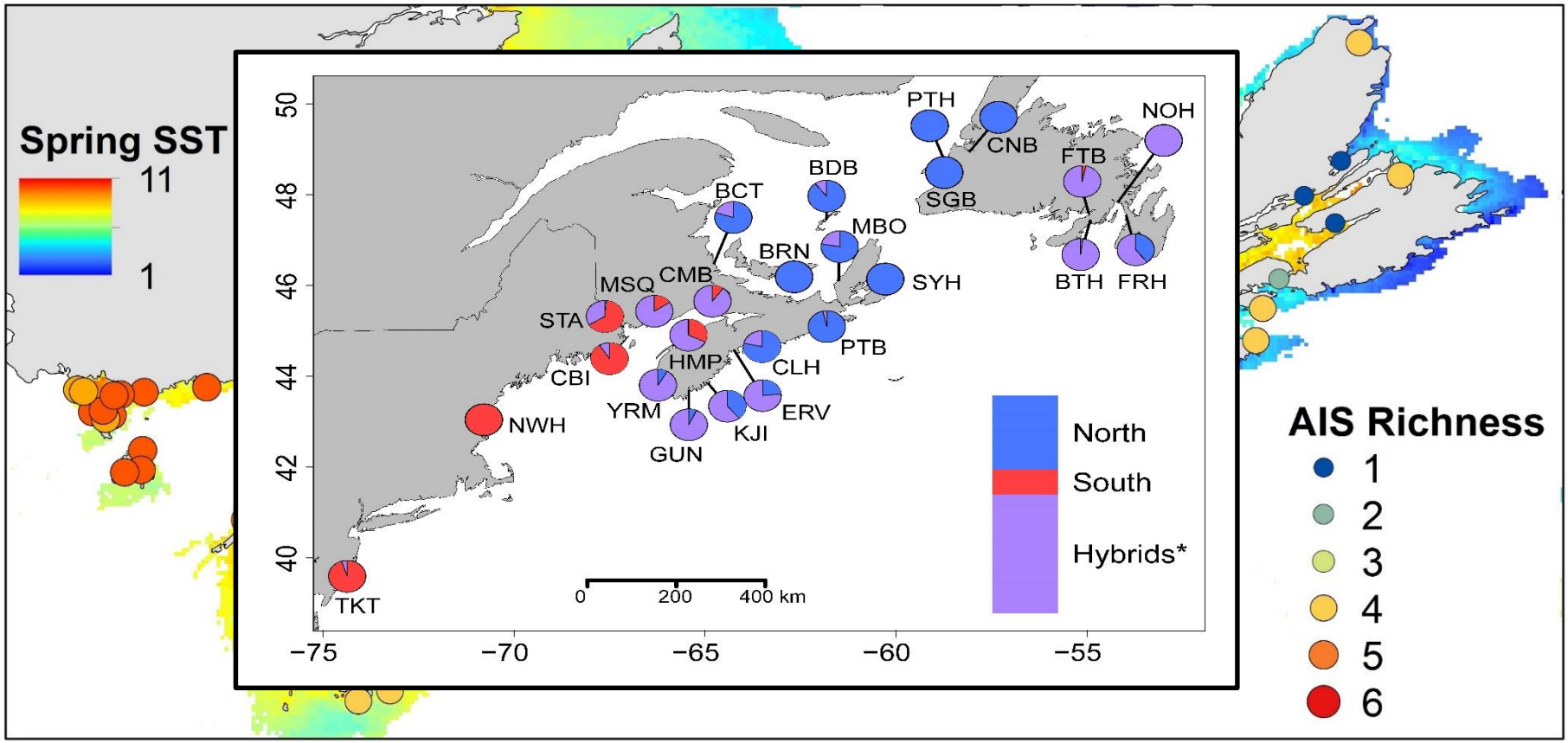
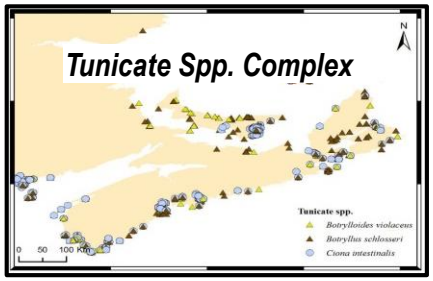
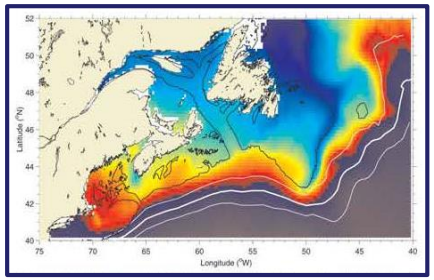
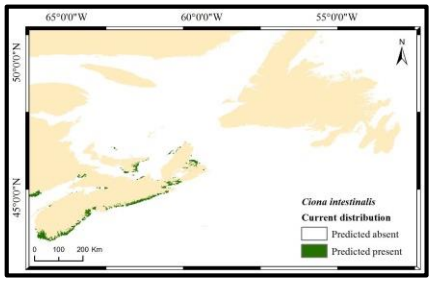
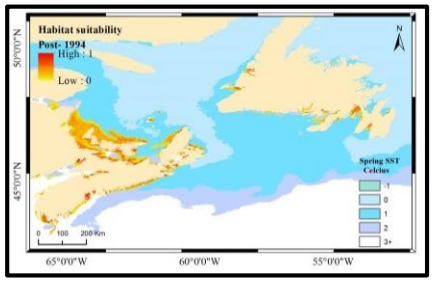


Environmental Matching & Prediction





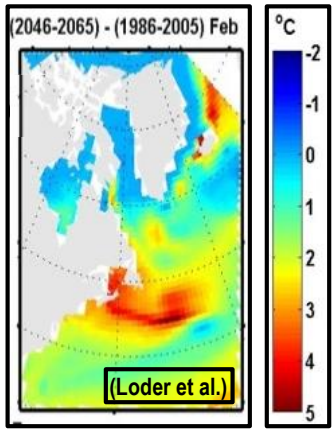




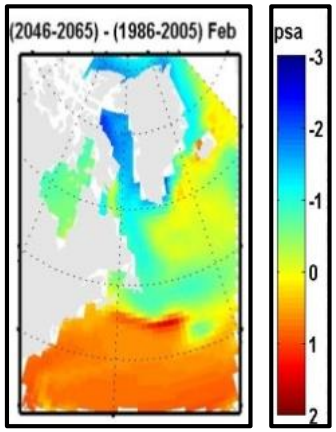
- **AIS Distributions**
  - 2006 - present
  - ~50 sites yr-1
  - Spring to Fall Deployment
- **Climate Matching**
  - Environmental Mon. (T & S)
- **Suitable Habitat Modelling**

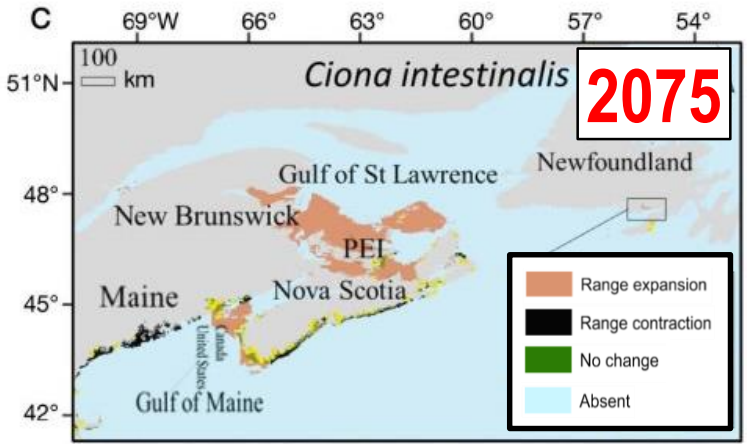
Climate Change Projections

Temperature Anomalies



Salinity Anomalies





- **AIS Distributions**
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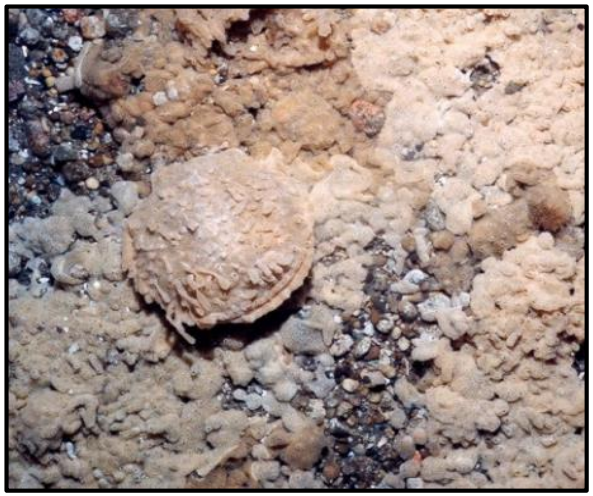
- **Climate Matching**
  - Environmental Mon. (T & S)
- **Suitable Habitat Modelling**
- **Projections & Predictions**
  - decades to centuries

Case Study: Pancake Batter Tunicate (Didemnum vexillum) in Atlantic Canada

'Established' 2013

- Rapid Assessment (confirm ID; local distribution)
- Communication (DFO, Stakeholders, Industry)
- Delineation Survey (regional distribution)



Pancake batter tunicate
(Didemnum vexillum)

Case Study: Pancake Batter Tunicate (Didemnum vexillum) in Atlantic Canada

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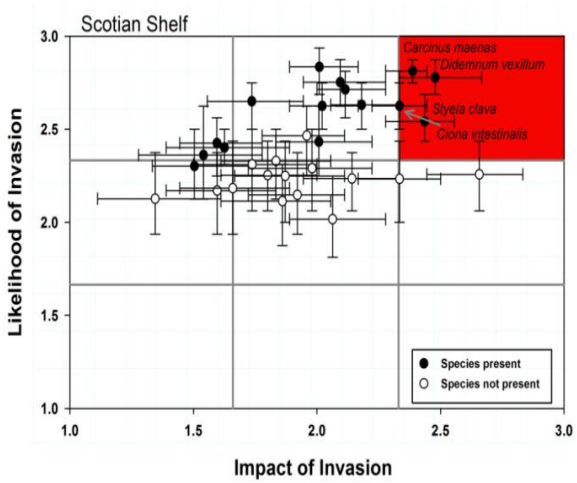
- Rapid Assessment (confirm ID; local distribution)
- Communication (DFO, Stakeholders, Industry)
- Delineation Survey (regional distribution)
- SLRA – Screening Level Risk Assessment
  - ***Canadian Marine Invasive Species Tool (CMIST)***



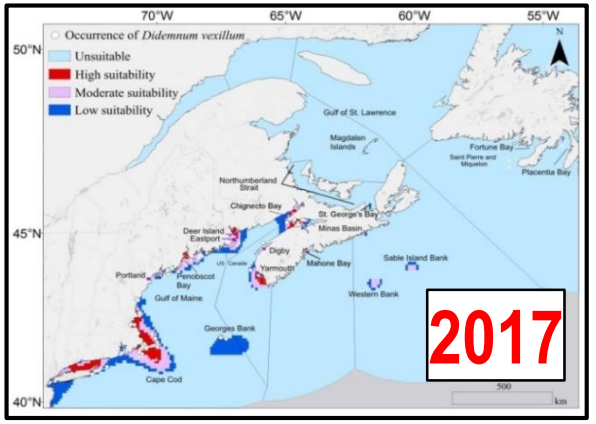
Pancake batter tunicate *(Didemnum vexillum)*

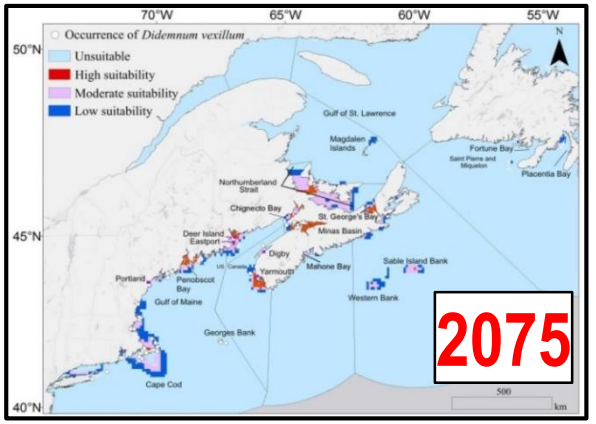
(Drolet et al. 2016)

Case Study: Pancake Batter Tunicate (Didemnum vexillum) in Atlantic Canada

‘Established’ 2013

- Rapid Assessment (confirm ID; local distribution)
- Communication (DFO, Stakeholders, Industry)
- Delineation Survey (regional distribution)
- SLRA – Screening Level Risk Assessment
- DLRA – Detailed Level Risk Assessment
  - Species dist. (AIS Mon., databases, pubs., …)
  - SDM (Present day, spatial risk assessment)
  - Climate Projection (Future risk)





Environmental Matching & Prediction

Recent Invaders (2014-2018)…

- Pancake batter tunicate (*Didemnum vexillum*)
- Green crab (*Carcinus maenas*) … ***Lineage I & II***

Future Invaders (2014-2018)…

- Diplosoma tunicate (*Diplosoma listerianum*)
- Asian shore crab (*Hemigrapsus sanguineus*)

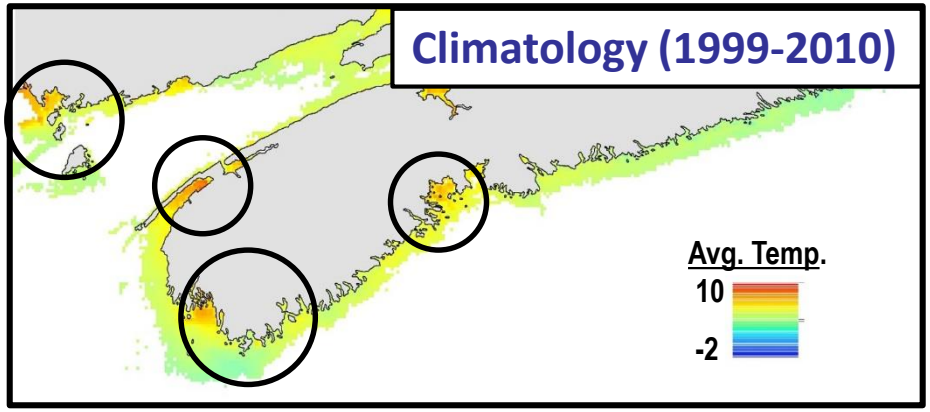
Informing AIS Monitoring: "Prioritizing What & Where We Monitor"

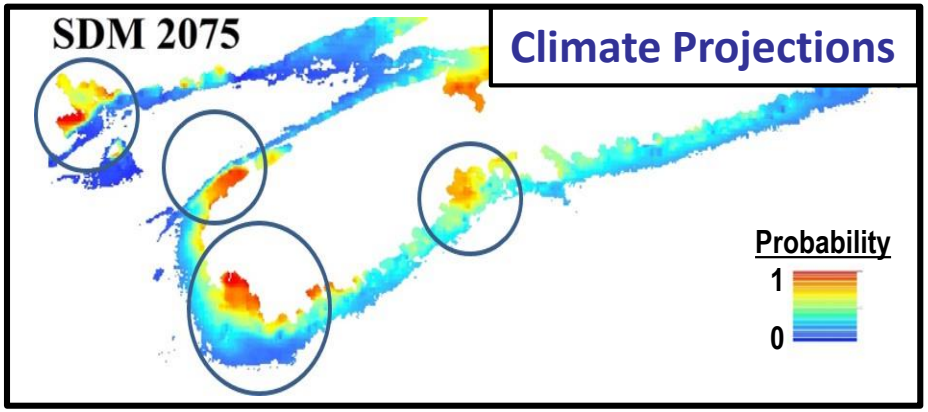
Risk Assessment … *next steps*

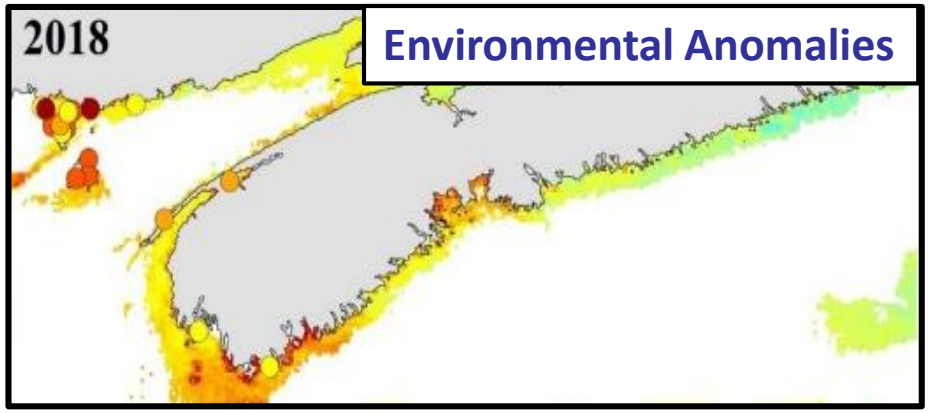
- Suitable Habitat Modeling …
- Climate Change Projections …
  - ***Environmental variability***

    (short term variability)

Real Time Environmental Monitoring & Prediction







Climate Projections (2075)

- Predicted Annual temperature
  - Increased ~1-3 ^{o}C
- SDM highly suitable habitats
  - e.g., swNB, swNS

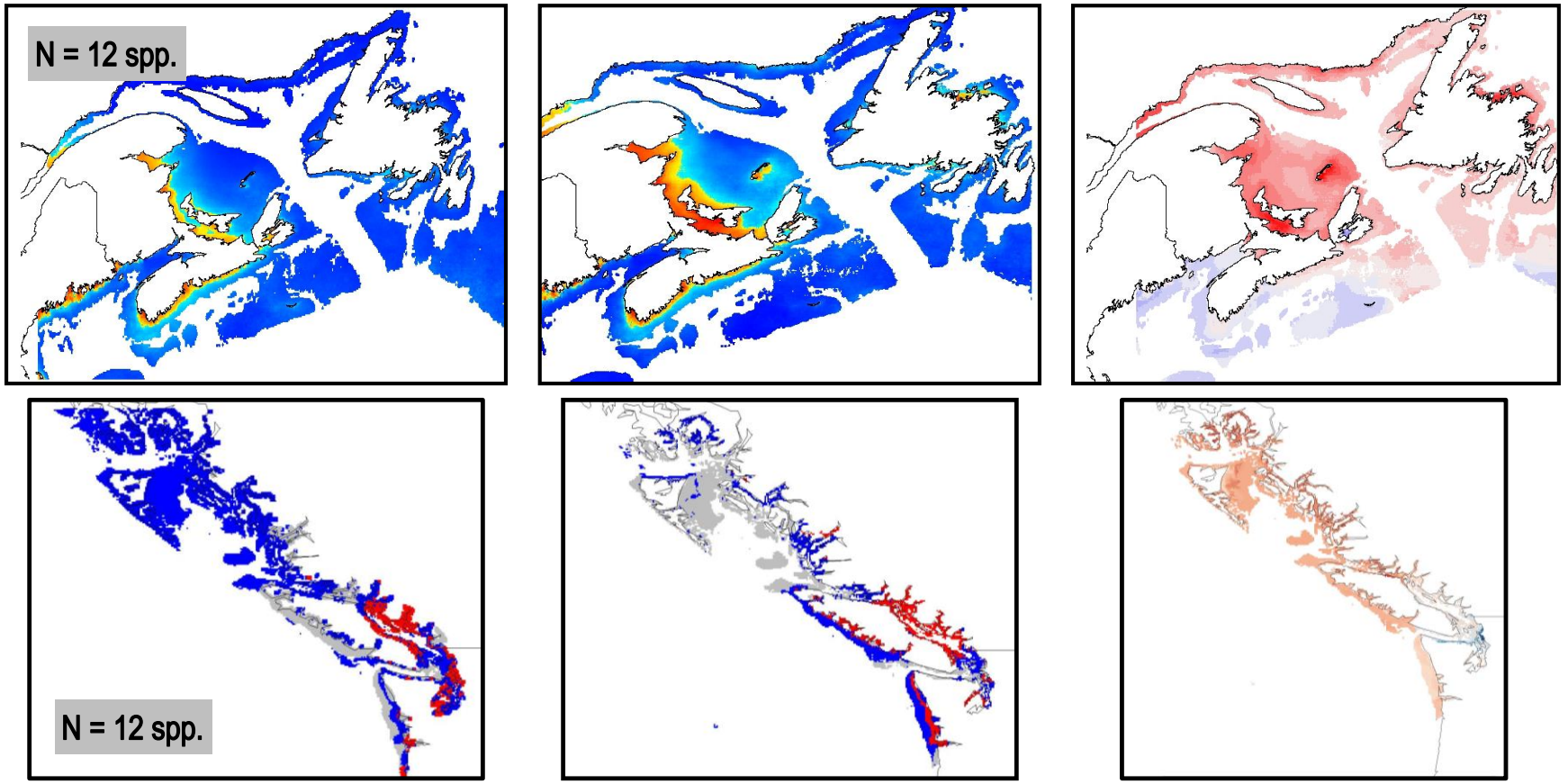
Informing AIS Monitoring: "Prioritizing What & Where We Monitor"

Risk Assessment Steps … *next steps*

- Suitable Habitat Modeling …
- Climate Change Projections …
  - *Environmental variability*
- **Hotspot analysis …**

Hotspot Analysis

Present Day | 2075 Projection | Anomaly (Projection-Present)



(Lyons et al., *pers. comm.*)

Informing AIS Monitoring: "Prioritizing What & Where We Monitor"

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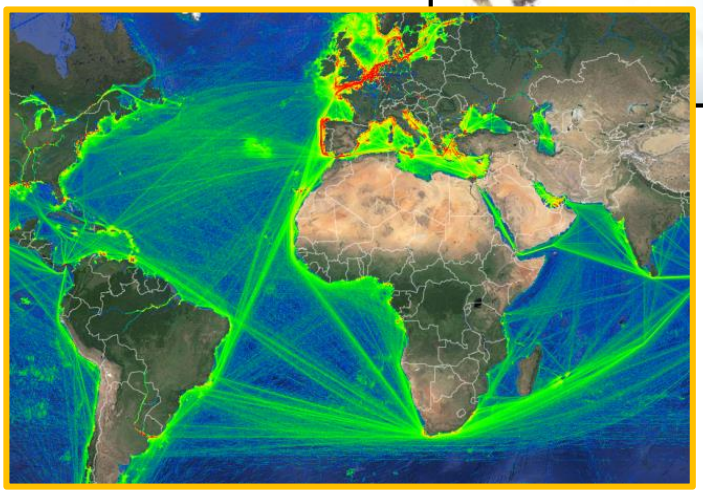

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Acknowledgements

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