PUGET SOUND INSTITUTE

UNIVERSITY of WASHINGTON | TACOMA

Temperature-Dependent Oxygen Thresholds for Marine Life

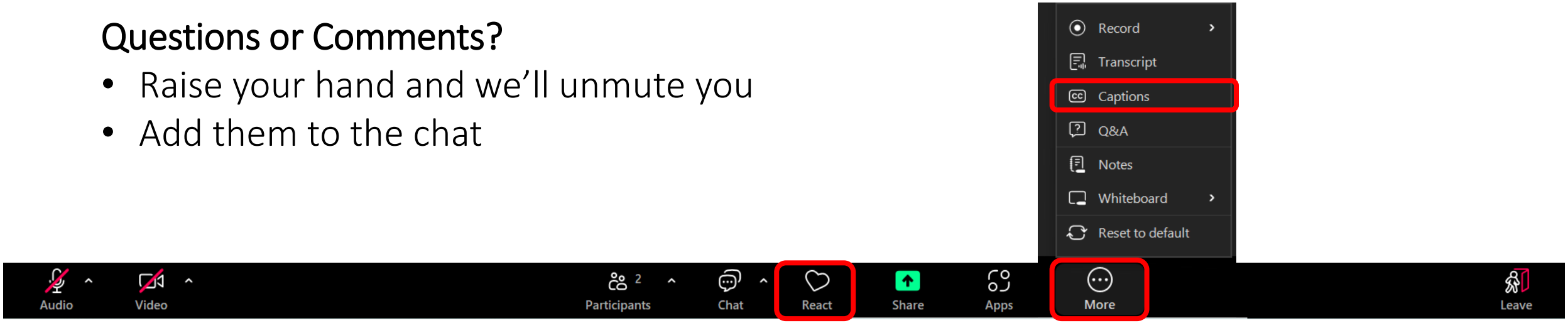
Temperature-Dependent Oxygen Thresholds for Marine Life

Welcome! While we wait, please:

- Update your name with your pronouns and organization
- Introduce yourself in the chat and share your favorite summer produce
- Message Marielle with any access needs

Questions or Comments?

- Raise your hand and we'll unmute you
- Add them to the chat



The slides and recording will be available on [Puget Sound Institute's website]

Continuation of scientific workshops

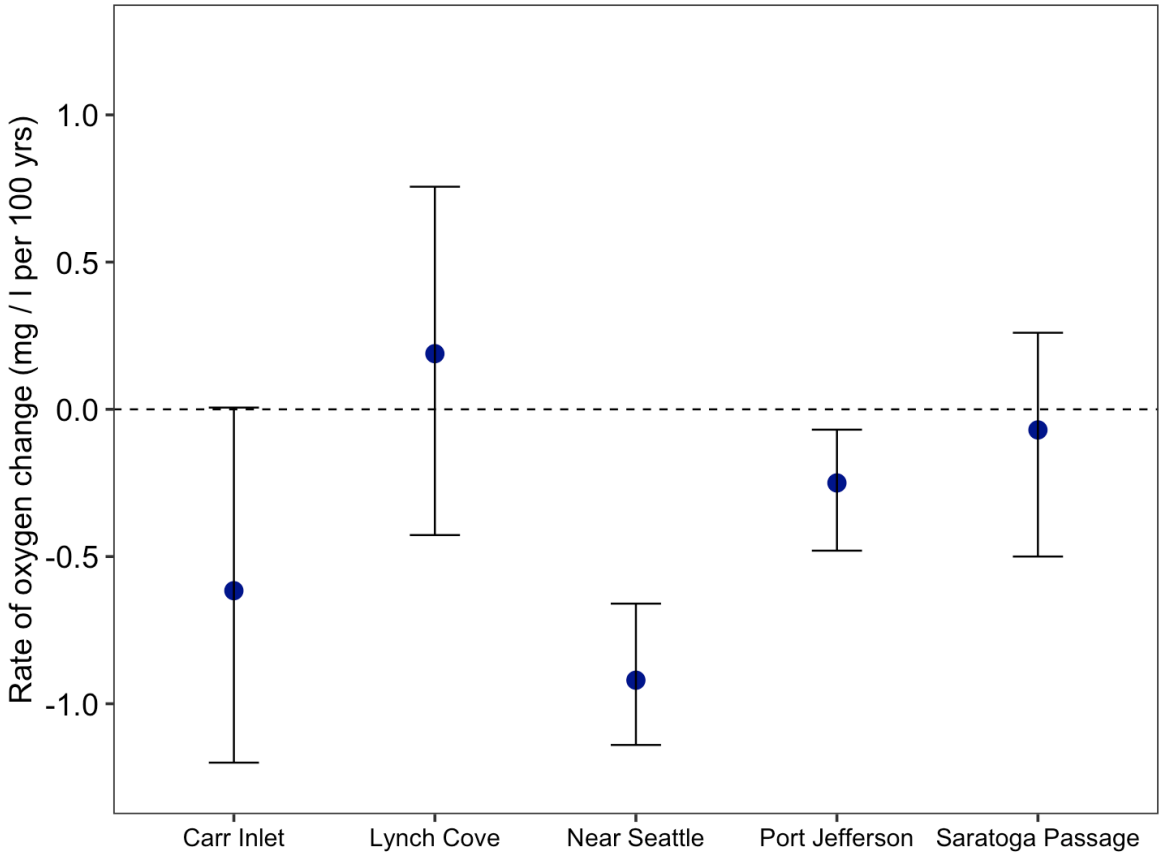
UW Puget Sound Institute continues to advance the science to protect Puget Sound.

- Kickoff: The Science of Puget Sound water quality
- Tools to Evaluate Water Quality
- Biological Integrity of Key Species and Habitats
- Sediment Exchange
- Phytoplankton & Primary Production
- Watershed Modeling
- Modeled and historical monitoring insights on water quality differences throughout Puget Sound

Explore the workshop summaries, highlight videos, and slides

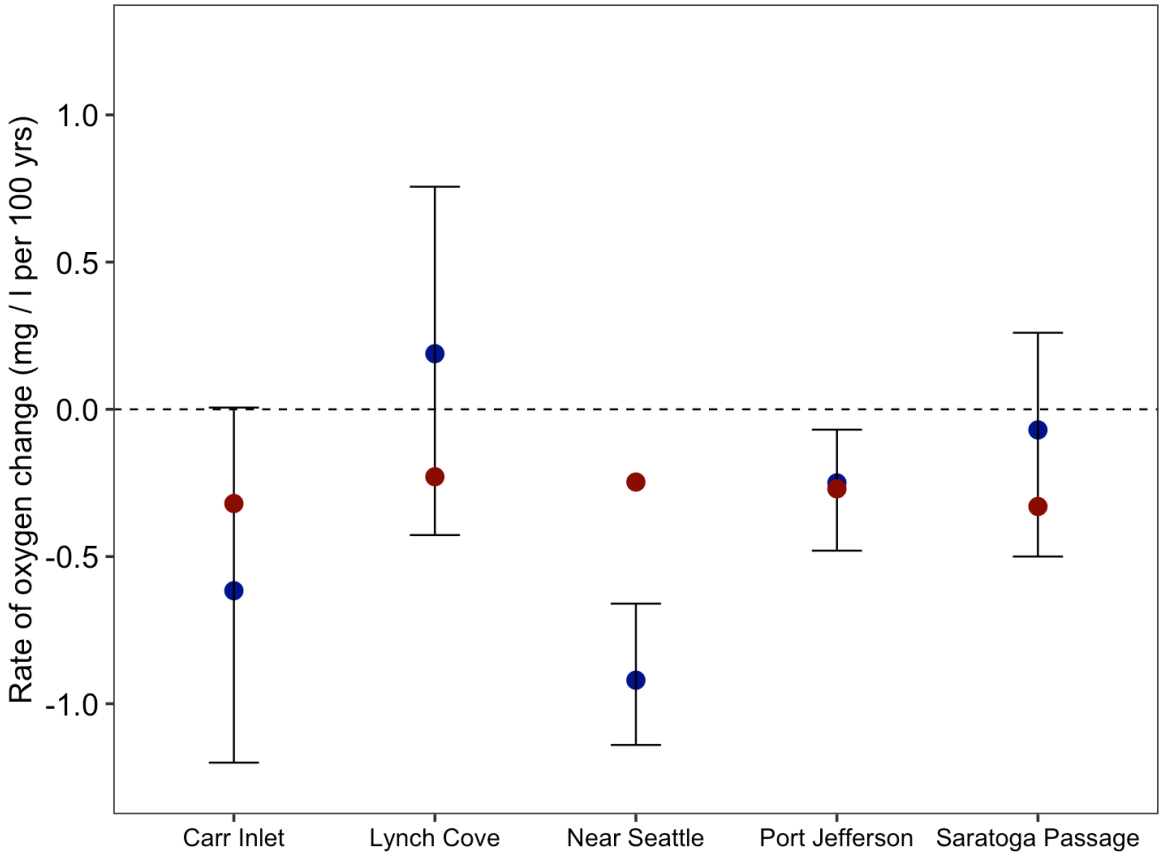
Scope of the problem: declining oxygen levels in some parts of Puget Sound

Dakota Mascarenas analyzed Ecology, King County, NOAA, and Collias (UW) data [Mascarenas and others (2025, in review)]



And > 50% of this decline is due to increased temperature

Dakota Mascarenas analyzed Ecology, King County, NOAA, and Collias (UW) data [Mascarenas and others (2025, in review)]



Predicted based on warming alone

Modeling suggests local human activities may also decrease dissolved oxygen

- 9% of nitrogen inputs are from human activities in the watershed or wastewater treatment plants

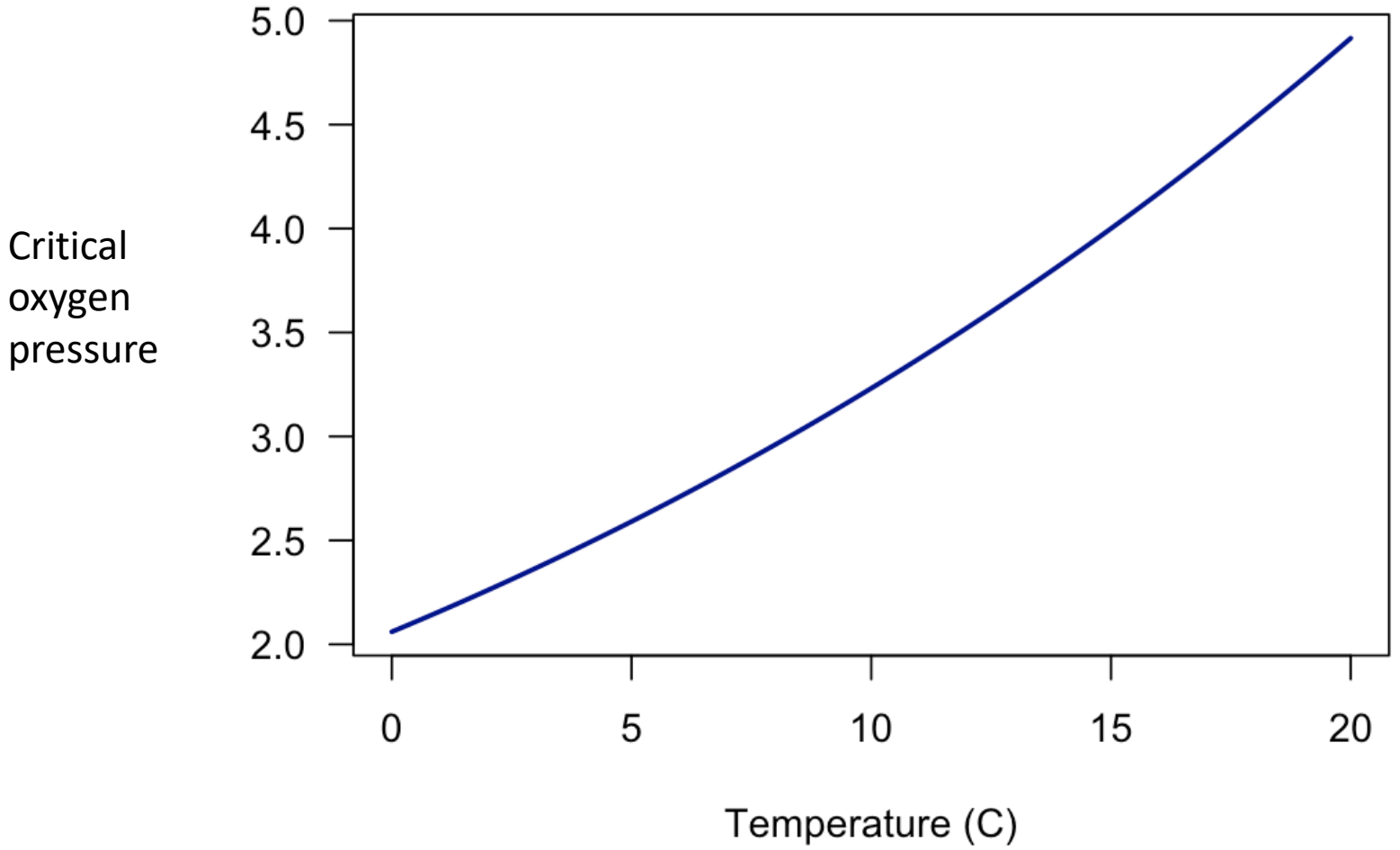
- Sensitive areas have long water residence times:
  - Shallow embayments
  - Deep fjord-like basins like southern Hood Canal

How do we effectively manage nutrients to support marine life in Puget Sound?

A few reminders

1. Low oxygen is problematic when it falls below physiological thresholds
2. Marine life may escape, temporarily acclimate, adapt over generations, or die
3. When and where oxygen is depleted matters

Warmer waters squeeze marine life: decreasing oxygen supply while increasing demand



Methods

Main questions

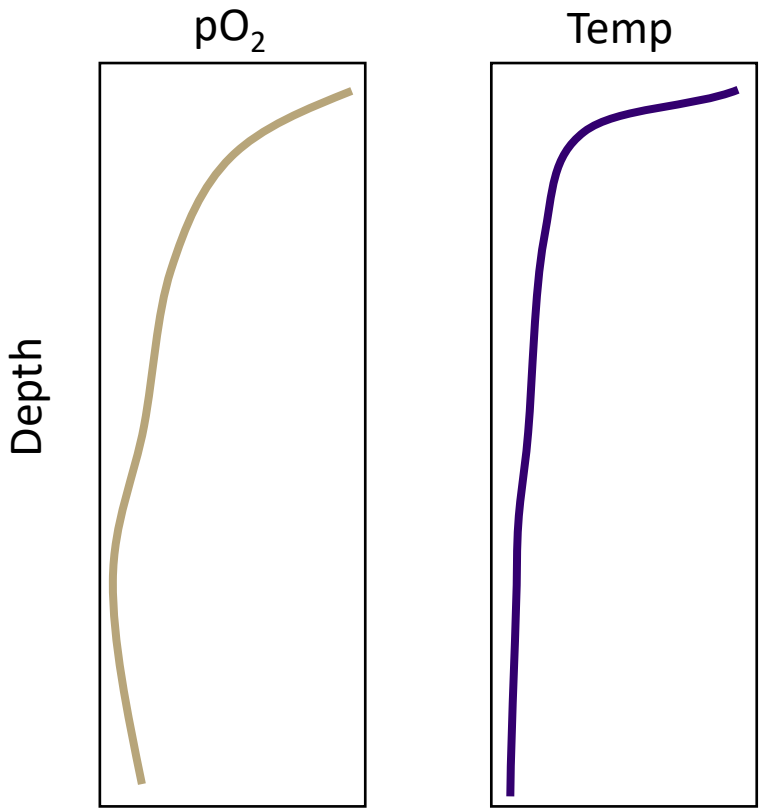
Oxygen partial pressure (pO_2)	Critical oxygen level (p_{crit})

We want to identify when and where oxygen partial pressure falls below p_{crit}

Doing this means we need to have a structured approach to consider

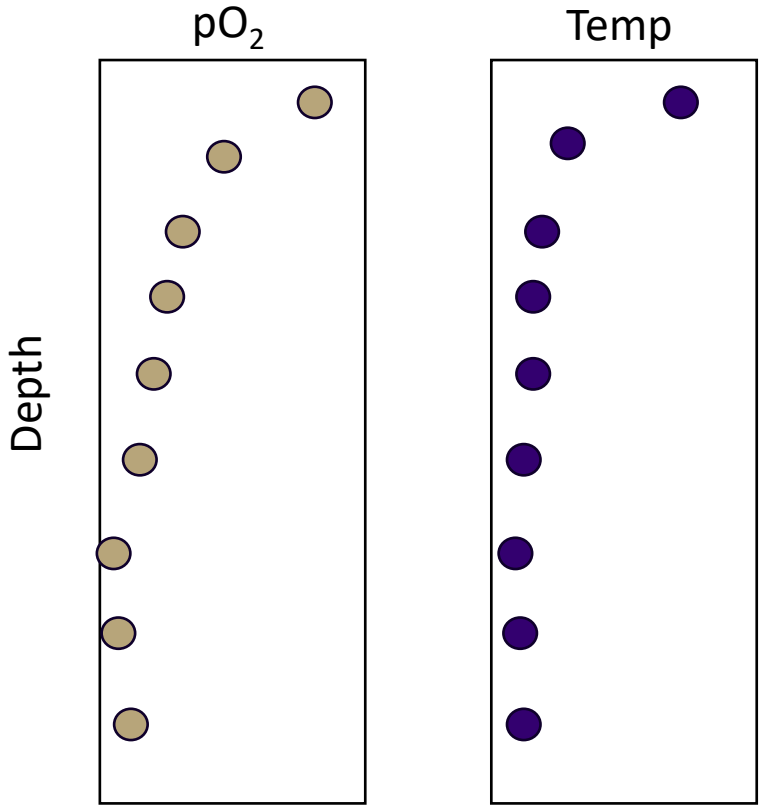
- Daily variation
- Variation with depth
- How to estimate p_{crit}

Hypothetical profile: one location on one day



In the model world: the profile becomes 10 points

The model has 10 layers per location

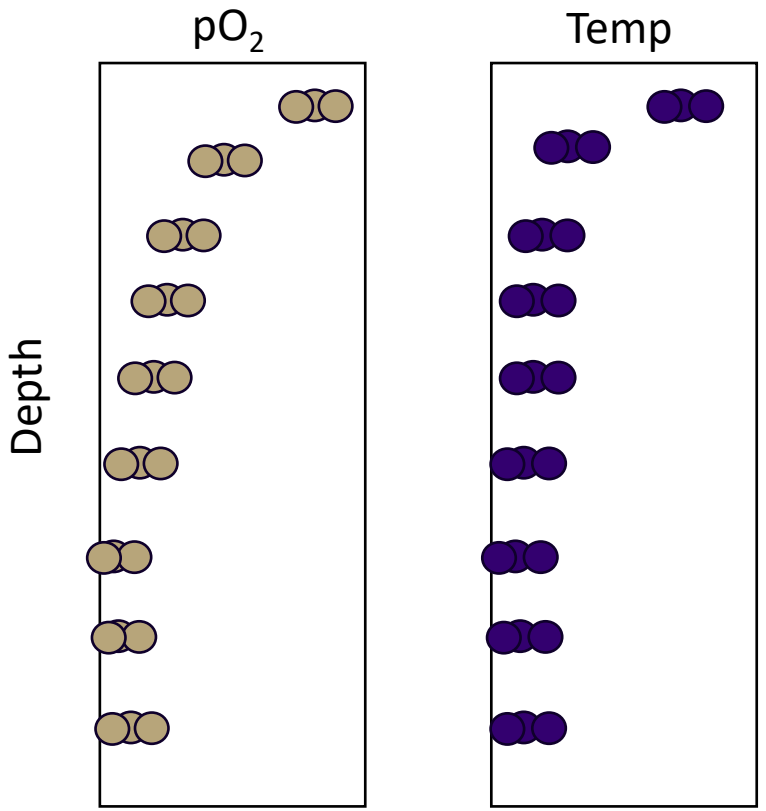


And there is a time dimension as well

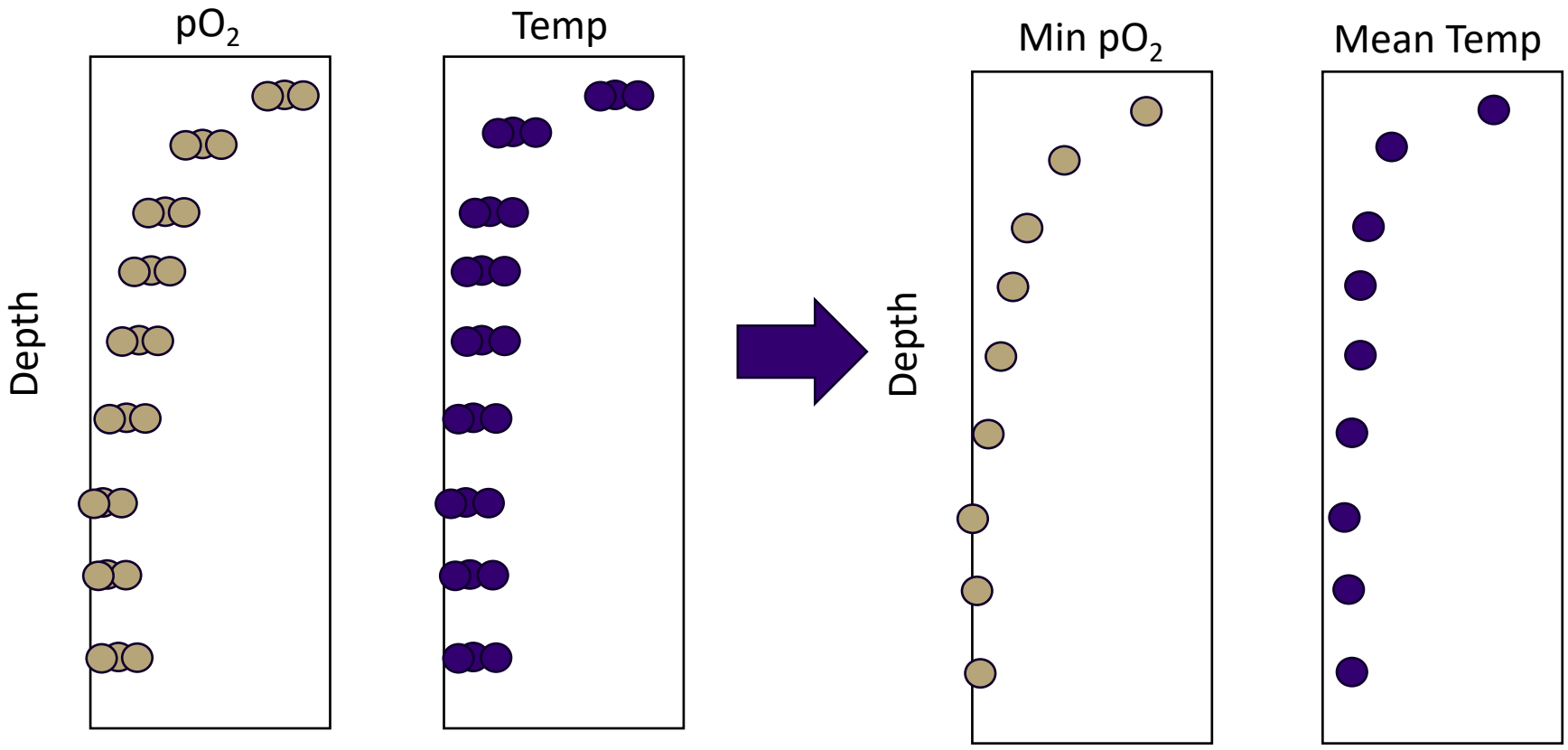
Because the model operates on a 24 hour cycle ….

There are 24 pO_2 and Temperature values per depth layer for each **day**

We needed to collapse this into a single number for each layer



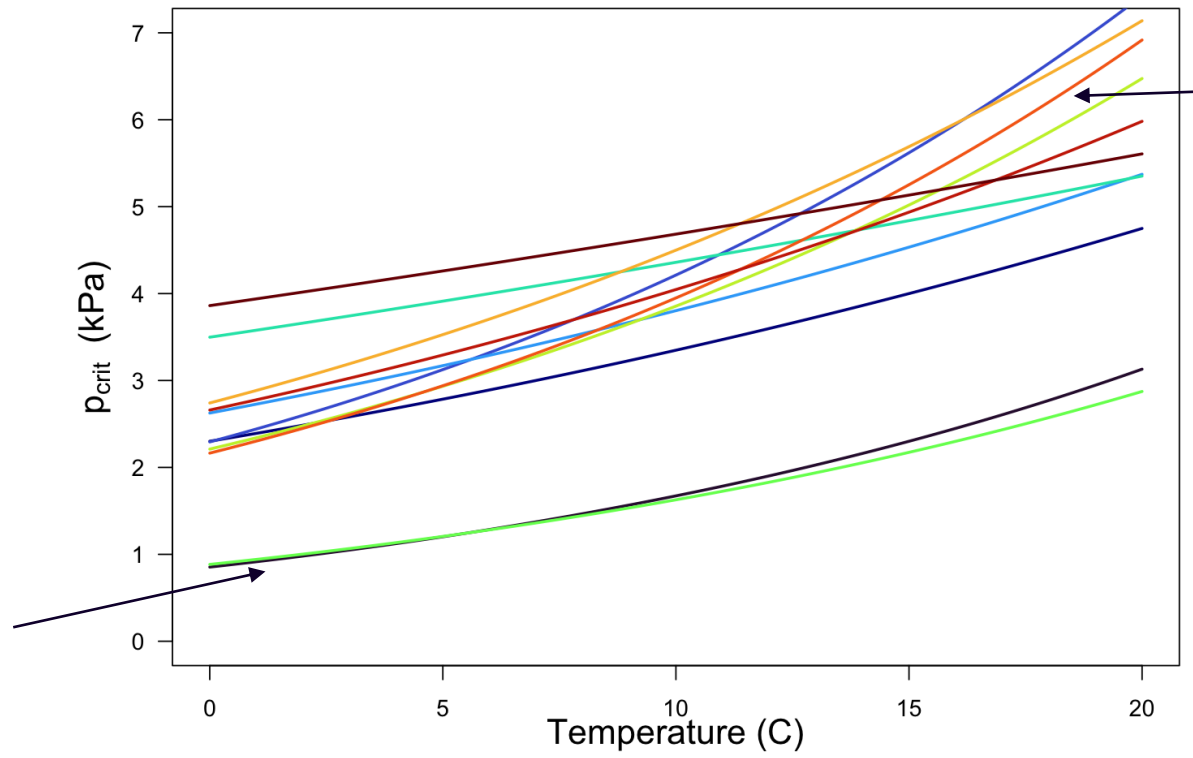
Simple and conservative approach: use smallest pO_2, average temperature



How is p_{crit} estimated?

- Essington et al. (in review) summarized data from 150+ species, over 450 laboratory measurements
- Developed a computational approach to estimate p_{crit} for any organism based on:
  - Taxonomy (related species should have similar pcrit)
  - Temperature
  - Body size
  - Laboratory method
- Considers species-specific temperature sensitivity, body size effects, and overall sensitivity to low pO_2

Variation among taxa: visually represented



Some taxa have high temperature sensitivity

Some taxa are very tolerant

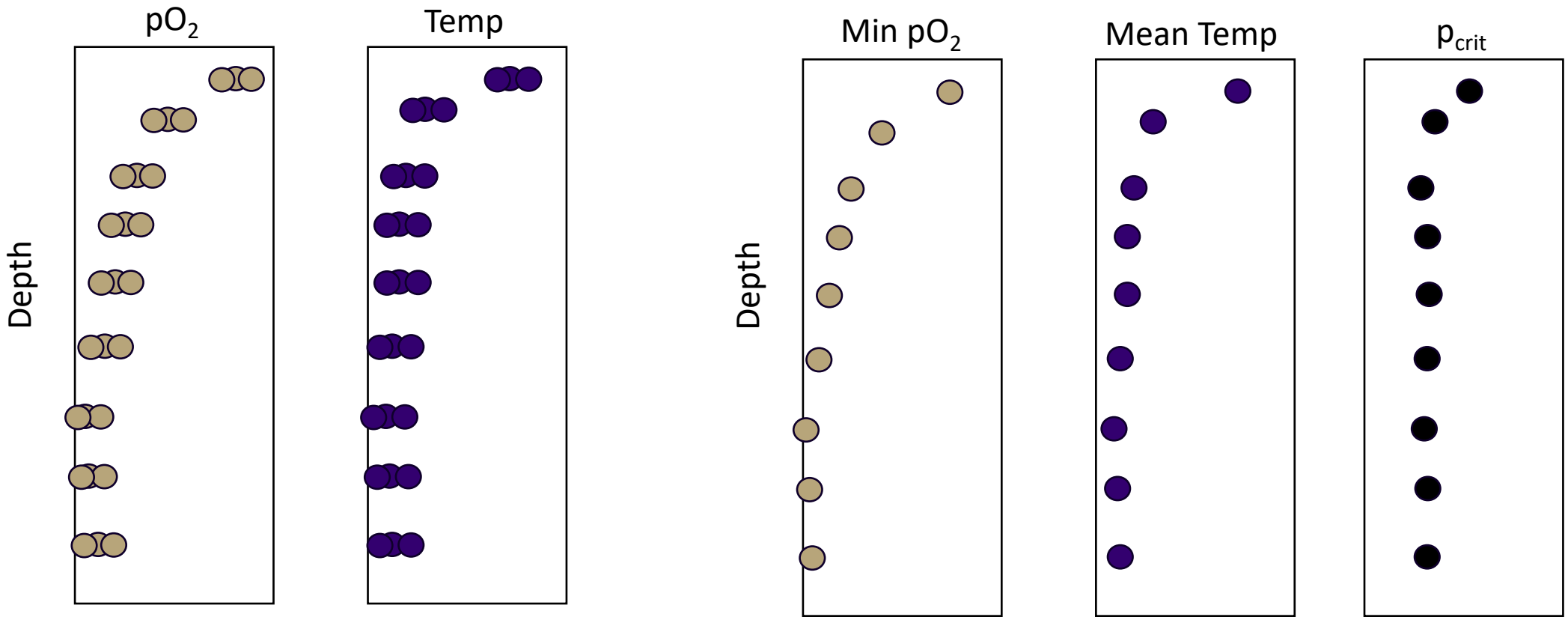
Different levels of oxygen demand

Basal
Minimum energy to maintain essential physiological functions at rest

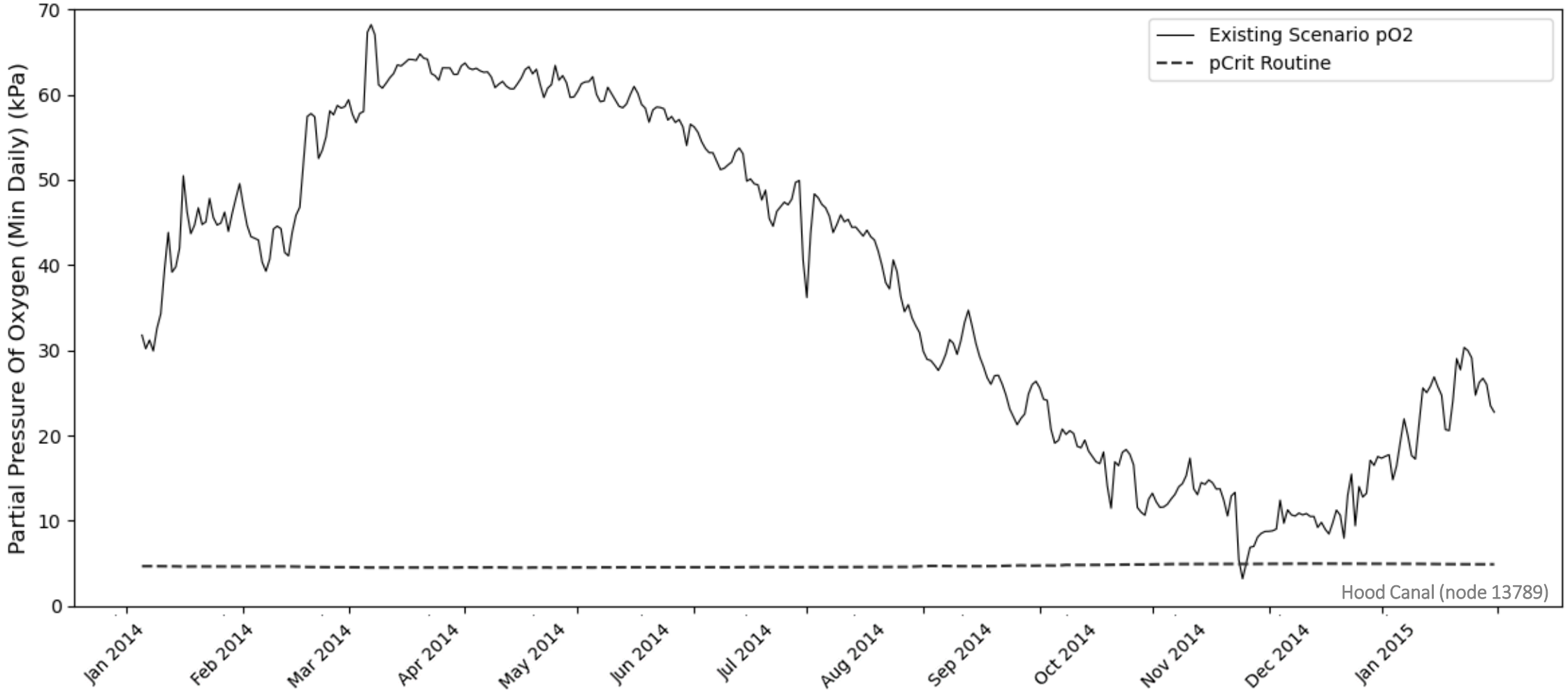
<

Routine
Minimum energy to maintain basal functions and routine activity

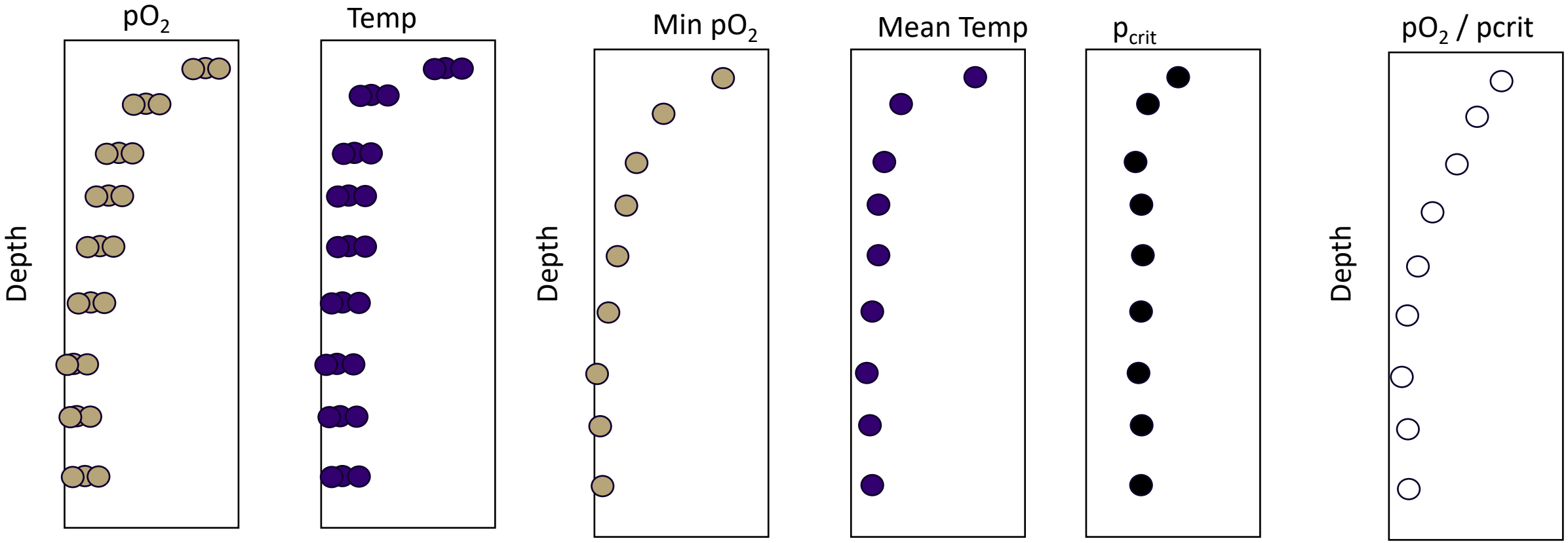
p_{crit} for a species is estimated at each layer from temperature



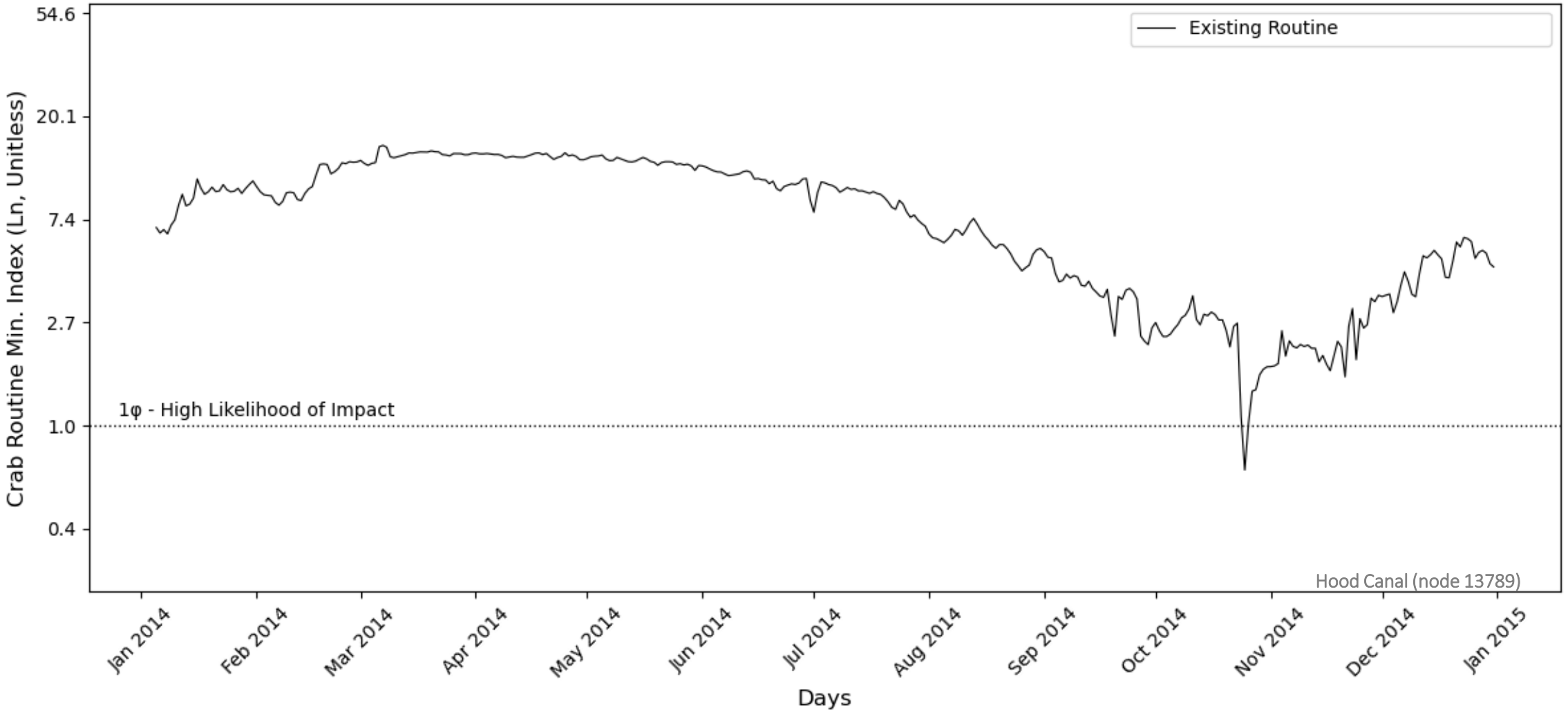
Are environmental conditions above the threshold oxygen level?
Dungeness Crab in Hood Canal



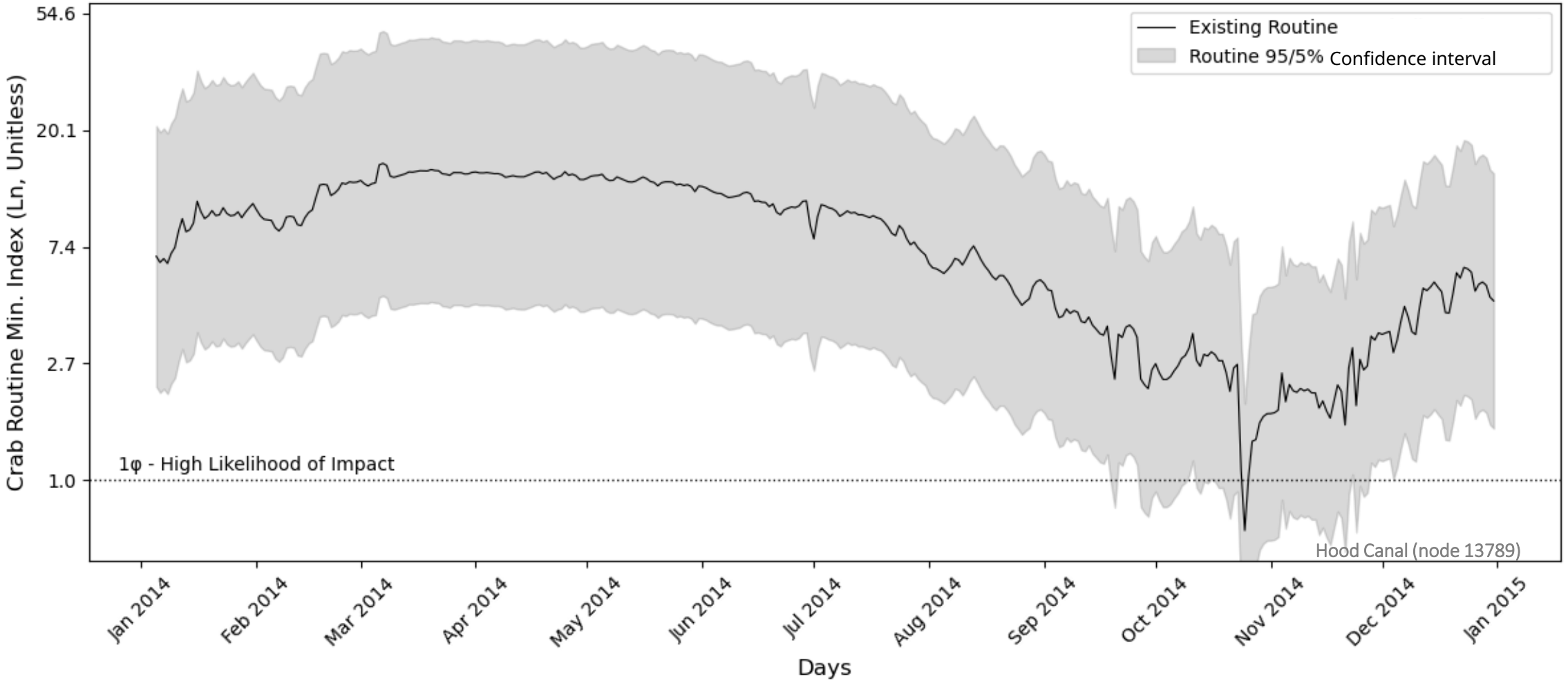
Take the ratio of pO_2 / p_{crit} for each layer



Ratio of p_{O2} / p_{crit}
Dungeness Crab in Hood Canal

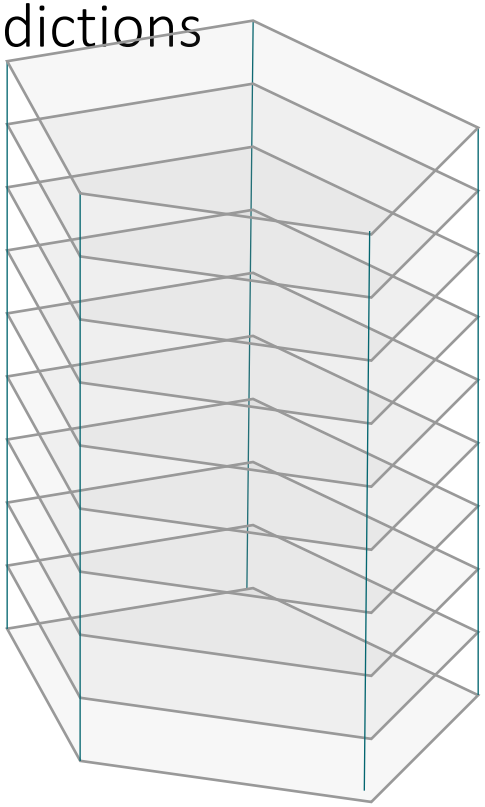


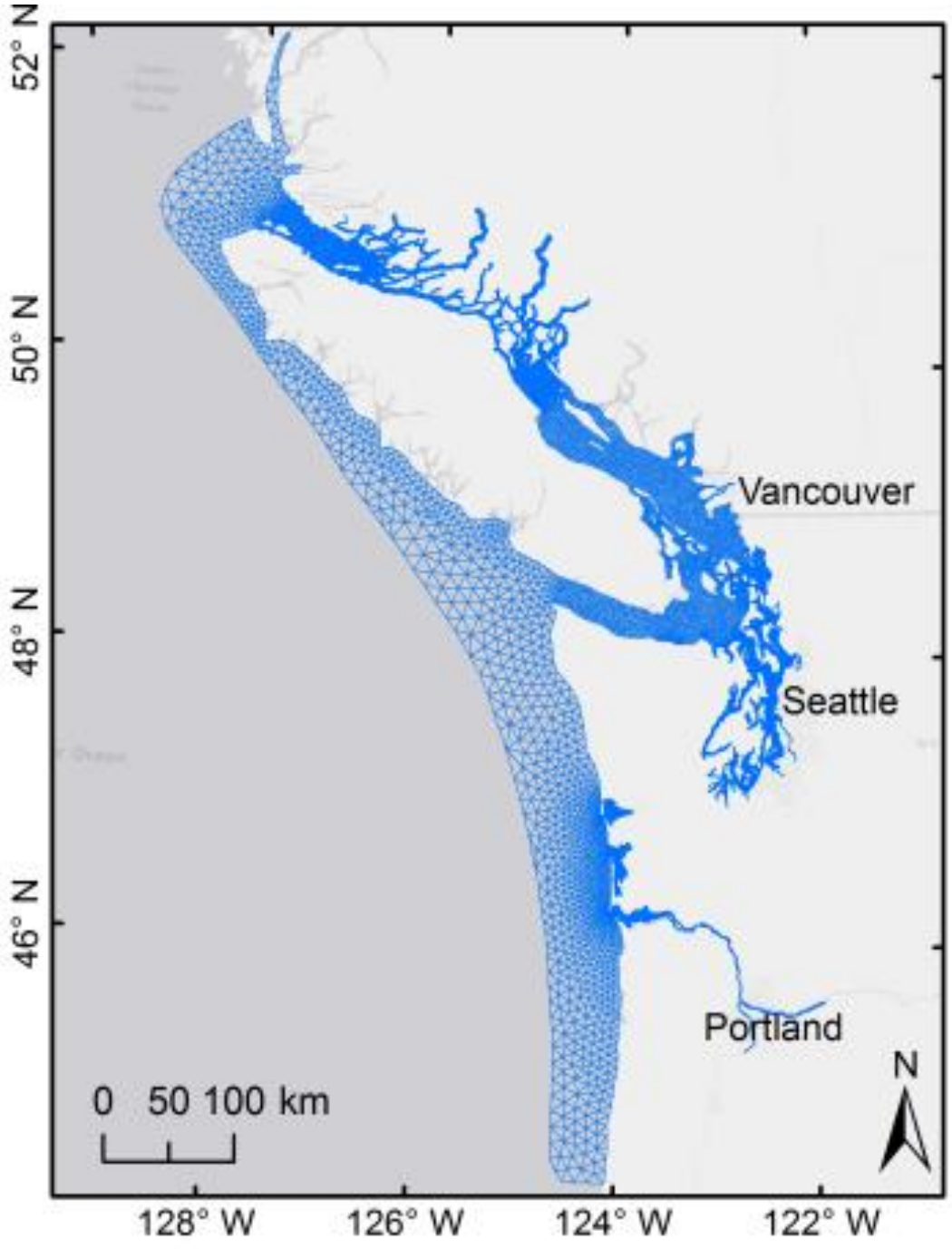
Confidence in oxygen demand
Dungeness Crab in Hood Canal



Salish Sea Model

- Predicts hydrodynamics and water quality for over 16 K model cells, with 10 layers each
- Model version aligned with Ahmed et al. (2021)
- Analysis based on 2014 predictions





Initial species

Selected species with economic, ecological, and cultural importance that also had physiological inputs for the metabolic index available.

Chinook Salmon

Dungeness Crab

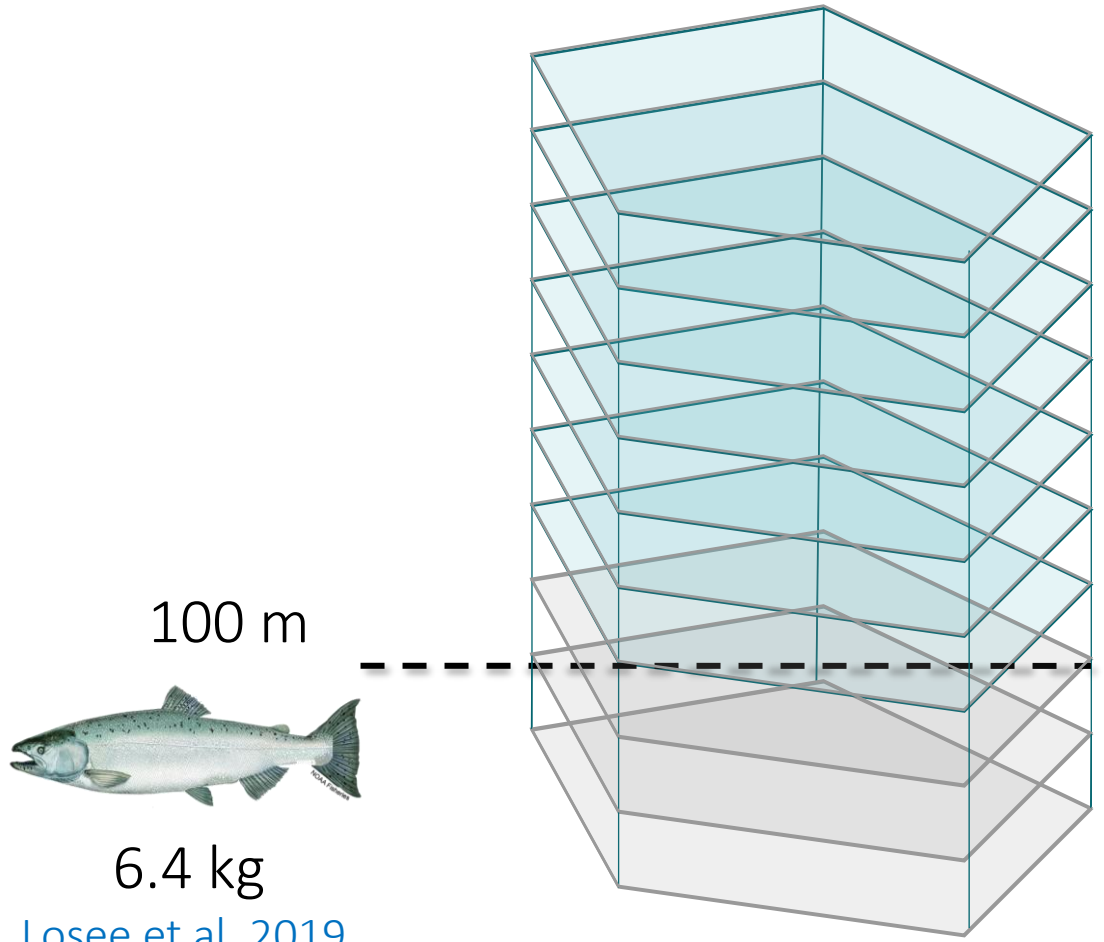
English Sole

Species-specific depth & weight

Adult Chinook

Top 100 m of water column

Freshwater et al., 2024; Smith et al., 2015



6.4 kg

Losee et al, 2019

Species-specific depth & weight

Adult Dungeness Crab

Bottom layer for areas < 80m

Ramuson 2013; Armstrong et al., 1988

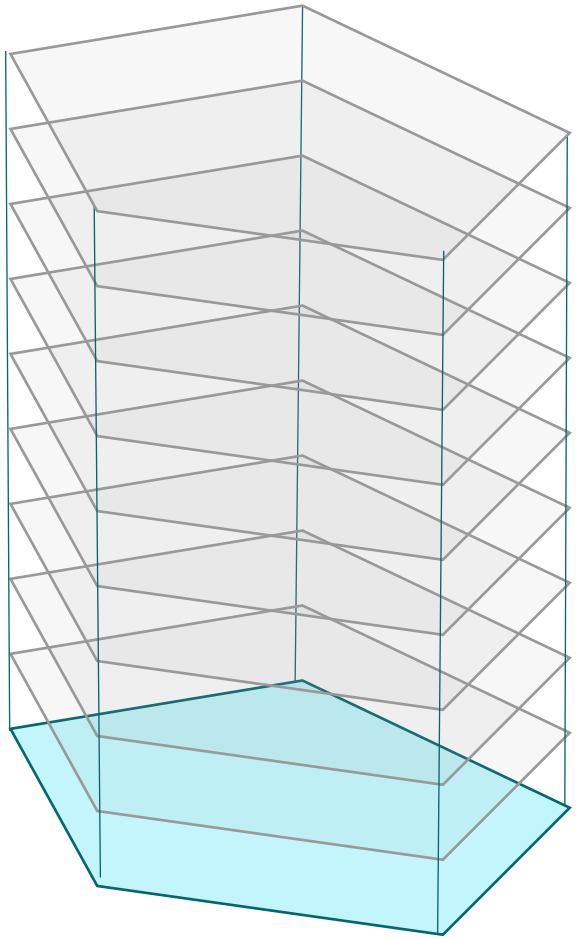
English Sole

Bottom layer for areas < 100 m

1 kg

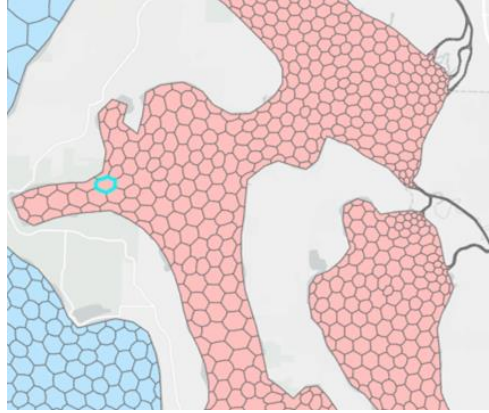
1.2 kg

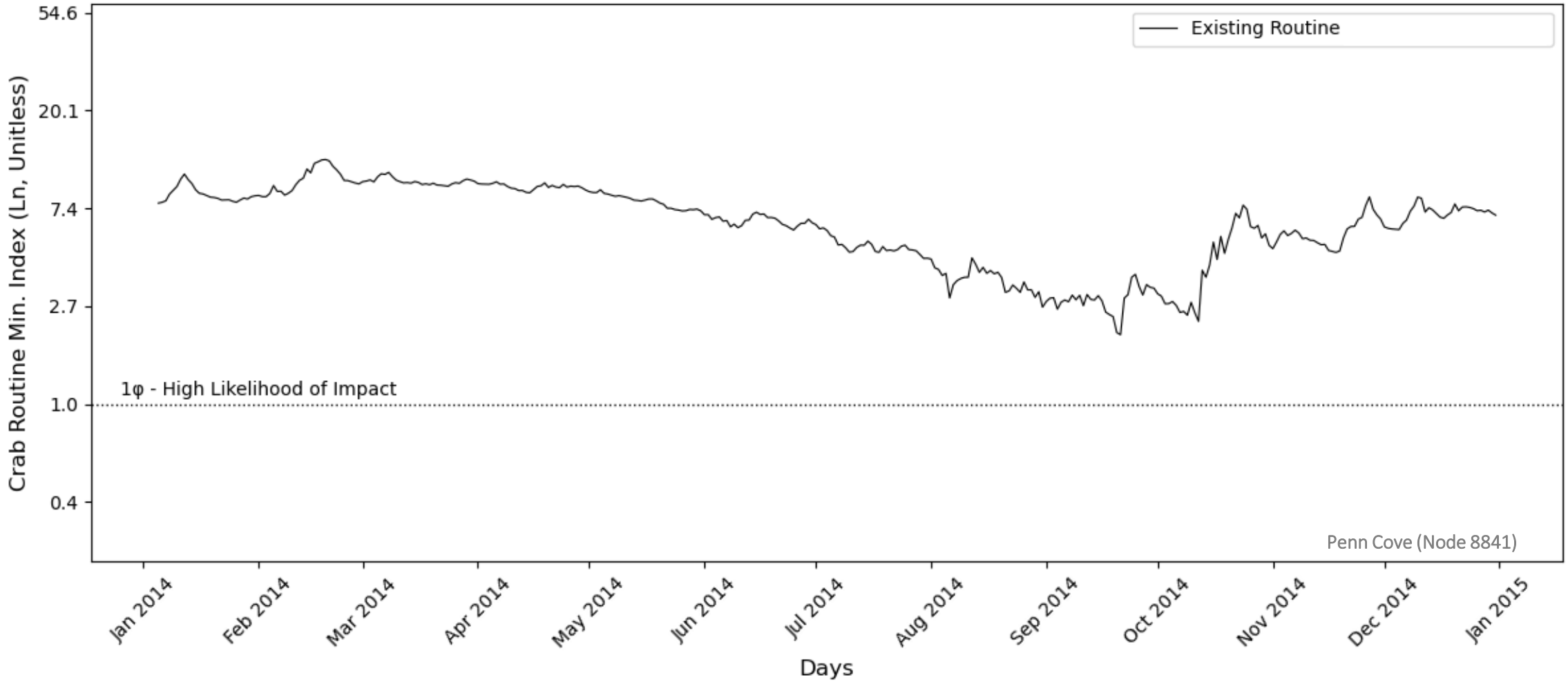
Gamblewood et al., 2018



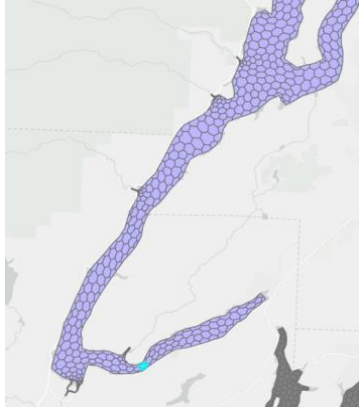
Preliminary Results

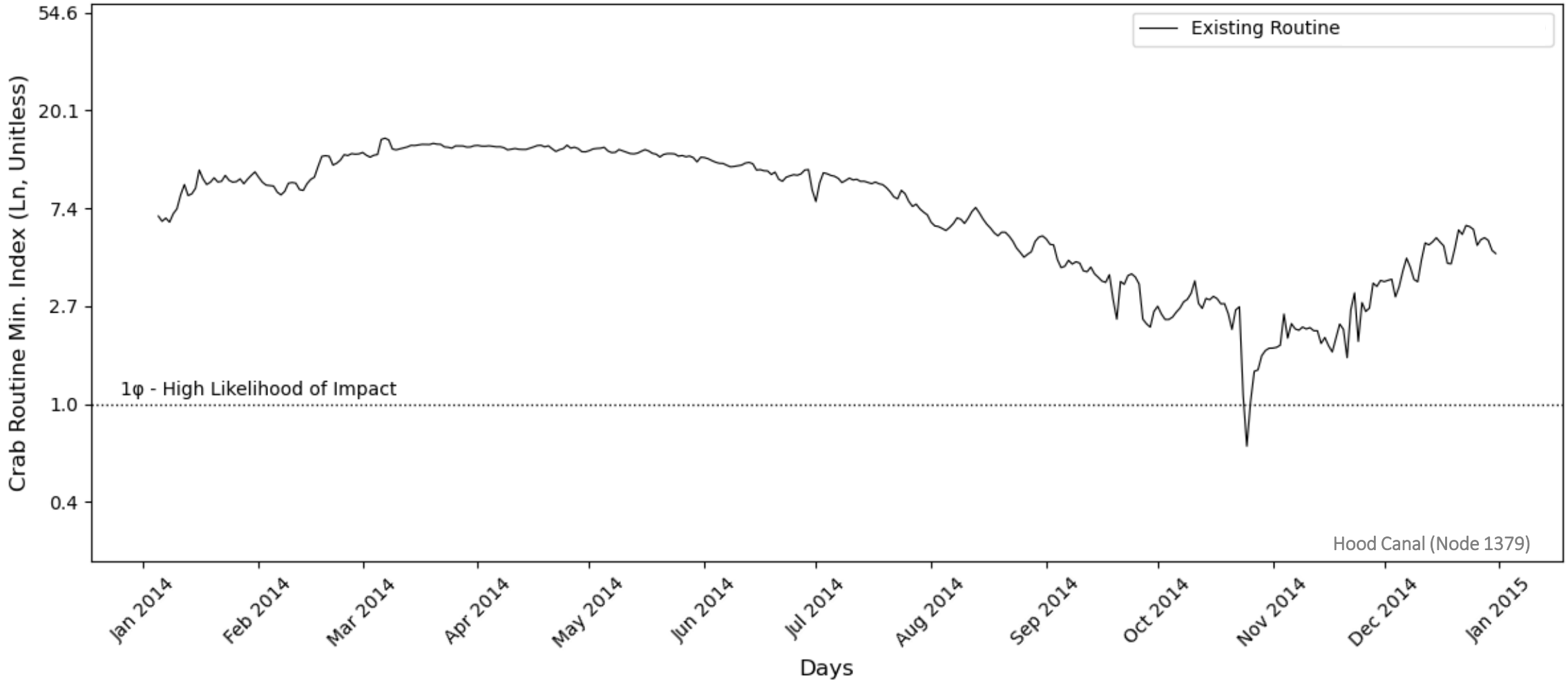
Spatial variability
Dungeness Crab in Penn Cove



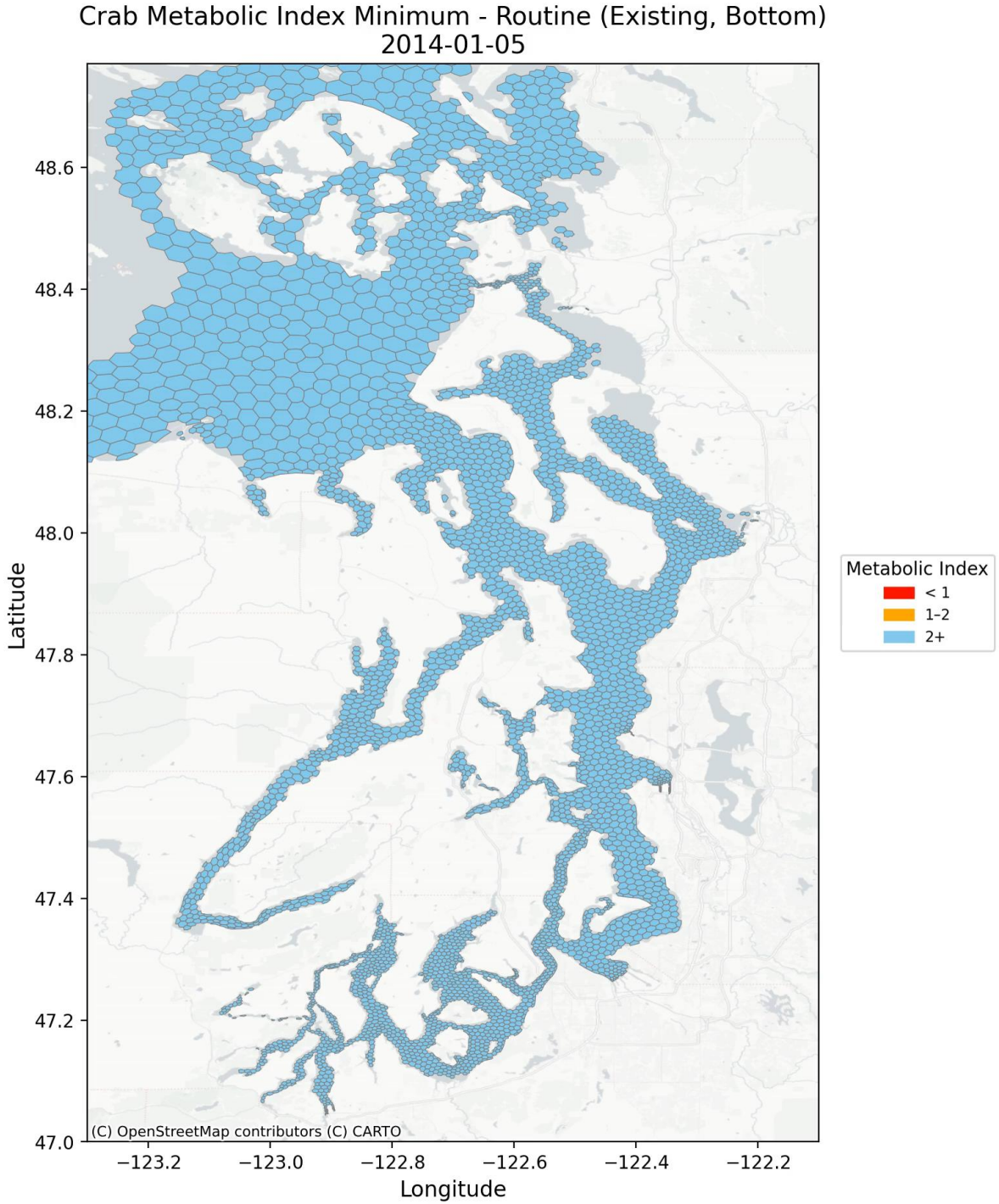


Spatial variability
Dungeness Crab in Southern Hood Canal

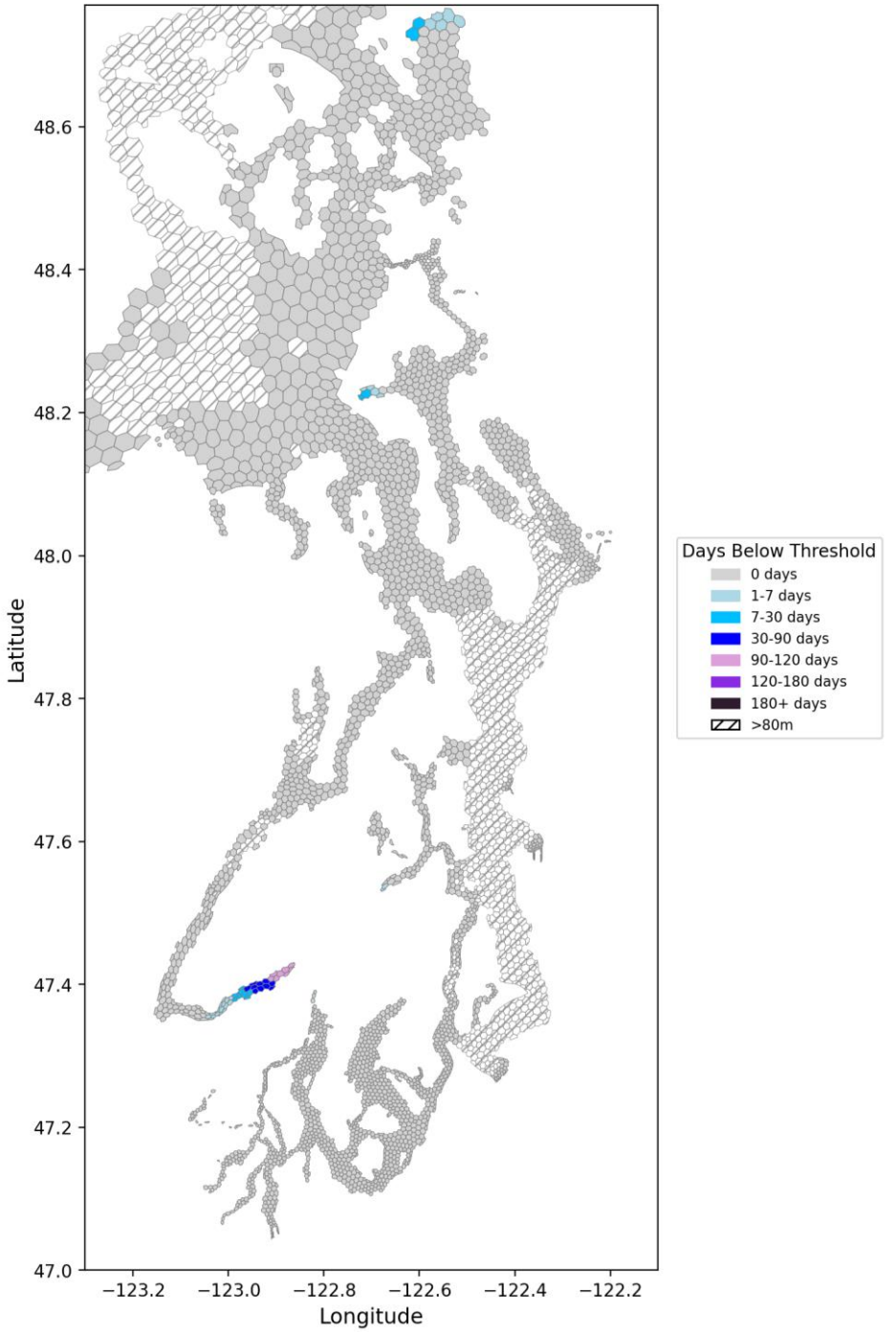




Spatial and temporal variability: Dungeness Crab

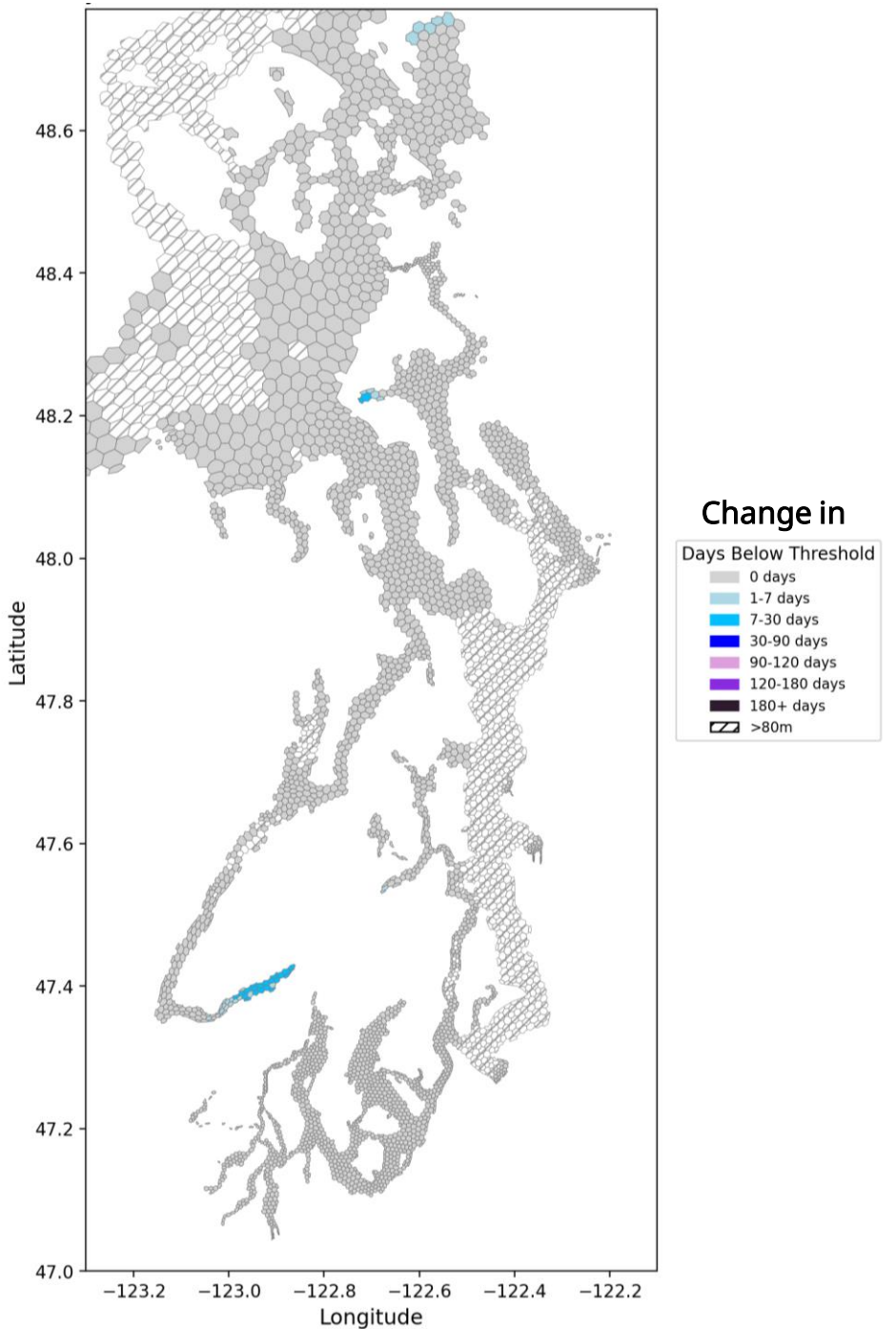


Dungeness Crab: Number of days where environmental oxygen concentrations fall below threshold oxygen levels

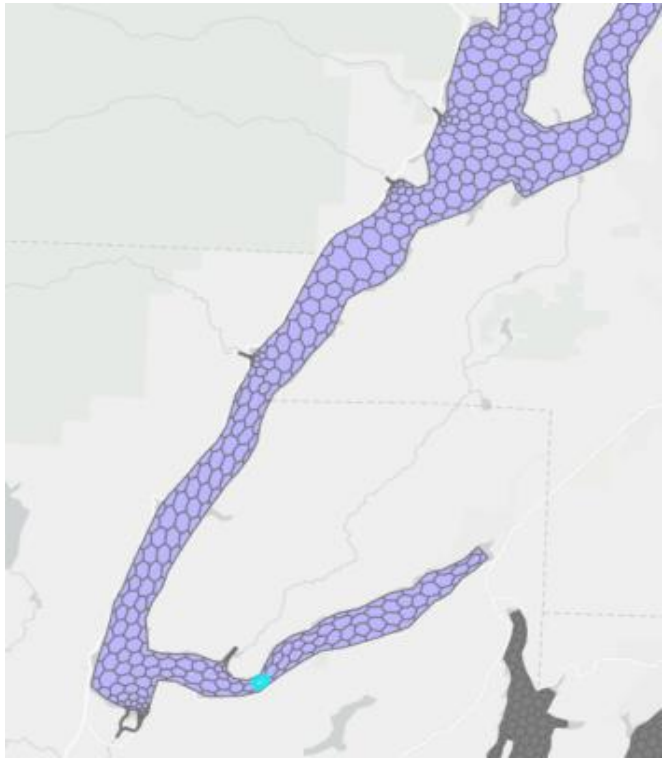


Dungeness Crab: Example of Habitat Compression

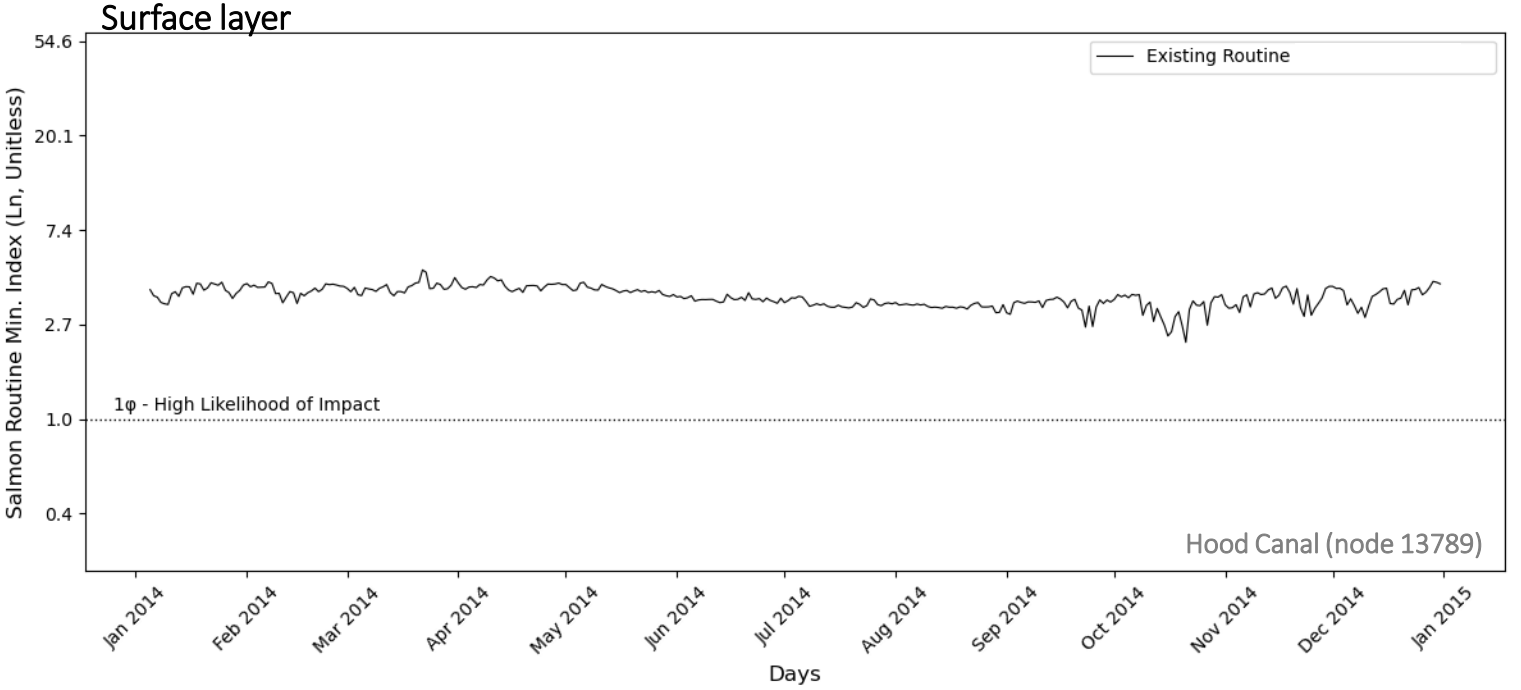
- Change between 2014 and reference conditions
  - Climate is held constant, so shows the impact of additional nutrients
  - Plan to explore how future changes in temperature may influence risk



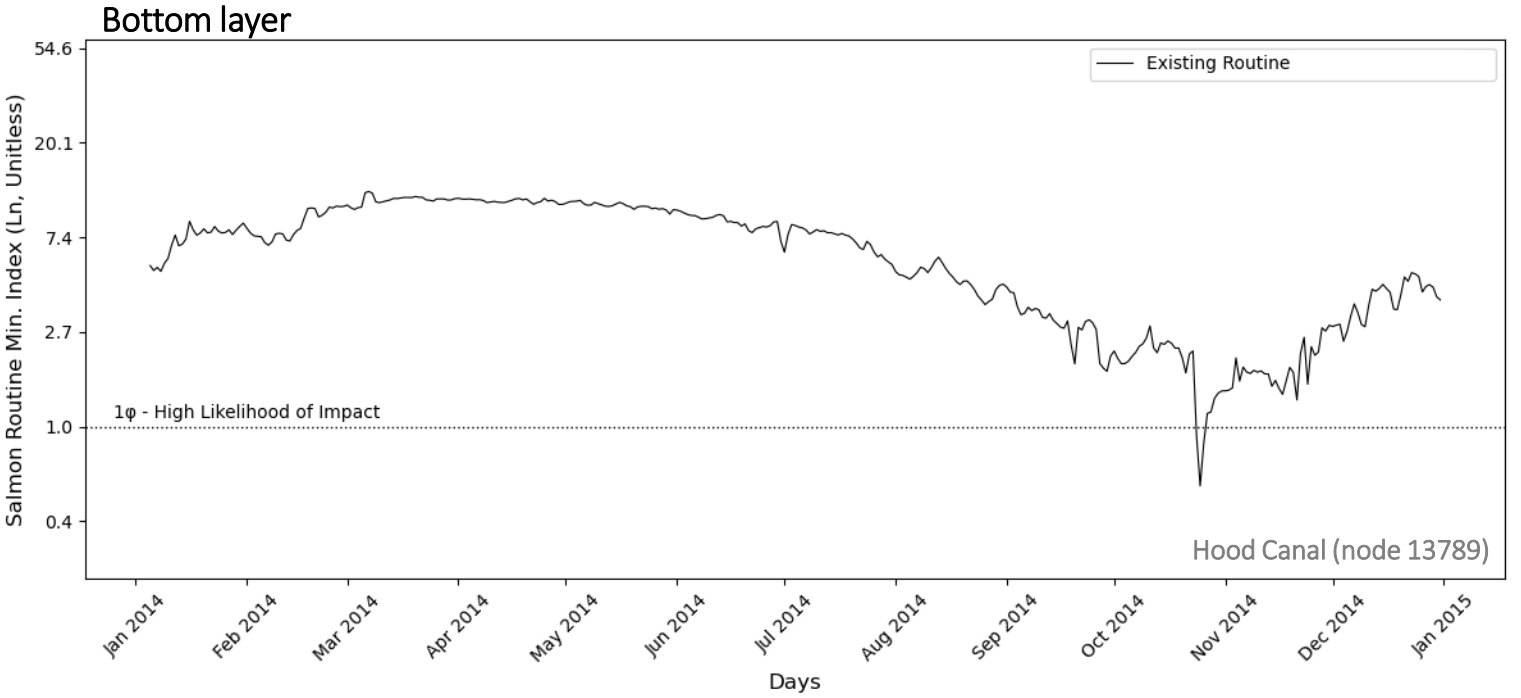
How to consider movement? *Chinook Salmon in Southern Hood Canal*



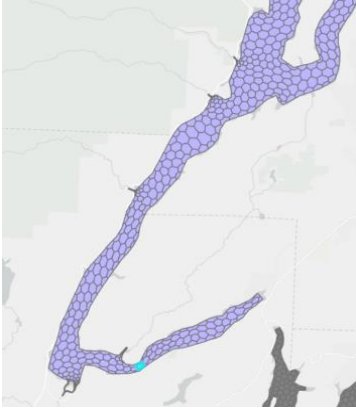
Surface layer



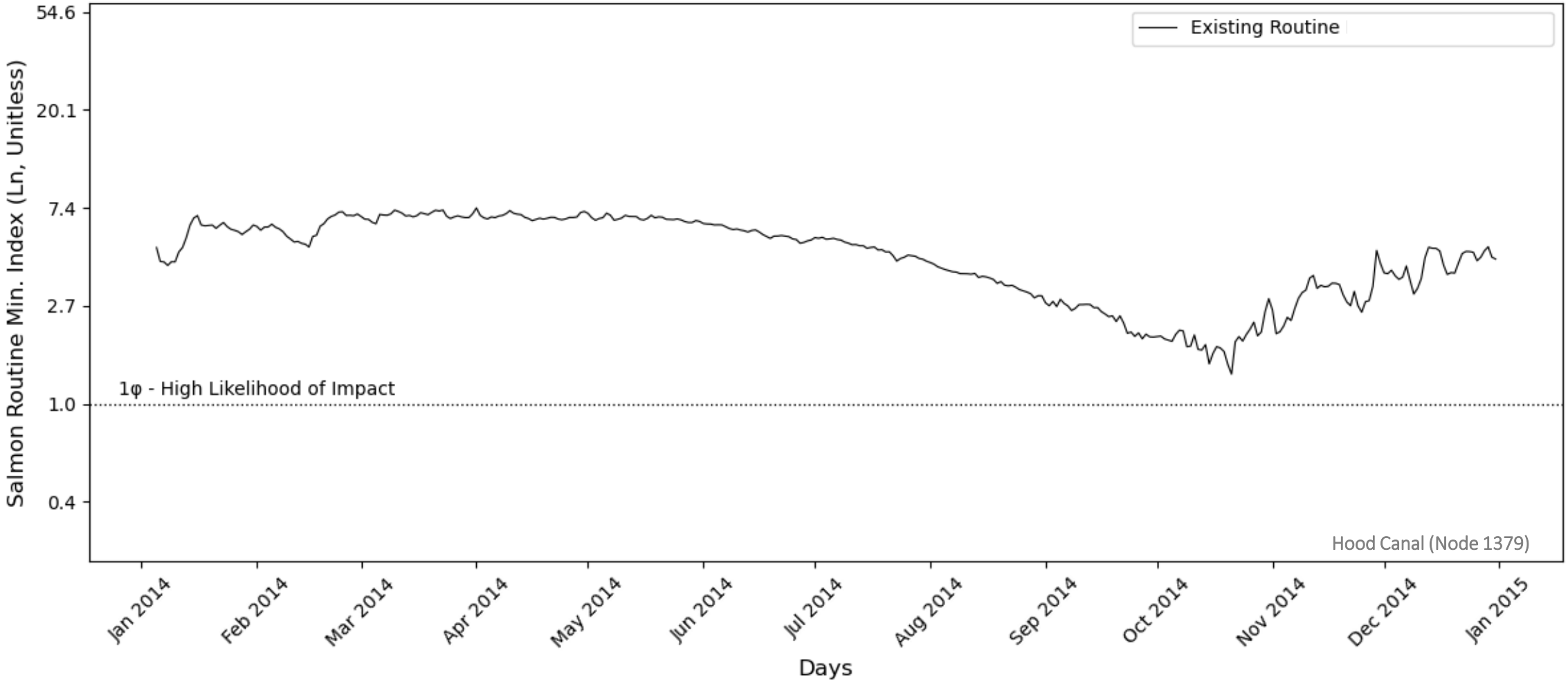
Bottom layer



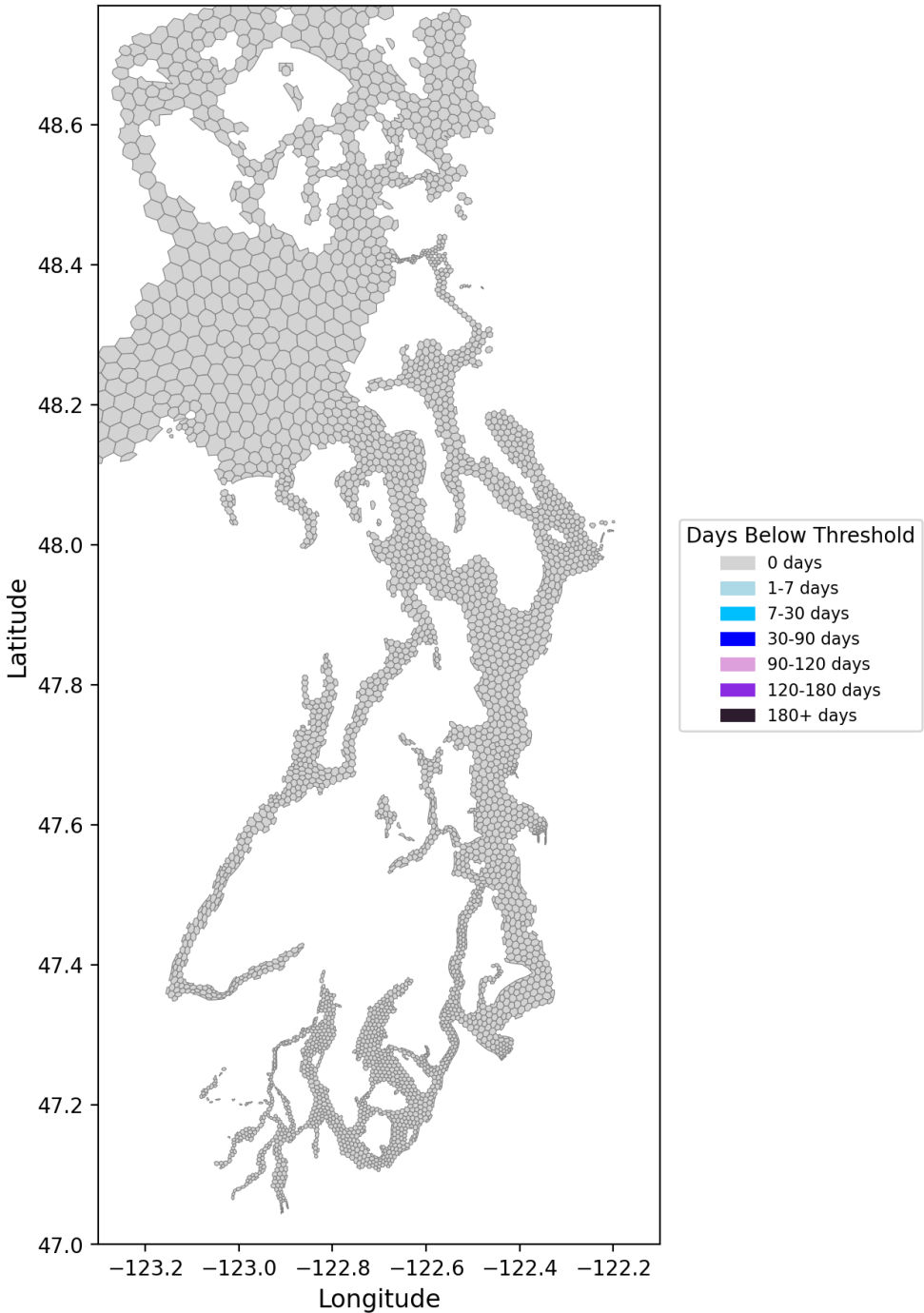
How to consider movement?
Chinook Salmon in Southern Hood Canal



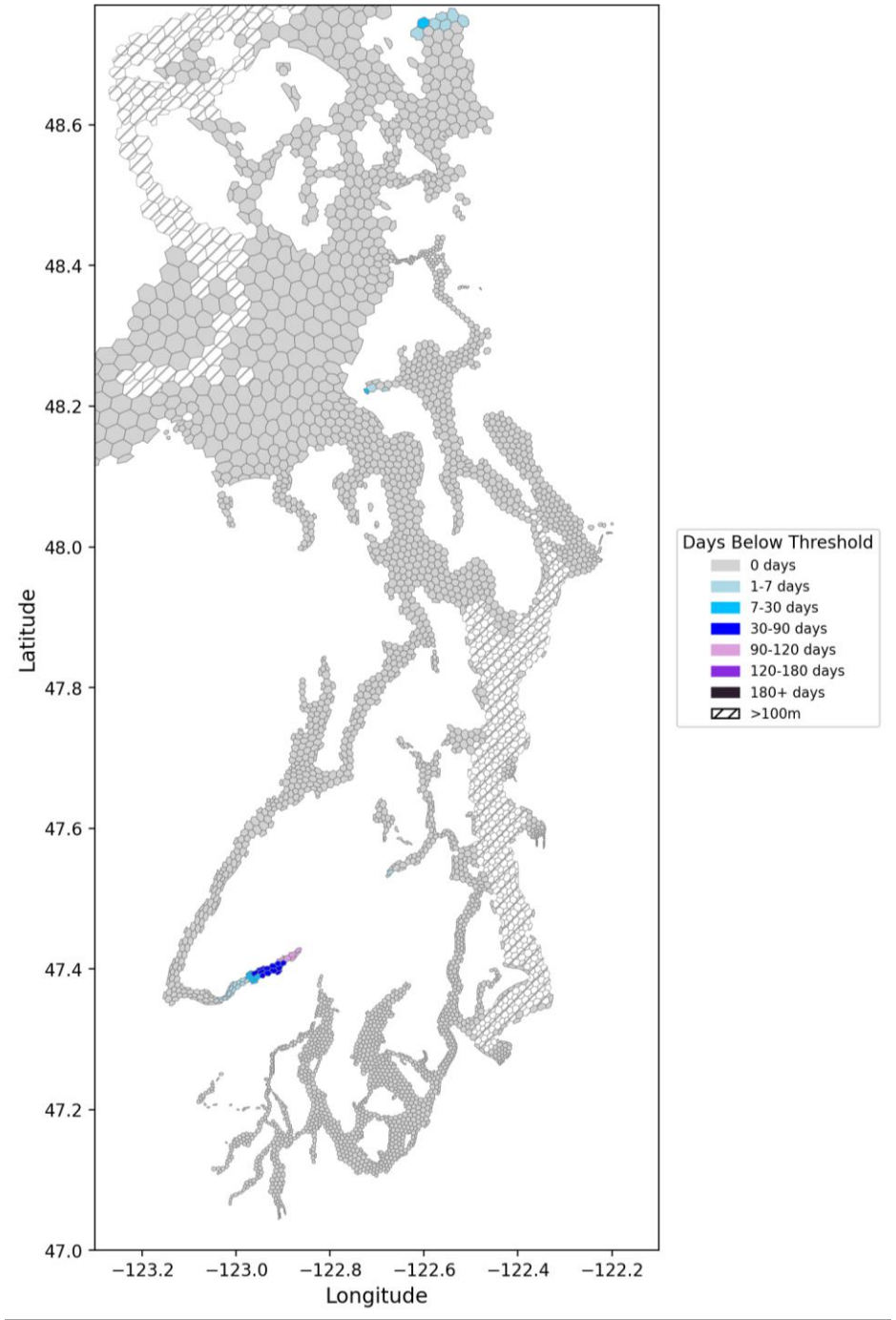
Water column average



Chinook Salmon: Days where environmental oxygen falls below threshold oxygen level



Sole: Days where environmental oxygen falls below threshold oxygen level



Initial observations

- Strong scientific foundation, supported by growing experimental evidence, to determine how much oxygen is required by species in Puget Sound
- Existing Puget Sound water quality models provide the dissolved oxygen, temperature, salinity, and depth pressure data needed to calculate oxygen availability for species
- It is feasible to determine oxygen requirements and consider species-specific habitats for water quality assessments
- Initial analysis confirms dissolved oxygen impacts for these species are limited to certain Puget Sound areas and periods of the year

Next steps

Continue to refine and expand the analysis:

- Analyze different life stages and sexes
- Expand to additional species (e.g., benthic)
- Refine metrics (e.g. habitat volume)
- Explore how future changes in temperature may influence risk

Questions to consider:

- How could we better quantify risk to help managers consider what is an appropriate level?
- For salmon, how would could we consider depth given their mobility?
- How should we define organisms' actual habitat for the analysis?

QUESTIONS?

Feel free to reach out

- Tim Essington essing@uw.edu
- Stefano Mazzilli mazzilli@uw.edu
- Marielle Kanojia marlars@uw.edu