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# TARP

Trent Aquatic Research Program

TRENT UNIVERSITY 

## Oxygen Decline in Kawartha Lakes Deep Water - A Growing Concern

Nolan J. T. Pearce

*Research Associate,  
Department of Biology at Trent University*

**Are lakes important to *you*? - Yes**

Are the *important* things that lakes provide under threat?

Are the 900,000 Canadian lakes equally important and equally threatened?

Are lakes important to *you*? - Yes

Are the *important* things that lakes provide under threat? - Probably

Are the 900,000 Canadian lakes equally important and equally threatened?

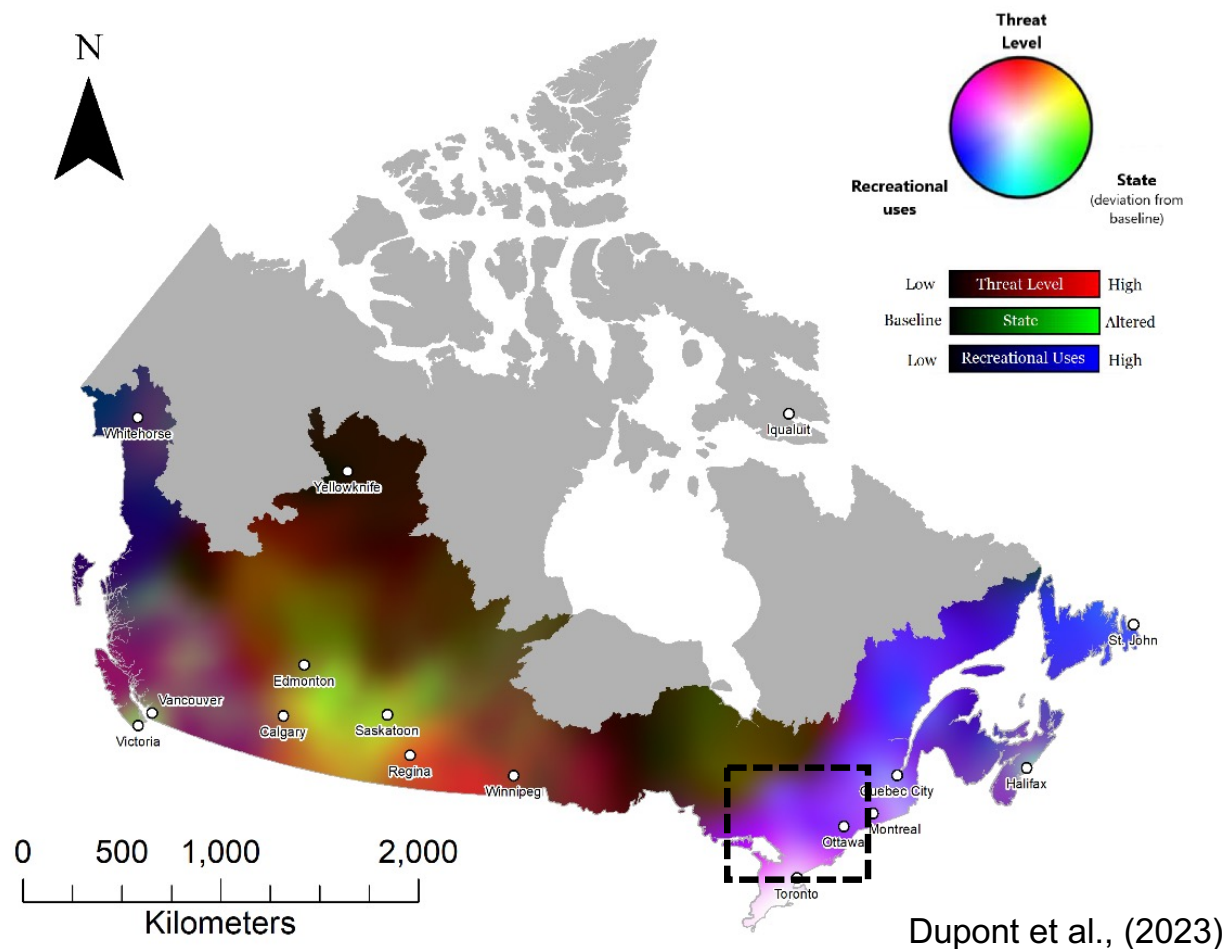
Are lakes important to *you*? - Yes

Are the *important* things that lakes provide under threat? - Probably

Are the 900,000 Canadian lakes equally important and equally threatened? - No



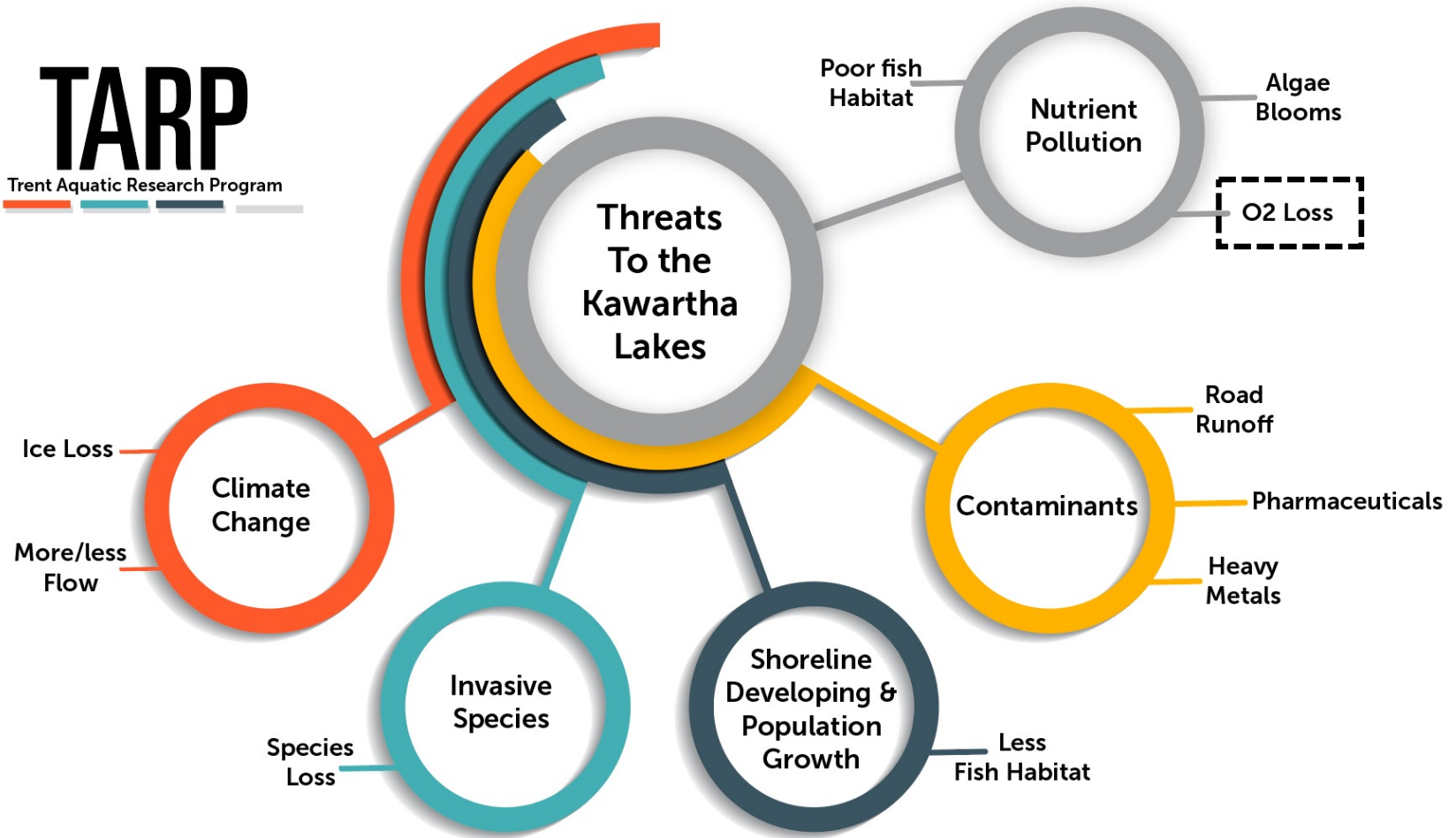
## A social-ecological geography of southern Canadian Lakes



Additive colour map of

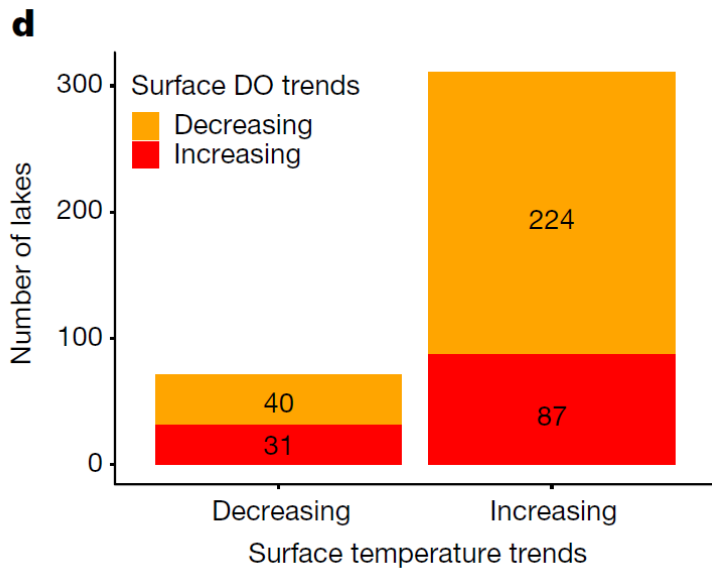
- Threat Level
- Lake Health
- Importance

Kawartha Lakes and Ontario “cottage country” = high importance, good health, but highly threatened



# Bad news for fishing: Climate change is sucking the oxygen out of lakes, study suggests

June 2021



Article


## Widespread deoxygenation of temperate lakes

<https://doi.org/10.1038/s41586-021-03550-y>

Received: 28 June 2019

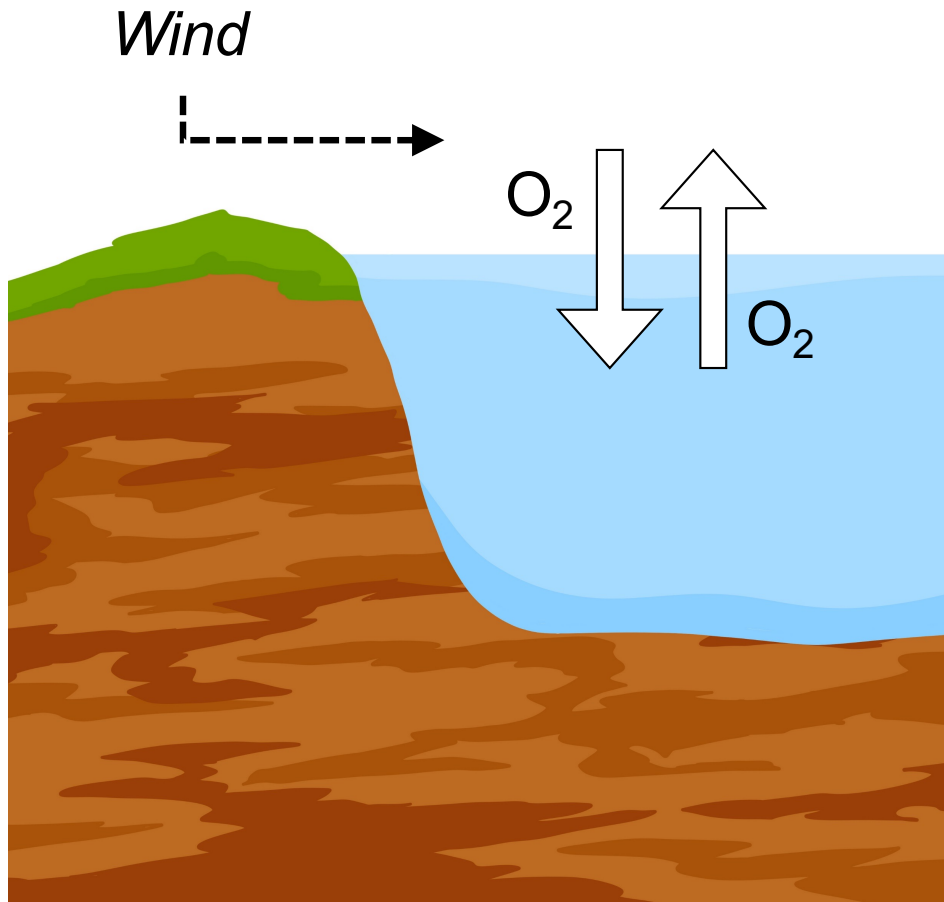
Accepted: 13 April 2021

Published online: 2 June 2021

 Check for updates



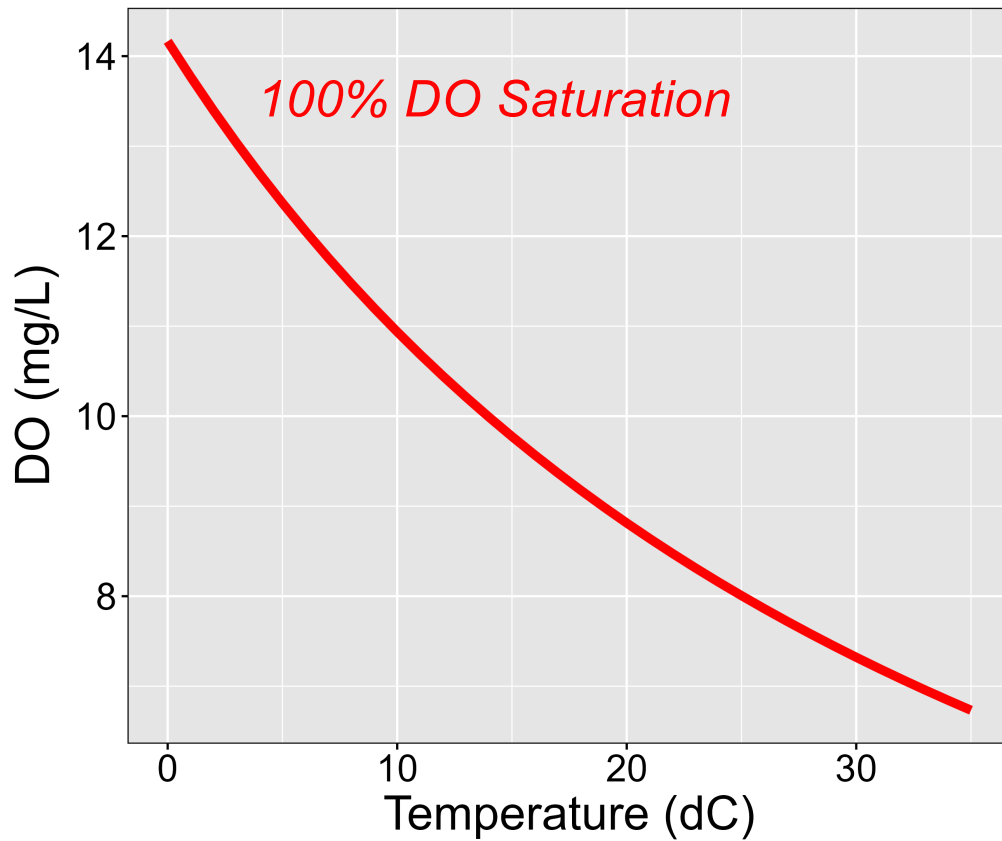
Stephen F. Jane<sup>1,2</sup>, Gretchen J. A. Hansen<sup>3</sup>, Benjamin M. Kraemer<sup>4</sup>, Peter R. Leavitt<sup>5,6</sup>, Joshua L. Mincer<sup>1</sup>, Rebecca L. North<sup>7</sup>, Rachel M. Pilla<sup>8</sup>, Jonathan T. Stetler<sup>1</sup>, Craig E. Williamson<sup>8</sup>, R. Iestyn Woolway<sup>9,10</sup>, Lauri Arvola<sup>11</sup>, Sudeep Chandra<sup>12</sup>, Curtis L. DeGasperi<sup>13</sup>, Laura Diemer<sup>14</sup>, Julita Dunalska<sup>15,16</sup>, Oxana Erina<sup>17</sup>, Giovanna Flaim<sup>18</sup>, Hans-Peter Grossart<sup>19,20</sup>, K. David Hambricht<sup>21</sup>, Catherine Hein<sup>22</sup>, Josef Hejzlar<sup>23</sup>, Lorraine L. Janus<sup>24</sup>, Jean-Philippe Jenny<sup>25</sup>, John R. Jones<sup>7</sup>, Lesley B. Knoll<sup>26</sup>, Barbara Leoni<sup>27</sup>, Eleanor Mackay<sup>28</sup>, Shin-Ichiro S. Matsuzaki<sup>29</sup>, Chris McBride<sup>30</sup>, Dörthe C. Müller-Navarra<sup>31</sup>, Andrew M. Paterson<sup>32</sup>, Don Pierson<sup>2</sup>, Michela Rogora<sup>33</sup>, James A. Rusak<sup>32</sup>, Steven Sadro<sup>34</sup>, Emilie Saulnier-Talbot<sup>35</sup>, Martin Schmid<sup>36</sup>, Ruben Sommaruga<sup>37</sup>, Wim Thiery<sup>38,39</sup>, Piet Verburg<sup>40</sup>, Kathleen C. Weathers<sup>41</sup>, Gesa A. Weyhenmeyer<sup>2</sup>, Kiyoko Yokota<sup>42</sup> & Kevin C. Rose<sup>1ES</sup>



**Gas Exchange:** physical process by which oxygen moves passively by diffusion in/out of lakes

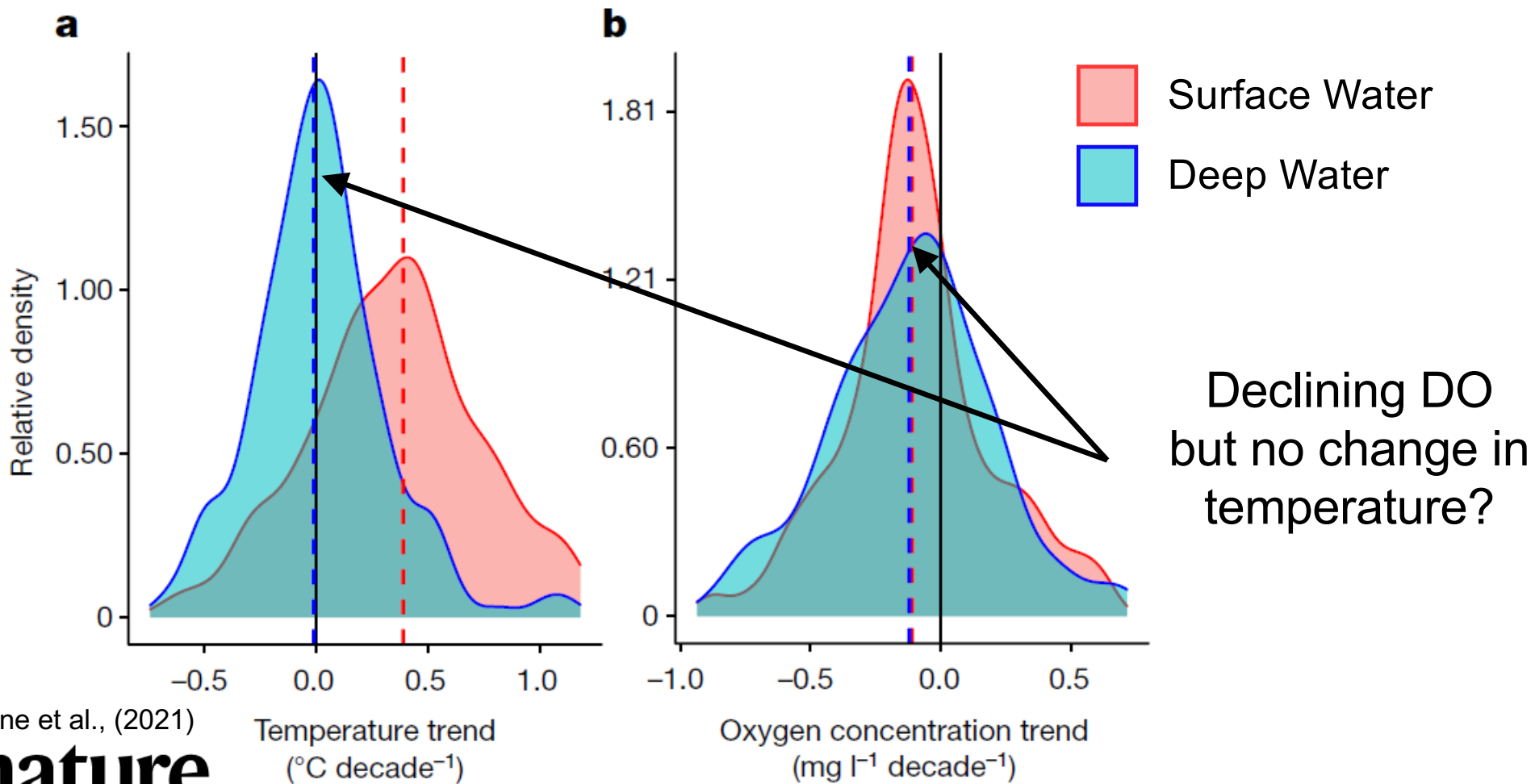
- Driven by wind and water turbulence
- Upper limit = 100% DO Saturation
- Saturation ~ Solubility

## DO Solubility



Colder waters have a greater capacity to hold oxygen

↑ surface water temperature  
=  
↓ dissolved oxygen



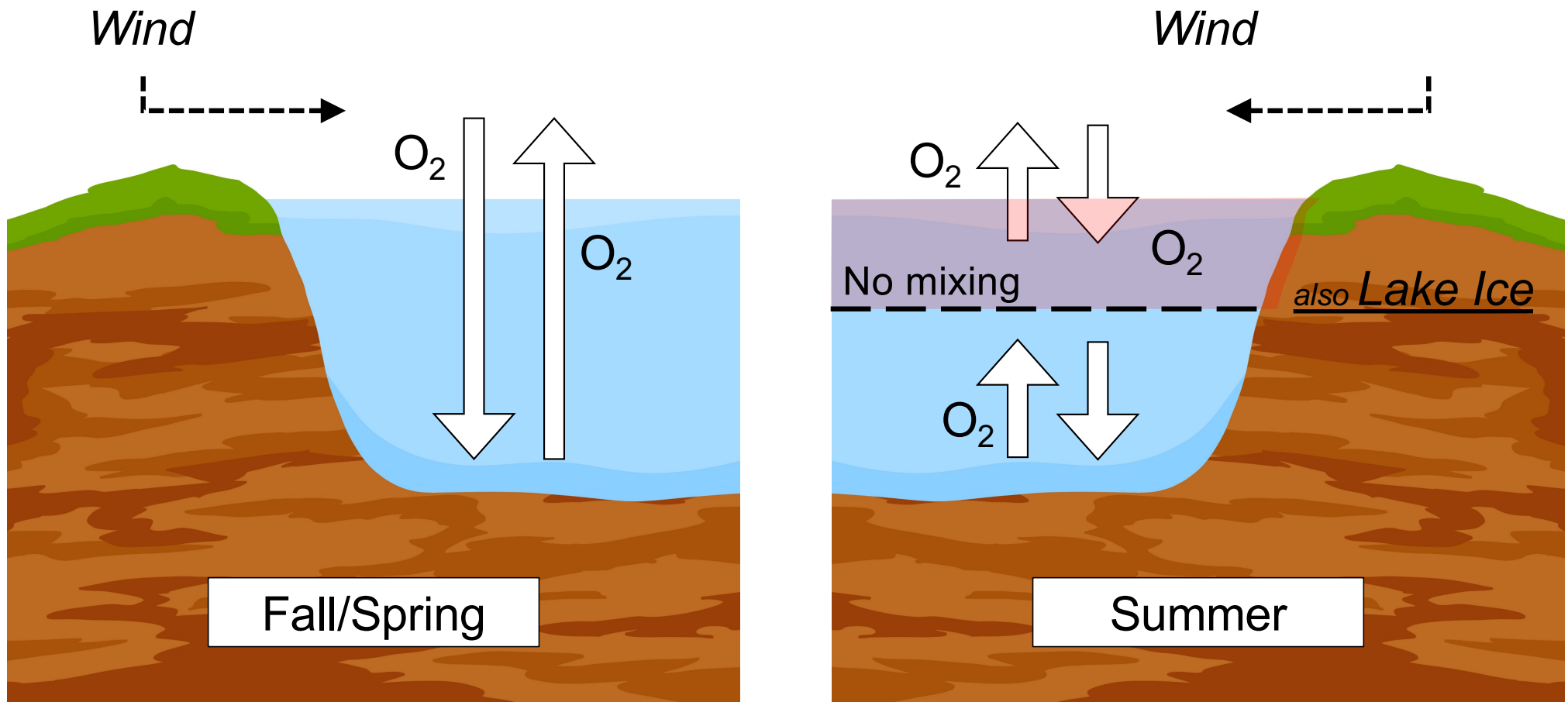
Jane et al., (2021)  
**nature**

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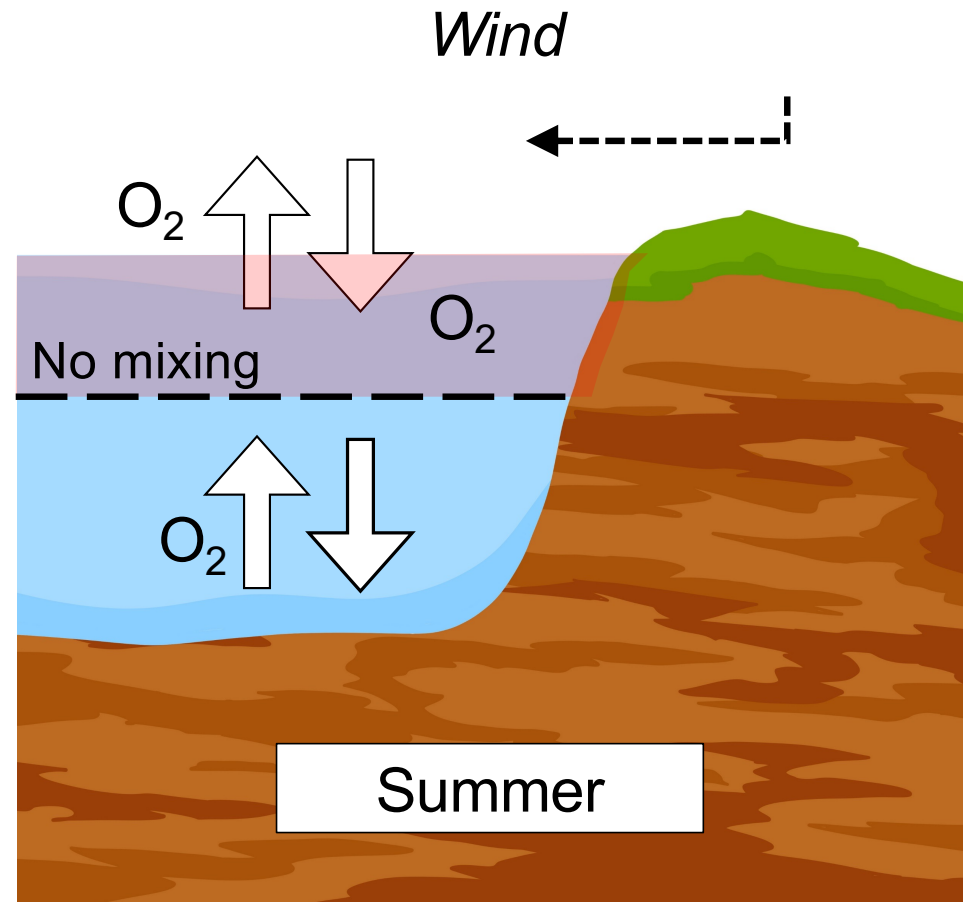
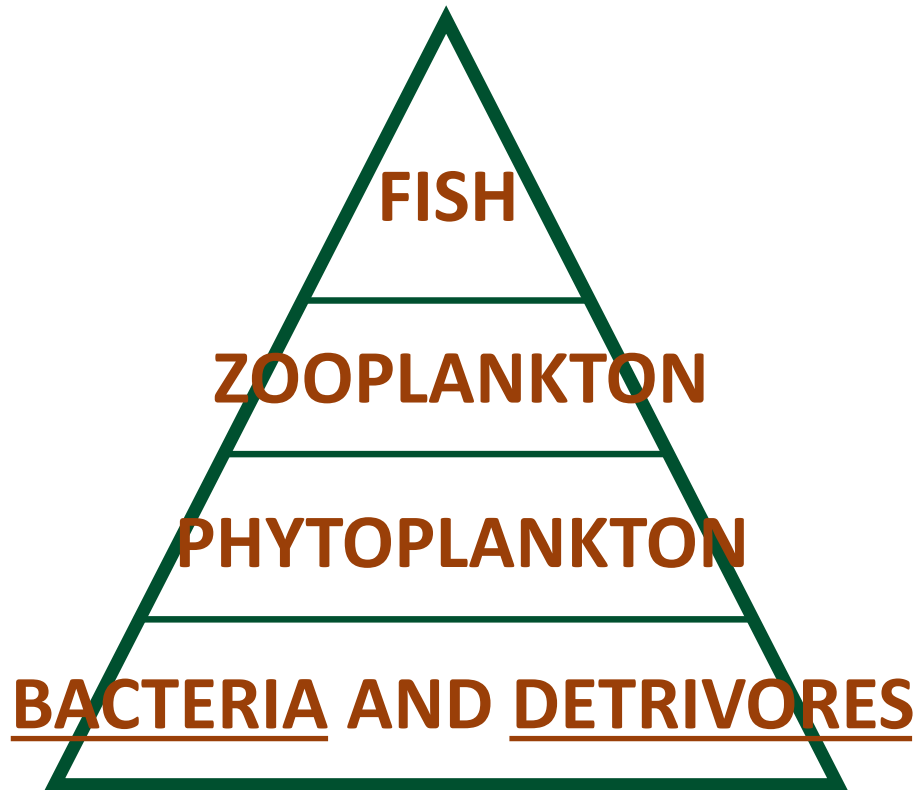
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# Thermal Stratification

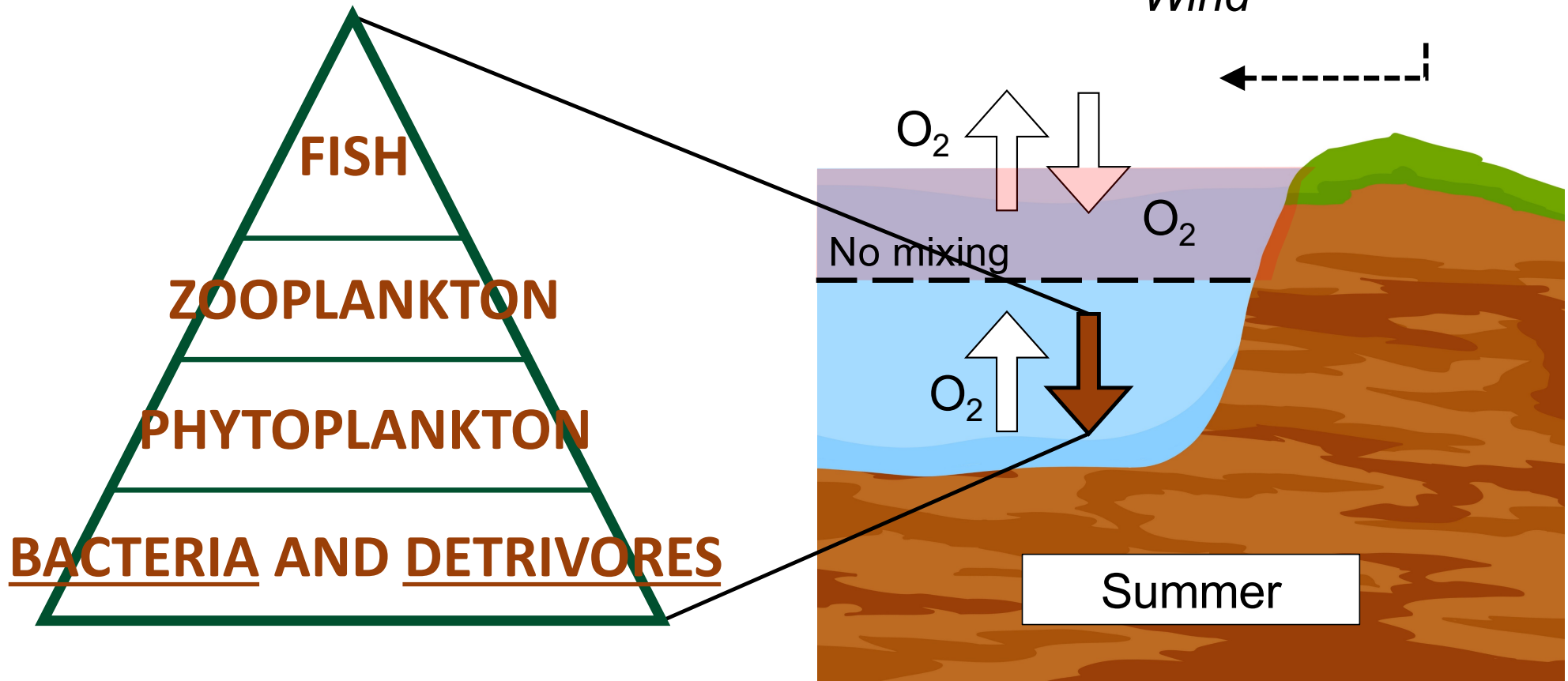


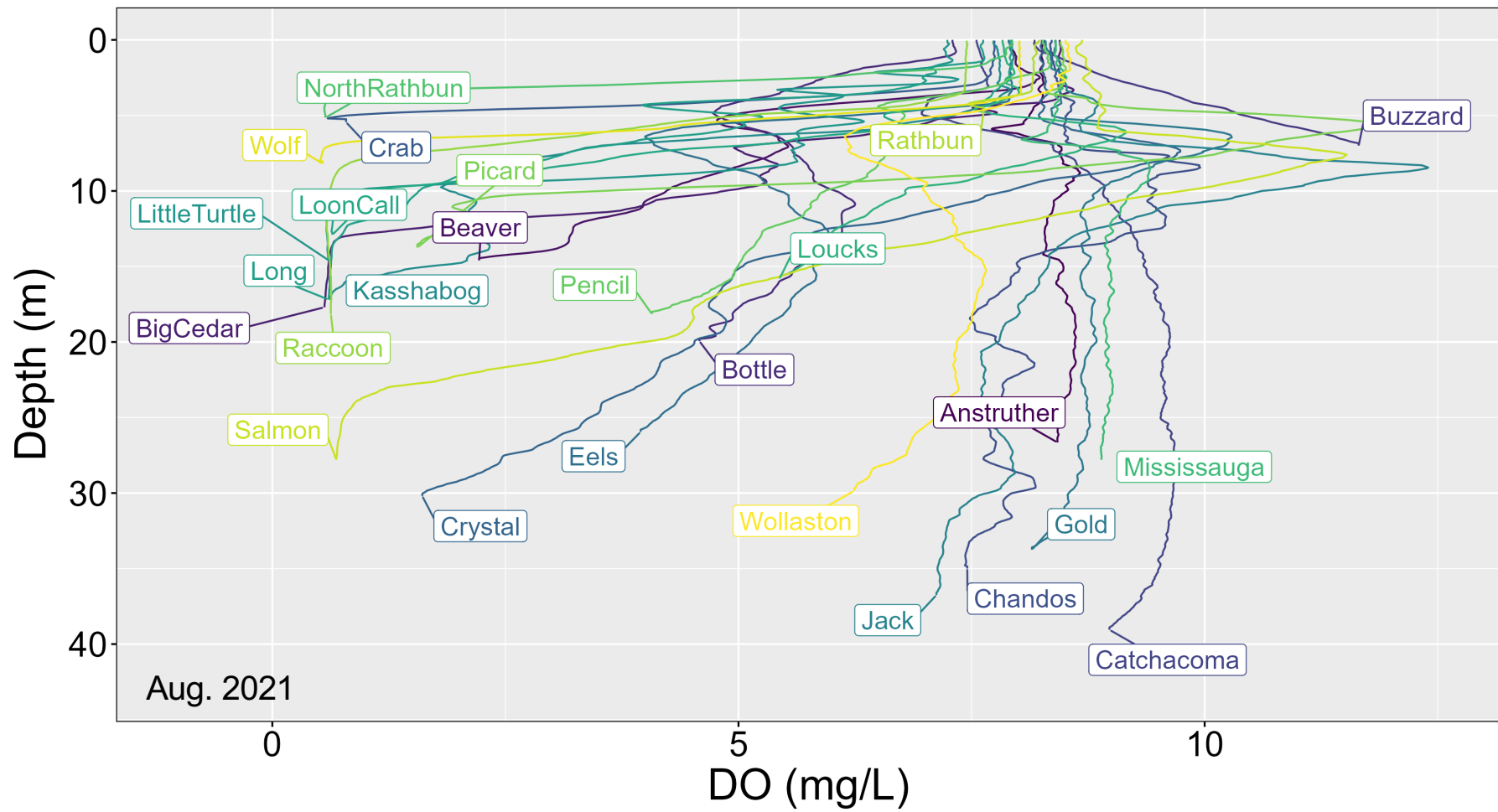
# Thermal Stratification





# Thermal Stratification

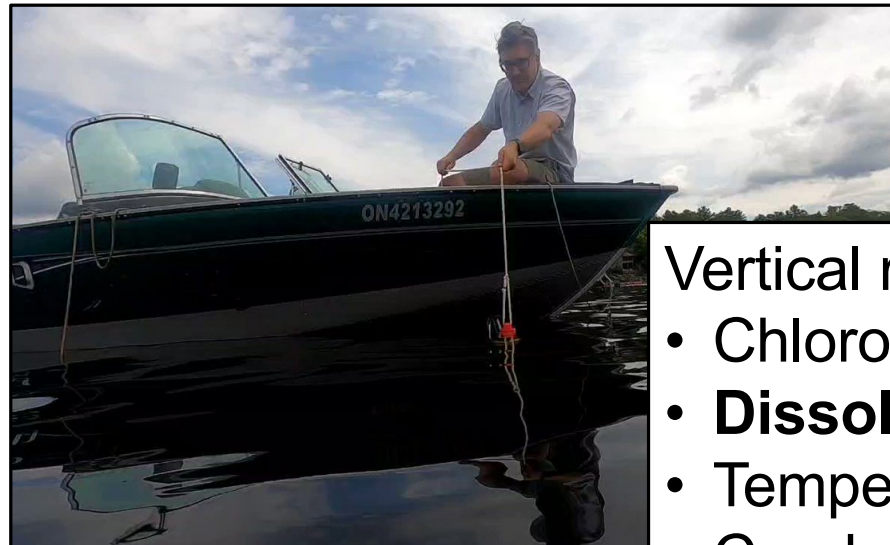




# Oxygen Decline in Kawartha Lakes

1. What are the rates of deep water DO depletion?
  - a) What factors drive differences in DO depletion rates among lakes?
  - b) Have these rates changed over time?
2. What are the ecological consequences of DO depletion?
3. Is DO depletion a concern regarding the sustainability of Kawartha Lakes?

# Oxygen Decline in Kawartha Lakes: Methods

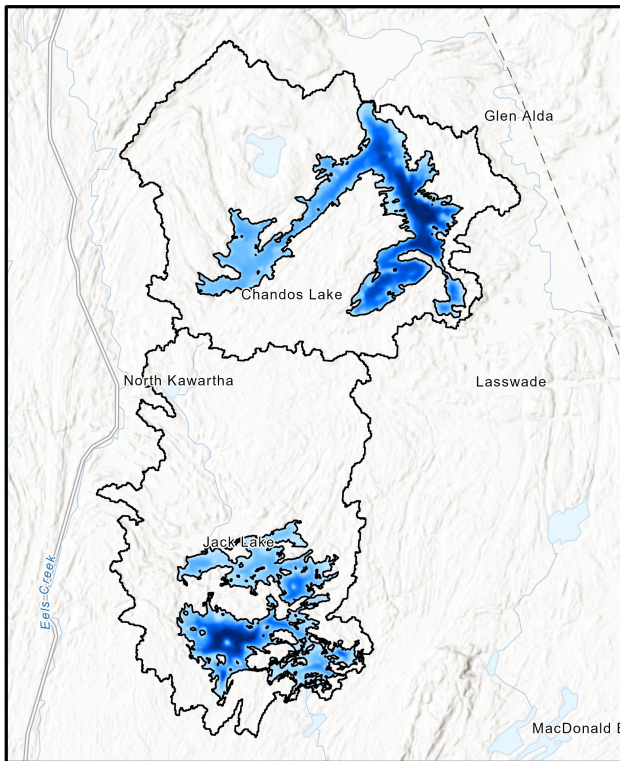


*8 measurements per second*

Vertical resolution (< 5 cm)

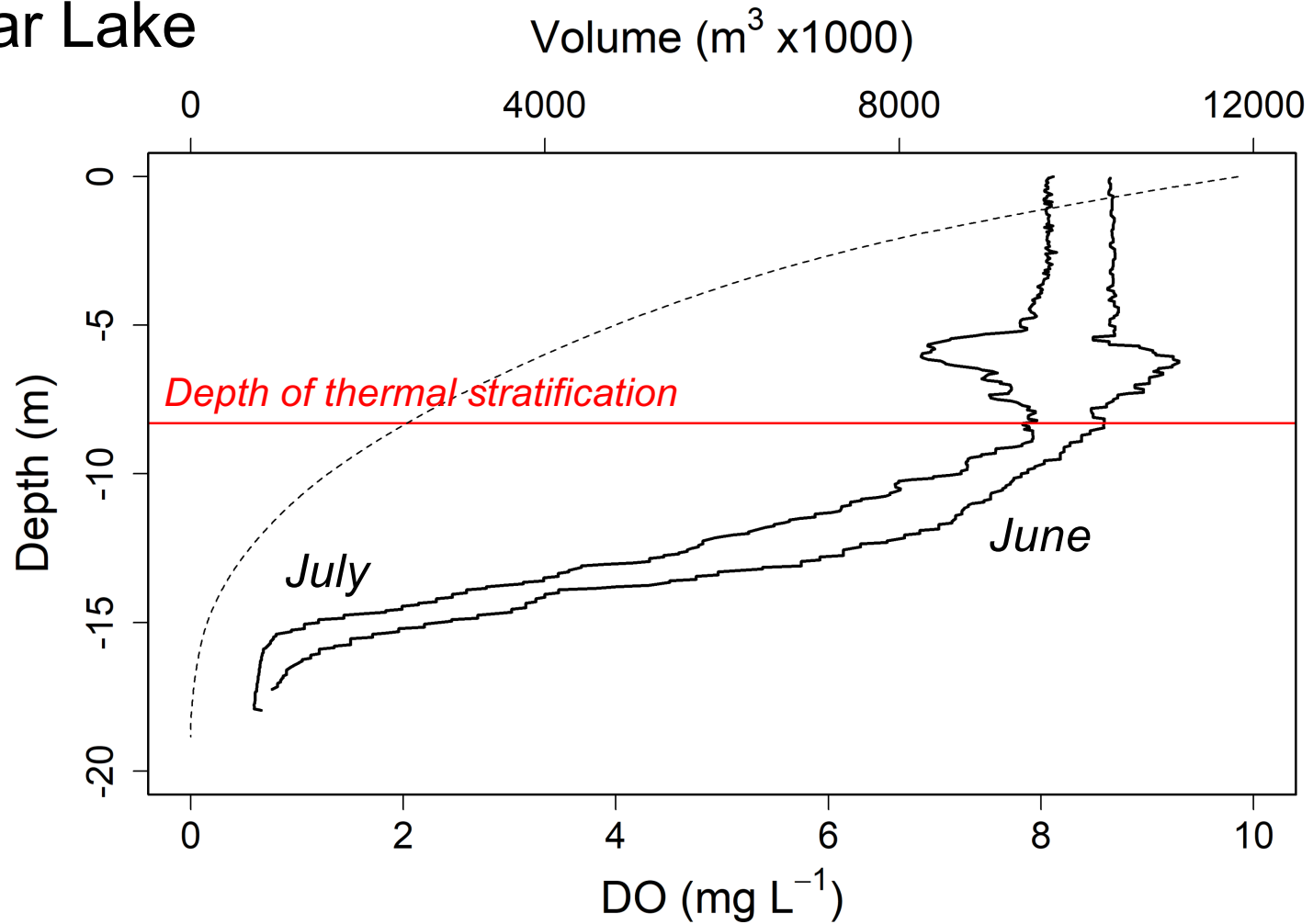
- Chlorophyll *a*
- **Dissolved Oxygen**
- Temperature
- Conductivity
- Dissolved Organic Matter
- Salinity
- ect...

# Oxygen Decline in Kawartha Lakes: Methods



- Classic limnology meets improved technology
- Common in broad scale monitoring, but only 1 time per year in mid-summer
- Lake morphology is heterogeneous!
- Need at least 2 timepoints and geographic data on lake volume + benthic surface area

# Big Cedar Lake



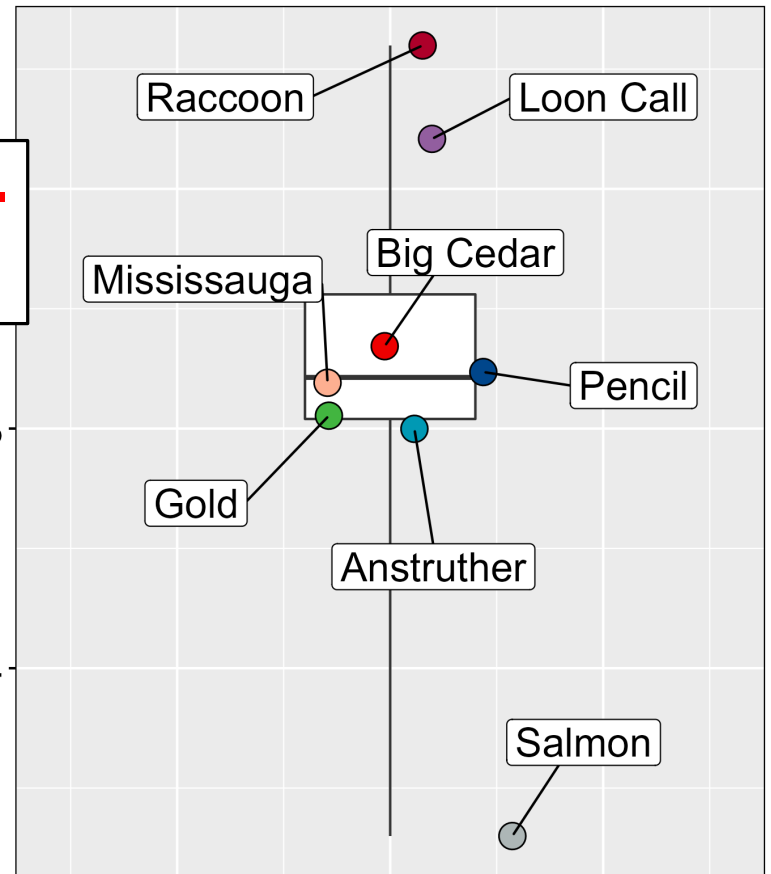
# Data Collection

- DO profiles and chemistry every 3 weeks from May to Sept. and in Feb.
  - *Big Cedar Lake every 3-days from Apr. to Dec.*
- Heterogeneous lake morphology and summer DO
- Calculate DO depletion →

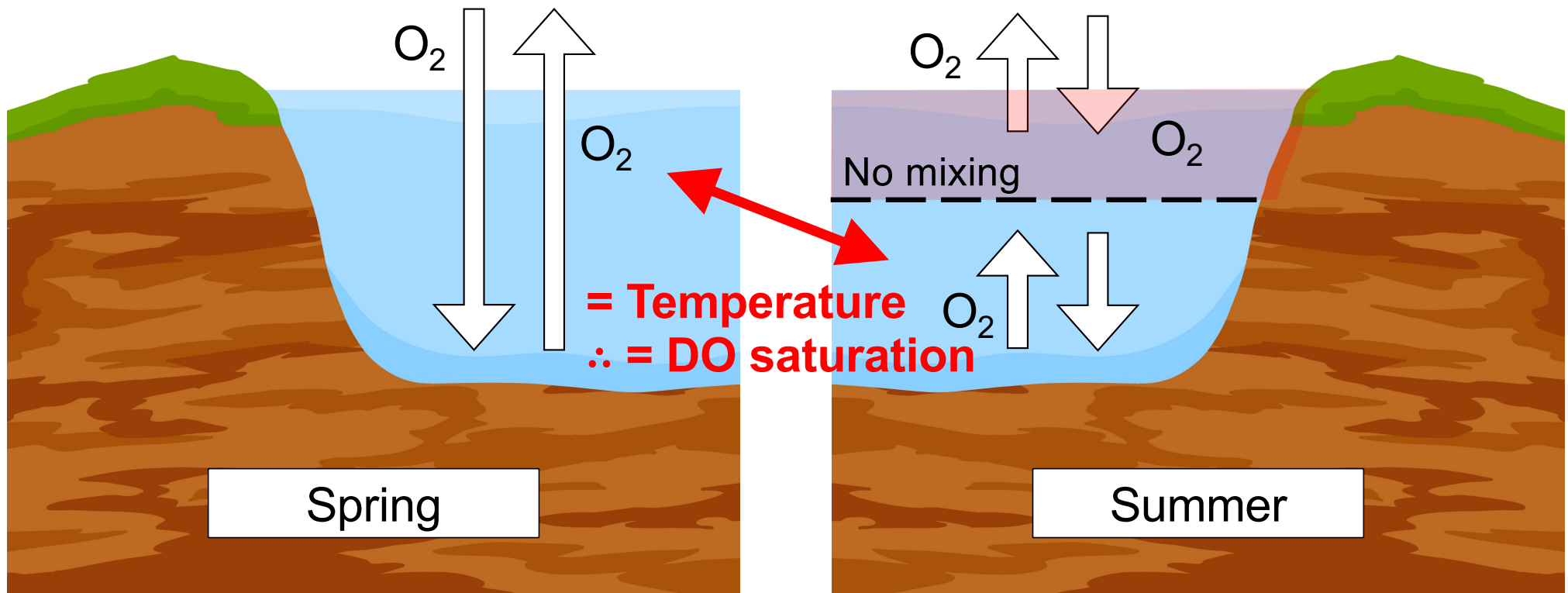
**Can we leverage broad-scale monitoring data?**

$\text{d}^{-1}$

DO Depletion ( $\text{g O}_2$ )



# Recall: Thermal Stratification + Solubility





*Limnol. Oceanogr.*, 38(5), 1993, 1077–1081

© 1993, by the American Society of Limnology and Oceanography, Inc.

## A simple model for predicting the date of spring stratification in temperate and subtropical lakes

### **Modelling ice cover, timing of spring stratification, and end-of-season mixing depth in small Precambrian Shield lakes**

Kendra L. Cahill, John M. Gunn, and Martyn N. Futter



**ARTICLE**

### Predicting open-water thermal regimes of temperate North American lakes

Daniel P. Gillis, Charles K. Minns, and Brian J. Shuter

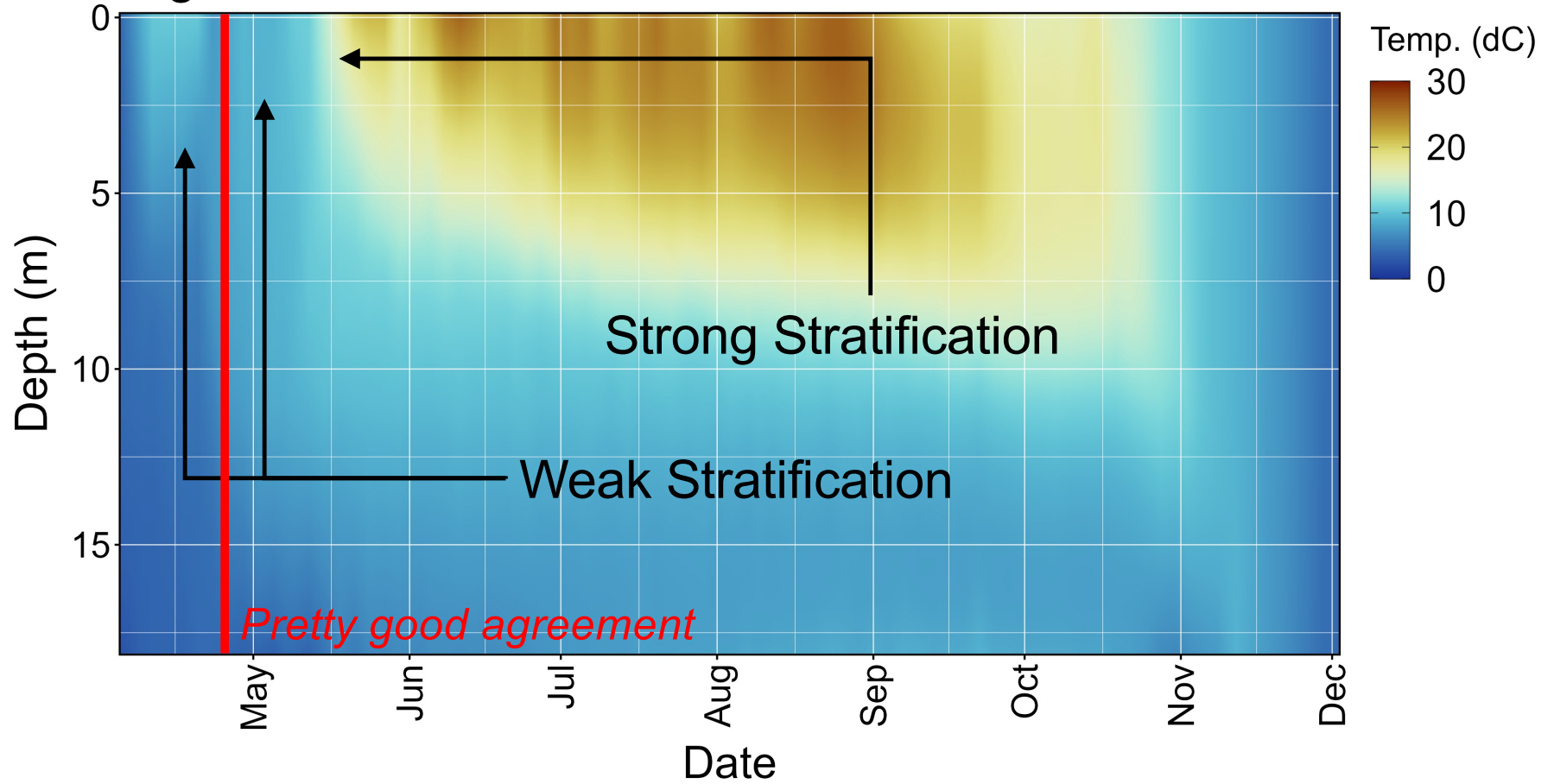
*Thermal stratification*  
*= air temperature*  
*+ lake surface area*  
*+ lake depth*

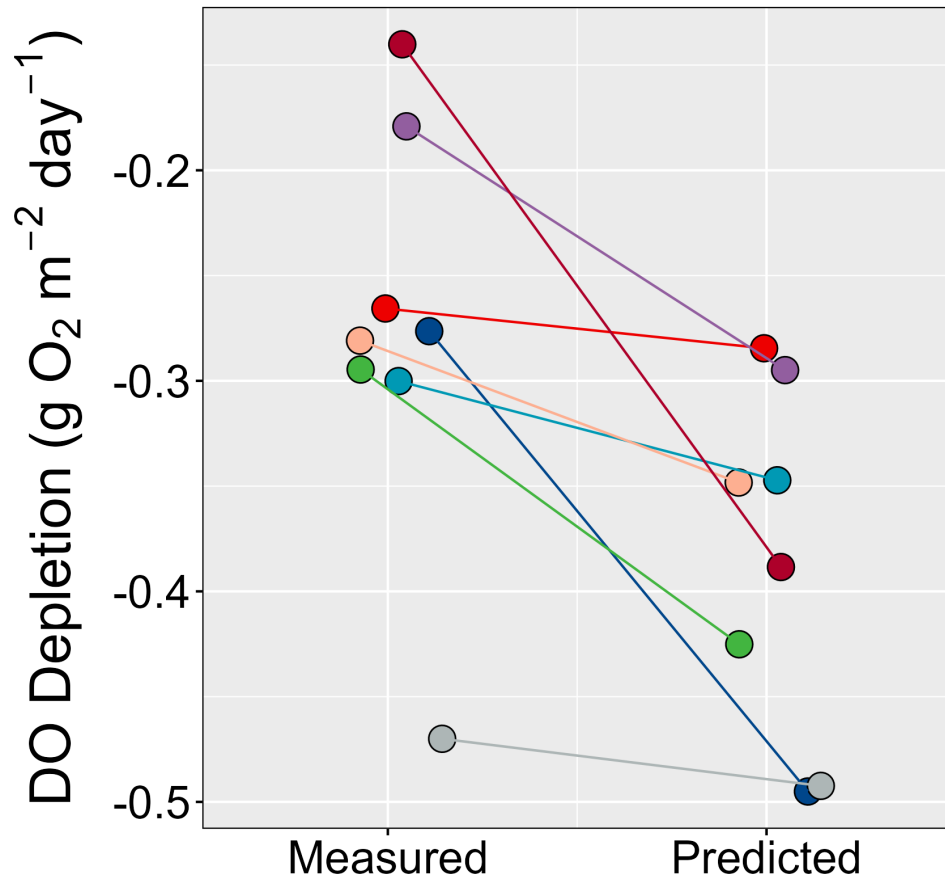
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# Big Cedar Lake





**|Predicted| > |Measured|**

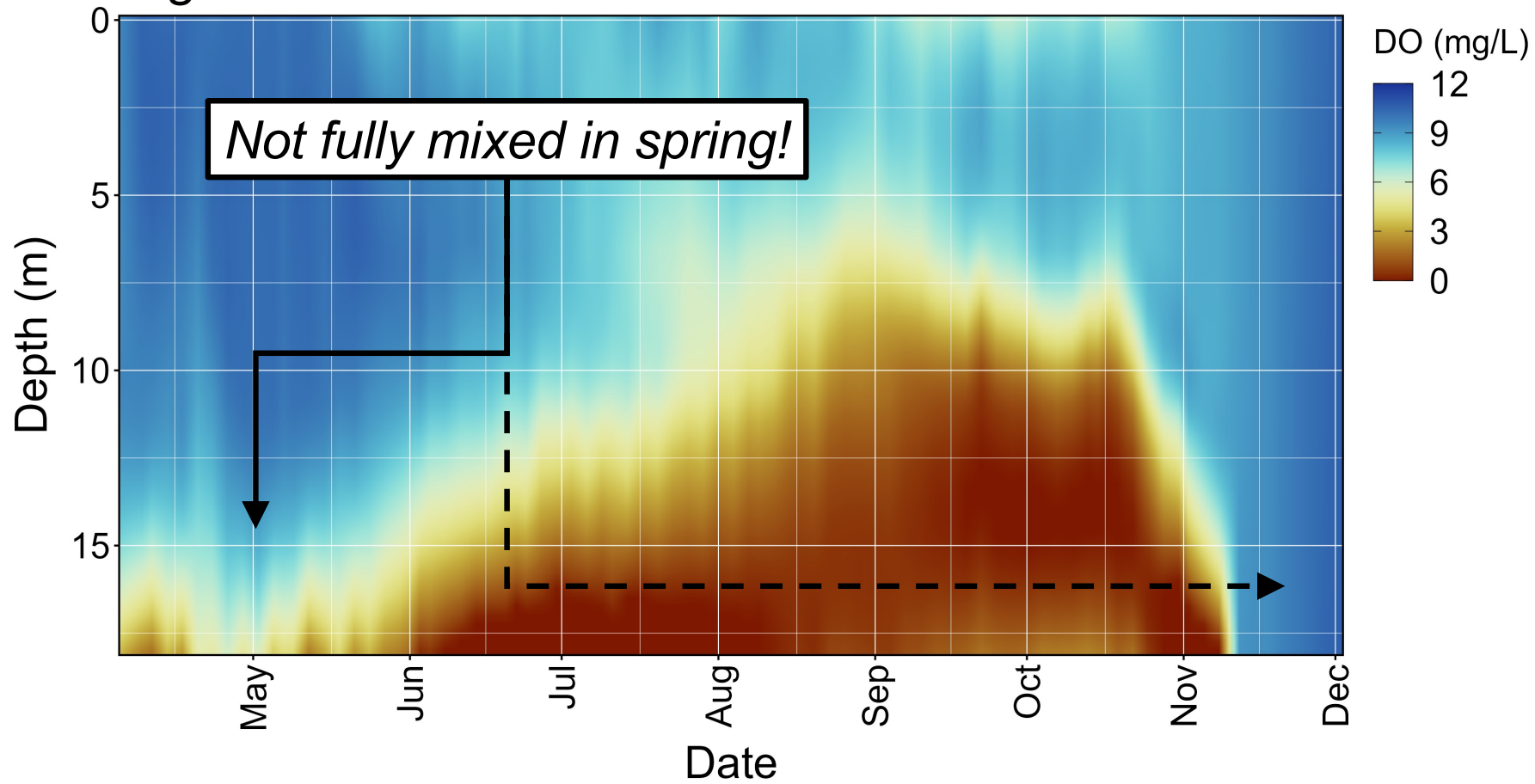
Within accepted error? **X**

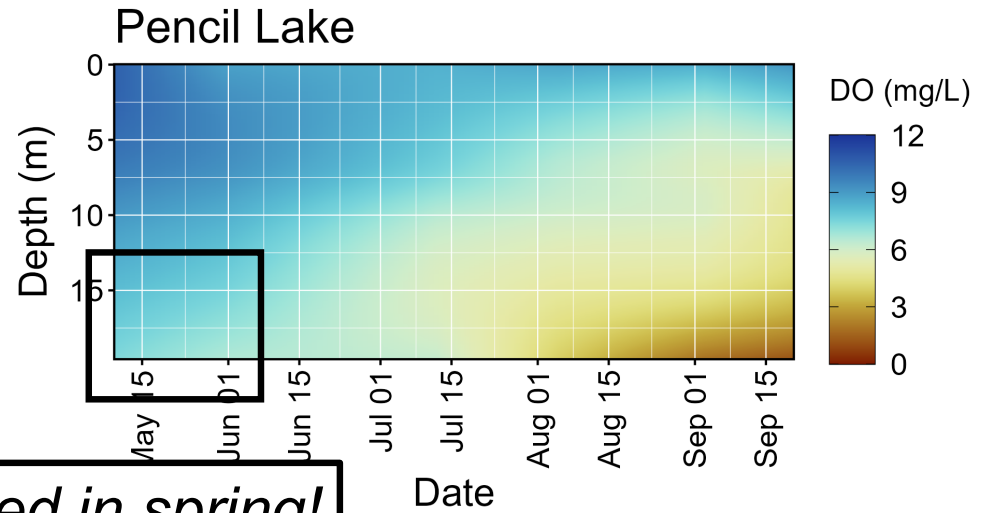
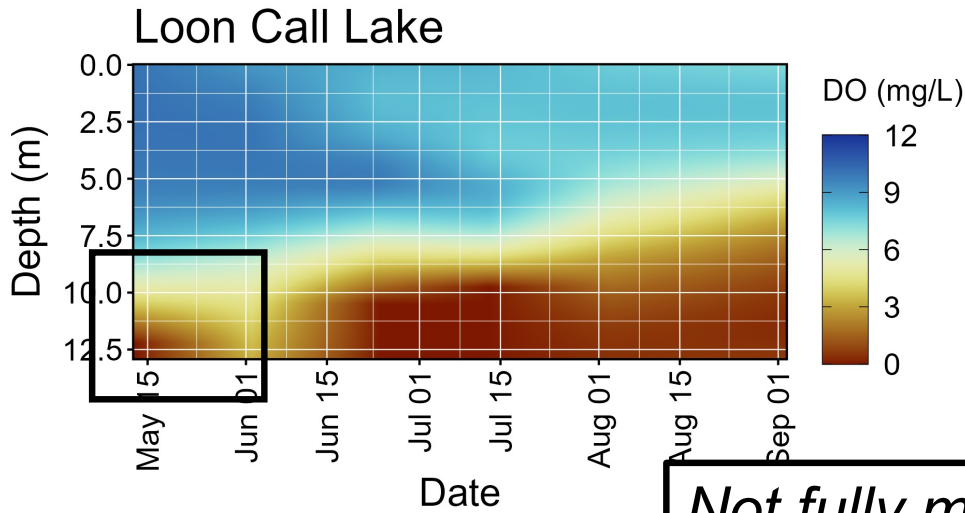
Stratification date? **X**

Non-linear DO depletion? **X**

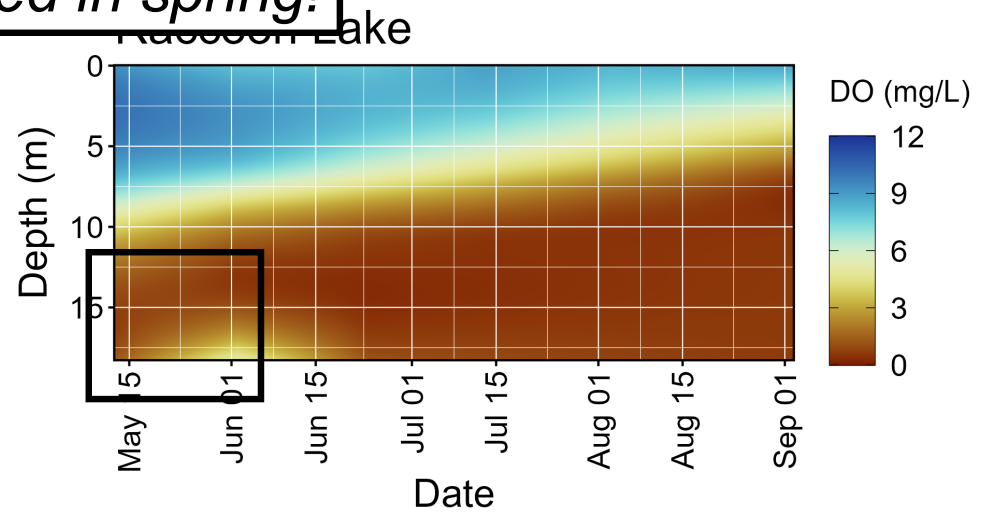
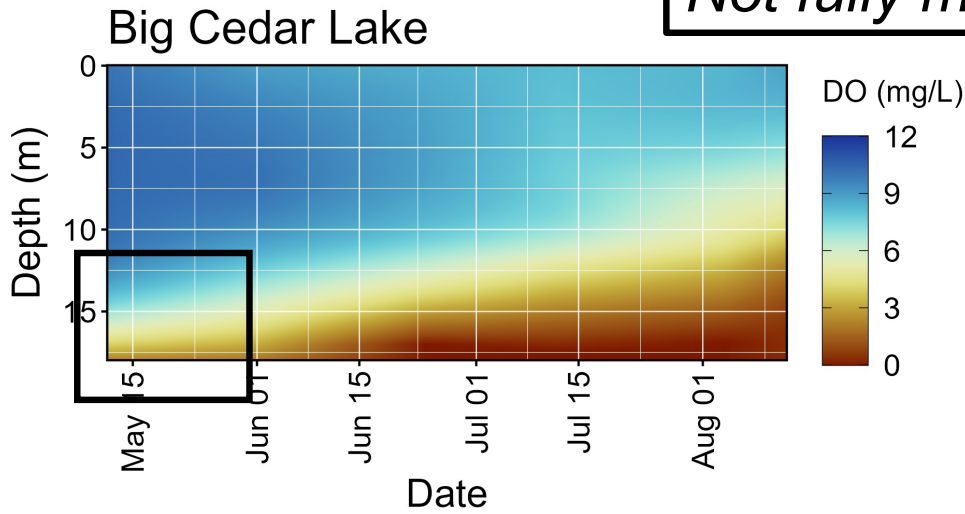
**???**

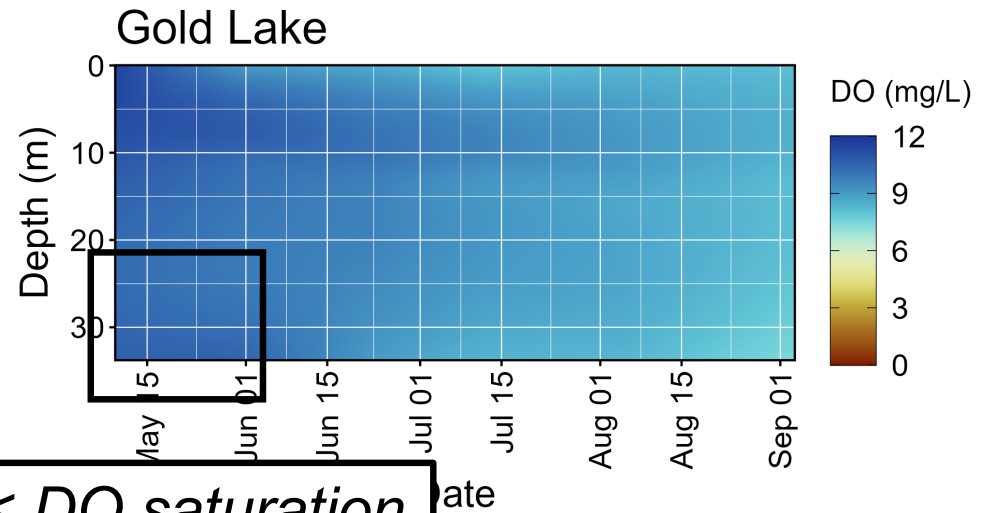
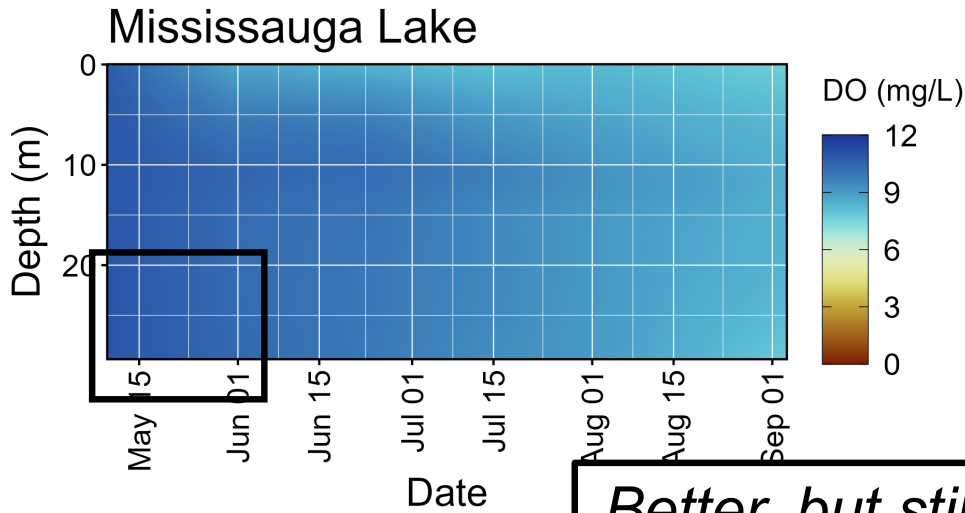
# Big Cedar Lake



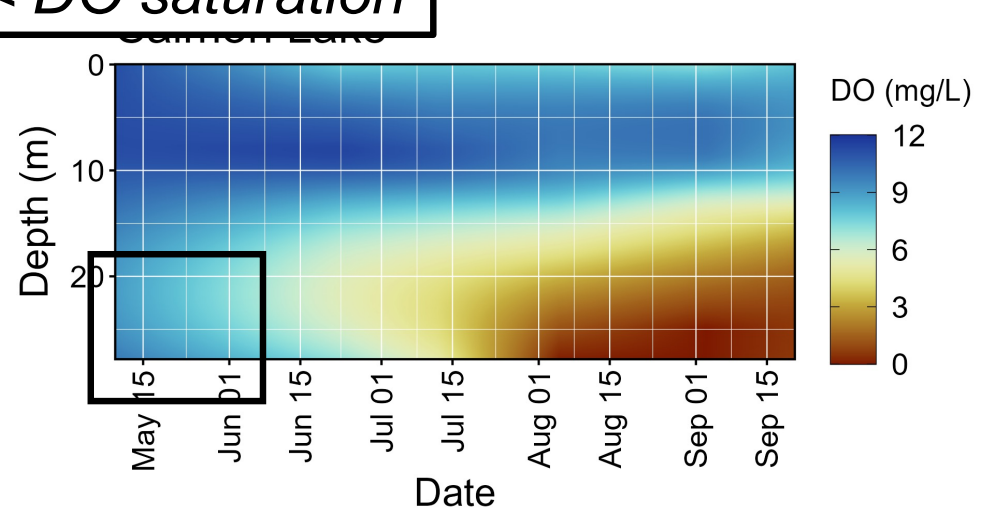
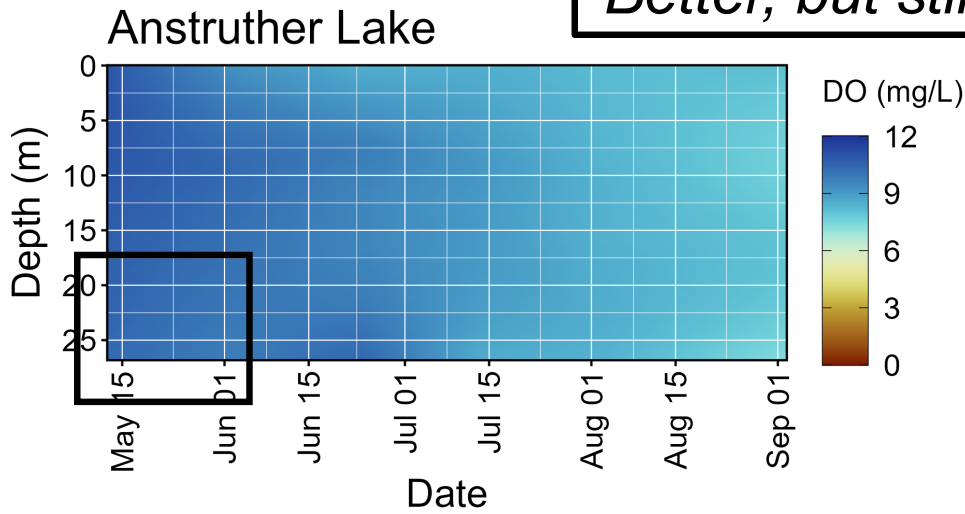


*Not fully mixed in spring!*





*Better, but still < DO saturation*



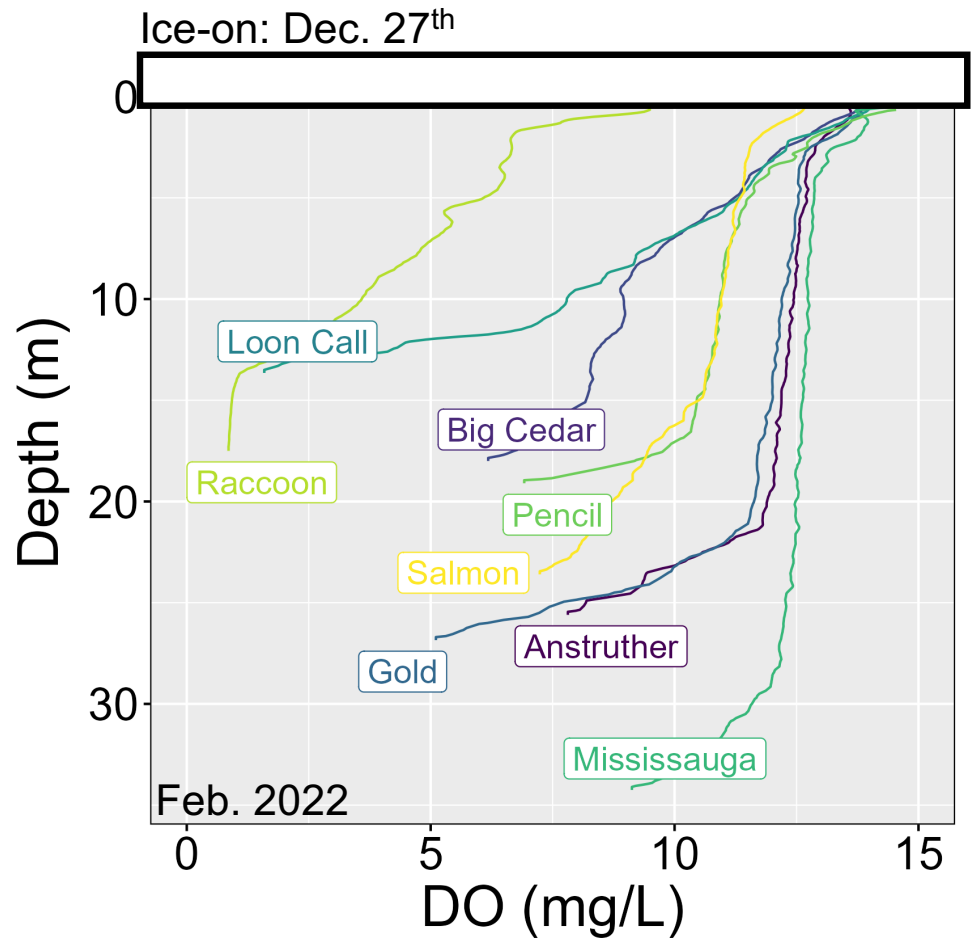
## Spring Mixing ≠ Textbook Knowledge

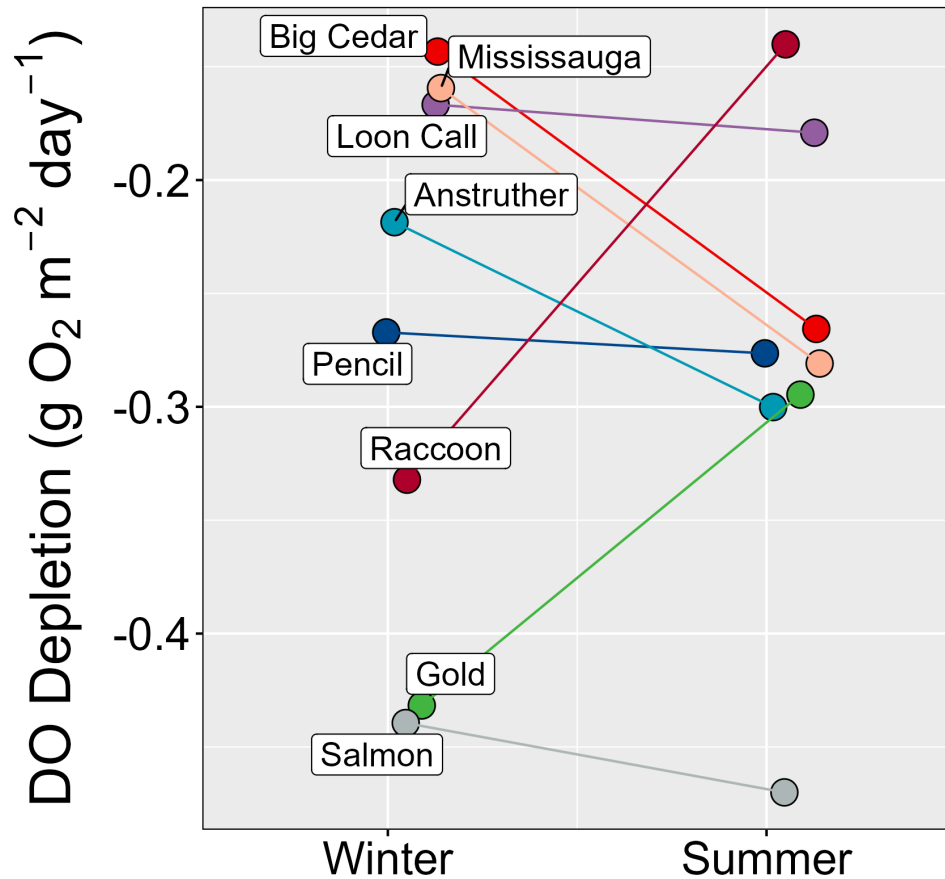
Is insufficient spring mixing common in Kawartha lakes?

Morphology?

Weather?

Winter DO depletion?





**|Summer| > |Winter|**

Expected? - ✓

Raccoon? - earlier ice on?

Gold? - spatial difference?



DO is complex – especially in the Spring

Winter → Spring sets the fixed supply of DO for the summer

Spatial variation in lake morphology is linked to differences in mixing

Temporal variation in spring conditions = interannual variability

1. What are the rates of deep water DO depletion?
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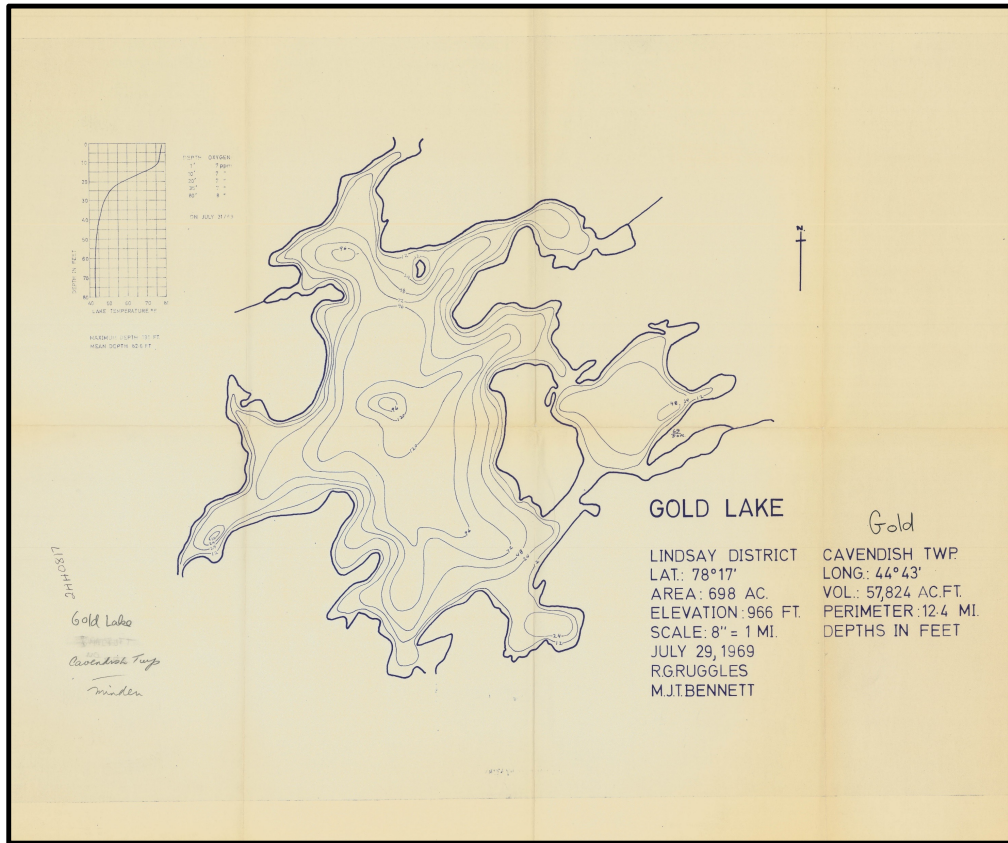
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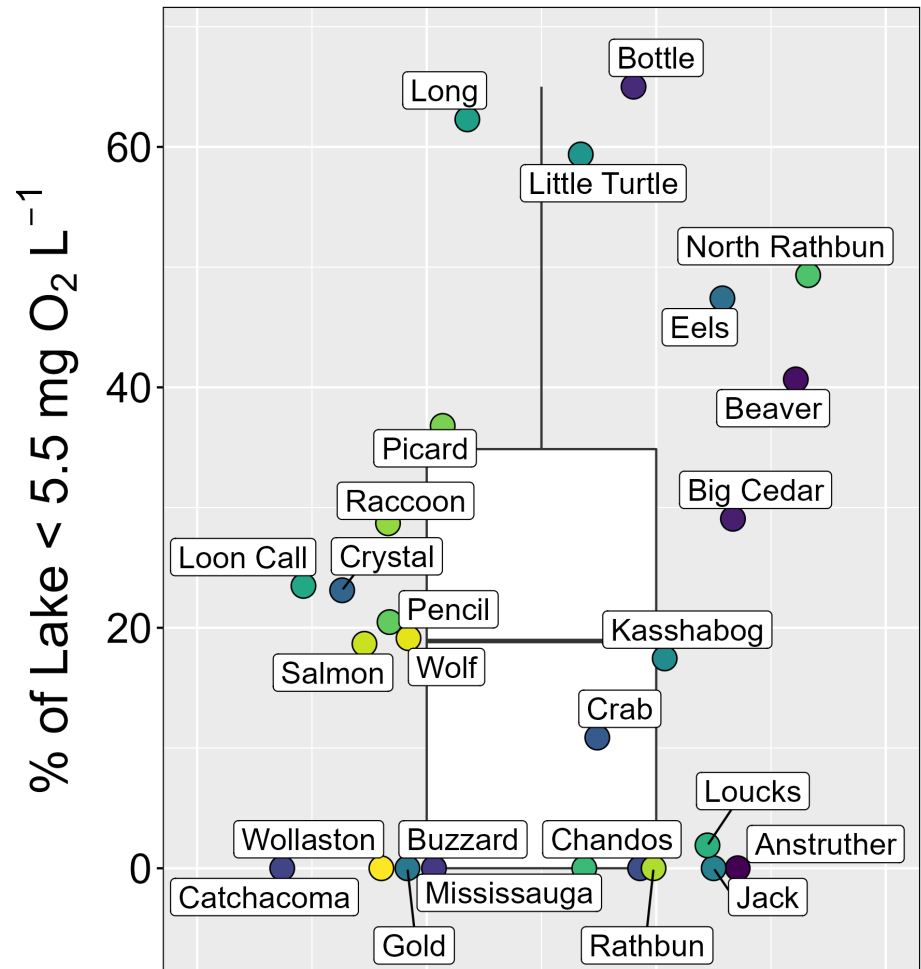
More targeted monitoring is needed

2. What are the ecological consequences of DO depletion?

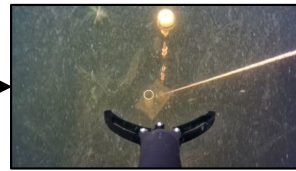
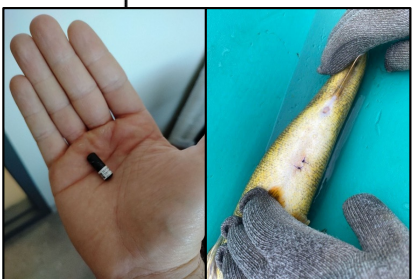
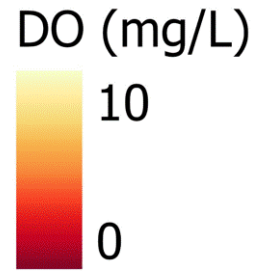
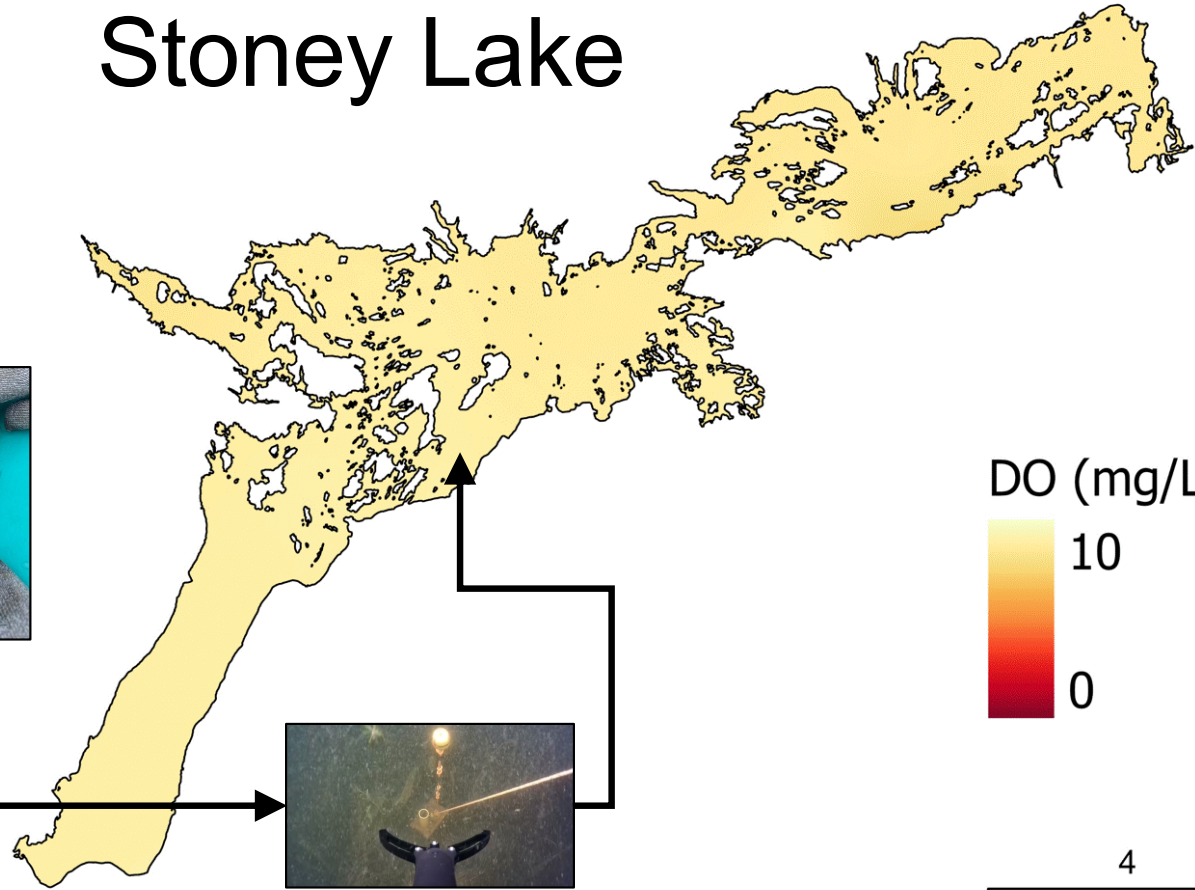
### Habitat Availability

Canadian Water Quality Guidelines for the Protection of Aquatic Life =  $5.5 \text{ mg O}_2 \text{ L}^{-1}$

~ 50% of Kawartha Lakes sampled have >20% of lake volume that is **unsuitable** for aquatic life



# 0 m Stoney Lake





2. What are the ecological consequences of DO depletion?

### Biogeochemistry

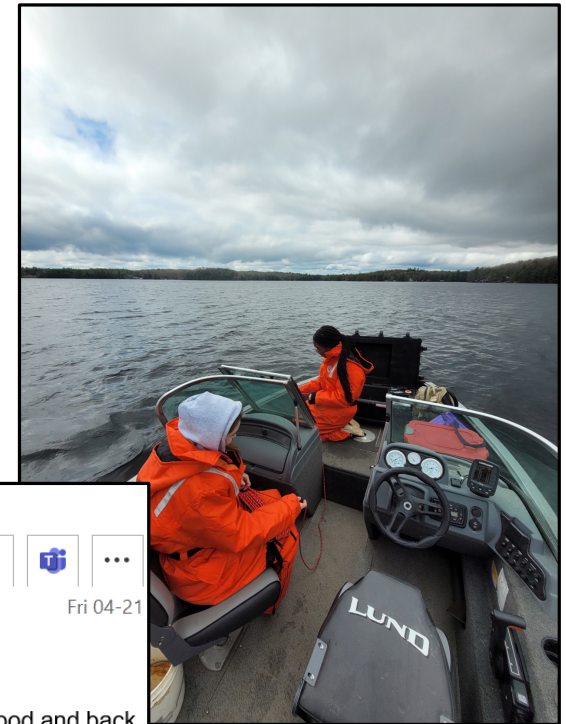
Low DO → Internal P release →  
Increased nutrient availability →  
Stimulate phytoplankton



### 3. Is DO depletion a concern regarding the sustainability of Kawartha Lakes?

Probably, but we are data deficient

Moving forward: Need for an increased understanding of DO depletion to help safeguard these lakes – especially deep high DO habitats



Re: Big Boat



Katlin Doughty <katlindoughty@tre>  
To Graham Raby; Nolan Pearce; Paul Frost



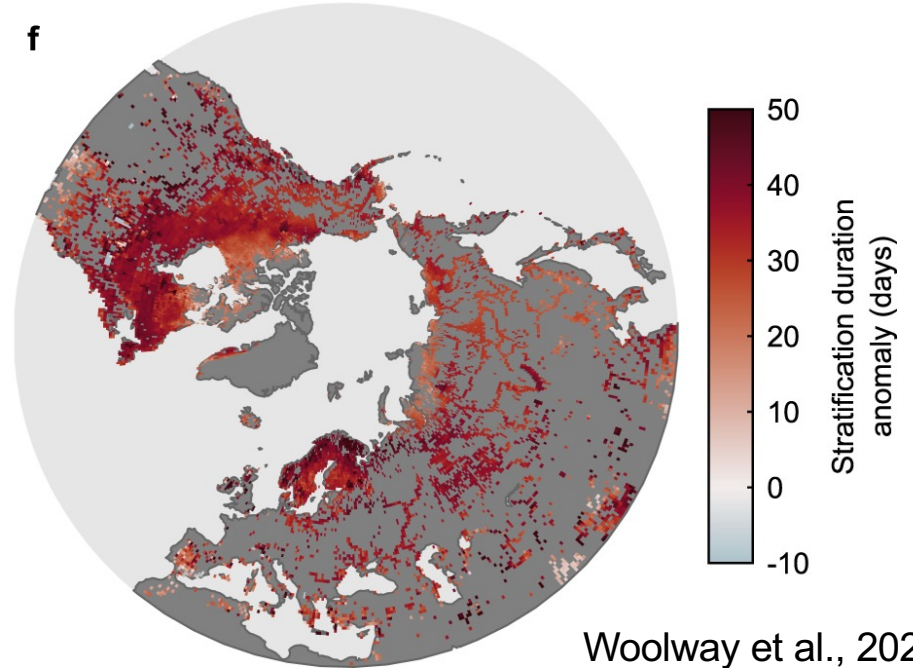
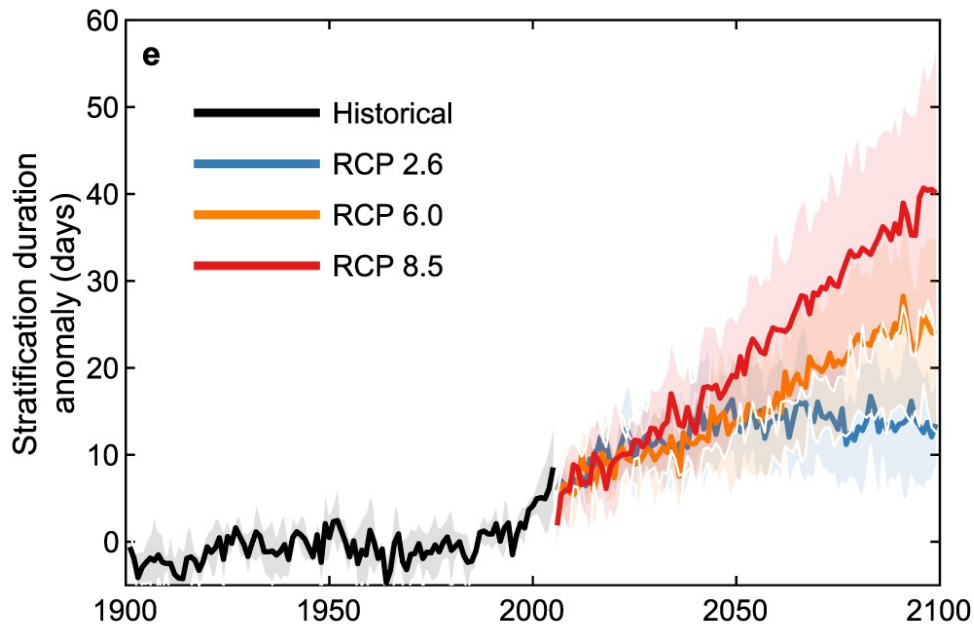
Fri 04-21

You replied to this message on 2023-04-21 10:11 AM.

Hi All,  
Just wanted to send over a quick msg to say that the big boat is all good and back in the compound-

### 3. Is DO depletion a concern regarding the sustainability of Kawartha Lakes?

There is cause for concern...



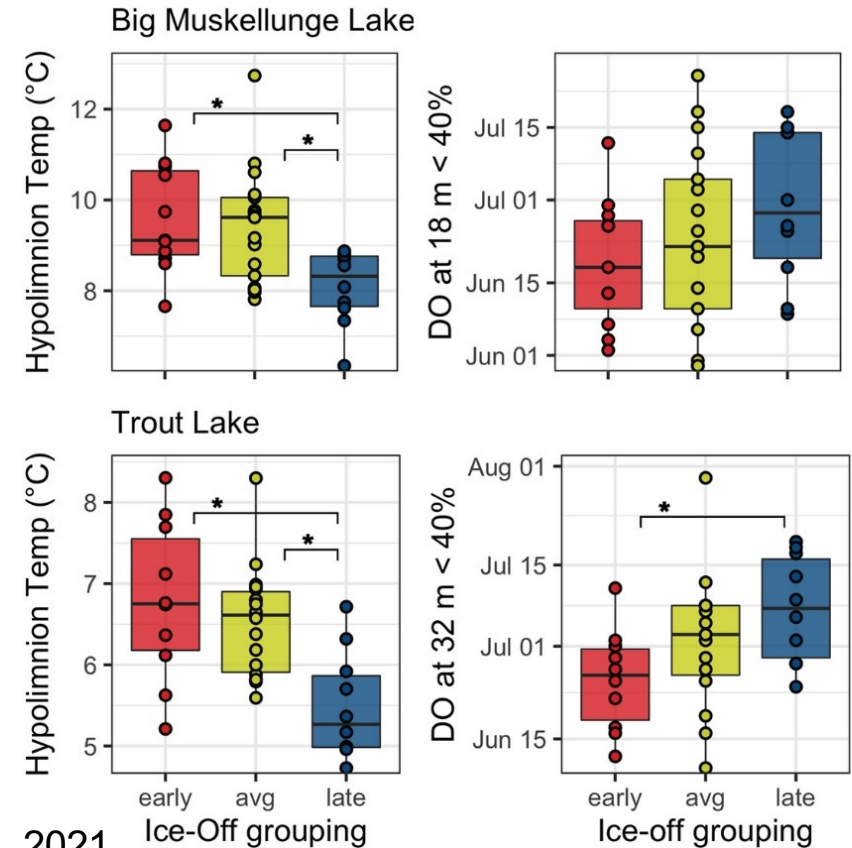
Woolway et al., 2021



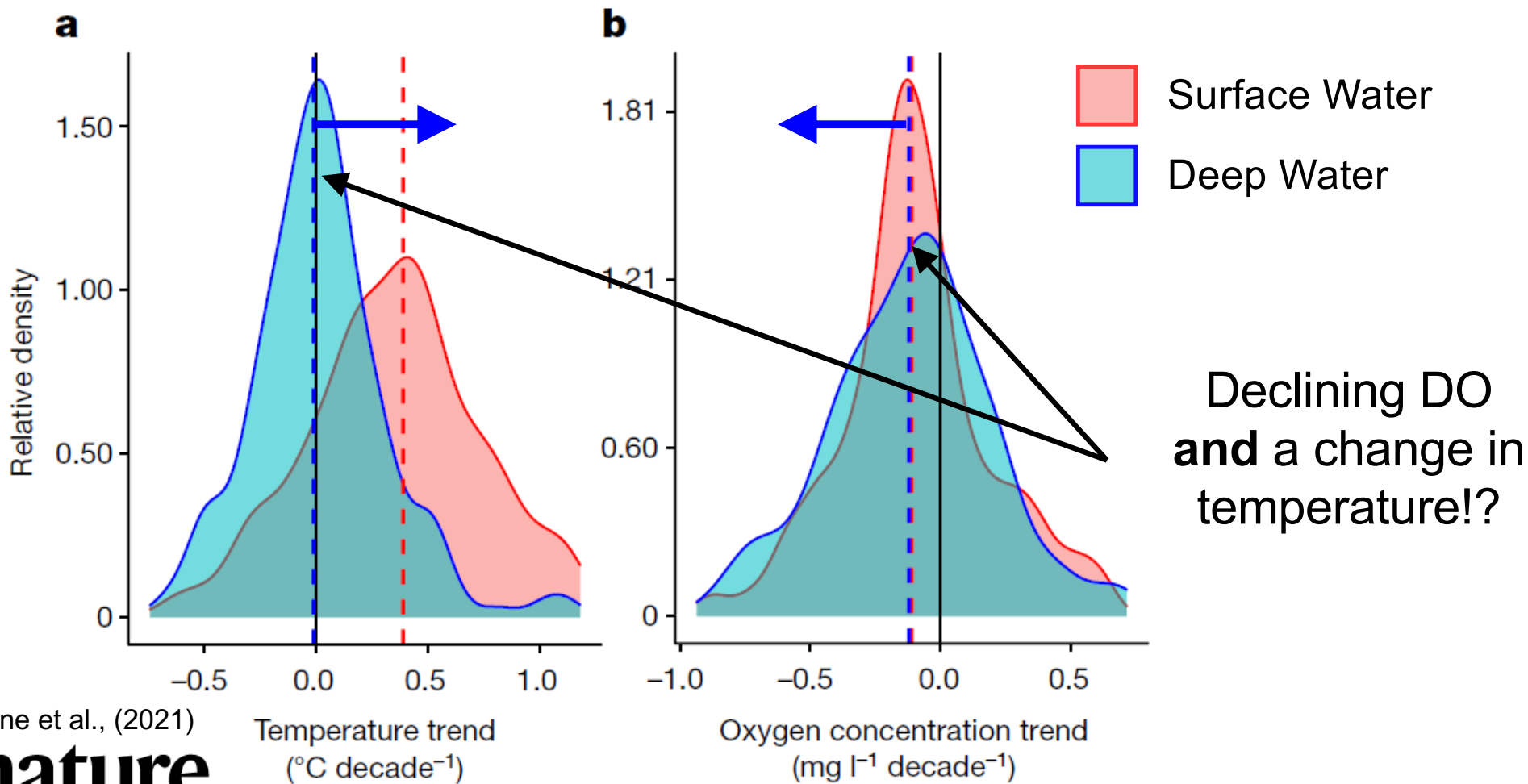
### 3. Is DO depletion a concern regarding the sustainability of Kawartha Lakes?

There is cause for concern...

Early ice-off → warmer temp. →  
lower DO Sat. → higher microbial  
activity → more DO depletion



Dugan, 2021



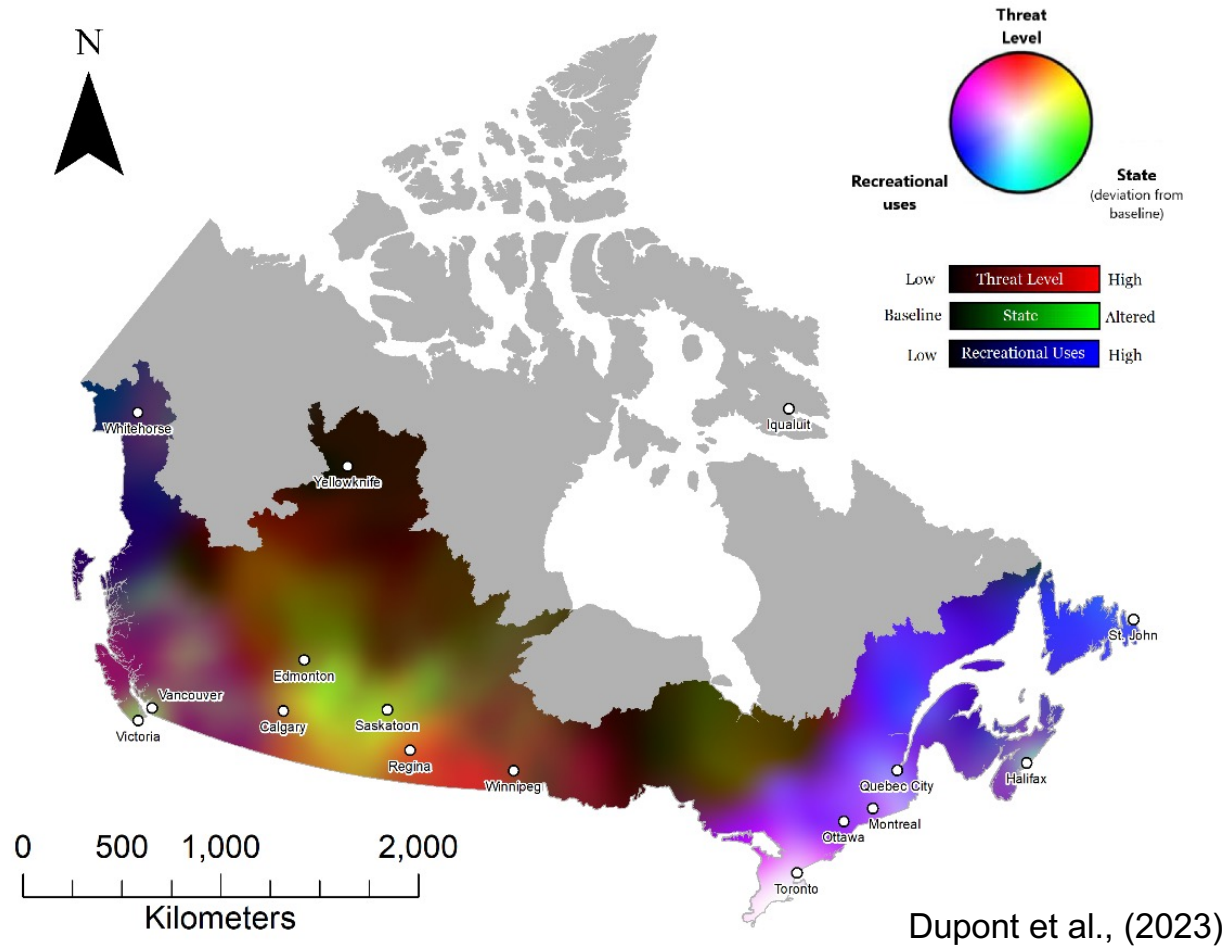
Jane et al., (2021)  
**nature**

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# A social-ecological geography of southern Canadian Lakes



Kawartha Lakes and Ontario “cottage country” = high importance, good health, but highly threatened

Effective ecological monitoring fundamentally important here...

Dupont et al., (2023)

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**Thank You**  
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Special thanks to...  
Paul Frost  
Marguerite Xenopoulos  
Graham Raby  
Katlin Doughty

