Freshwater Climate Risk Index: A case study for Atlantic Salmon in Eastern Canada

Megan Shin, Christine Stortini, Daniel Boyce, Nancy Shackell, Sarah Tuziak, Aimee Gromack

Fisheries and Oceans Canada
Pêches et Océans Canada
DALHOUSIE UNIVERSITY

Acknowledgements

- Derek Hogen
- Ben Collison
- Jeremy Broome
- Michael van Zyll de Jong
- Cindy Breau
- Sarah Kingsbury
- Daniel Caissie
- Antoin O'Sullivan
- Brent Wilson

Climate Change Vulnerability/Risk Assessments

Exposure

What is the magnitude of impact climate change will have?

+

Sensitivity

Is the species already imperiled?

-

Adaptive capacity

Can the species adapt or shift in distribution?

Boyce et al. 2022: Climate Risk Index for Biodiversity (CRIB):

- Quantitative
- Considers other stressors
- Open "big" data sources
- Originally developed for marine ecosystems
- Generalized and flexible – broadly applicable ecological concepts

Adapting CRIB for freshwater ecosystems

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- **Some indices removed**, e.g., global distributional range, proportion of global temperature range within tolerance range, depth range.
- **Assumptions:** watershed fidelity – vulnerability based on individual watersheds, not regional range of species.
- **Some indices added**, e.g., precipitation extremes, human impacts in freshwater.

Freshwater-adapted CRIB

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What is the magnitude of impact climate change will have?

- Projected habitat loss
- Timing of emergence from thermal niche
- Velocity of warming
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- Historical thermal variability
- Amount of habitat
- Connectivity of habitat
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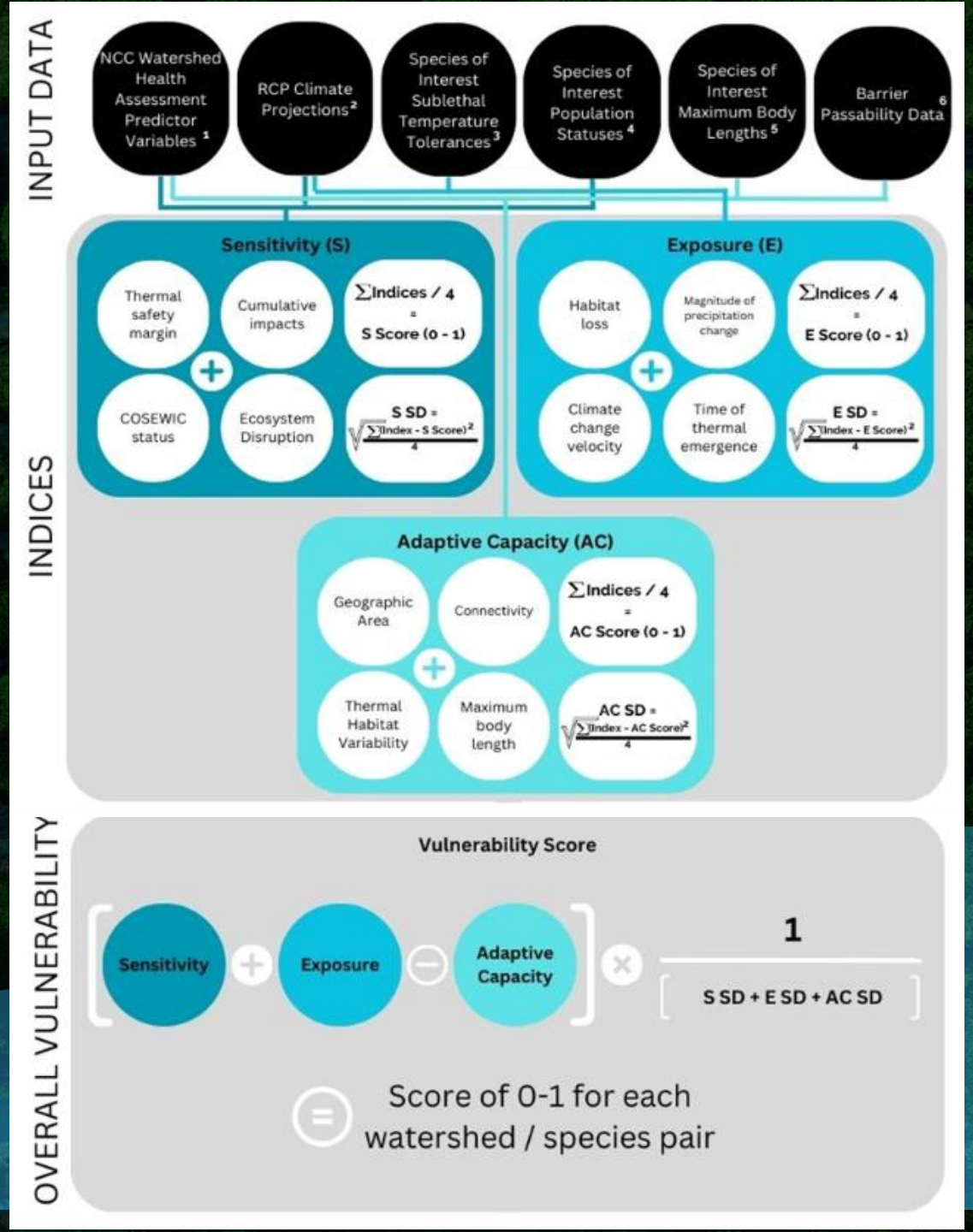
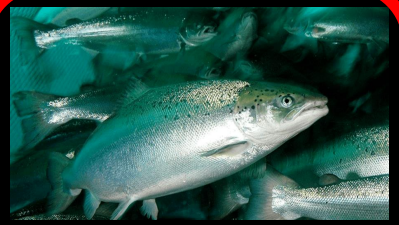
Quantitative **(scaled 0-1),** generalized and flexible, uses widely accessible data

Freshwater-adapted CRIB Methodology



3 Maritime provinces

Primary watershed boundaries from Canada Open Data



Atlantic salmon
(Salmo salar)

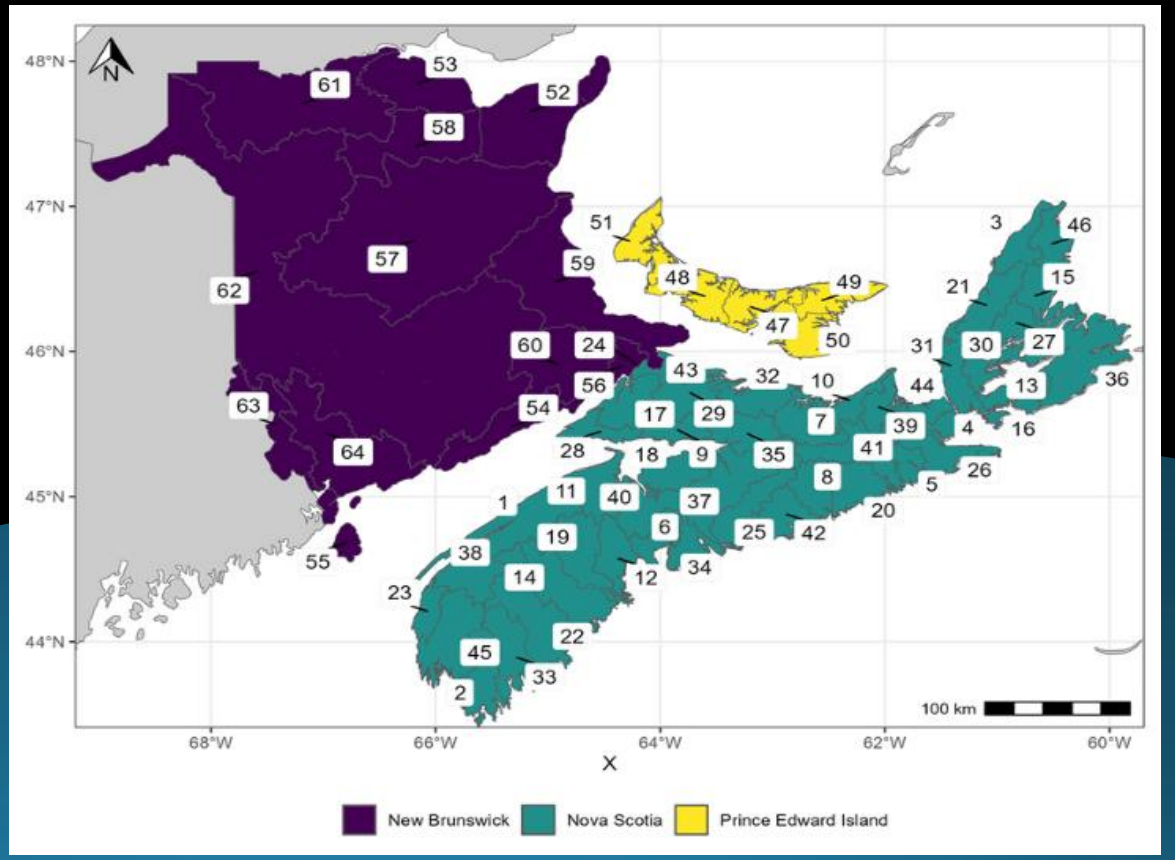
American eel
(Anguilla rostrata)

Atlantic whitefish
(Coregonus huntsmani)

Striped bass
(Morone saxatilis)

Brook trout
(Salvelinus fontinalis)

Alewife/ Gaspereau
(Alosa pseudoharengus)



Methods and data sources

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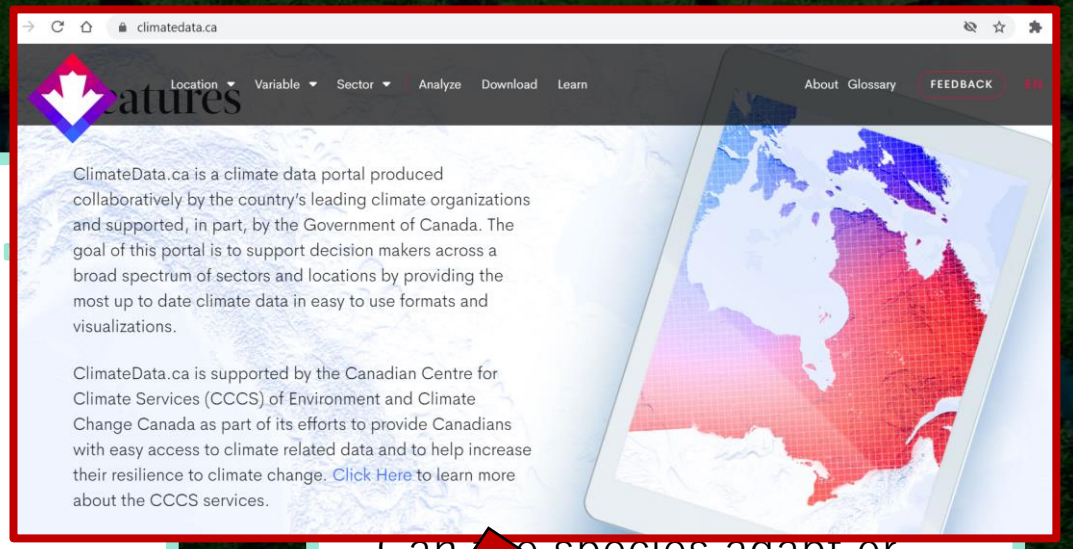

-3°C

Canadian Centre for Climate Services, Environment and Climate Change Canada -- 24 statistically downscaled climate scenario datasets, 3 emissions scenarios, from the Coupled Model Intercomparison Project Phase 5 (CMIP5).

- **Monthly mean and max near-surface (~1.5m) air temperature at 10km² resolution (2005-2100)**
- **Monthly total precipitation (mm), 1950-2100**

Time of thermal emergence

Thermal safety margin

- Projected habitat loss
- Timing of emergence from thermal niche
- Velocity of warming
- Magnitude of change in extreme precipitation frequency

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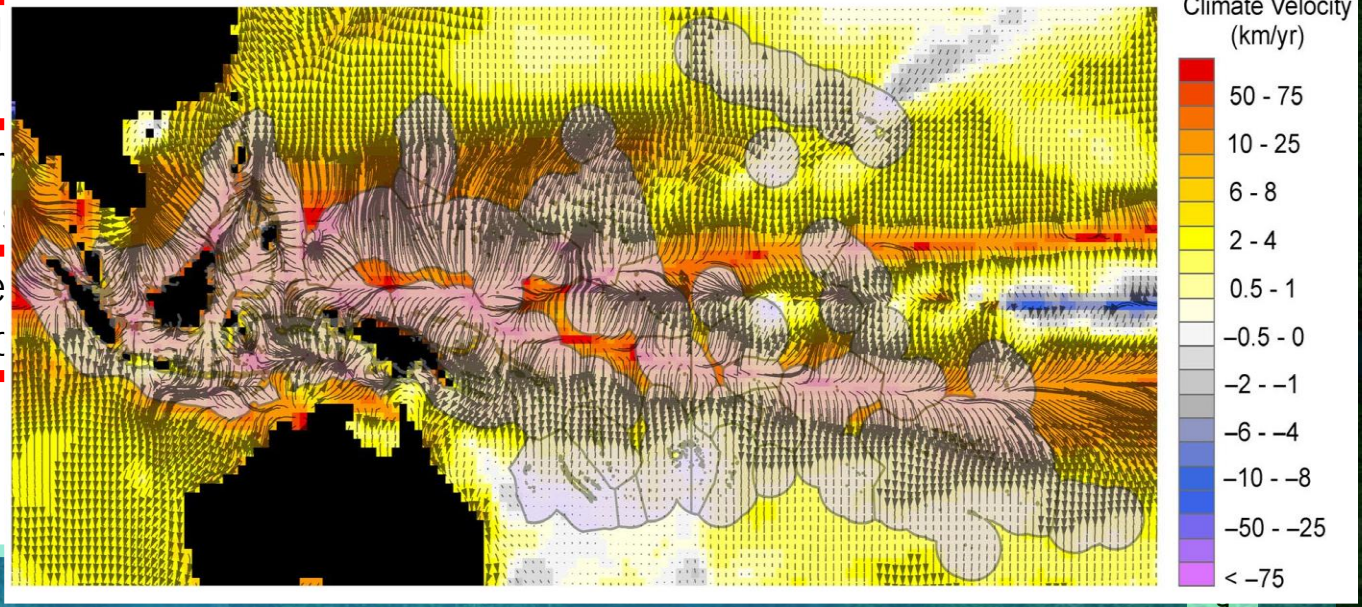
- Exploitation status
- Thermal margin
- Other ar stressor
- Projecte disruptic

Climate velocity (warming)



García Molinos et al. 2019: VoCC R package

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Average proportion of "extreme" (sd > 1) days per year over 2075-2100

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Committee on the Status of Endangered Wildlife in Canada

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Fishbase.org / local literature

FishBase
ver. (02/2022)

Methods and data sources

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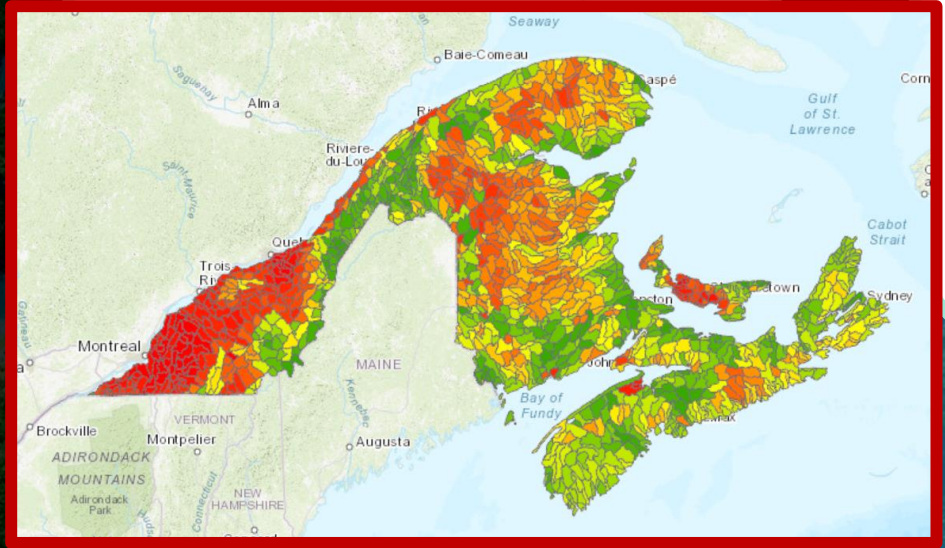
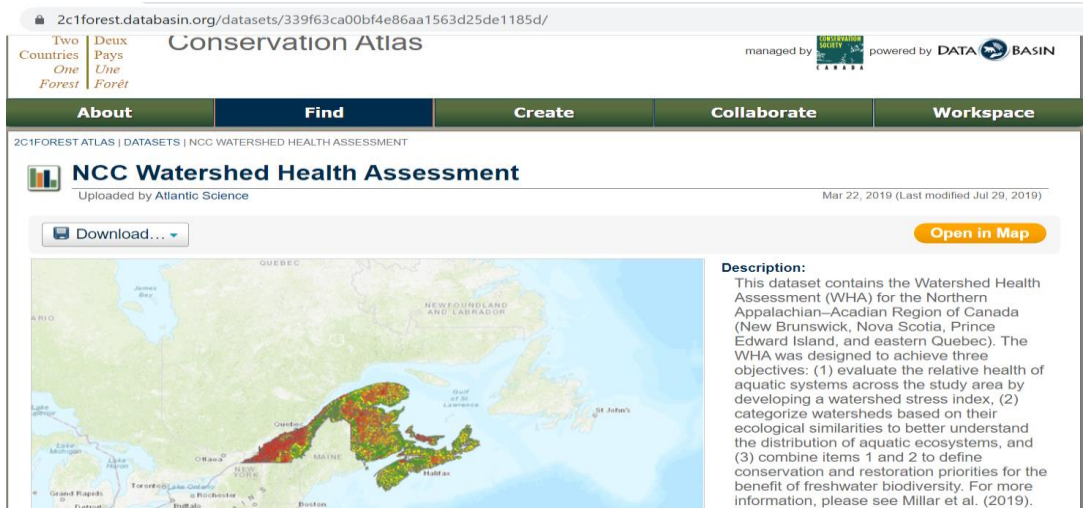


- Cumulative human impacts and climate resilience (including habitat connectivity and diversity) data available through Nature Conservancy of Canada



- Other anthropogenic stressors
- Projected ecosystem disruption

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Index Results

Atlantic salmon
(Salmo salar)

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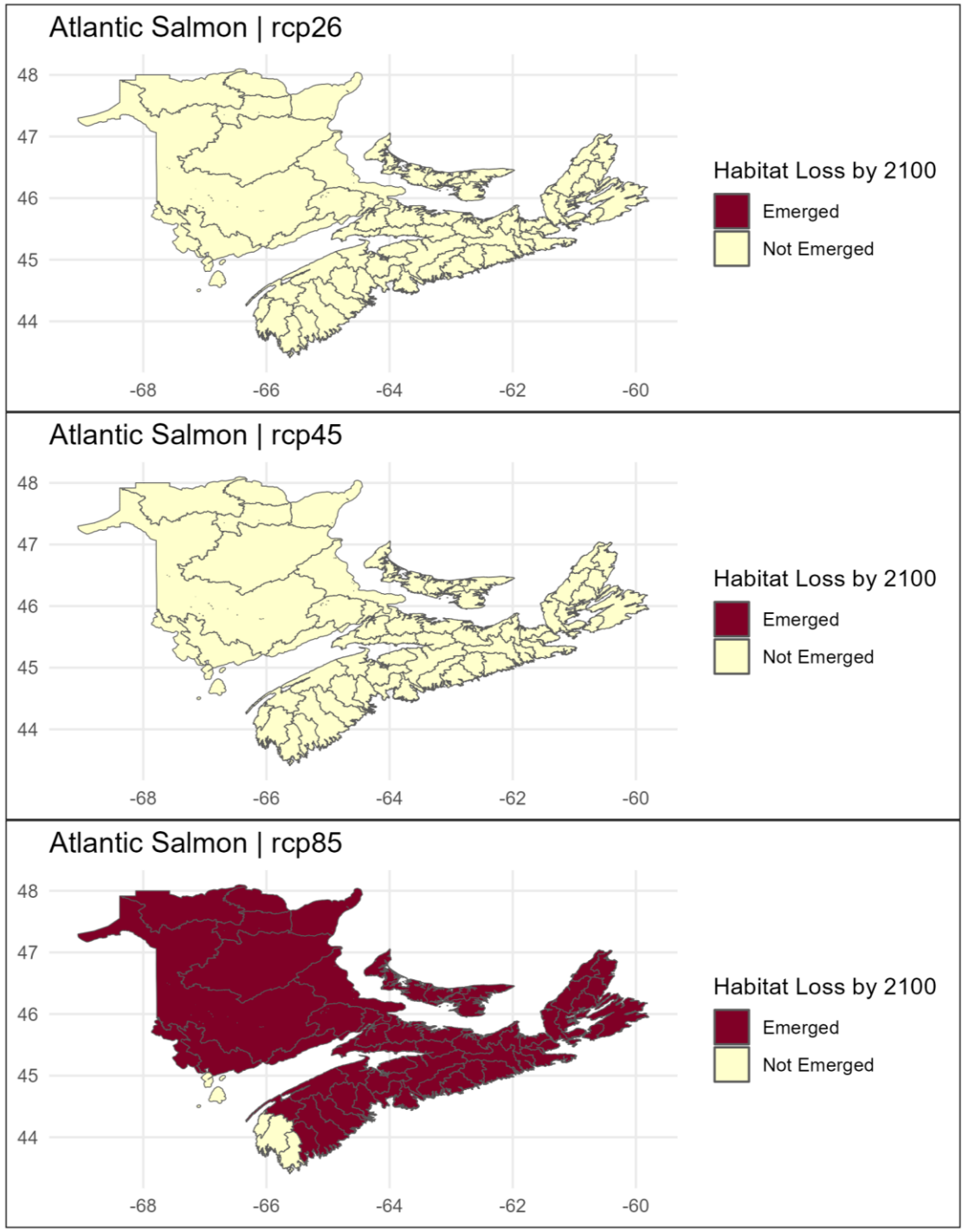

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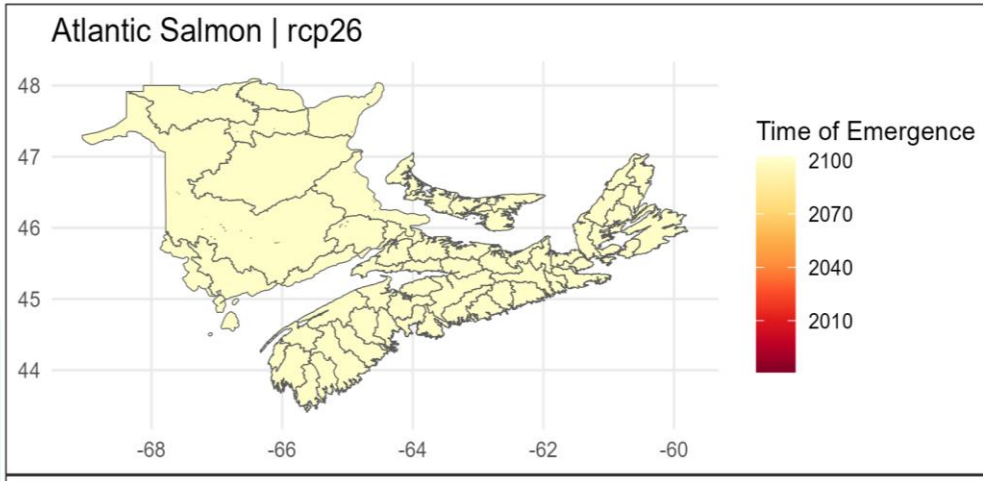

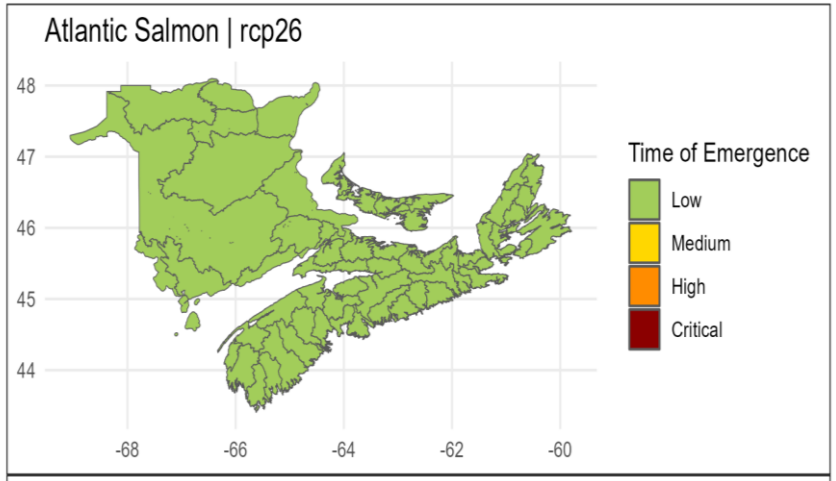

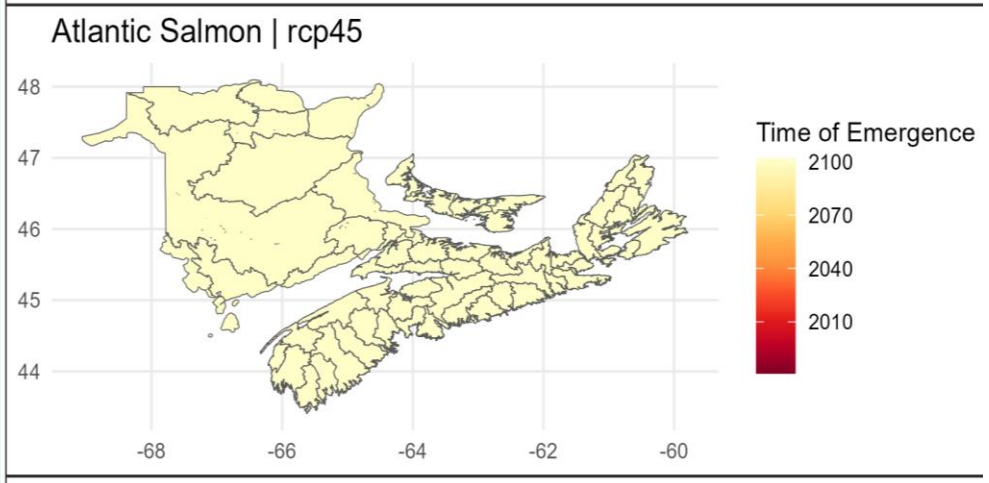

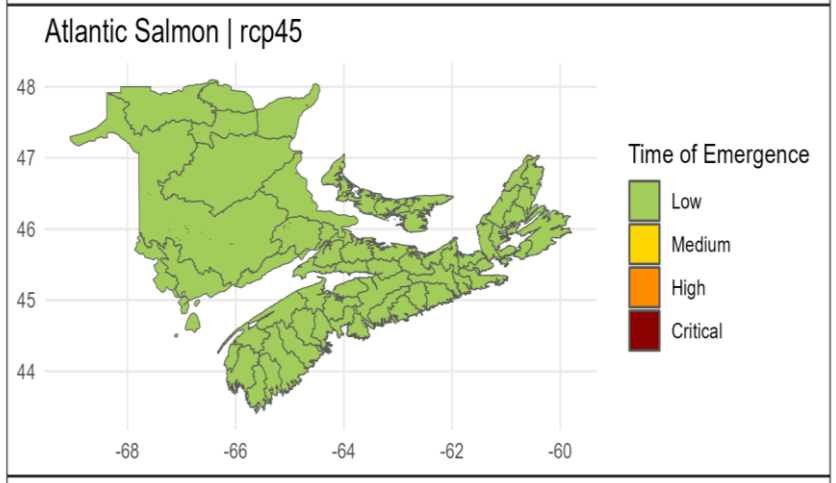

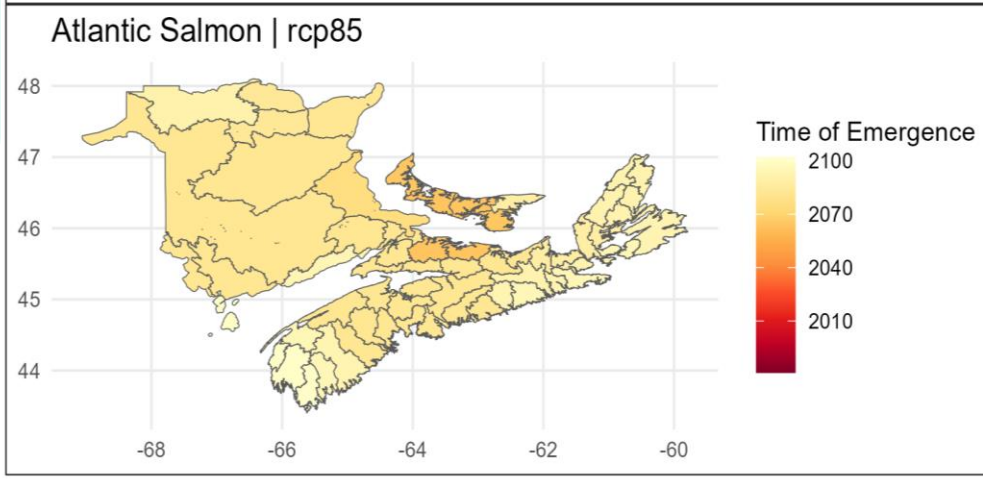

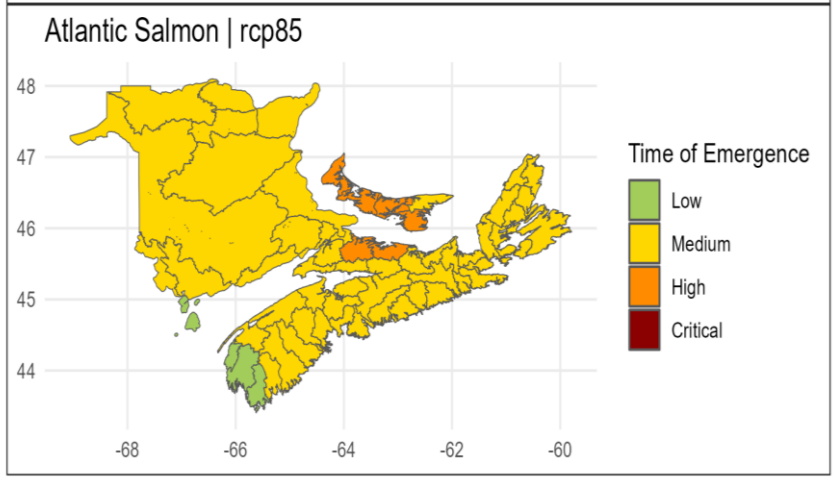

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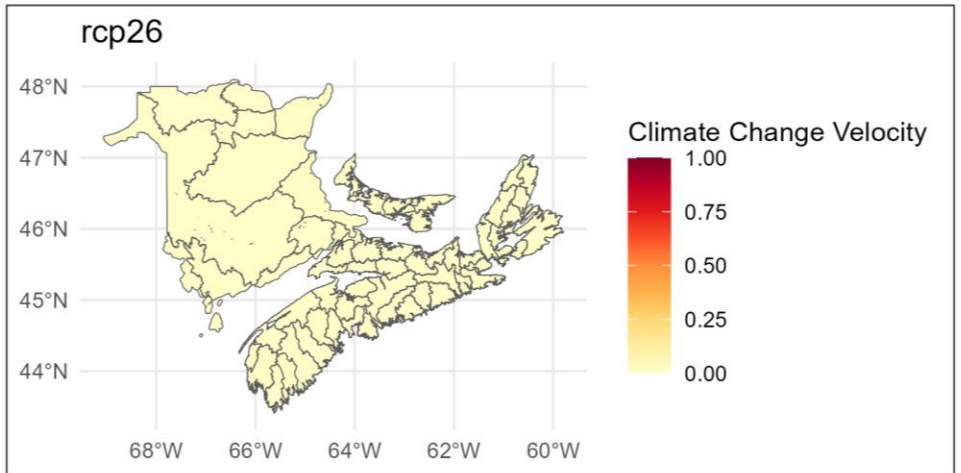

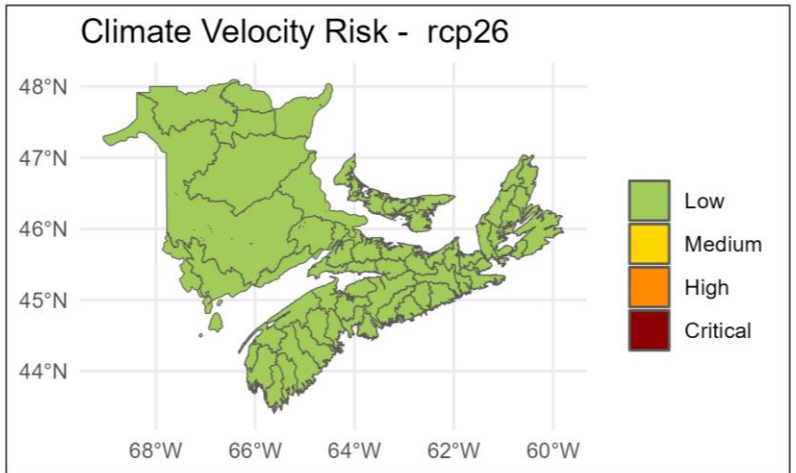

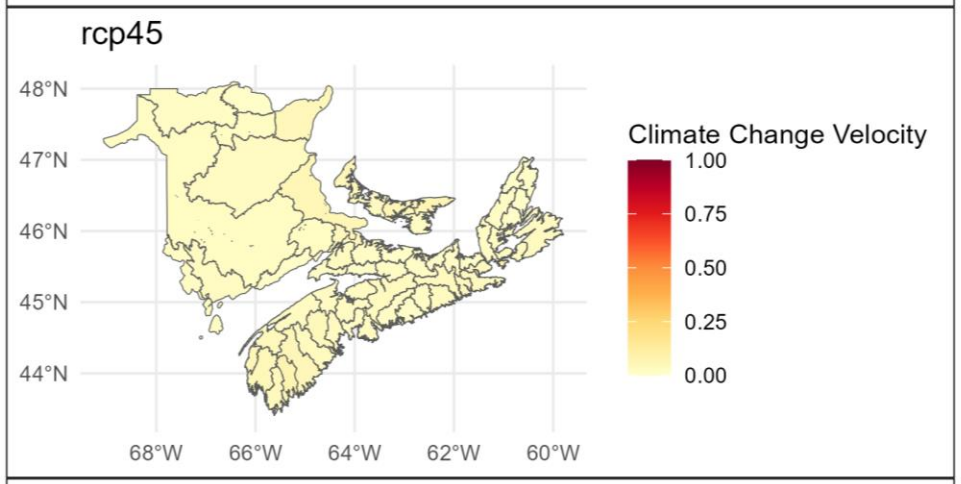

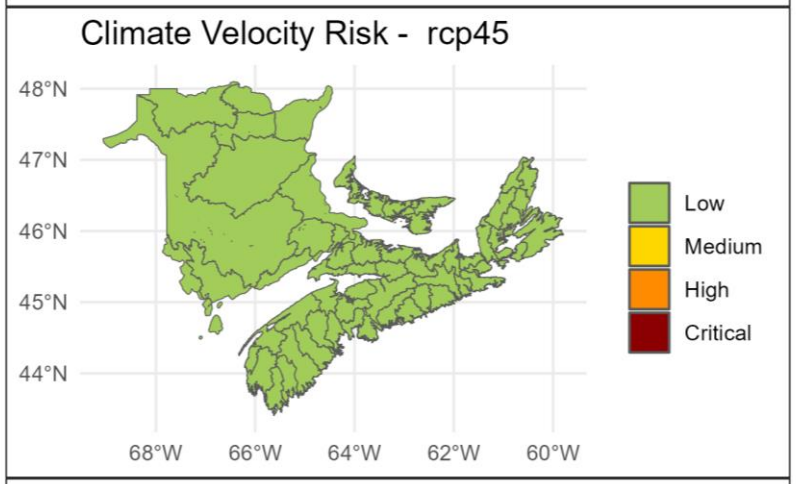

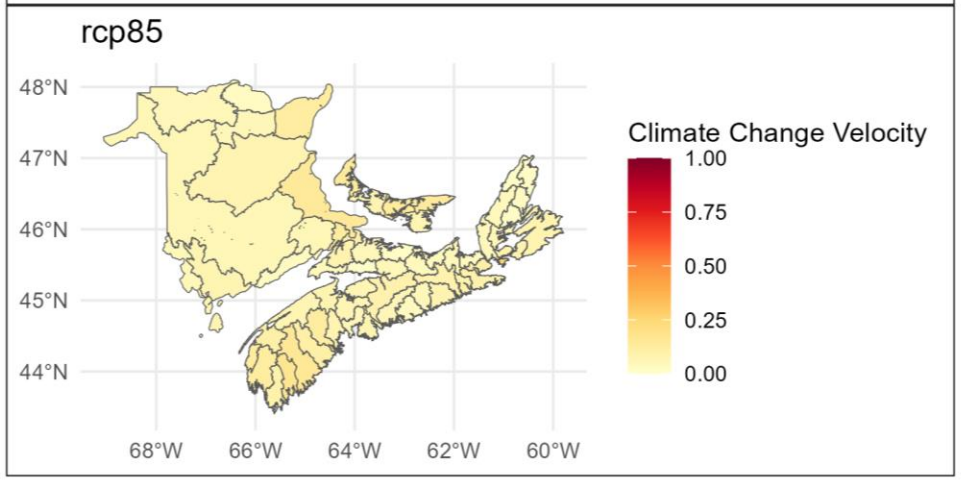

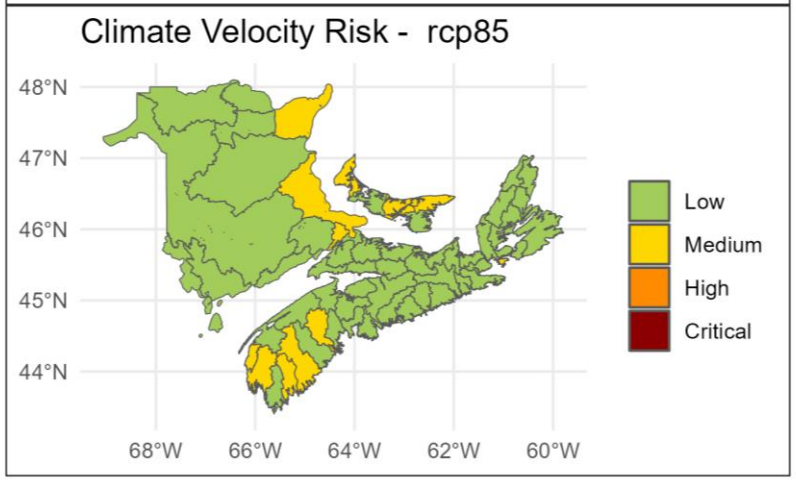

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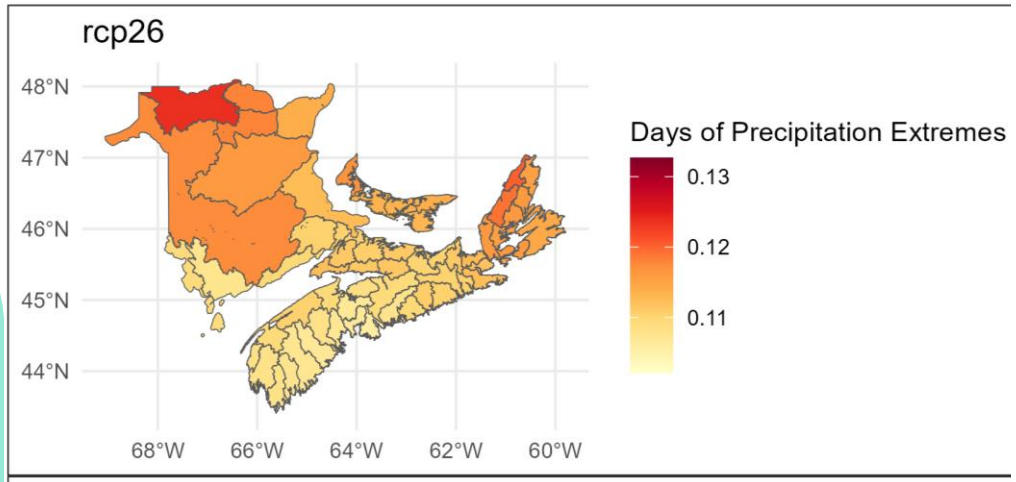
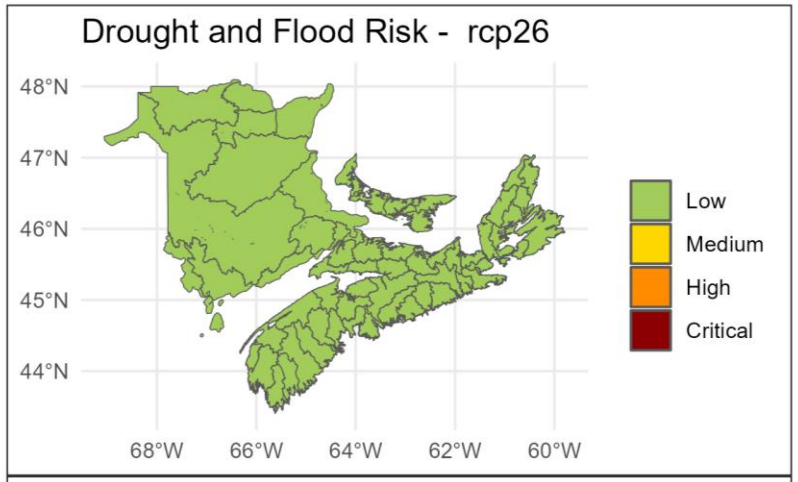
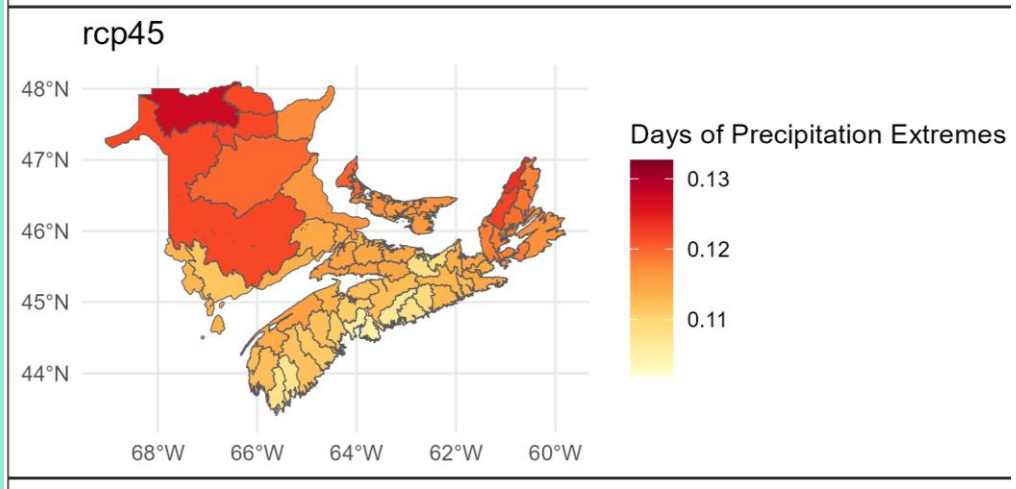
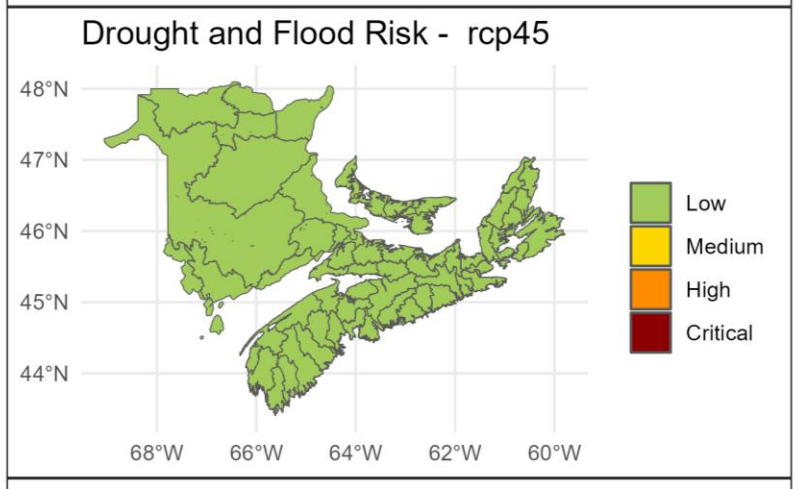
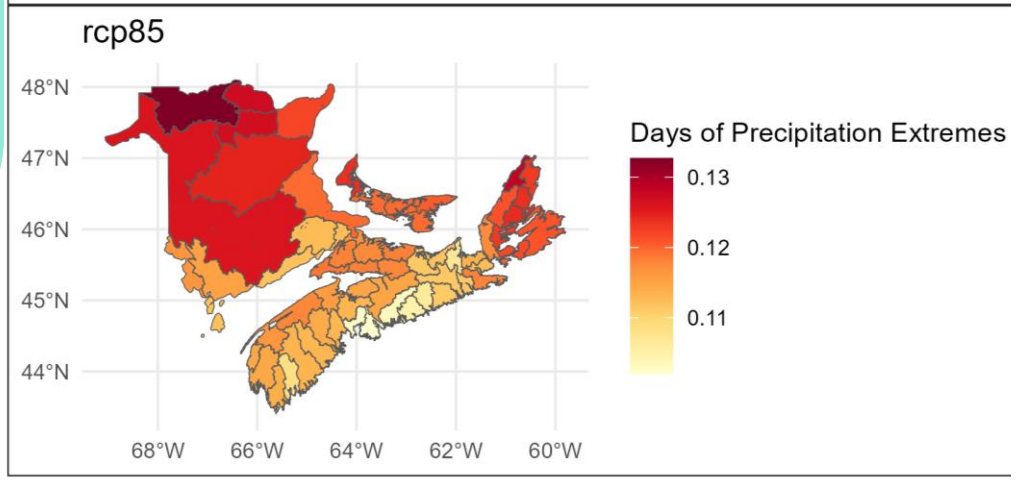
- ***Low Risk** for all watersheds, for all RCPs.

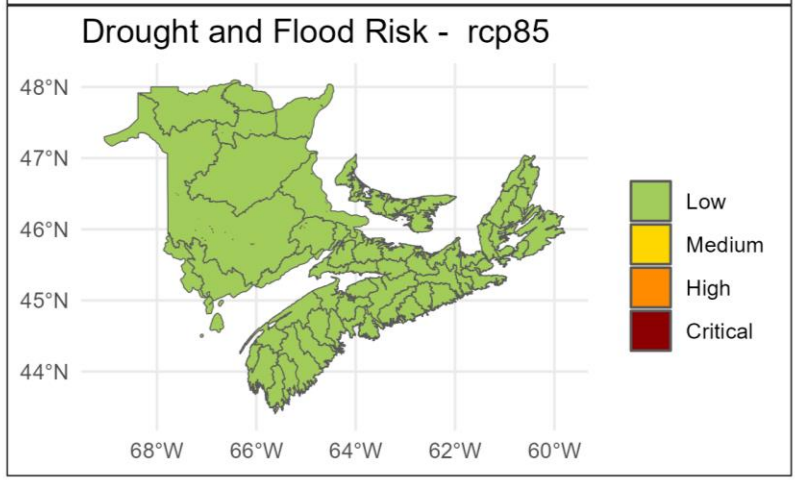










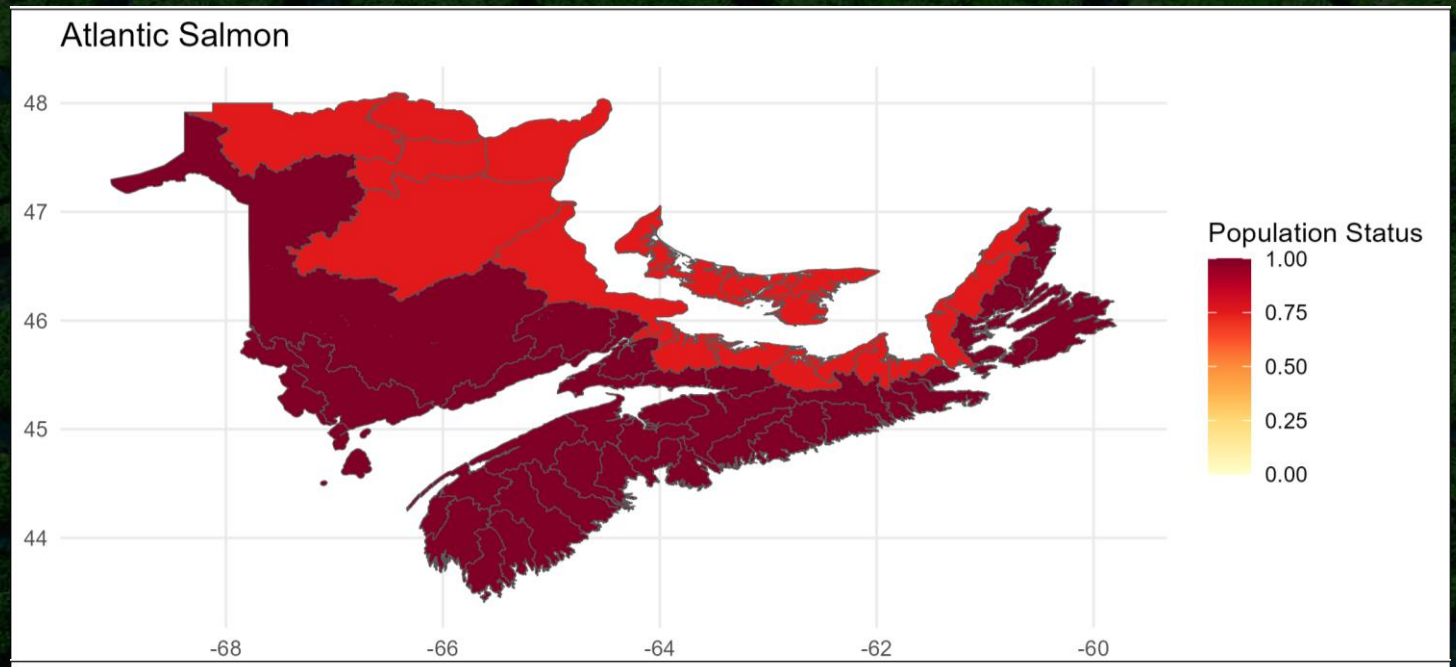


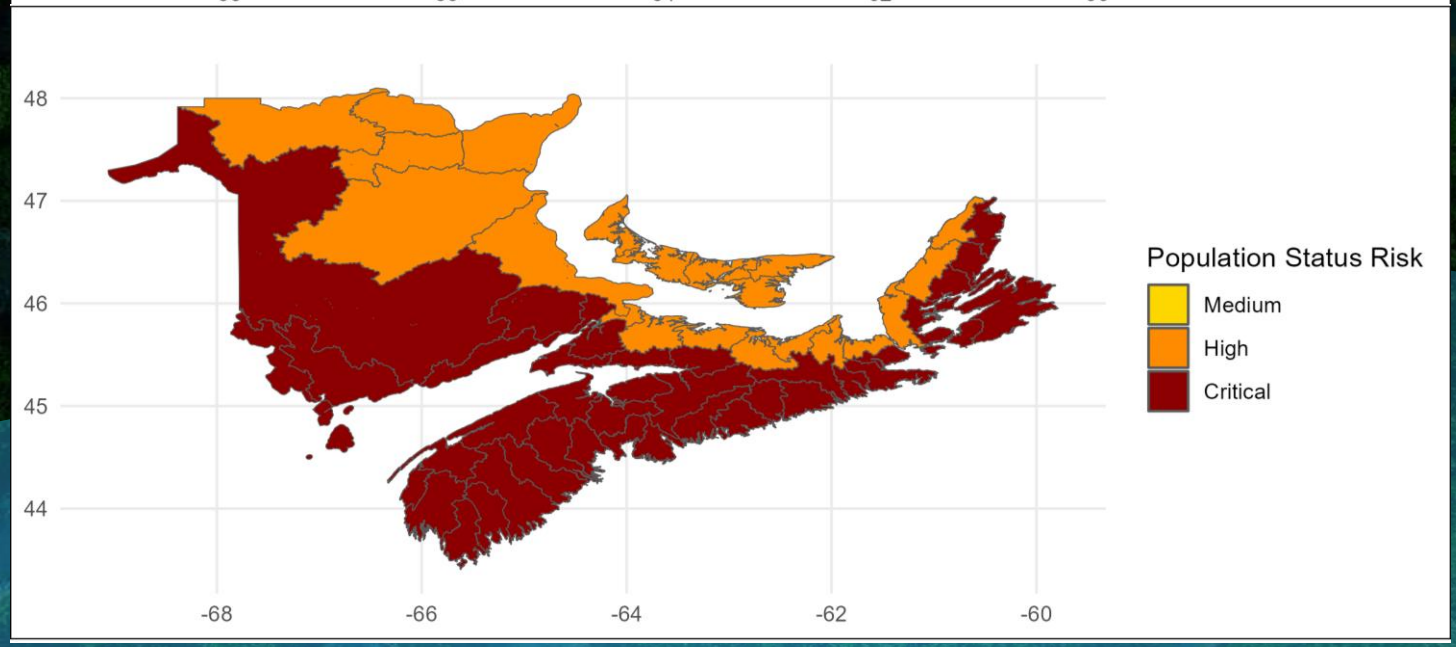
Sensitivity

Is the species already imperiled?

- Exploitation status
- Thermal pressure/safety margin
- Other anthropogenic stressors
- Projected ecosystem disruption

Committee on the Status of Endangered Wildlife in Canada (COSEWIC assessment)





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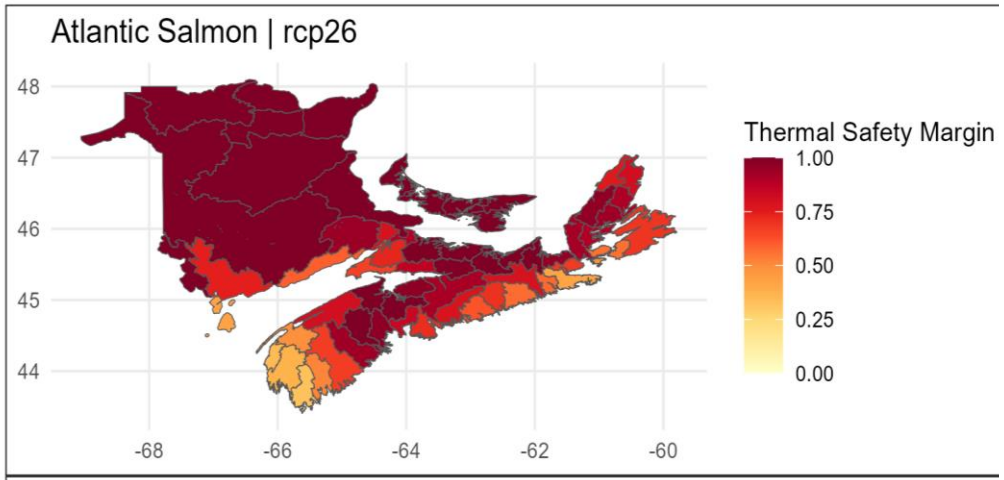

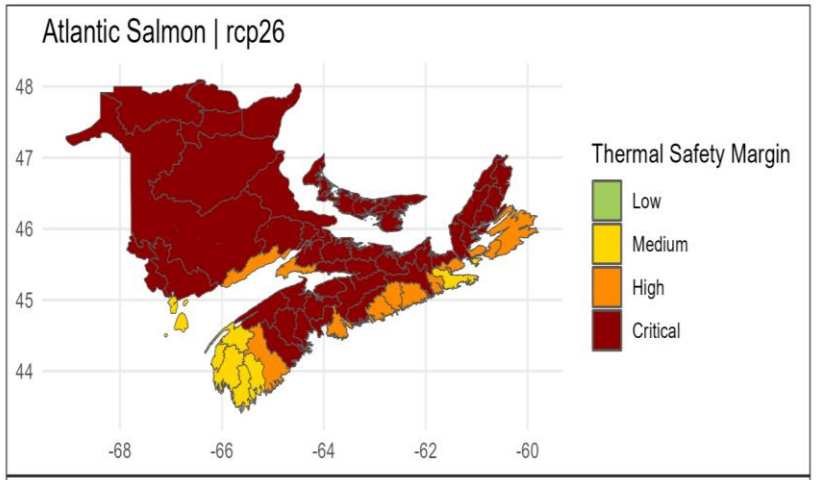

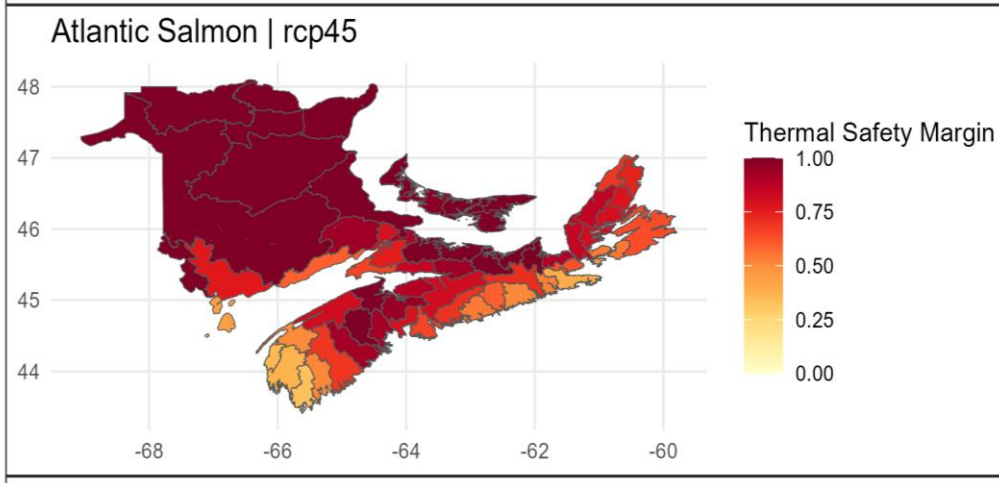

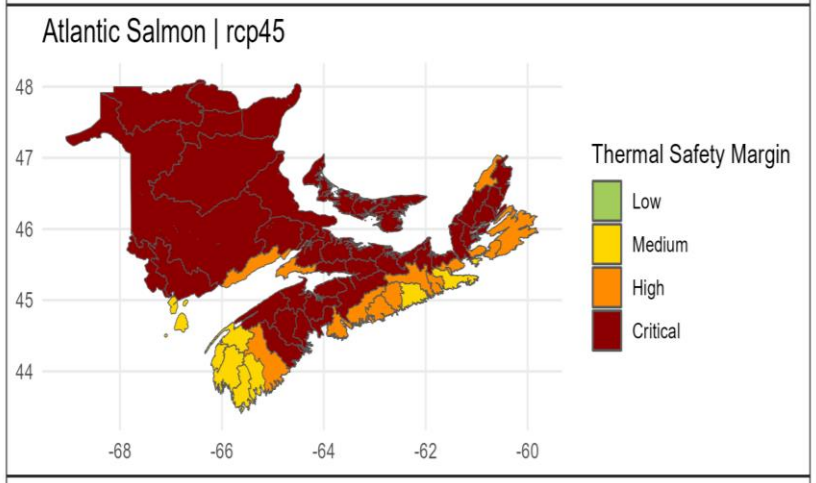

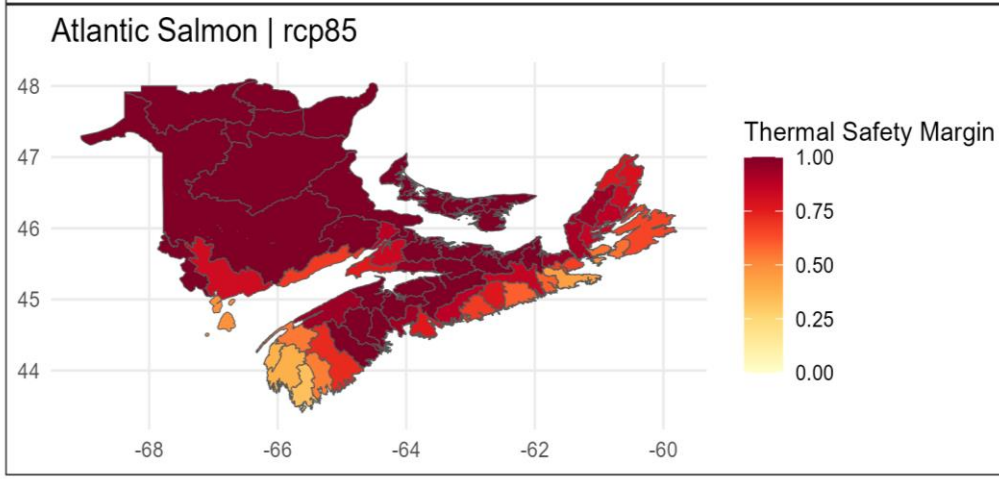

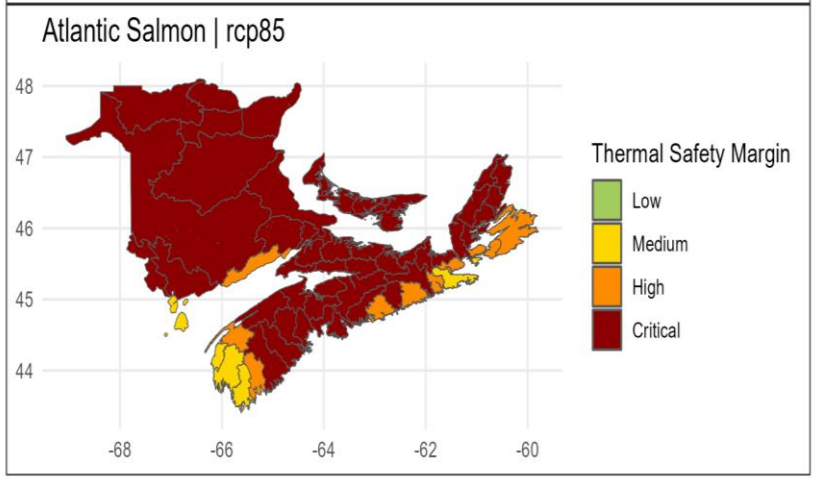

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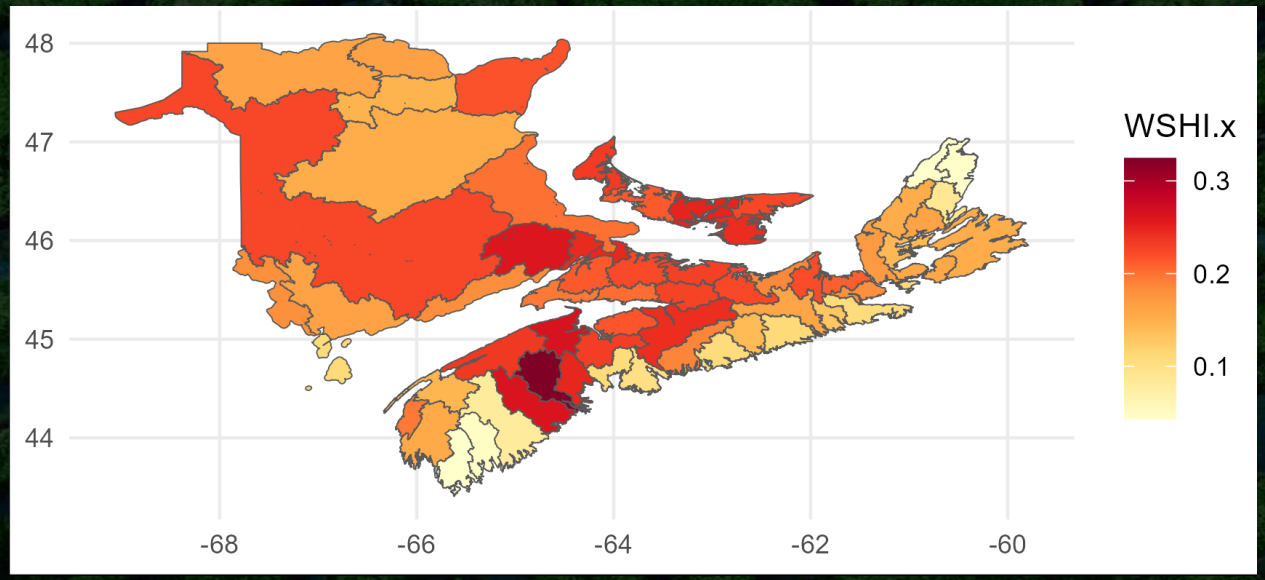

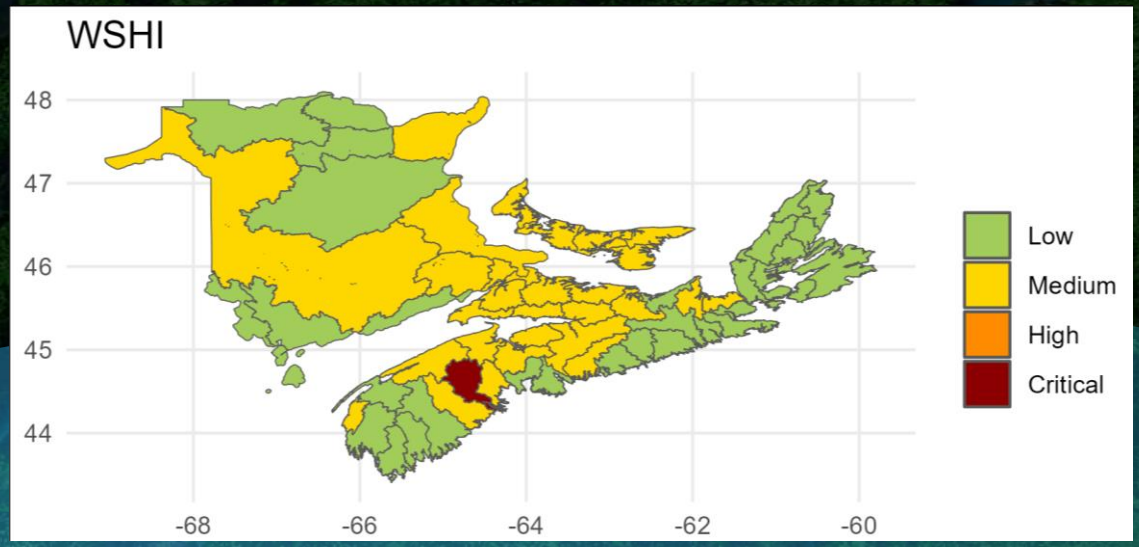

Other anthropogenic stressors

Un-paved roads, impervious surfaces, non-native fish, percent areal coverage of clear cut forests, crop land, and pasture land, point-source pollution (metal, nutrients, and organic), acid deposition, leaching (nitrogen, pesticides, and phosphorus)

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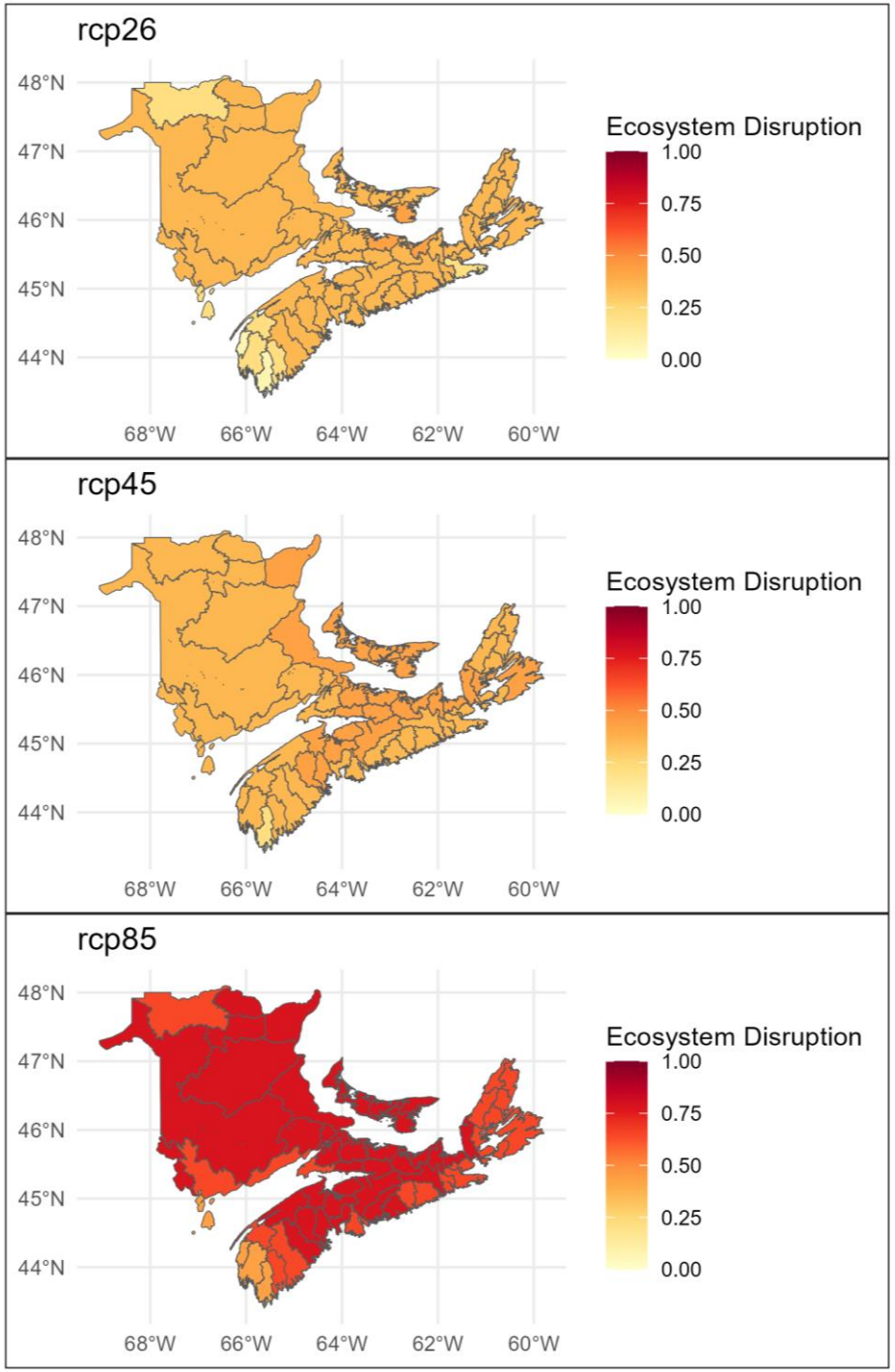

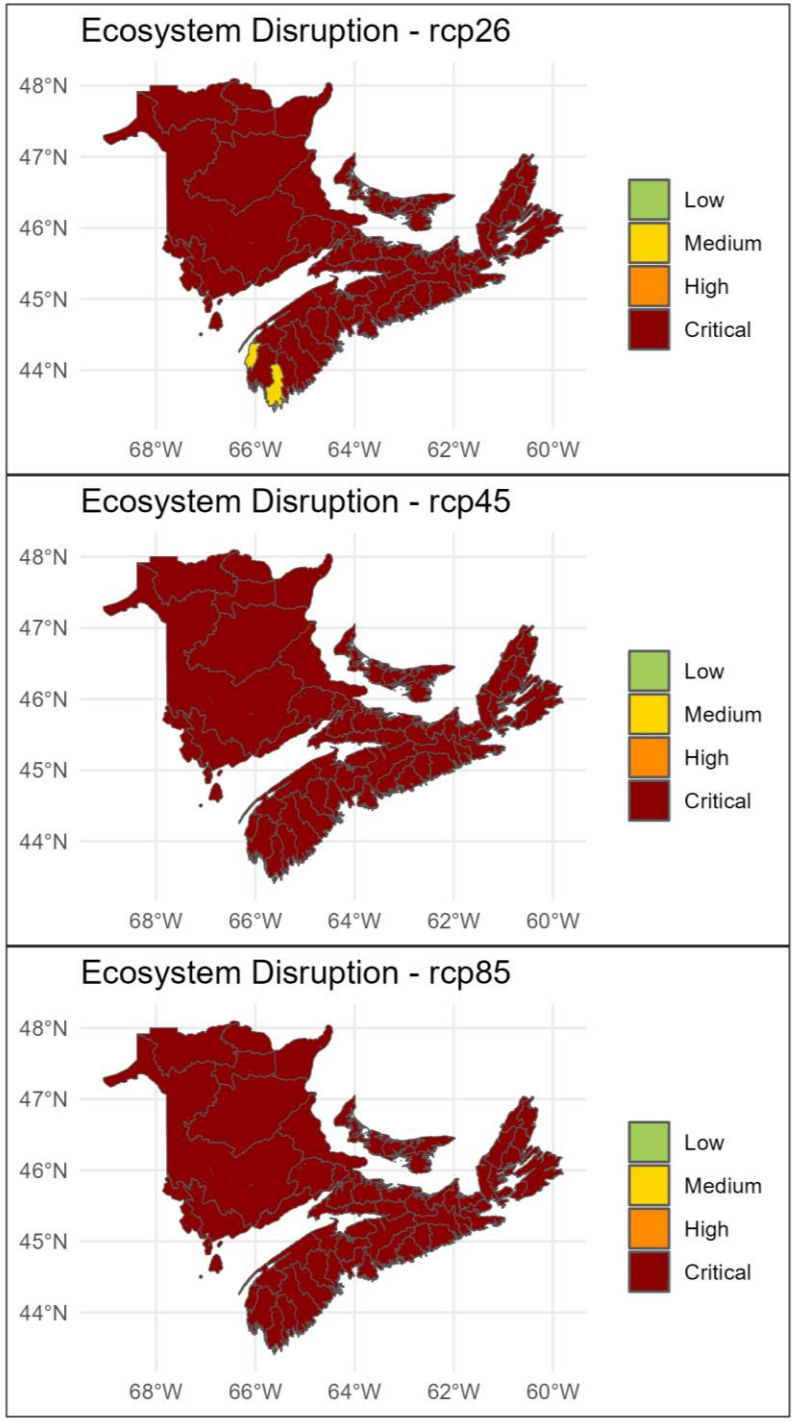

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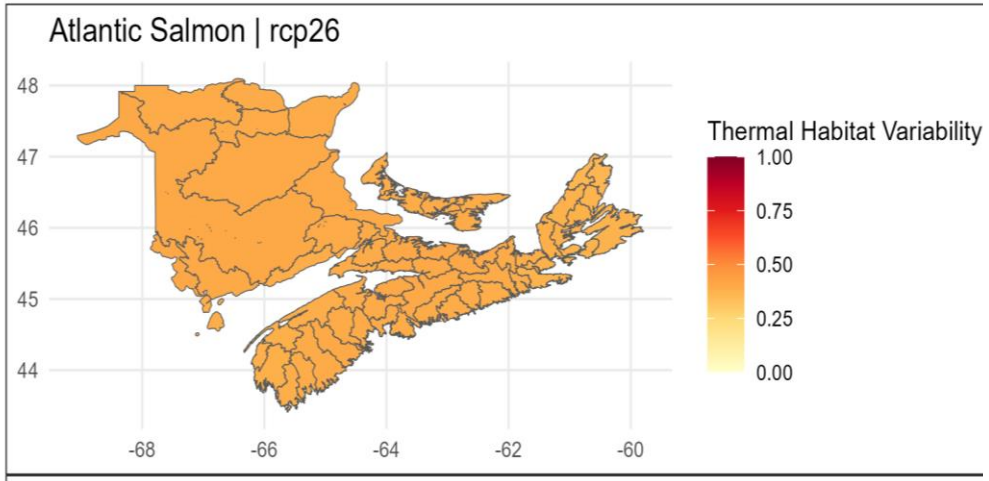

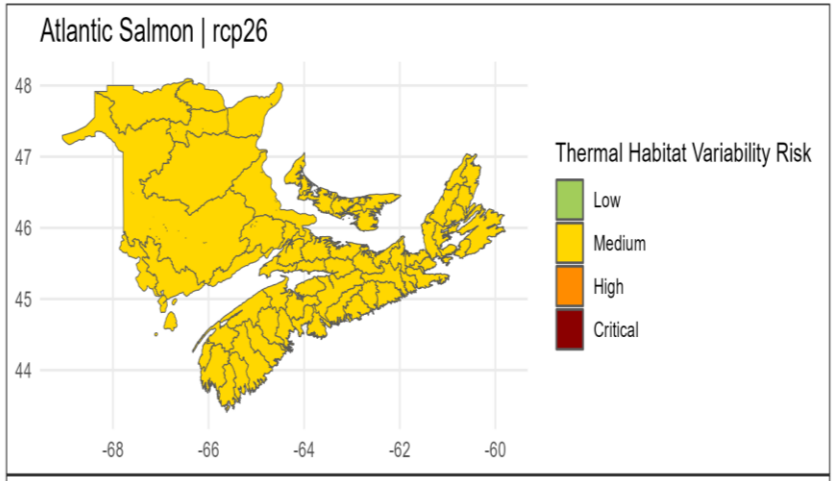

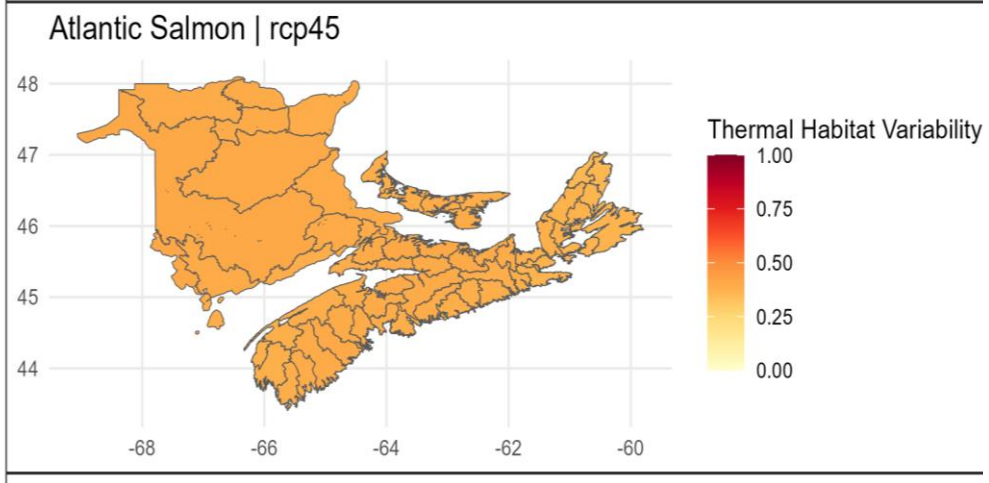

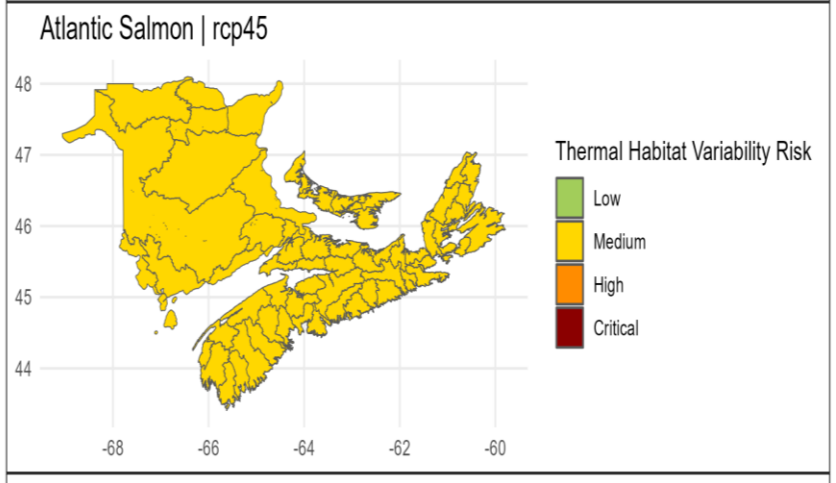

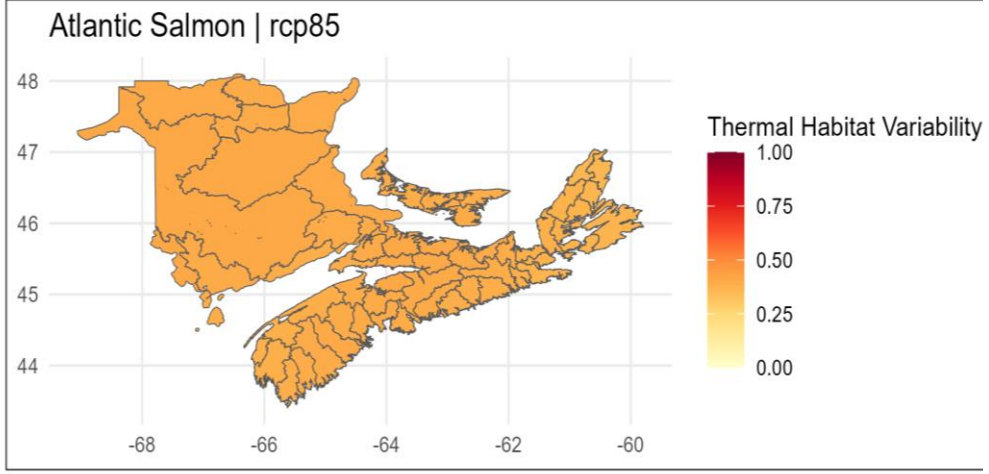

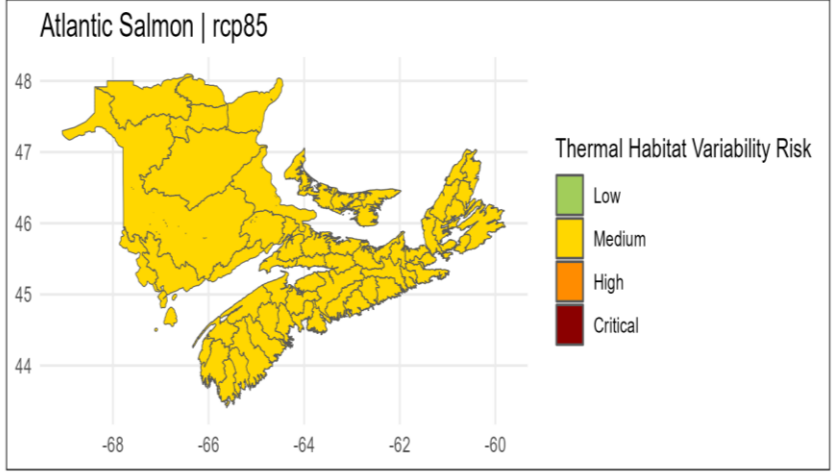

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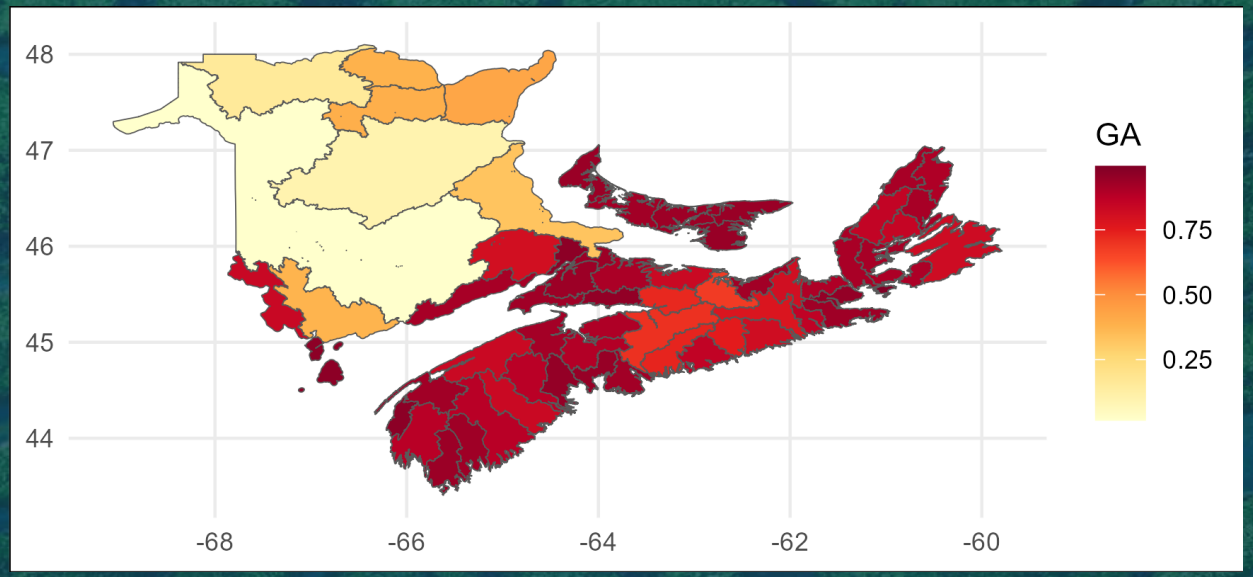

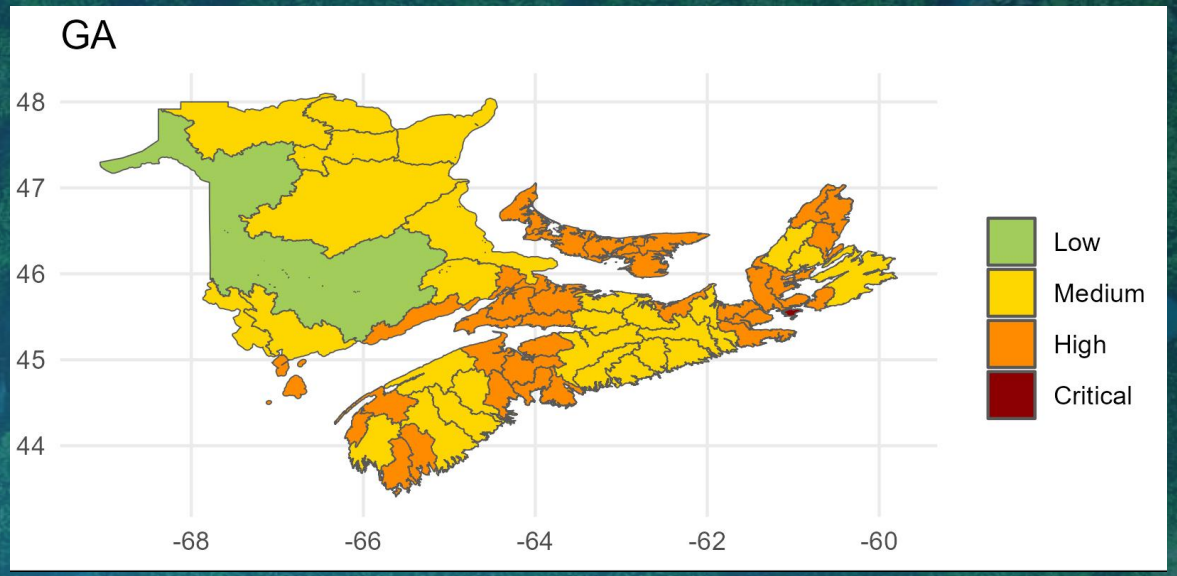

Amount of habitat

Km^2 of aquatic habitat (index of available habitat)

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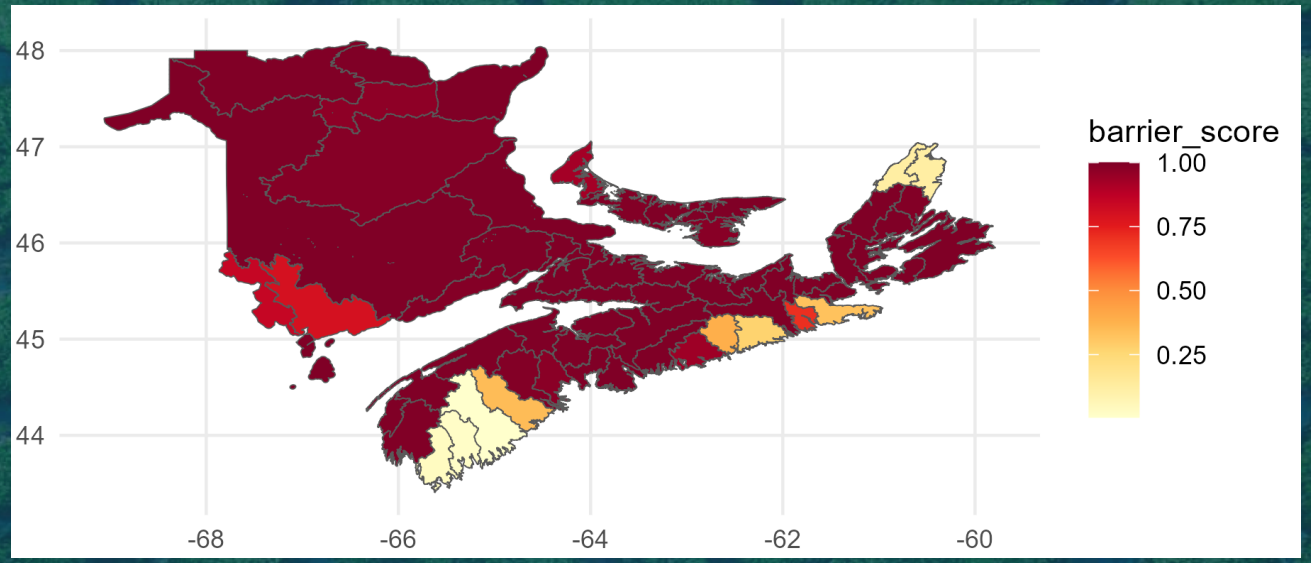
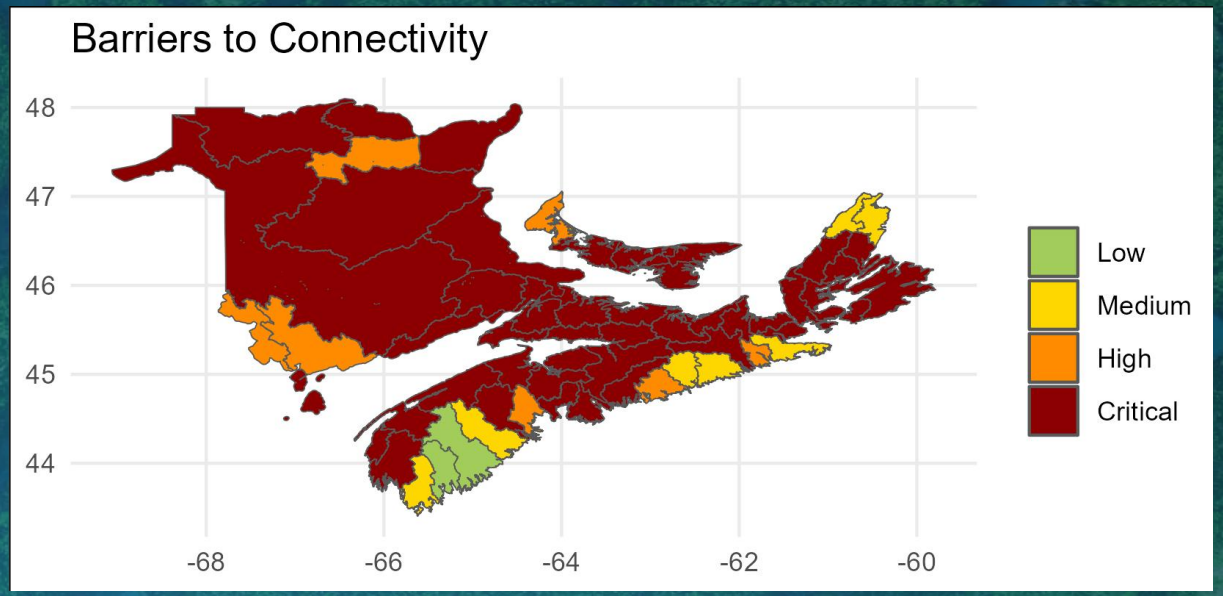
- Connectivity of habitat
- Body size as a proxy for life history





Connectivity
Density of roads, dams, culverts, weighted by passability

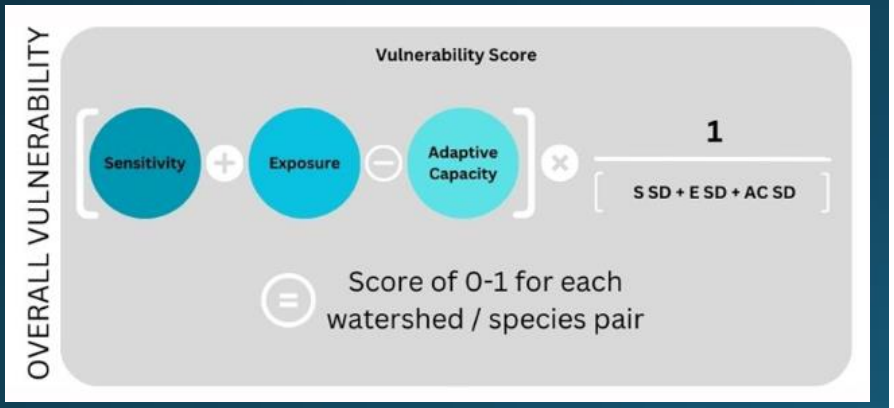
Adaptive capacity

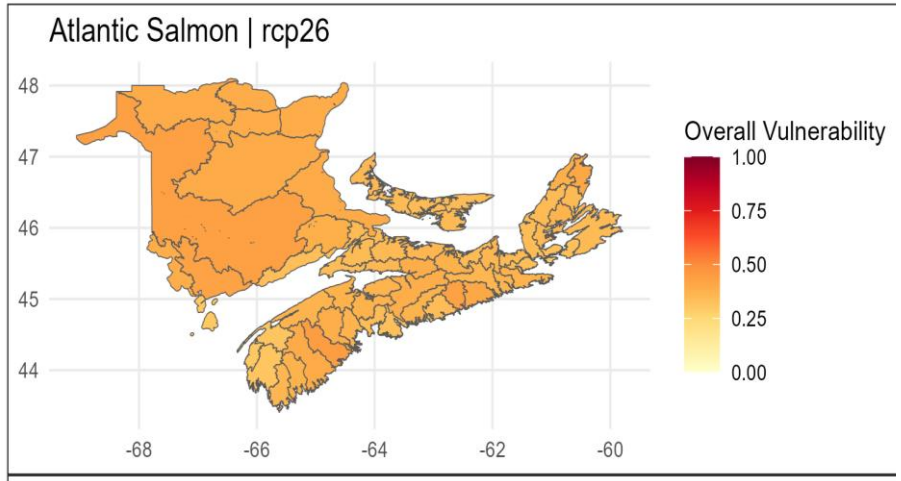
Can the species adapt or shift in distribution?

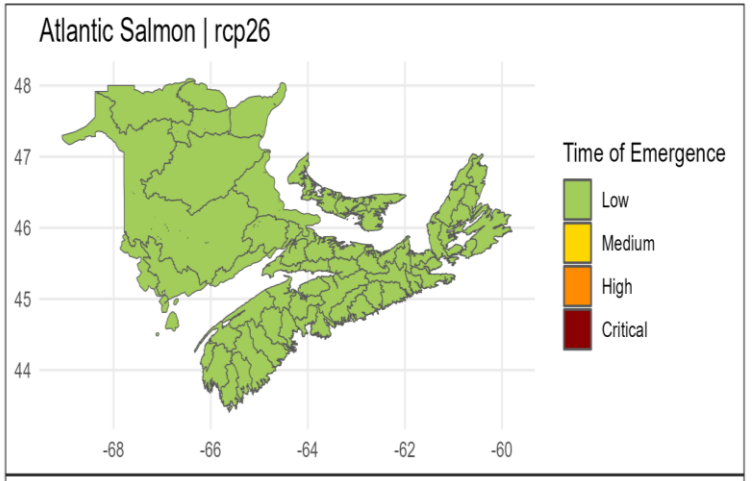
- Historical thermal variability
- Amount of habitat
- Connectivity of habitat
- Body size as a proxy for life history

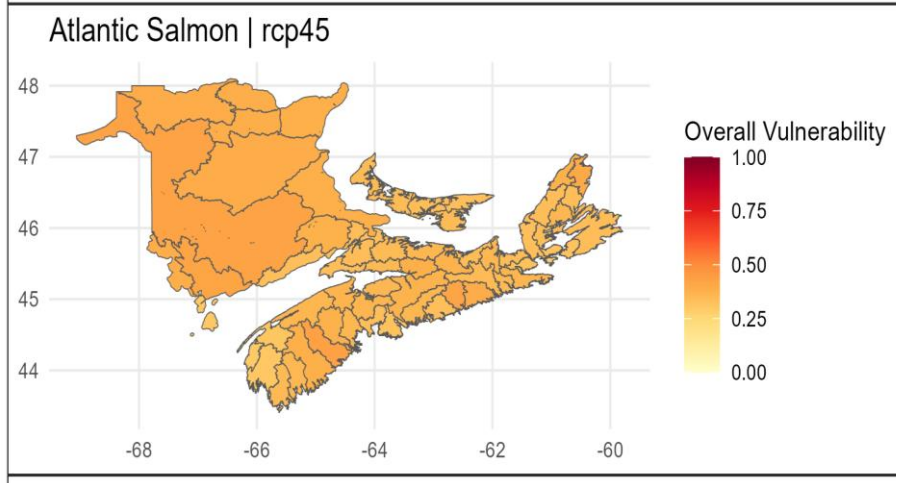
Atlantic salmon (*Salmo salar*)
Max length 150cm – low risk category

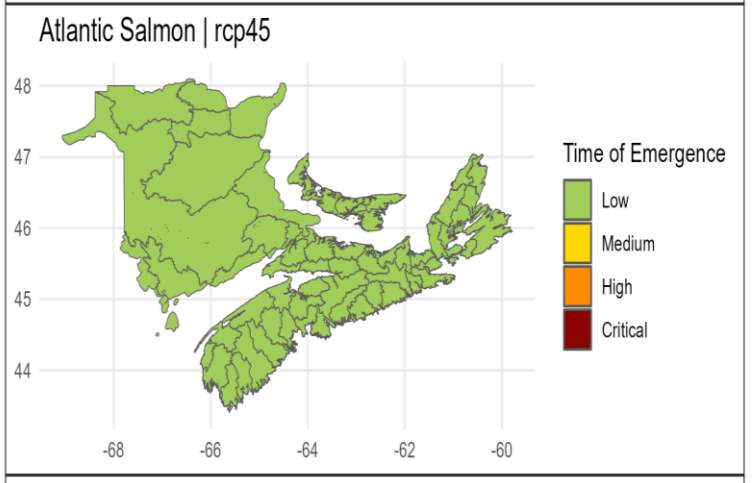
Overall Vulnerability

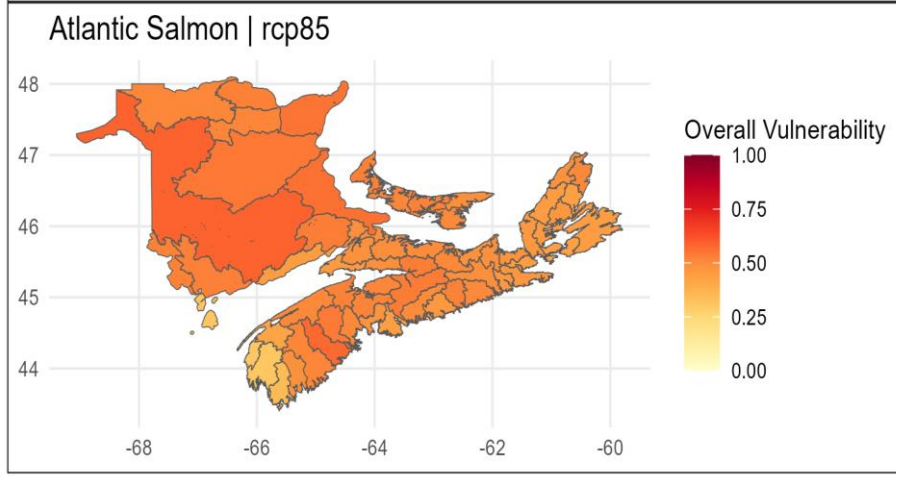


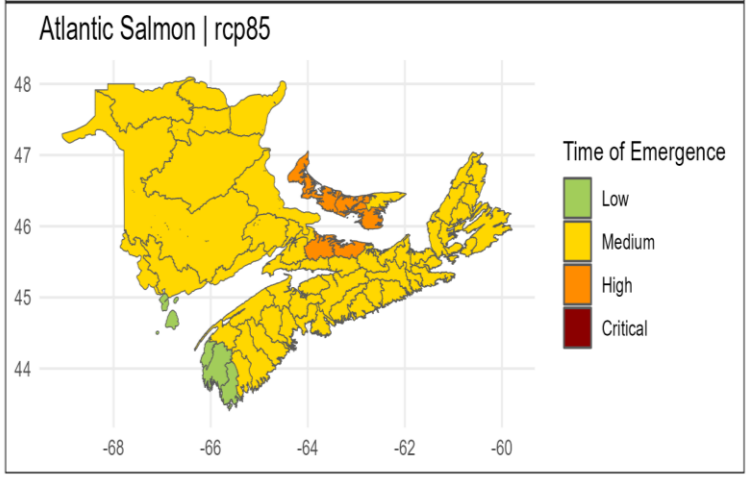


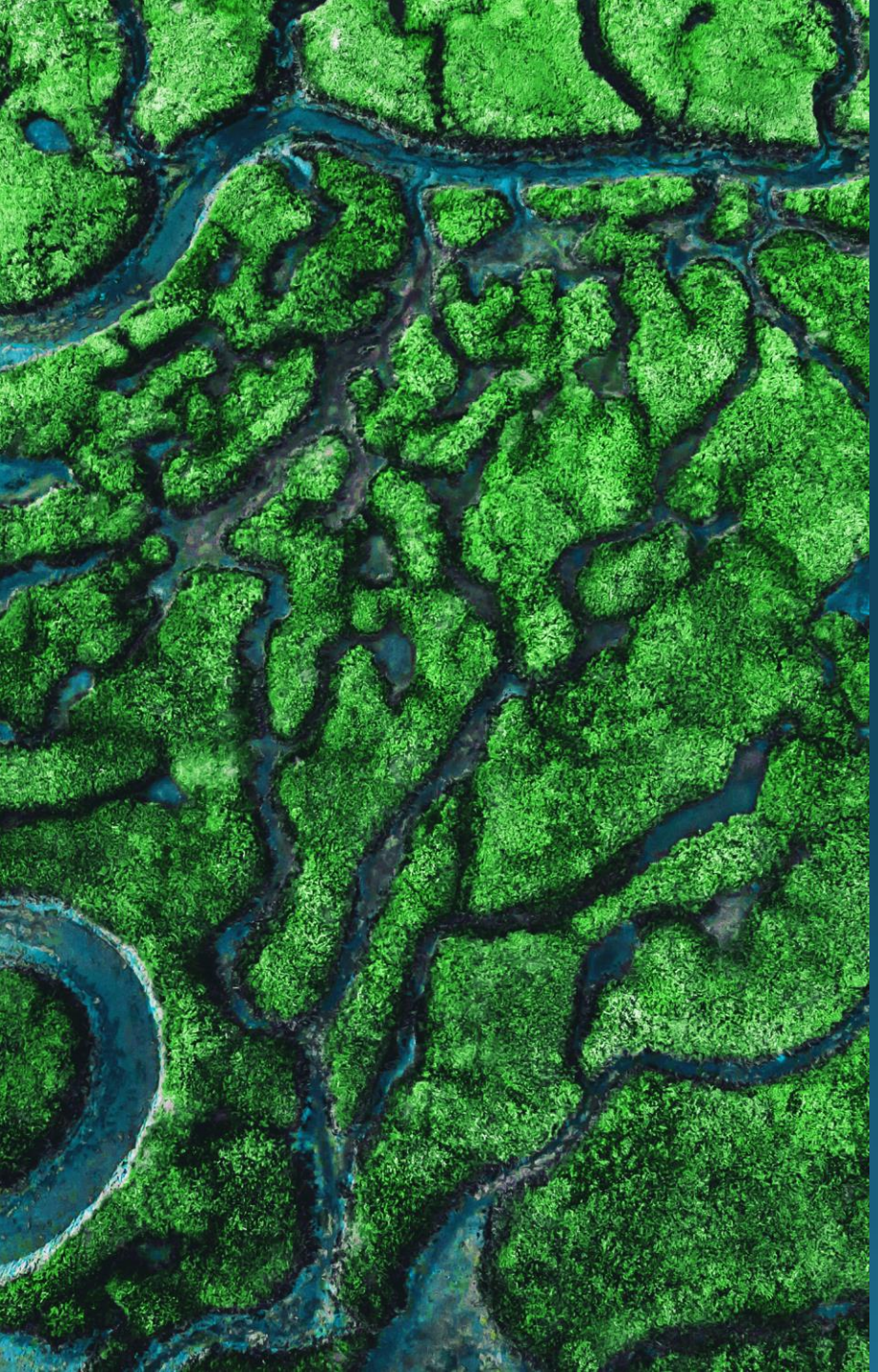












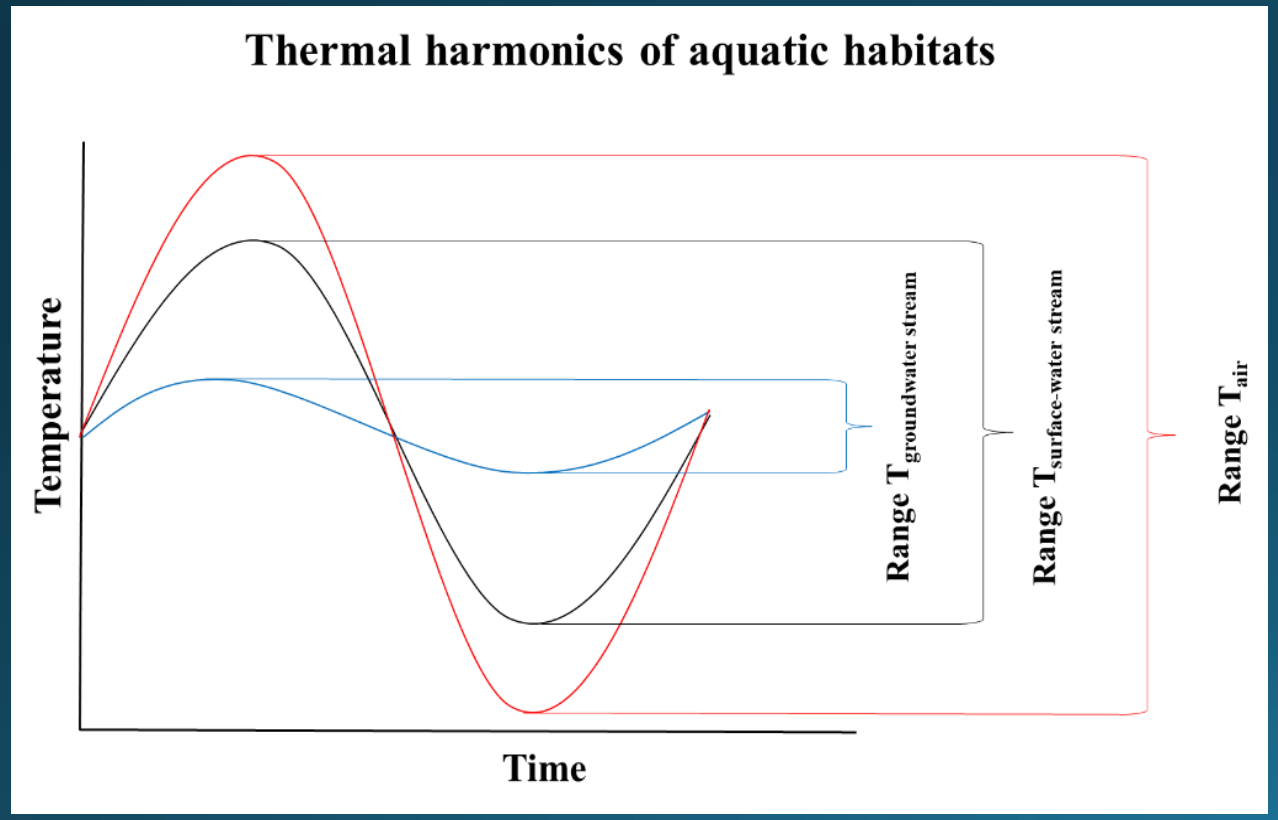
How can this help freshwater management?

- *NB: Important to consider vulnerability within the context of individual index scores*

- Low climate vulnerability areas can be protected as refuges.
- Low vulnerability areas where species is currently not observed may present opportunities for re-introduction.
- Low climate vulnerability areas with high impact from other stressors may require remediation/ restoration
- High climate vulnerability areas with low impact from other stressors may be monitored for change as date of expected extirpation approaches.

CAVEAT:
Watershed resistance to warming

Thermal resilience is linked to groundwater (Hare et al., 2021 – Nat. Comm).



Credit: Antoin O'Sullivan, UNB

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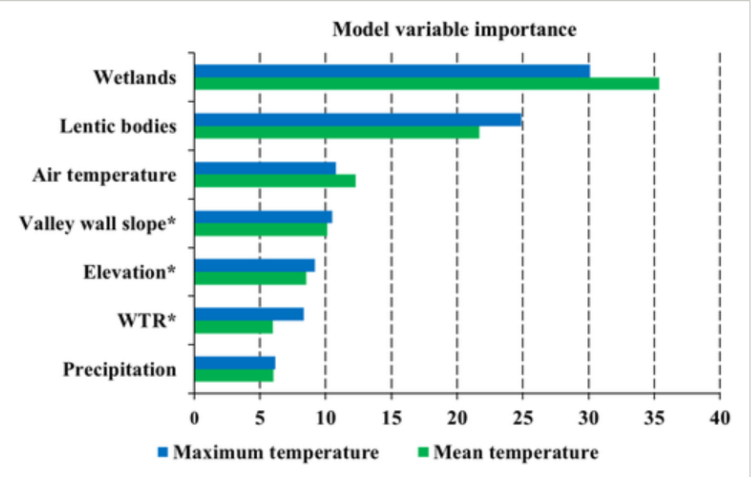
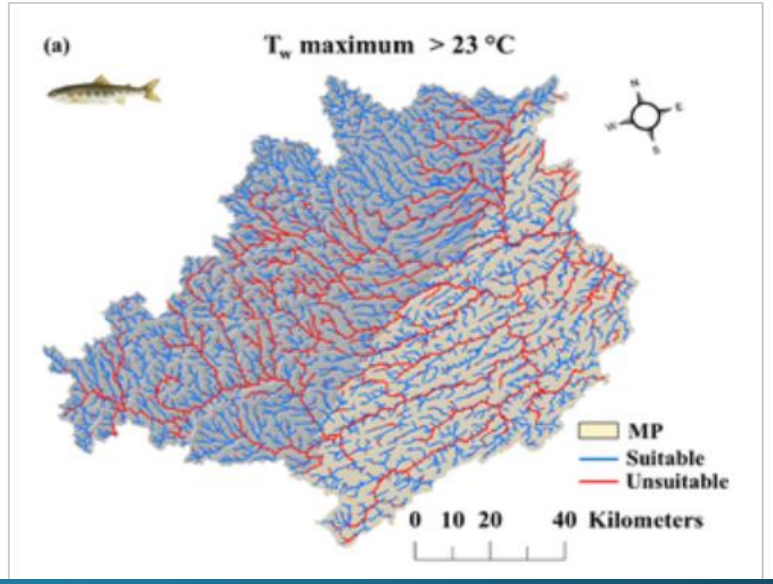
Salmonid thermal habitat contraction in a hydrogeologically complex setting

Antóin M. O'Sullivan, Emily Corey, Richard A. Cunjak, Tommi Linnansaari, R. Allen Curry,

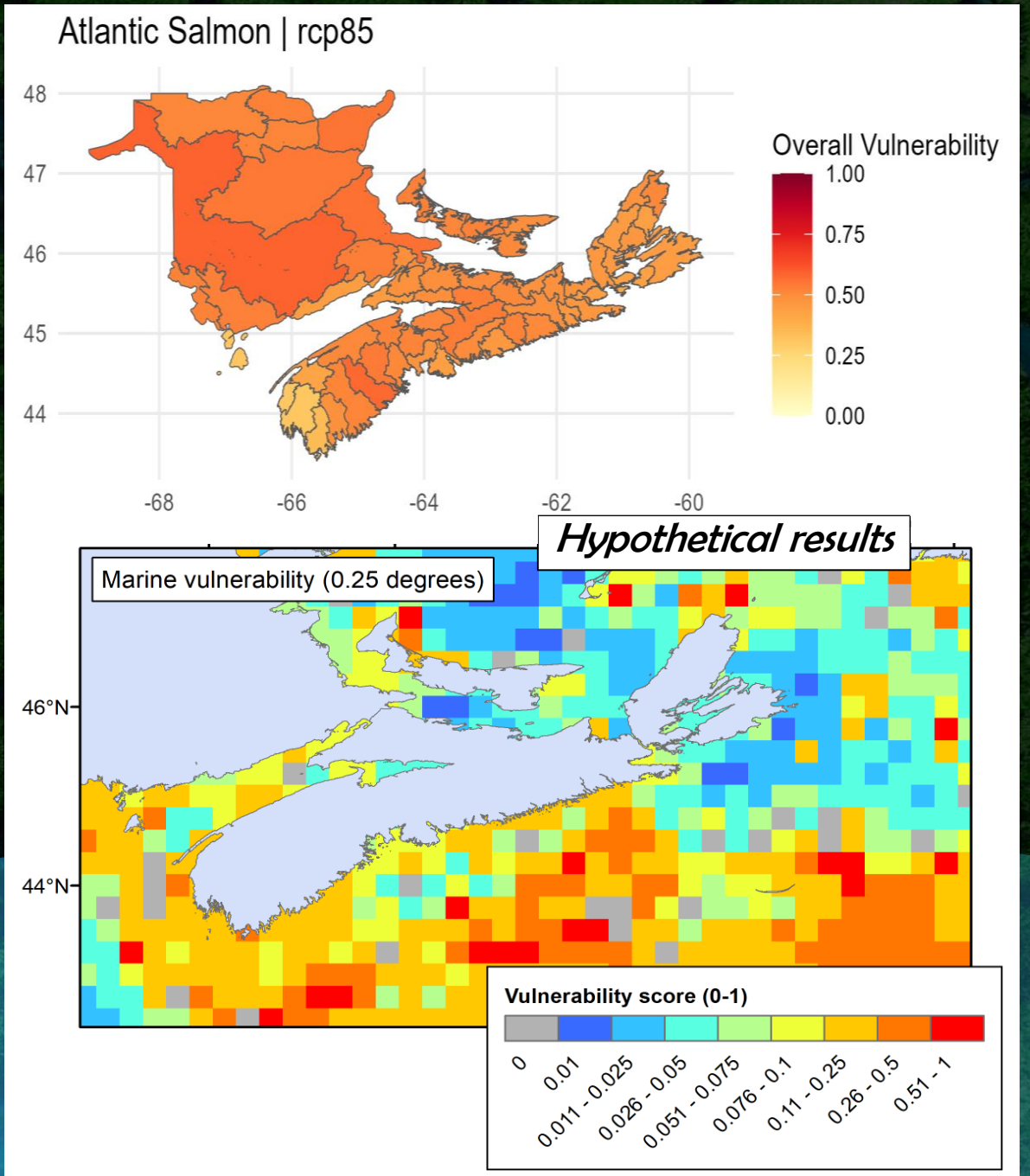
First published: 27 October 2021 | https://doi.org/10.1002/ecs2.3797





Plan to combine with marine vulnerability scores from D. Boyce et al. following marine assessment for diadromous species.

(not previously included).



Thank you!

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Freshwater Climate Risk Index for Biodiversity (FW-CRIB): Using Climate Change Vulnerability and Risk Assessments (CCVA/CCRA) to Guide Freshwater Management in Canada's Maritime Provinces (dal.ca)

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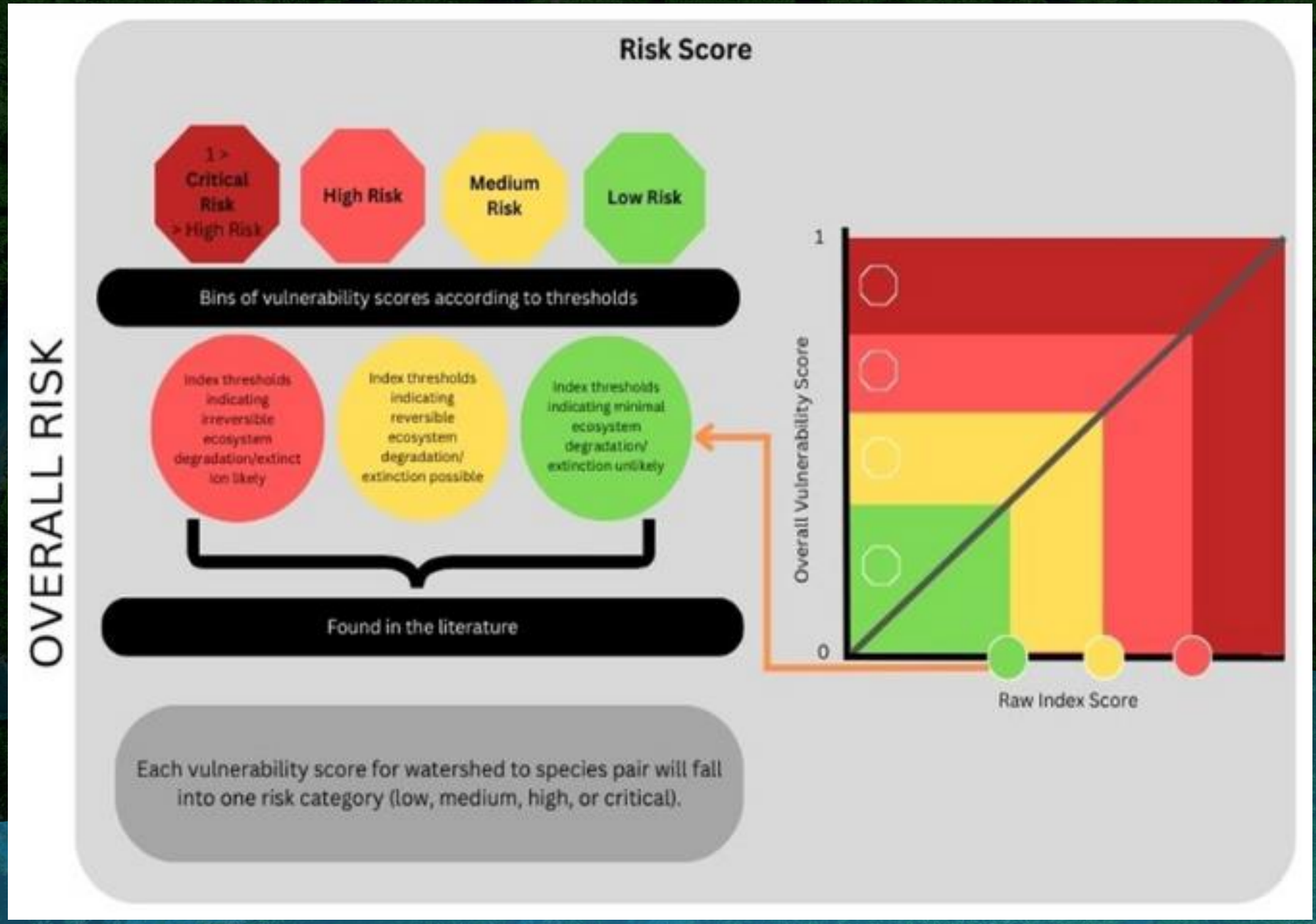
Extras

Freshwater-adapted CRIB Methodology



Caveats cont'd

- Some watersheds might be more or less vulnerability to saltwater intrusions due to sea level rise. This was not considered, but could be included as another index of climate exposure using existing models of sea level rise.
- New CMIP6 models may be more accurate, but were not yet available through ClimateData.ca