Let's connect! Tracking the connectivity-associated movement of water and sediment through Arctic deltas using satellite imagery

Wayana Dolan

5/19/2026

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

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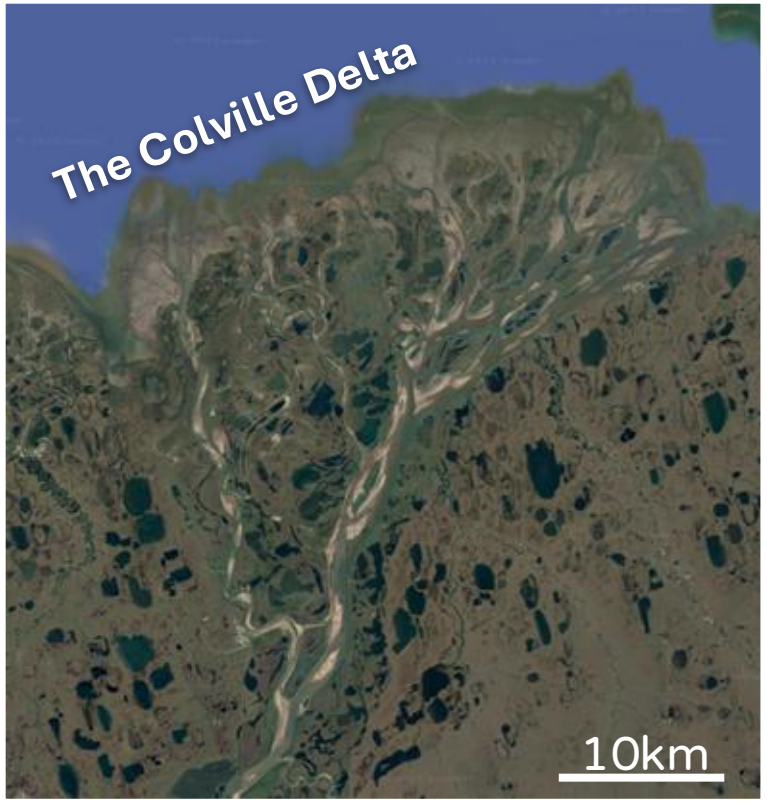

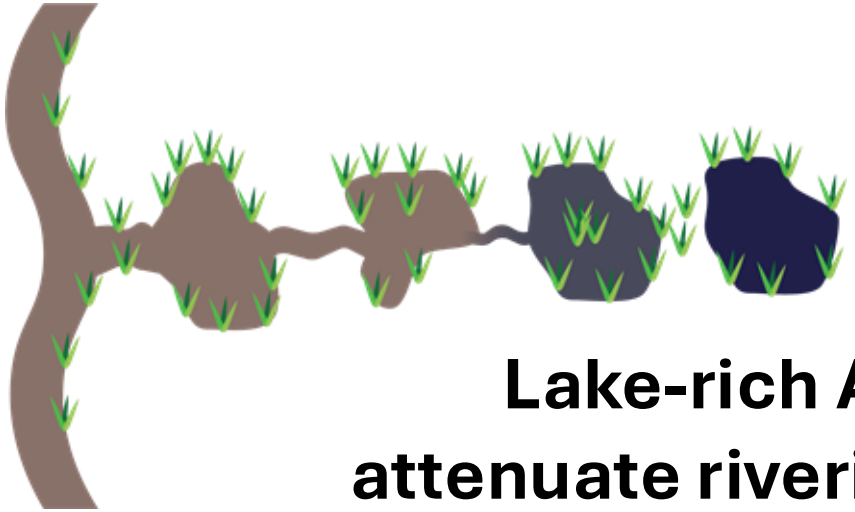

Lake-rich Arctic and boreal deltas attenuate riverine water and sediment

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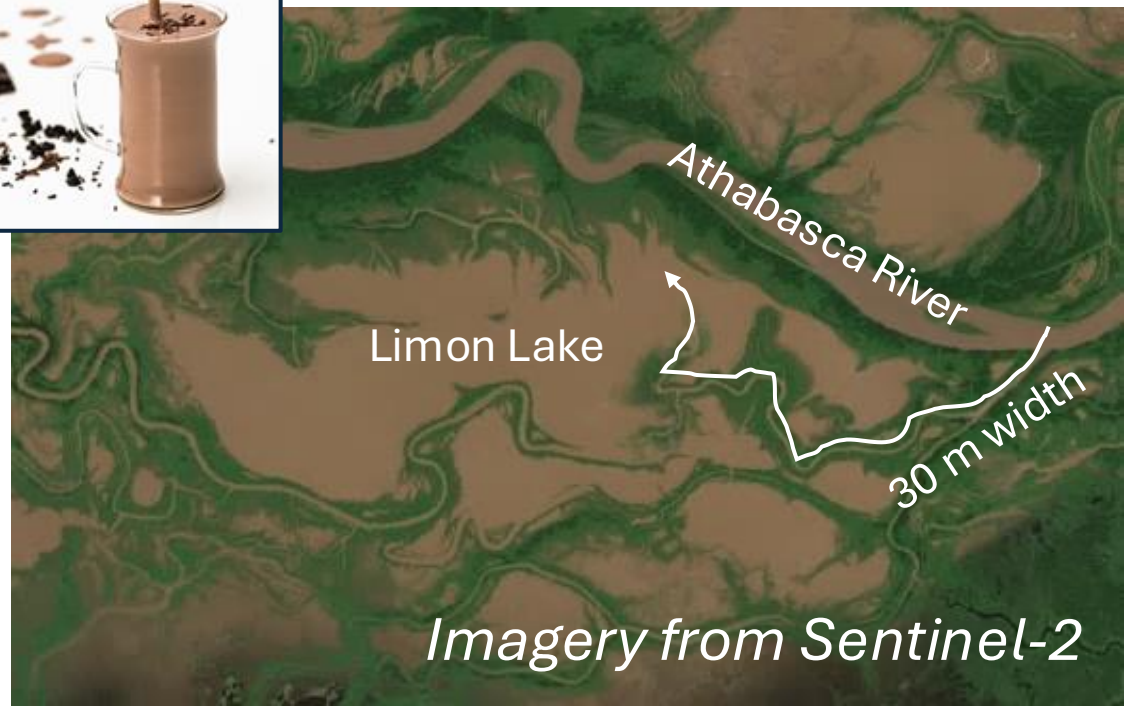
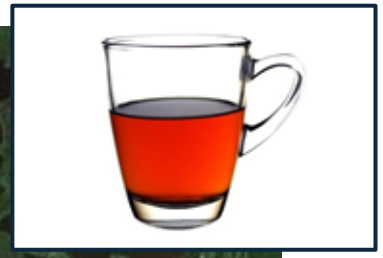
June 2020 – High Connectivity

August 2020 – Low Connectivity





Lake connectivity to the channel network controls which lakes store and attenuate riverine floodwater and sediment

Structural Connectivity *(e.g., channel presence/absence)*

Marsh & Hay (1988), Piliouras & Rowland (2020), Wolfe et al. (2007), and others

Functional Connectivity *(input of high sediment river water)*

Dolan et al. (2021, 2024), Long & Pavelsky (2013), and others

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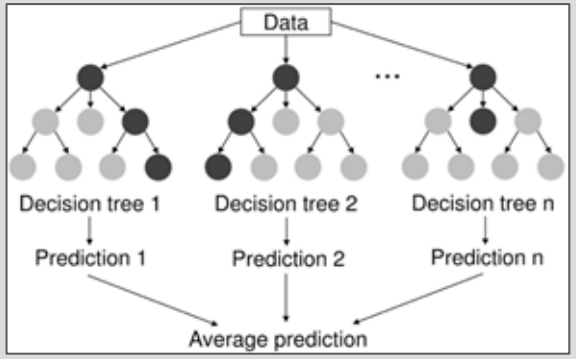
- **Which lakes are connected to the channel network?**
- When are they connected (and under what conditions)?
- How much riverine flood water is stored in these delta lakes?
- How long does that flood water stay in the delta?



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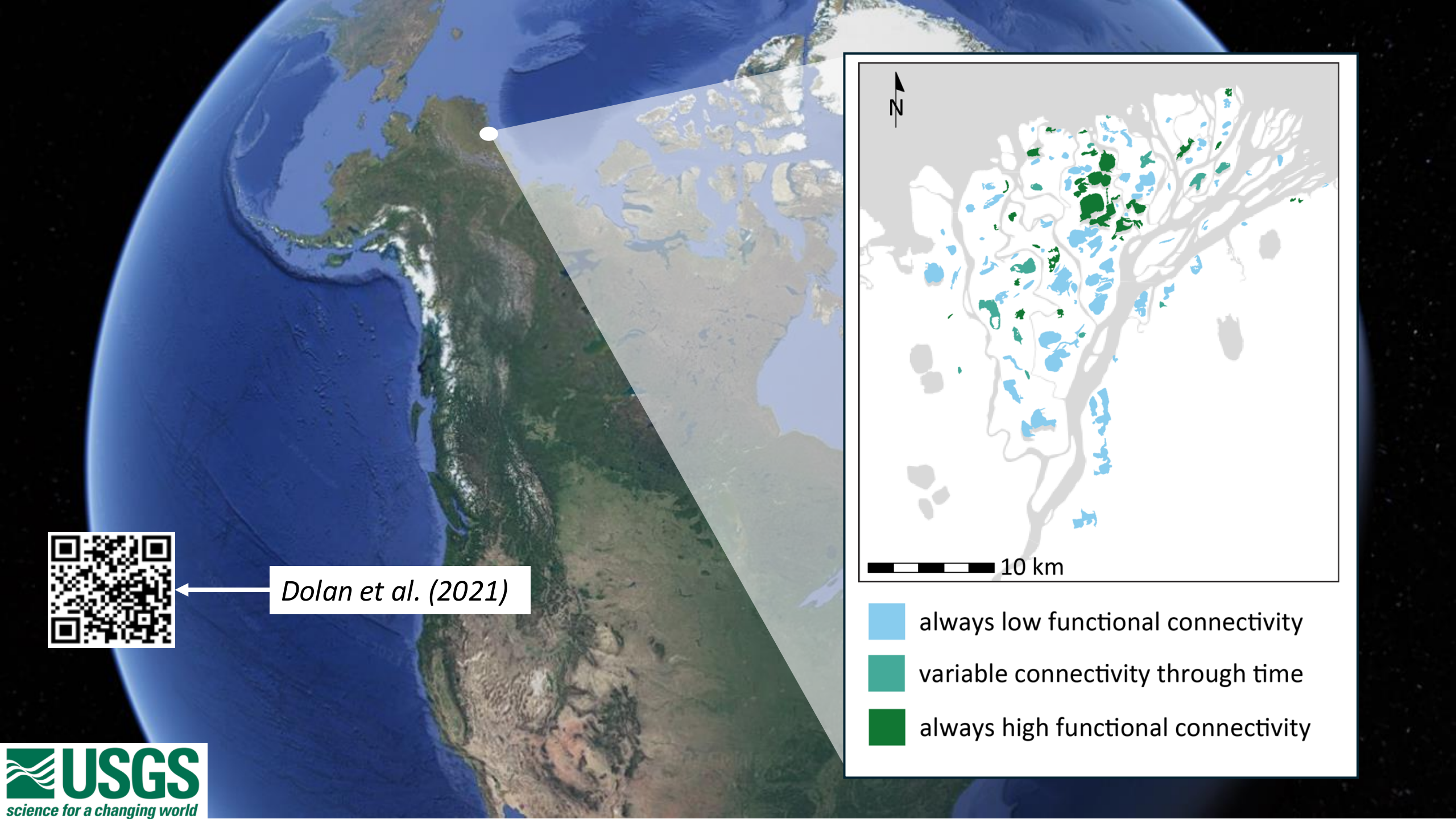
N
10 km
always low functional connectivity
variable connectivity through time
always high functional connectivity
Dolan et al. (2021)
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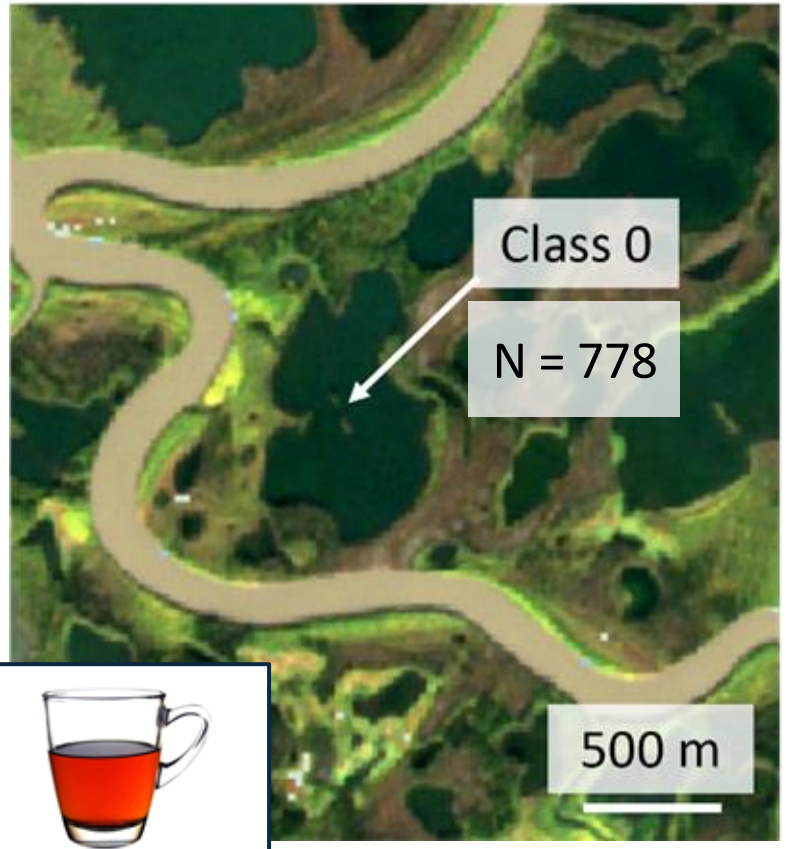

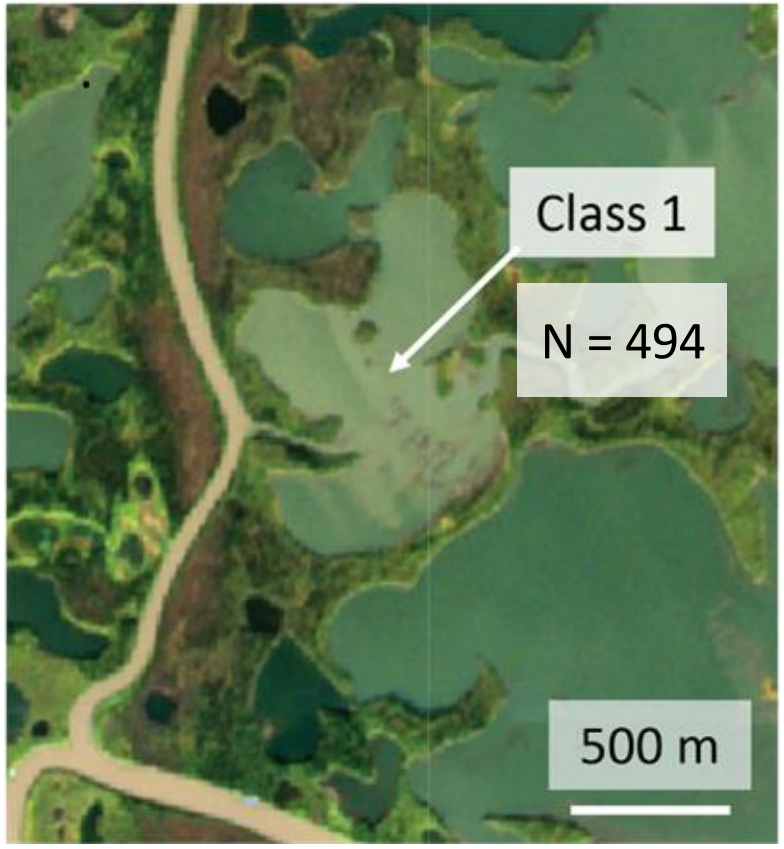

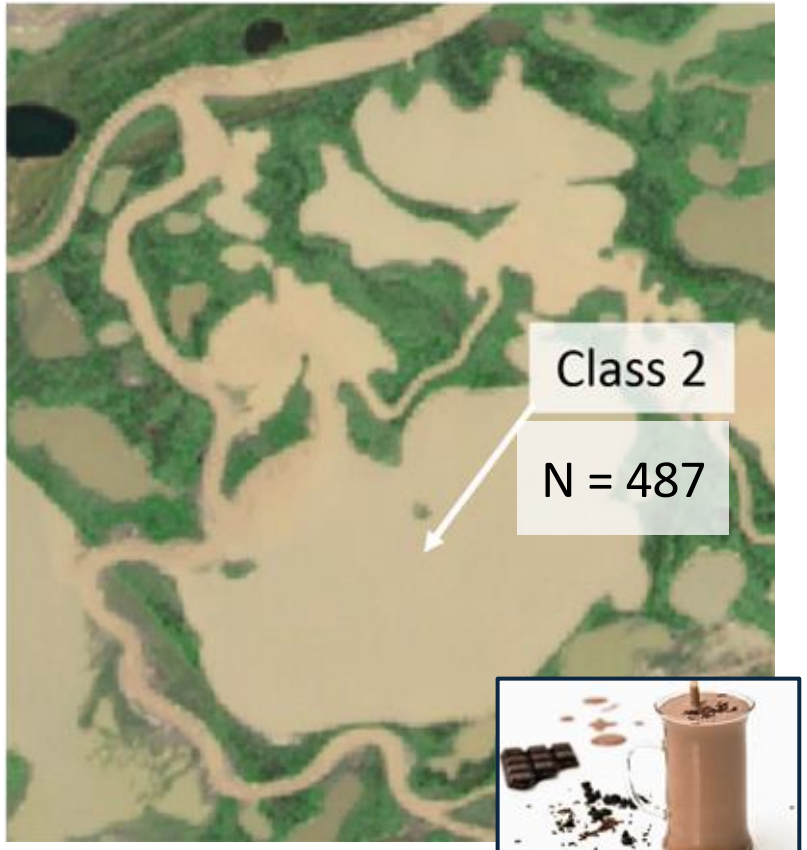

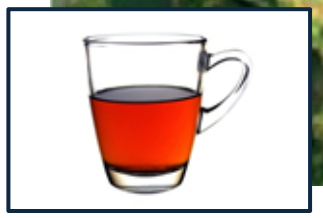

Because functional connectivity is clearly visible via satellite imagery, we built and trained a Random Forest model based on visual classification of Landsat imagery

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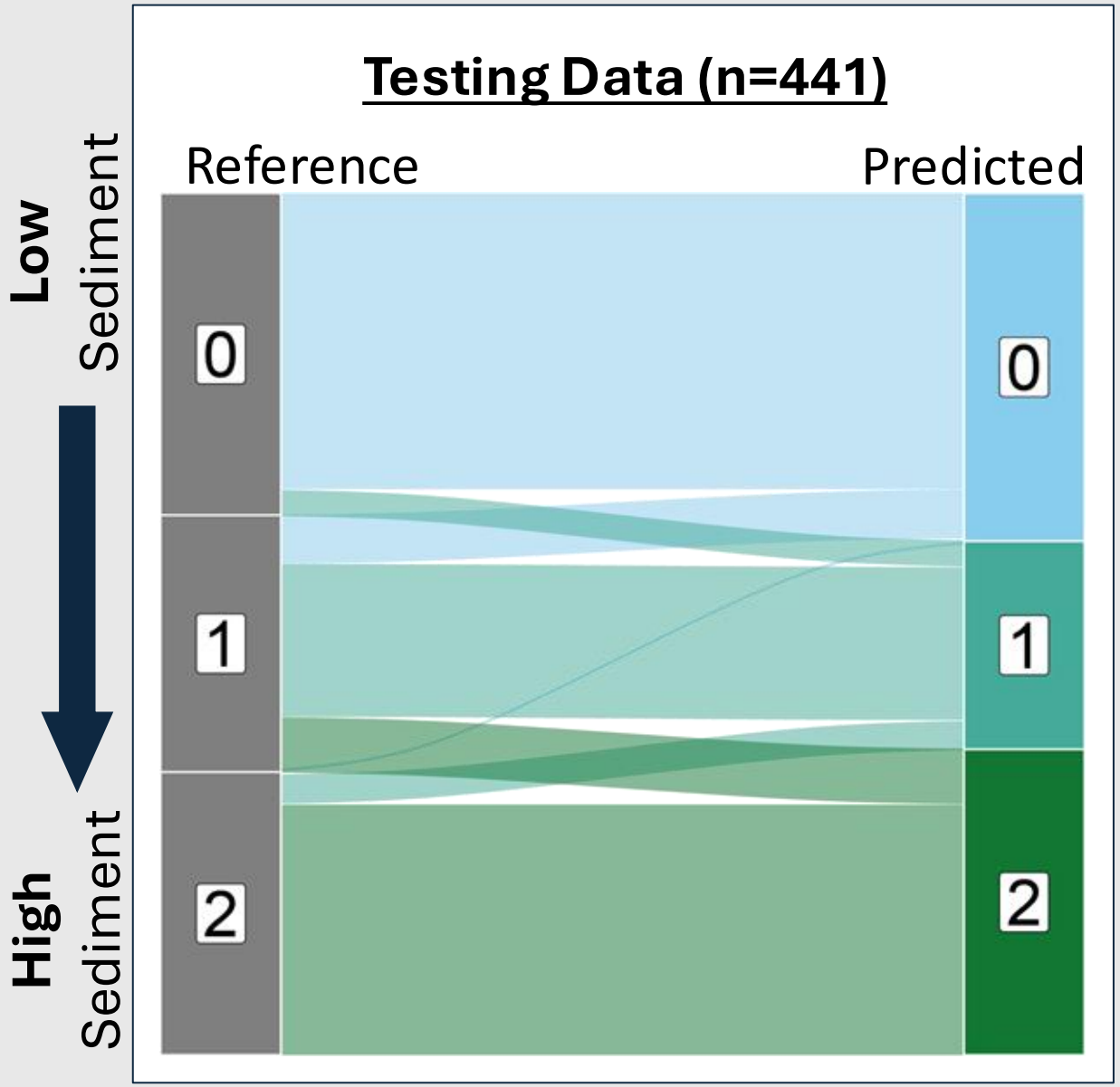
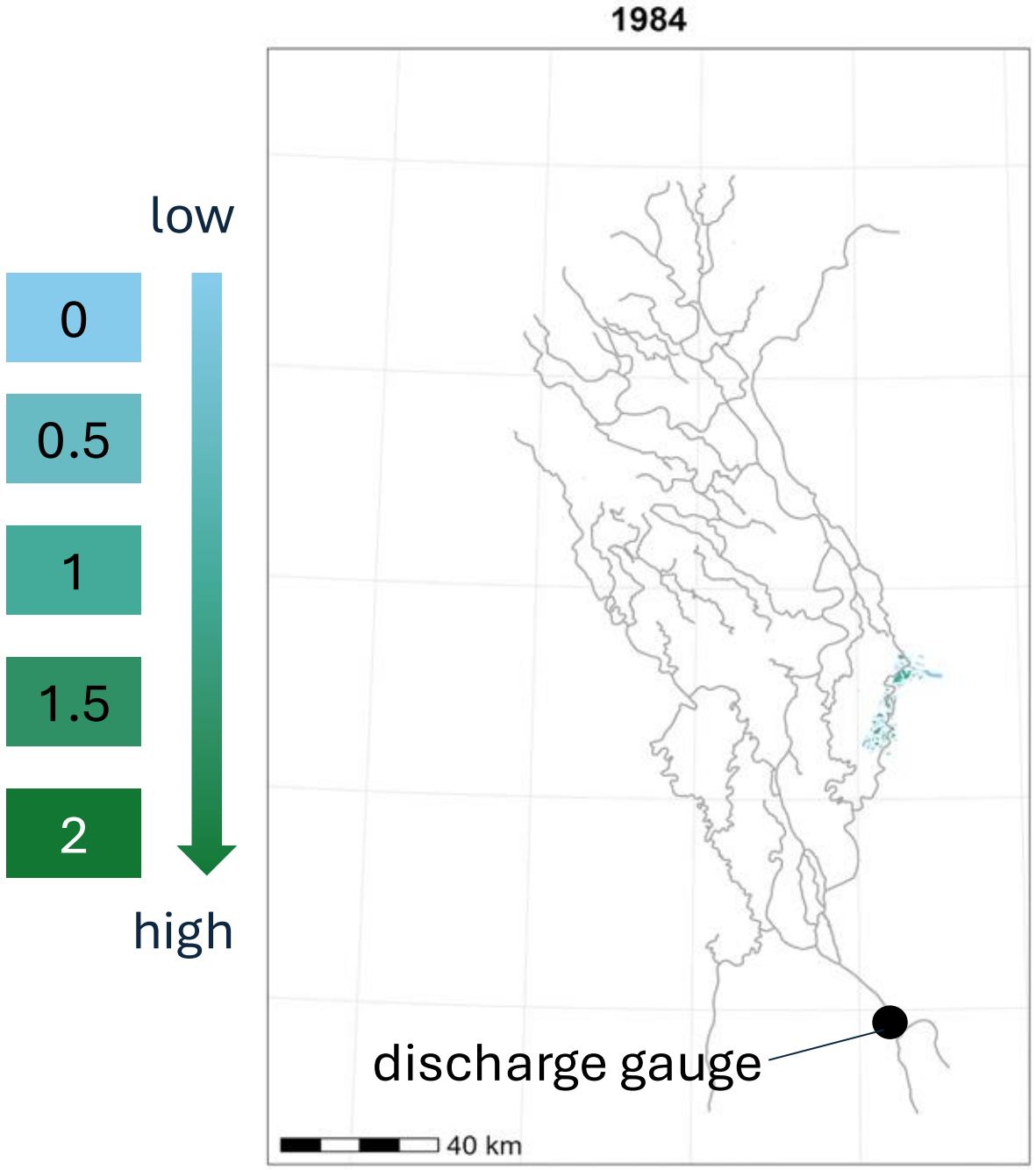
Validation

Overall accuracy: 0.81

Misclassifications typically occur near class boundaries

This is expected because we are taking a continuous variable and making it discreet





Average connectivity the month after peak discharge upstream of the delta is **highly variable through time**

We now have connectivity observations of each lake anytime there is a cloud-free Landsat overpass during the open water season, since 1984.

2.8 million observations of 10,362 lakes

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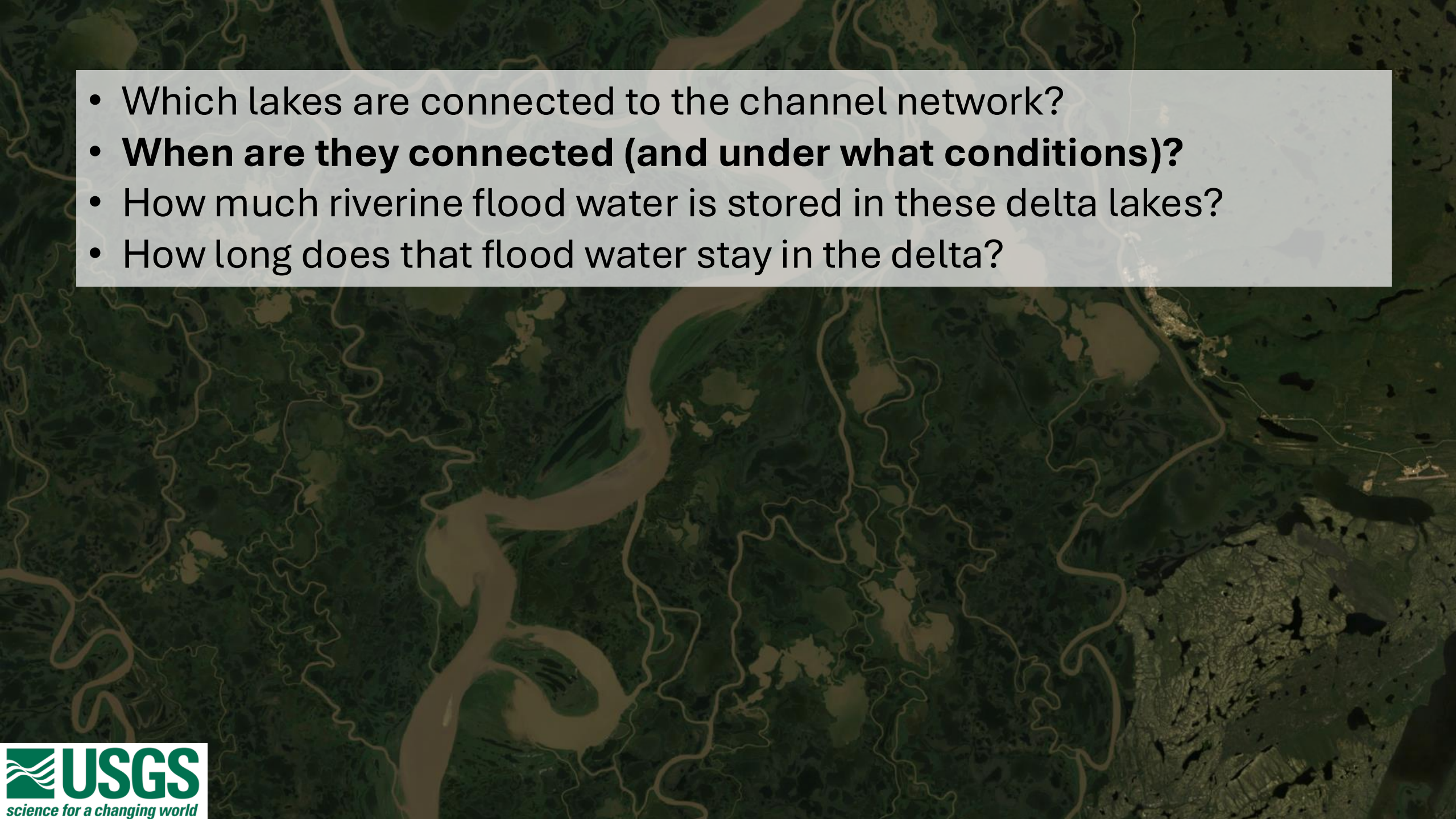

- Which lakes are connected to the channel network?
- **When are they connected (and under what conditions)?**
- How much riverine flood water is stored in these delta lakes?
- How long does that flood water stay in the delta?

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Functional Connectivity Elevation Thresholds

The height that water levels in the delta need to reach for high sediment river water to reach a lake

June 2020

August 2020

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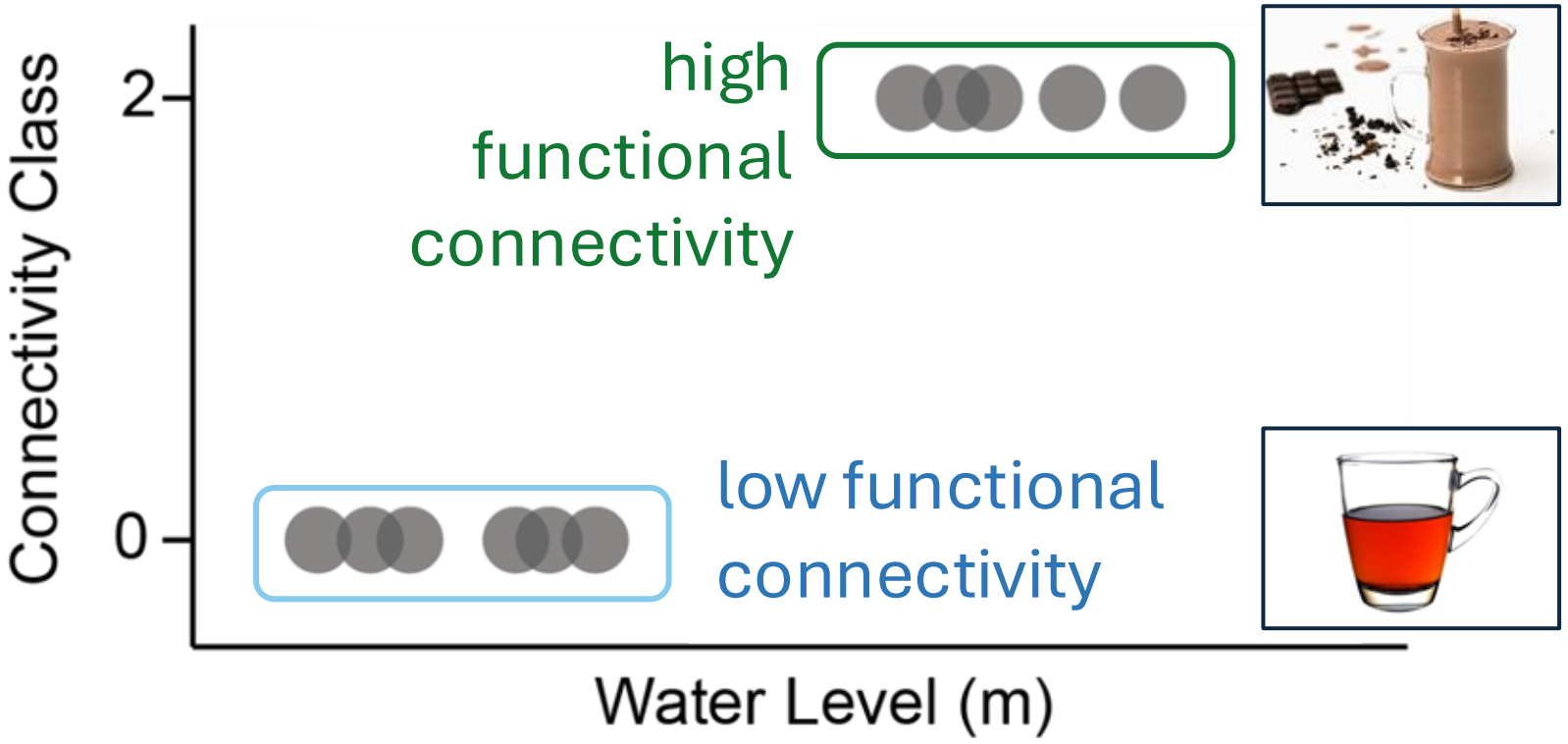
Functional Connectivity Elevation Thresholds

The height that water levels in the delta need to reach for high sediment river water to reach a lake

For each lake, compare **same-day water levels** at **nearby gauges** to class 0 and class 2 connectivity observations



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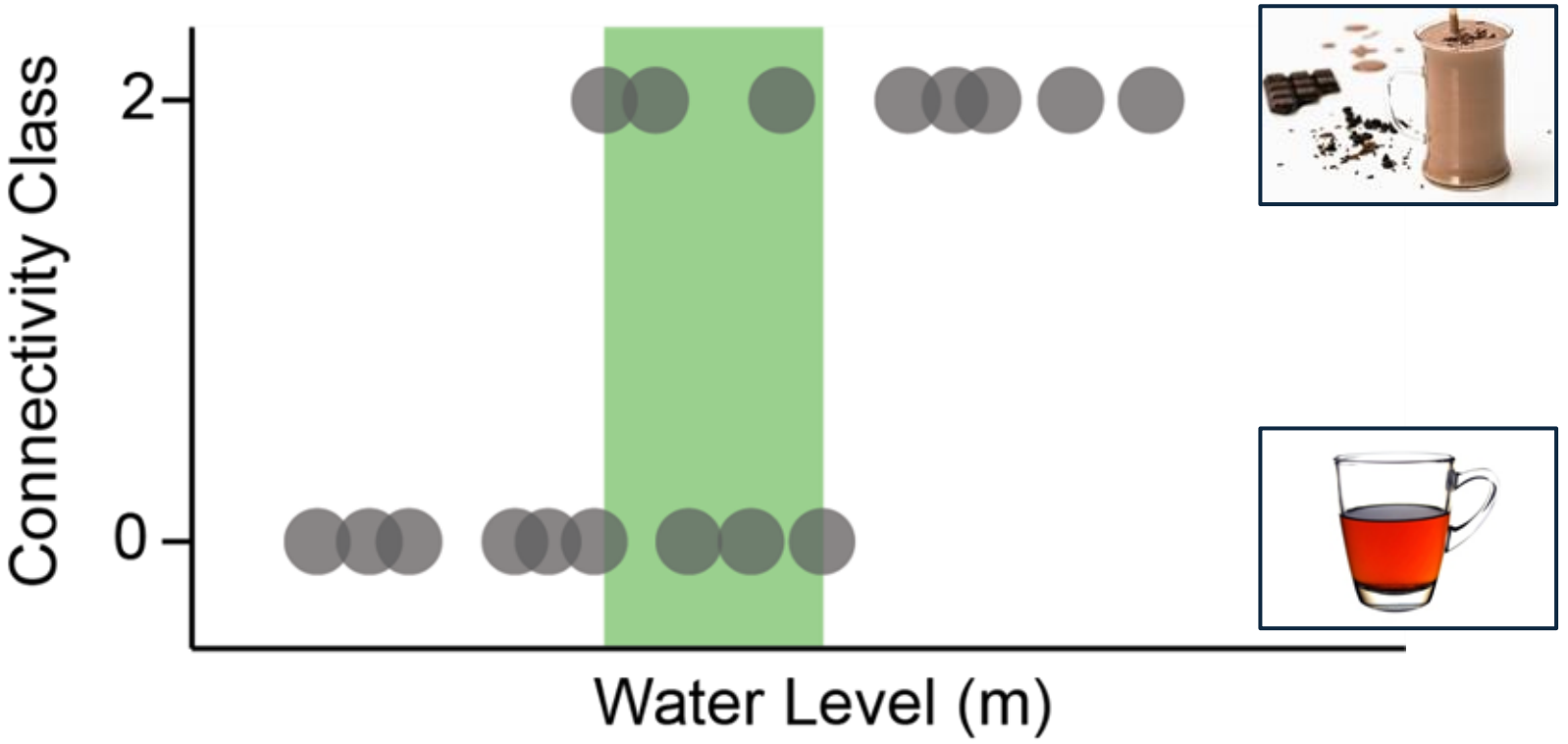
Functional Connectivity Elevation Thresholds

The height that water levels in the delta need to reach for high sediment river water to reach a lake

Option 1: Identify the overlap between class 0 and class 2 water levels



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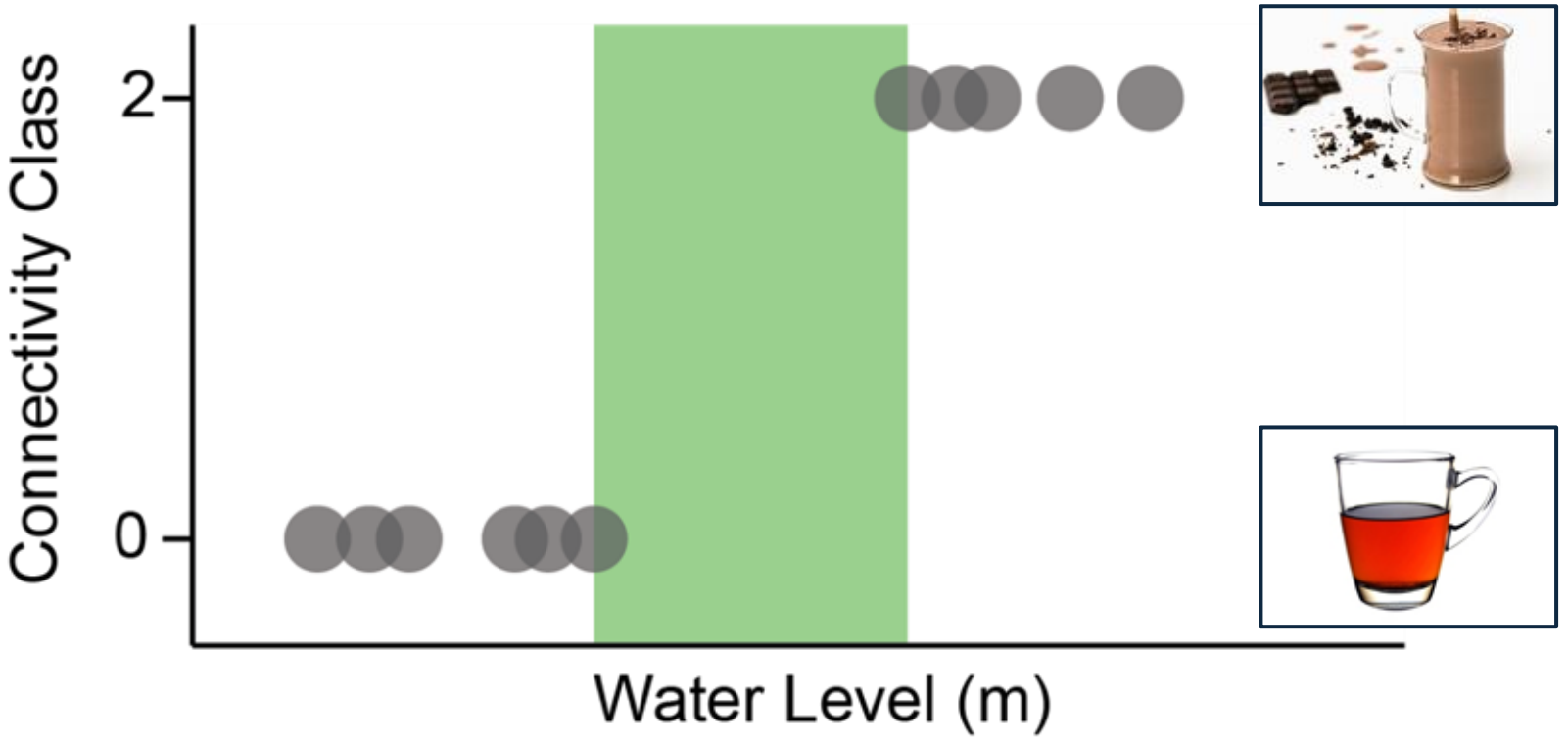
Functional Connectivity Elevation Thresholds

The height that water levels in the delta need to reach for high sediment river water to reach a lake

Option 2: Identify the gap in water level between class 0 and class 2 observations



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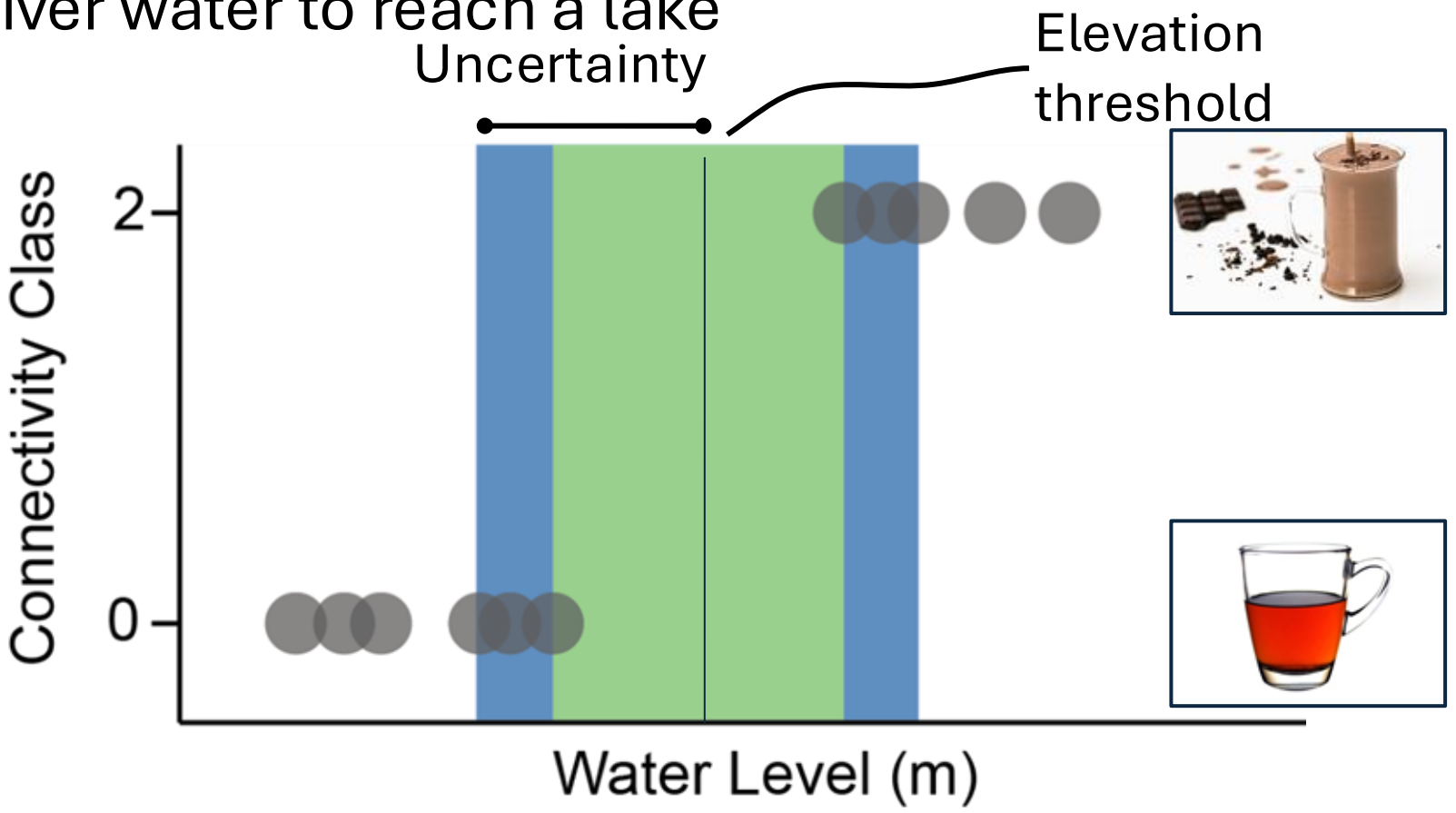
Functional Connectivity Elevation Thresholds

The height that water levels in the delta need to reach for high sediment river water to reach a lake

Add uncertainty due to distance between lake and gauge station (1.15×10^{-5} m / m)



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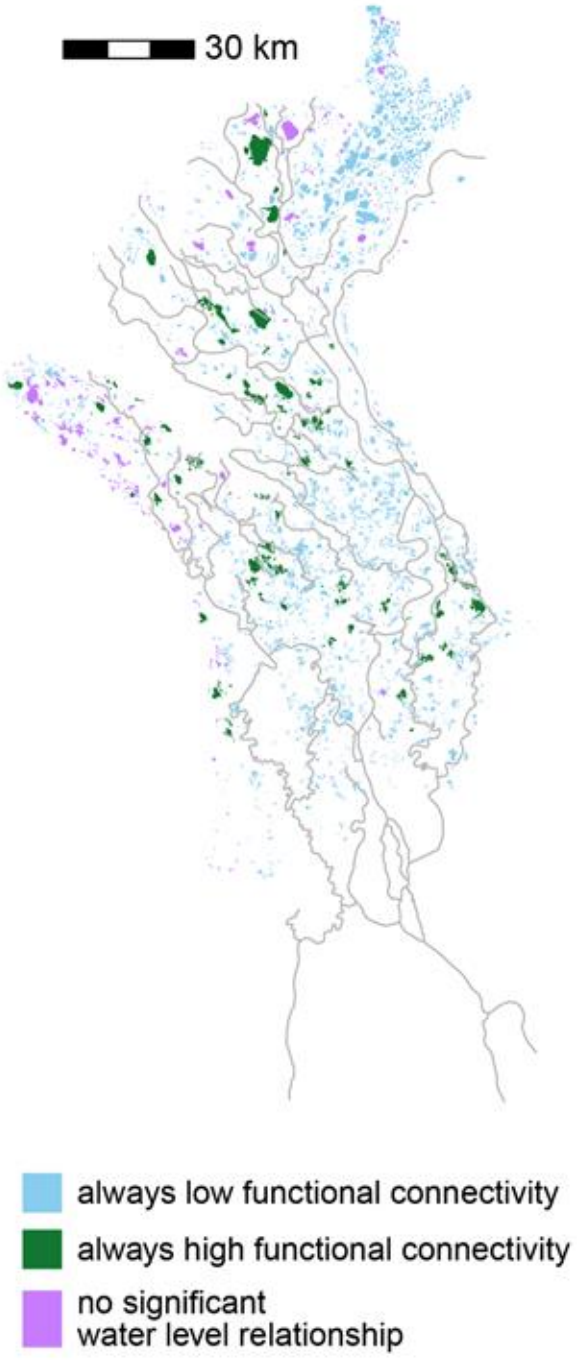

We can’t calculate elevation thresholds for all lakes

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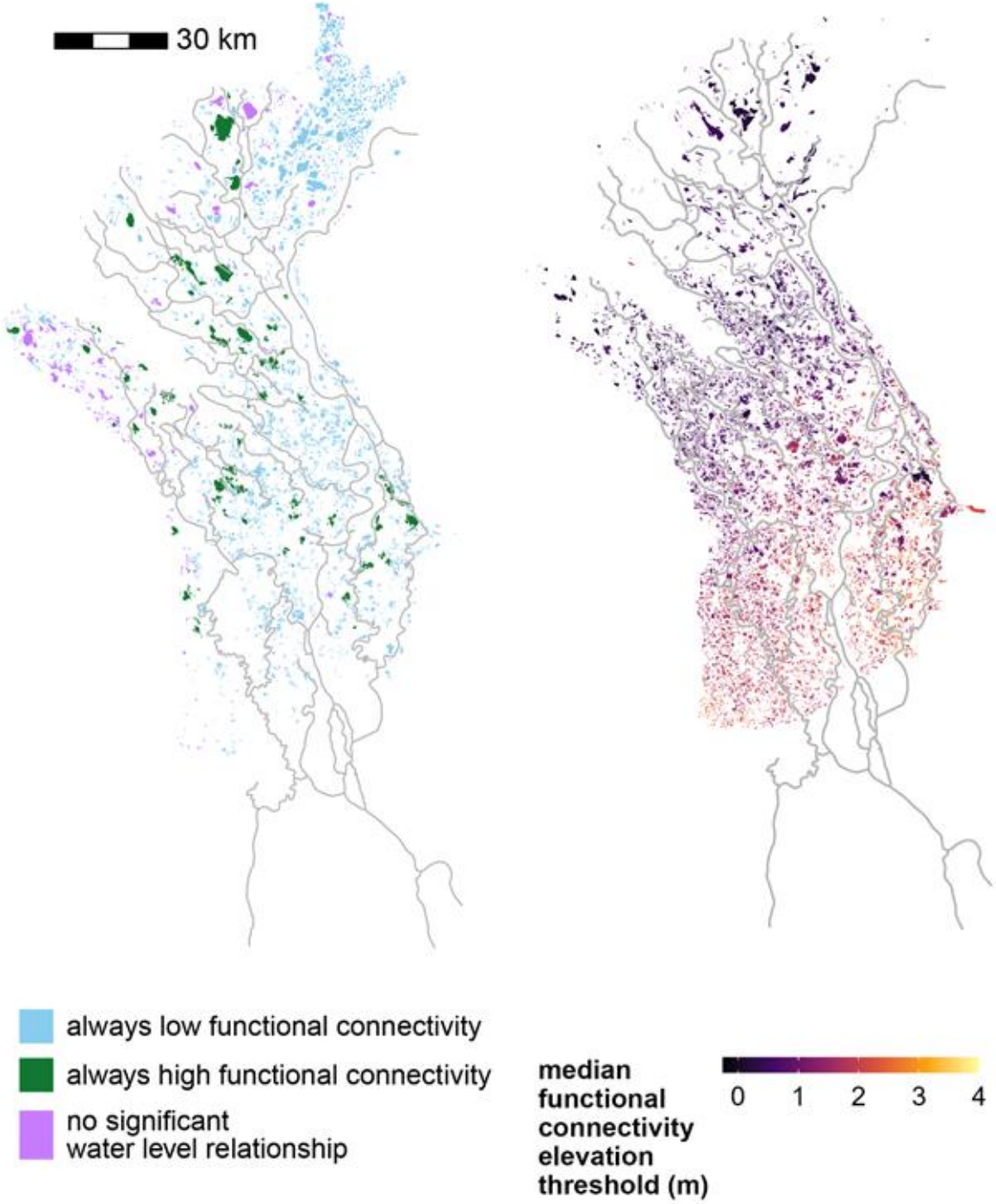

We can’t calculate elevation thresholds for all lakes

Elevation thresholds range from **0 - 4 m asl** and **decrease in elevation** downstream

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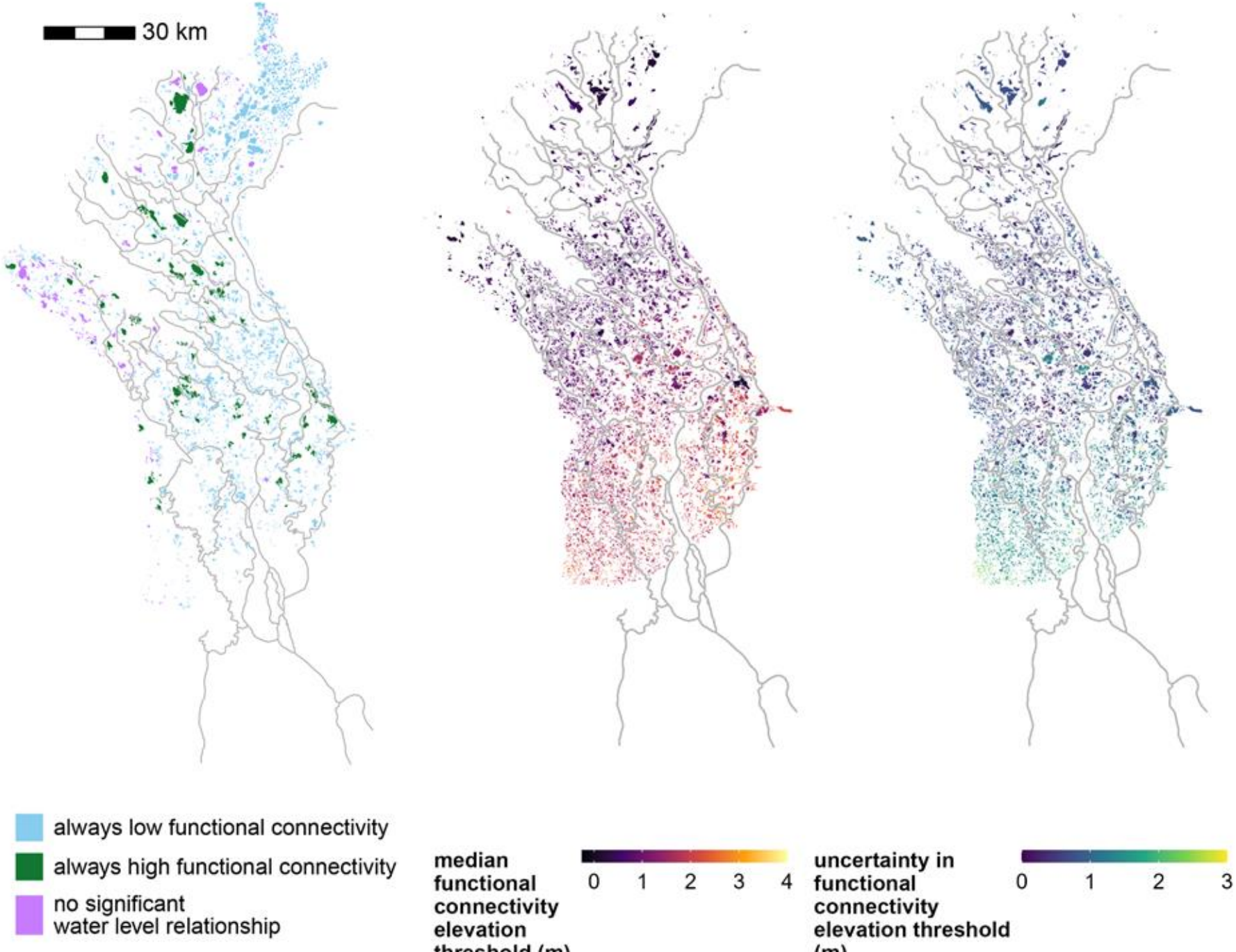

We can't calculate elevation thresholds for all lakes

Elevation thresholds range from **0 - 4 m asl** and **decrease in elevation** downstream

Uncertainty is **highest in the southwest corner** of the delta

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Dolan et al. (2024)

<u>Out of 10,362 Landsat-observable lakes:</u>

(9%) 908 lakes have elevation threshold uncertainties < ± 0.5 m

(27%) 2764 are always low functional connectivity

(1%) 135 are always high functional connectivity

Total: 37%

SWOT

Would improve the accuracy of these elevation thresholds for more lakes!

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- Which lakes are connected to the channel network?
- When are they connected (and under what conditions)?
- **How much riverine flood water is stored in these delta lakes?**
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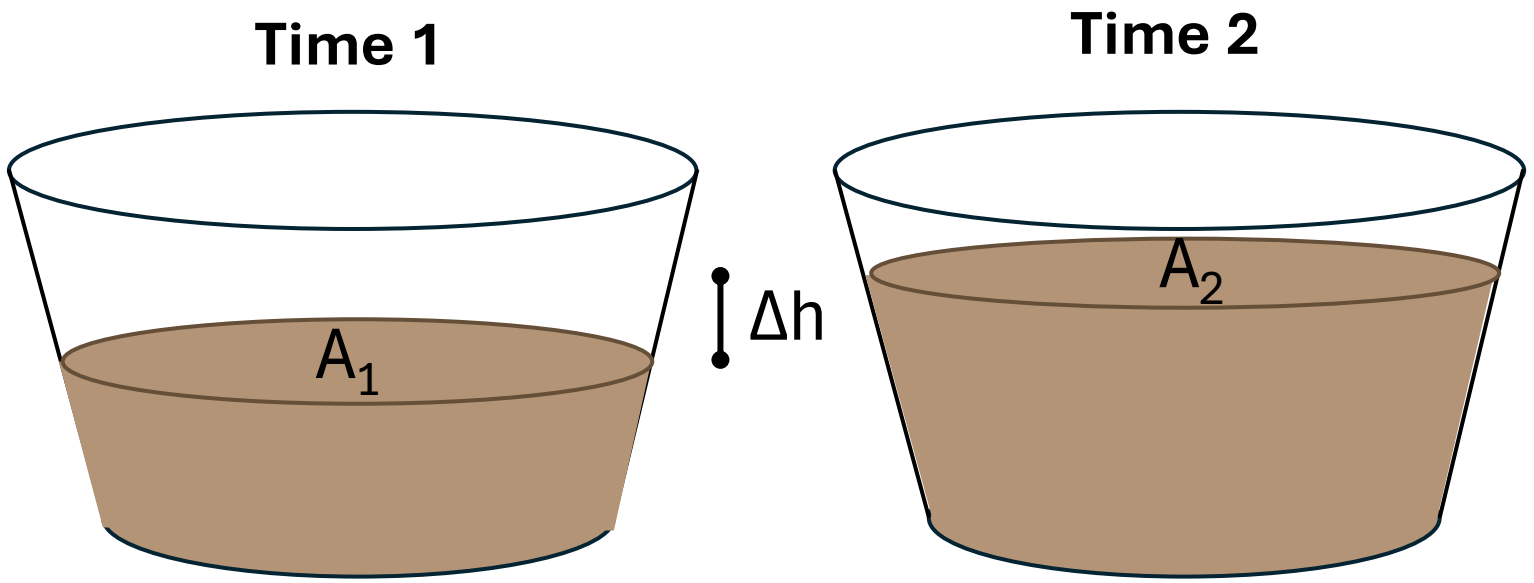

SWOT

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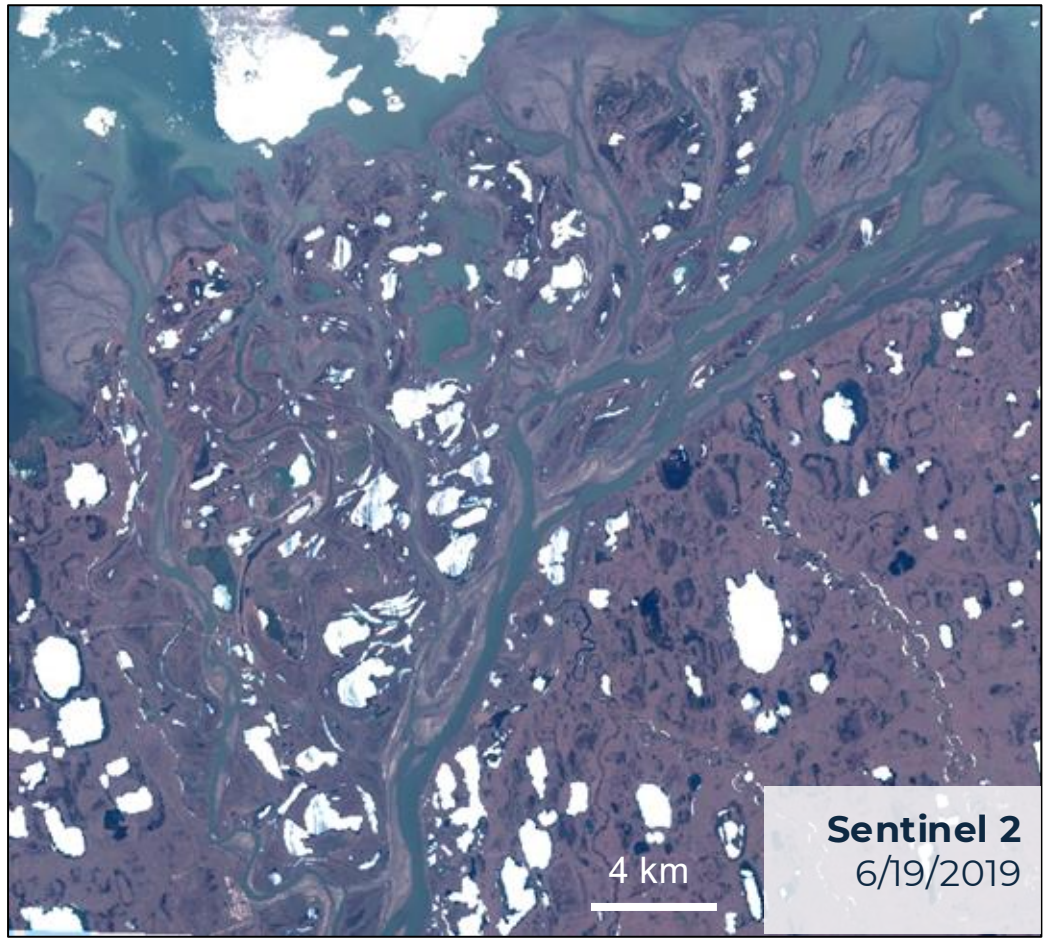
Main Takeaways

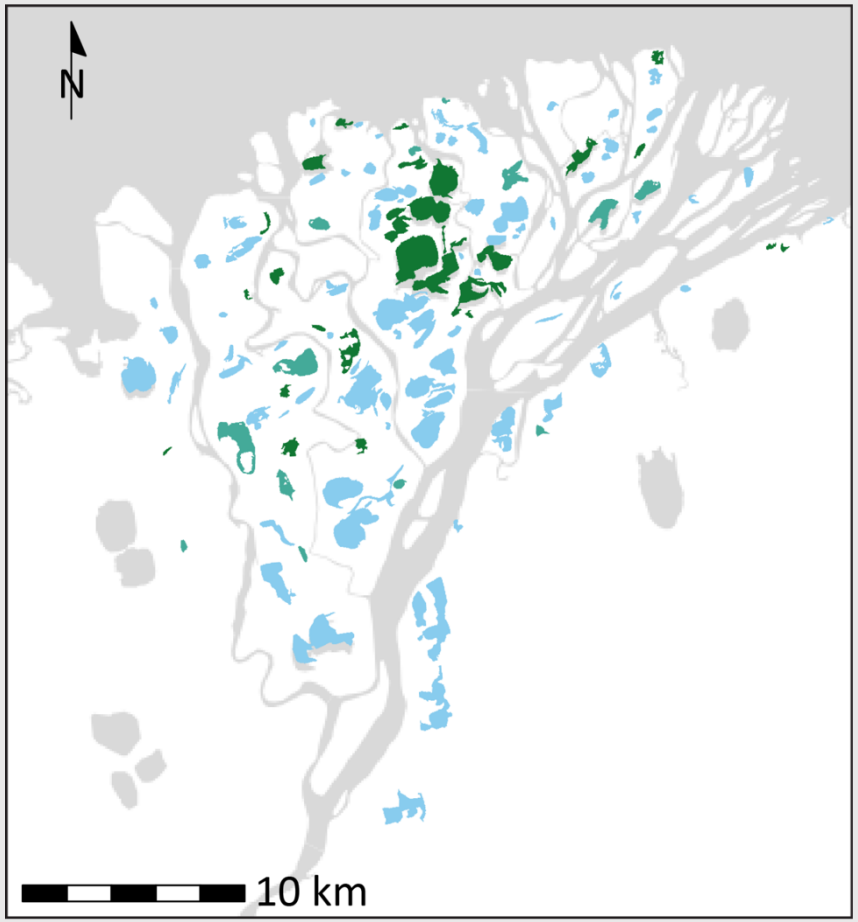
- We know long-term average connectivity in the Colville Delta, as well as connectivity each day there is a clear-sky Landsat observation in the Mackenzie Delta
- We developed a new method to understand how high riverine water levels need to be to lead to connectivity in Mackenzie Delta lakes
- SWOT will improve accuracy of those methods, and allow us to measure storage changes (amount and timing), which will help quantify the impact of the delta on riverine fluxes to the coast

Many thanks to collaborators: Tamlin Pavelsky, Anastasia Piliouras

Bonus slides



Ice-off in the Colville Delta, AK



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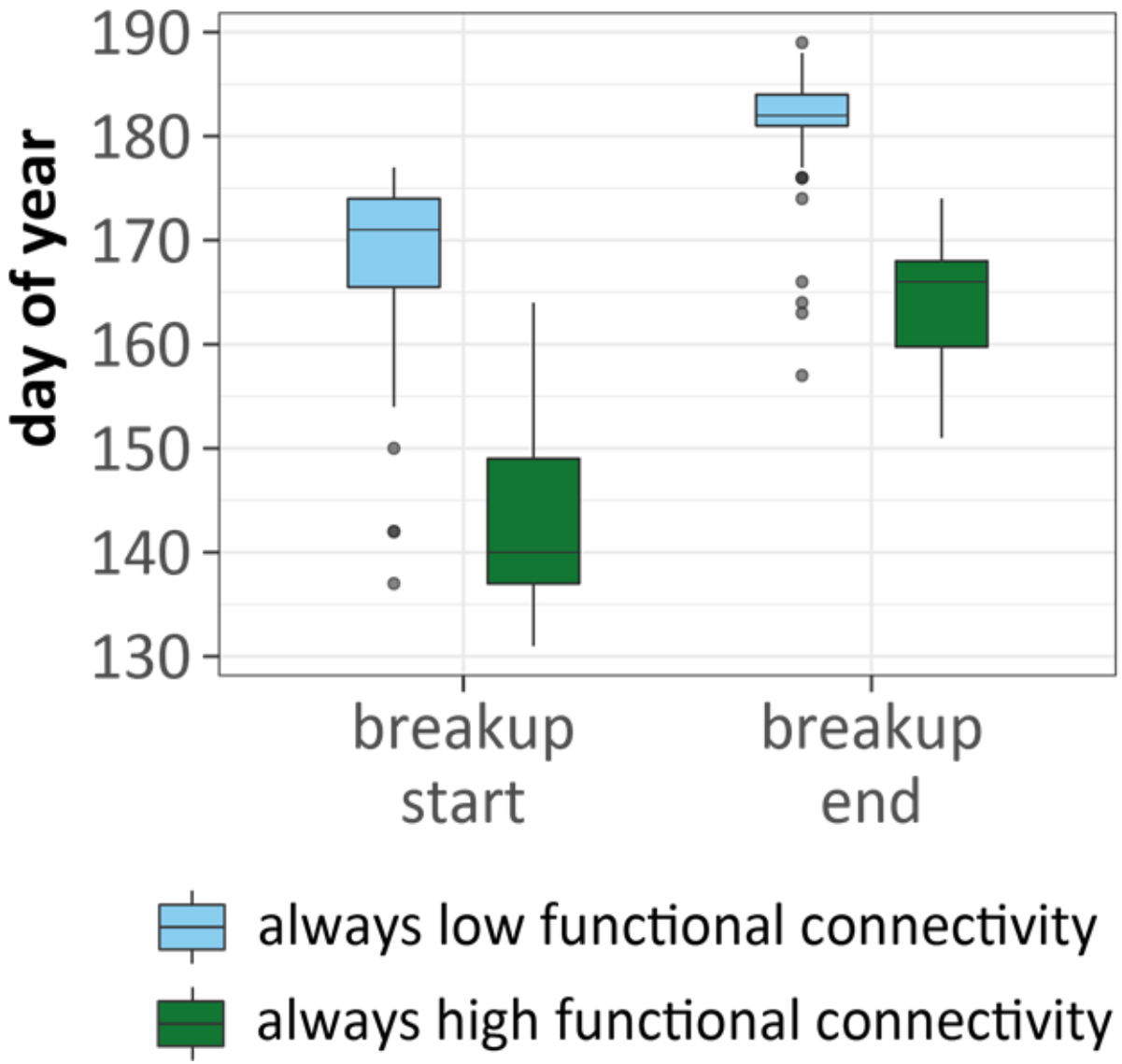
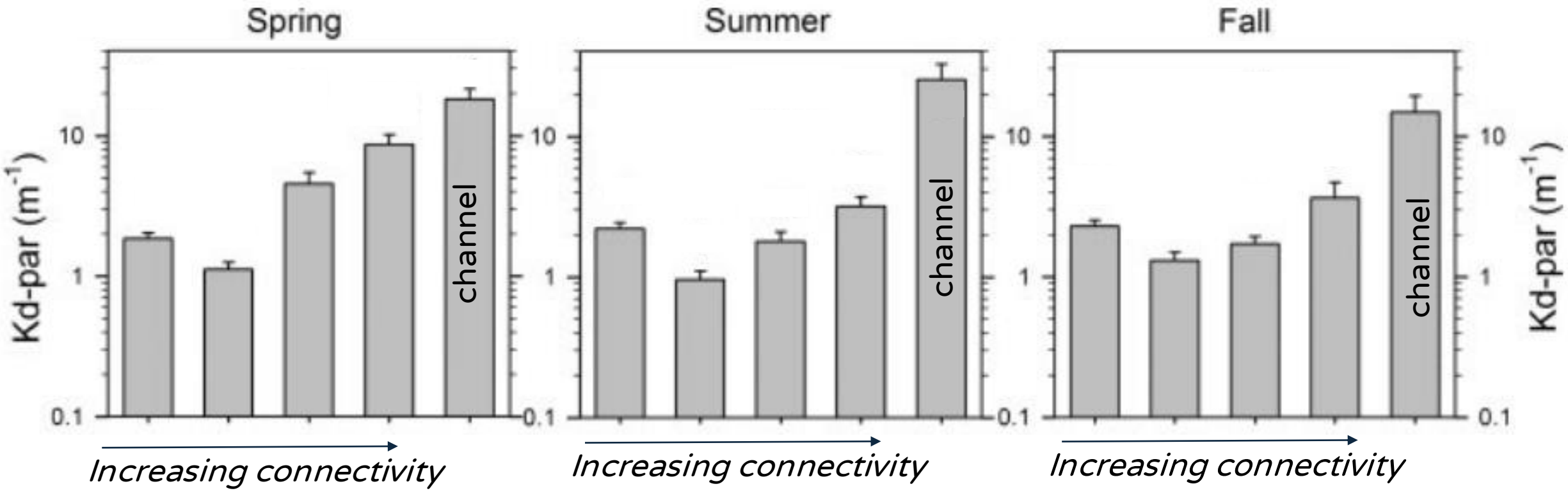
Highly connected lakes **begin breakup a mean of 25.7 days earlier** and **end breakup 17.3 days earlier** than their always disconnected counterparts



← *Dolan et al. (2021)*



Increasing connectivity

Increasing light absorption between 400-700nm ($\mathbf{K_{d\text{-}par}}$)

Figures modified from Wiklund et al. (2012)

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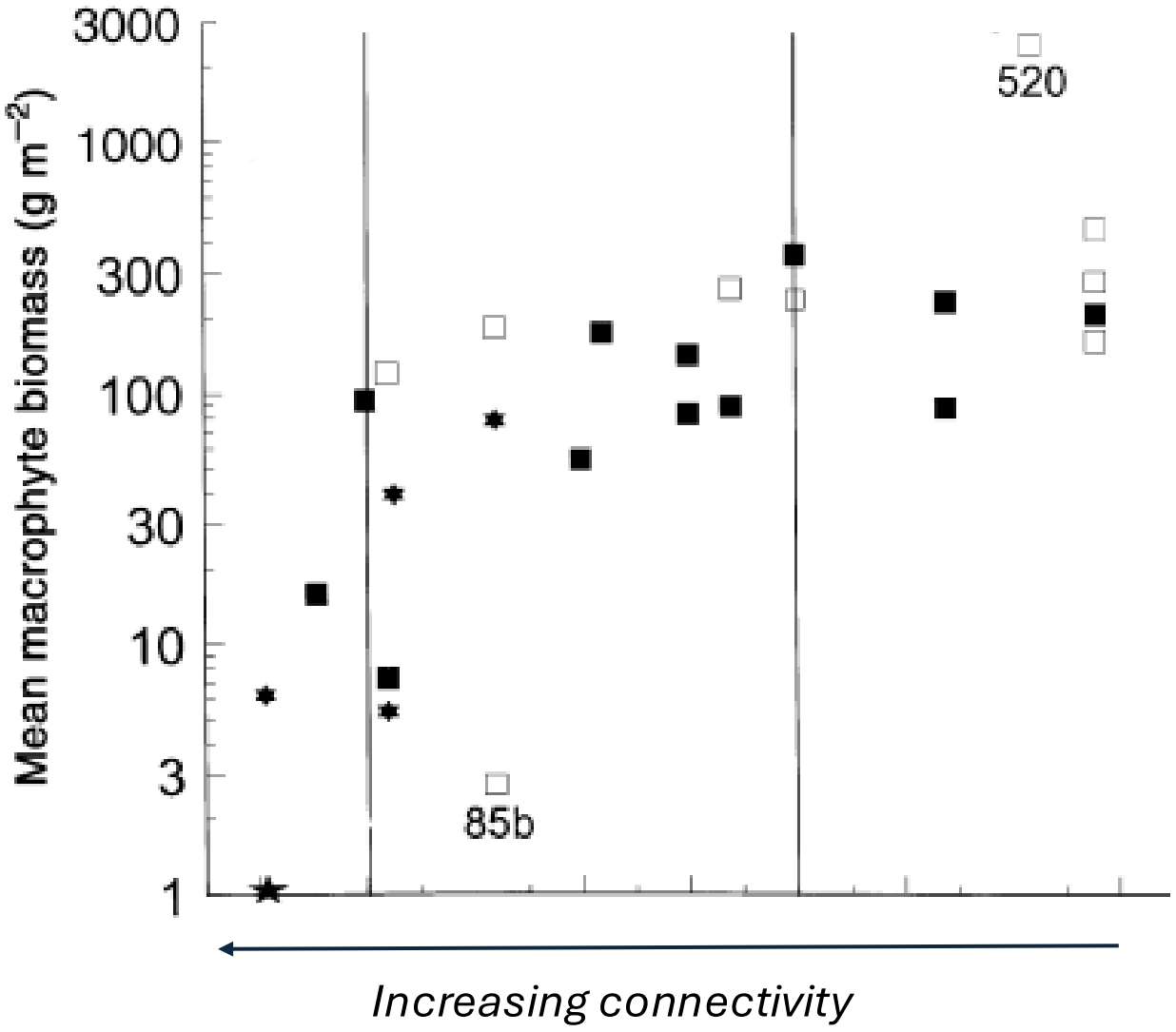

Decreasing
connectivity

Increasing
macrophyte (plant)
productivity

Figures modified from Squires et al. (2022)

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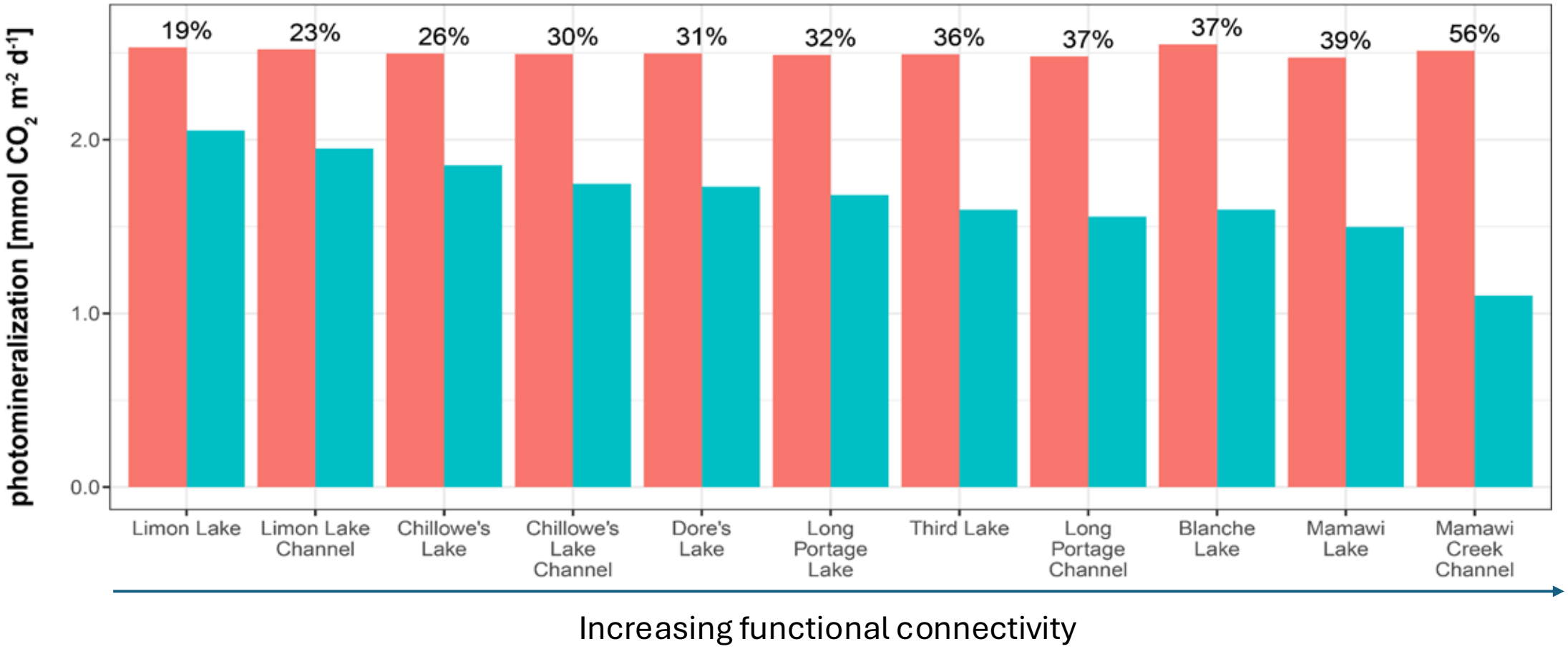
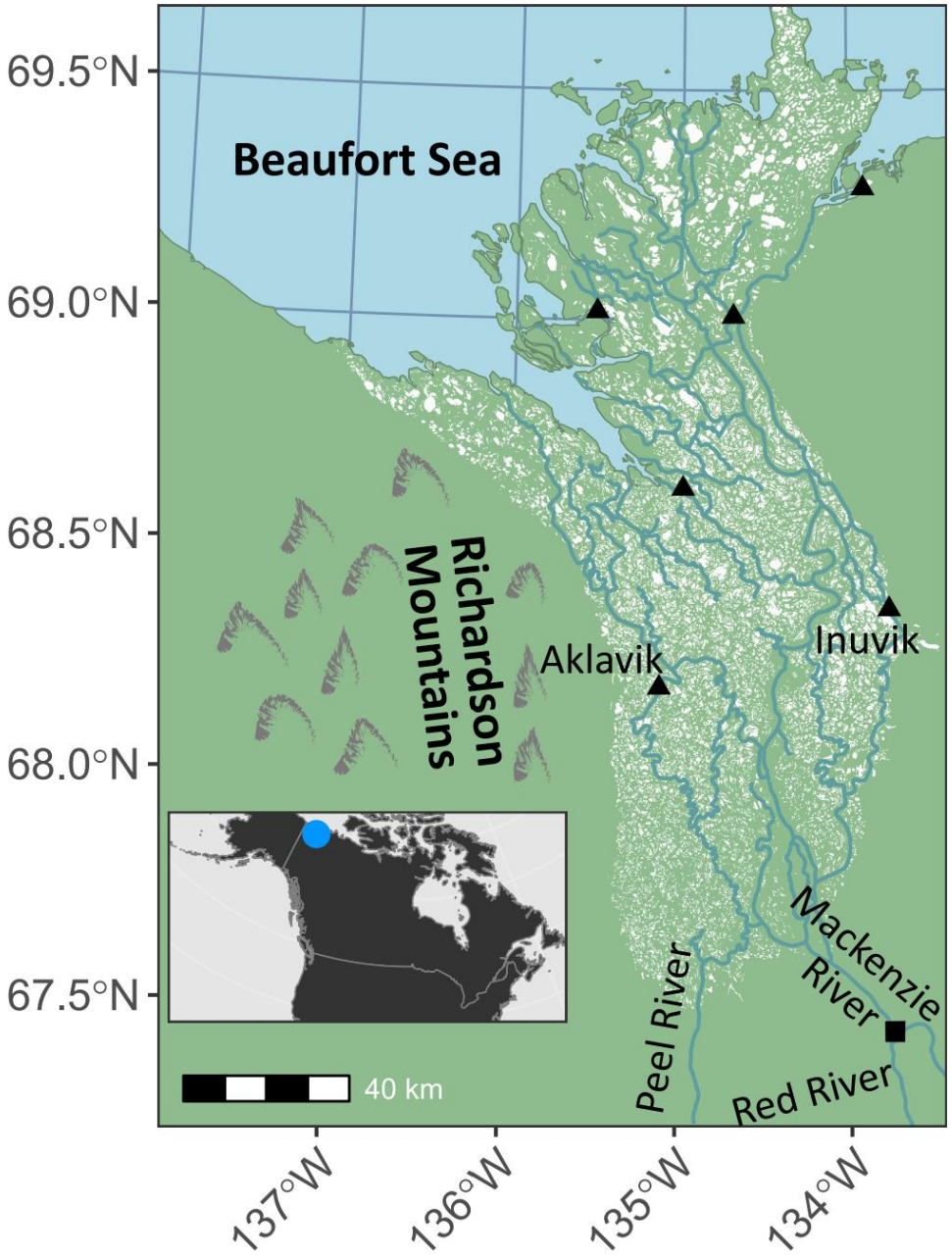
Dolan et al. (2025)

19 to 56% reduction in photomineralization rates



All sunlight absorbed by CDOM

CDOM shaded by TSS



Location of Mackenzie Delta water level gages

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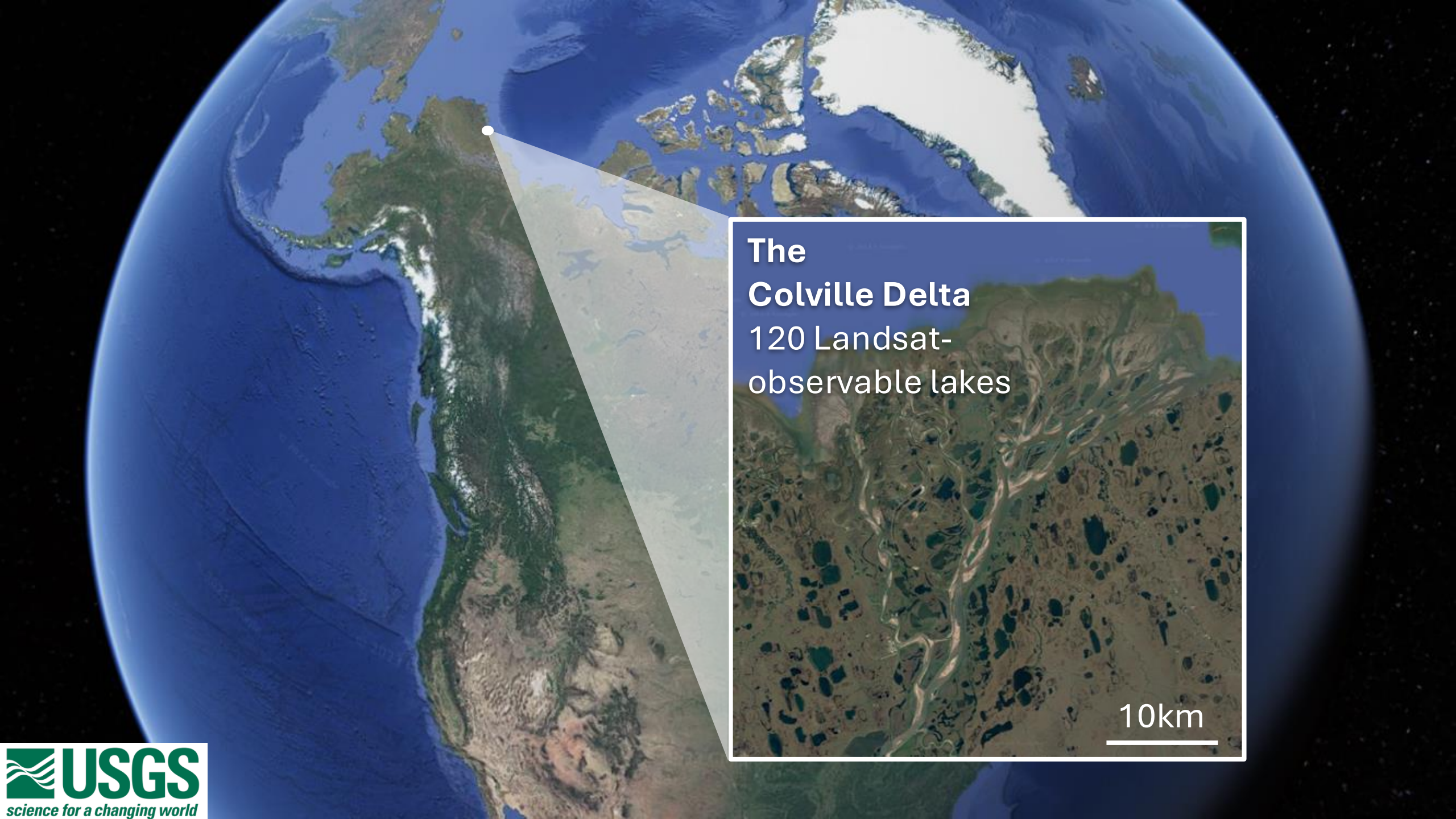

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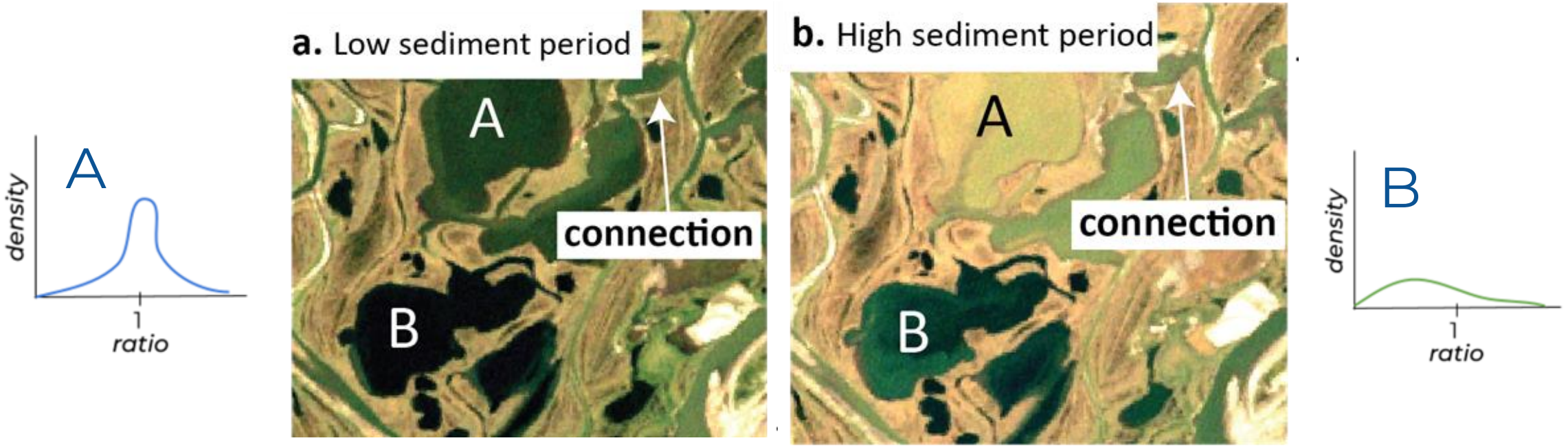

Images from Landsat 7 from (a) 7/17/ 2002 and (b) 7/14/2001

Connected lakes always look **similar** to the nearby channel network

Disconnected lakes may look similar to the nearby channel network at low discharge/sediment periods, but **look very different** at high discharge/sediment periods or during sed. resuspension

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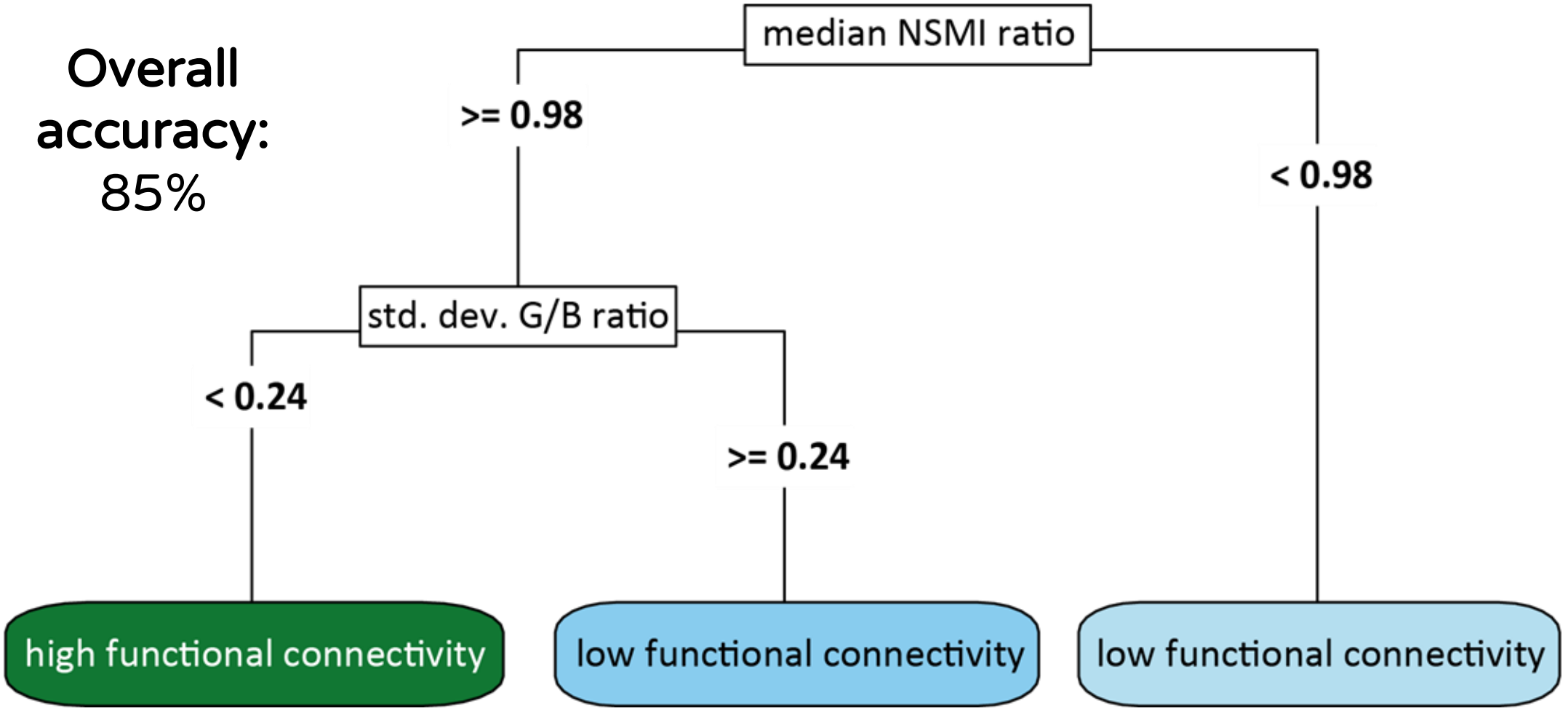
Model Development (Colville)

Overall accuracy: 85%



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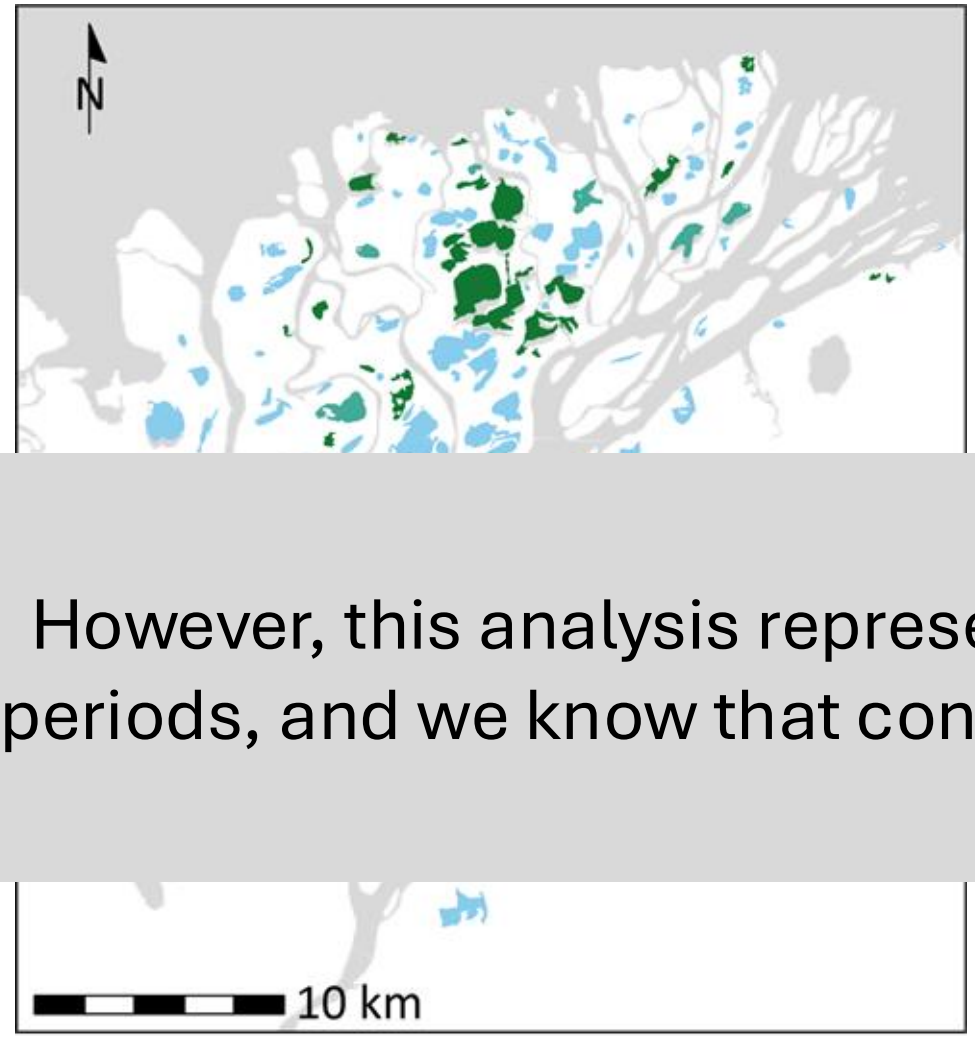
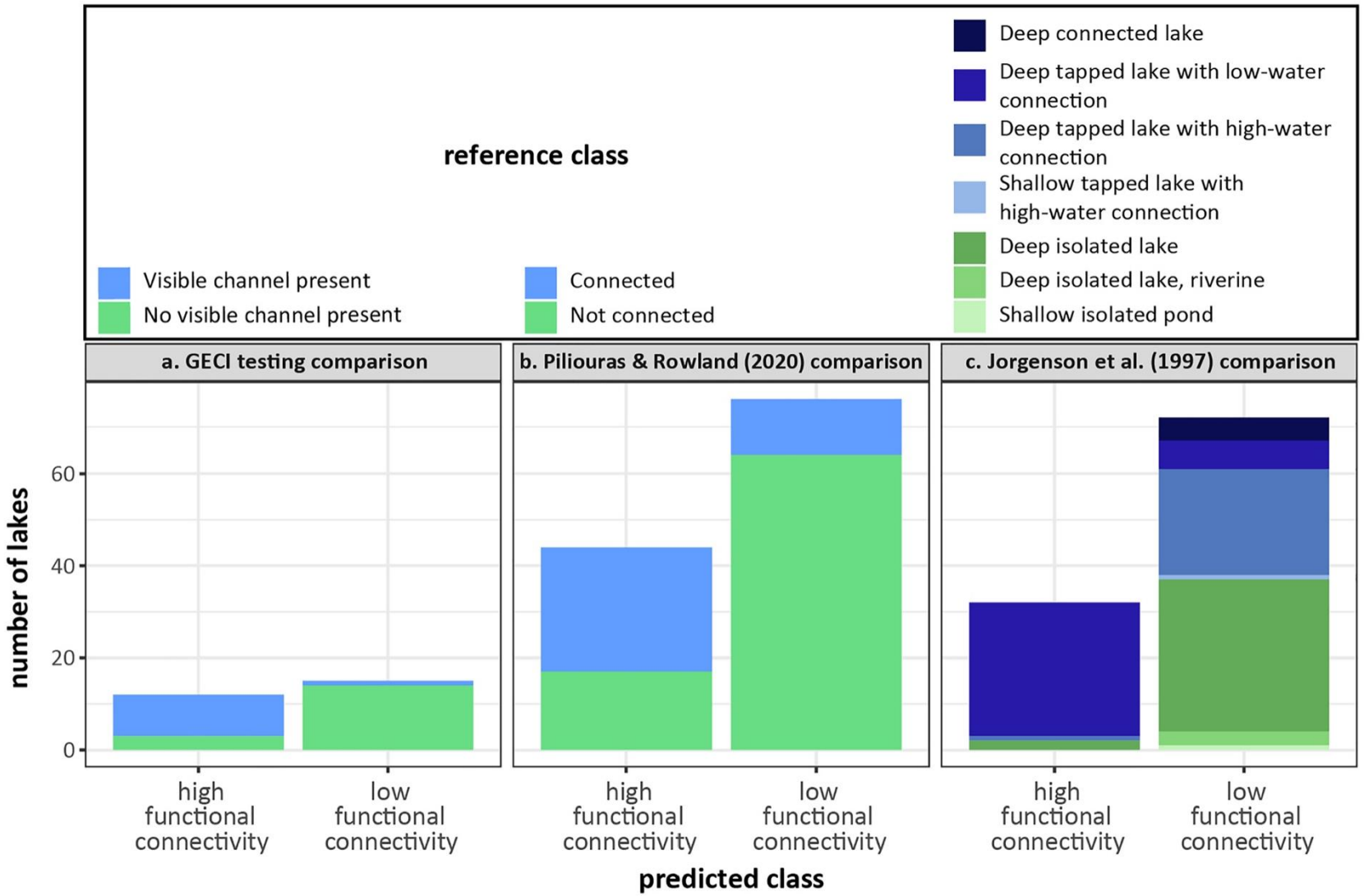


Colville Delta: Classified lakes as low or high connectivity during five-year periods using a decision tree model between 2000 and 2019.

However, this analysis represented ‘average’ conditions within five-year periods, and we know that connectivity is often quite seasonally variable.

13 lakes change connectivity between the five year periods

Most of the highly variable lakes have long and indirect channel connections



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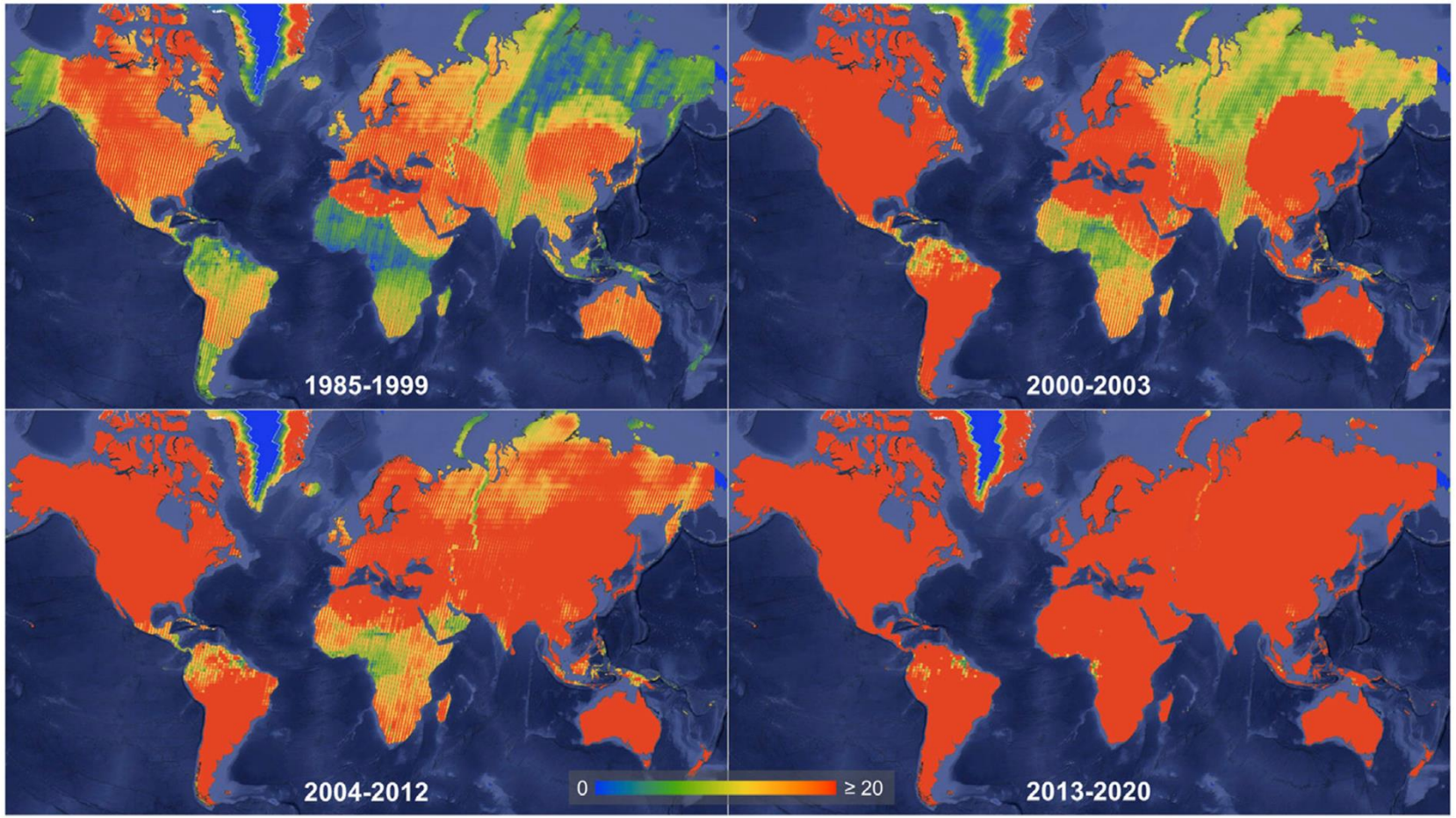

FIGURE 1 | The global average value of the annual number of observations for all images in Landsat archive (TM, ETM+, and OLI data) in four time periods 1) 1985–1999 (upper-left); 2) 2000–2003 (upper-right); 3) 2004–2012 (bottom-left); 4) 2013–2020 (bottom-right).

Zhang et al. (2022) https://doi.org/10.3389/frsen.2022.894618

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Mikhailova (2009): https://doi.org/10.1134%2FS0097807809010035

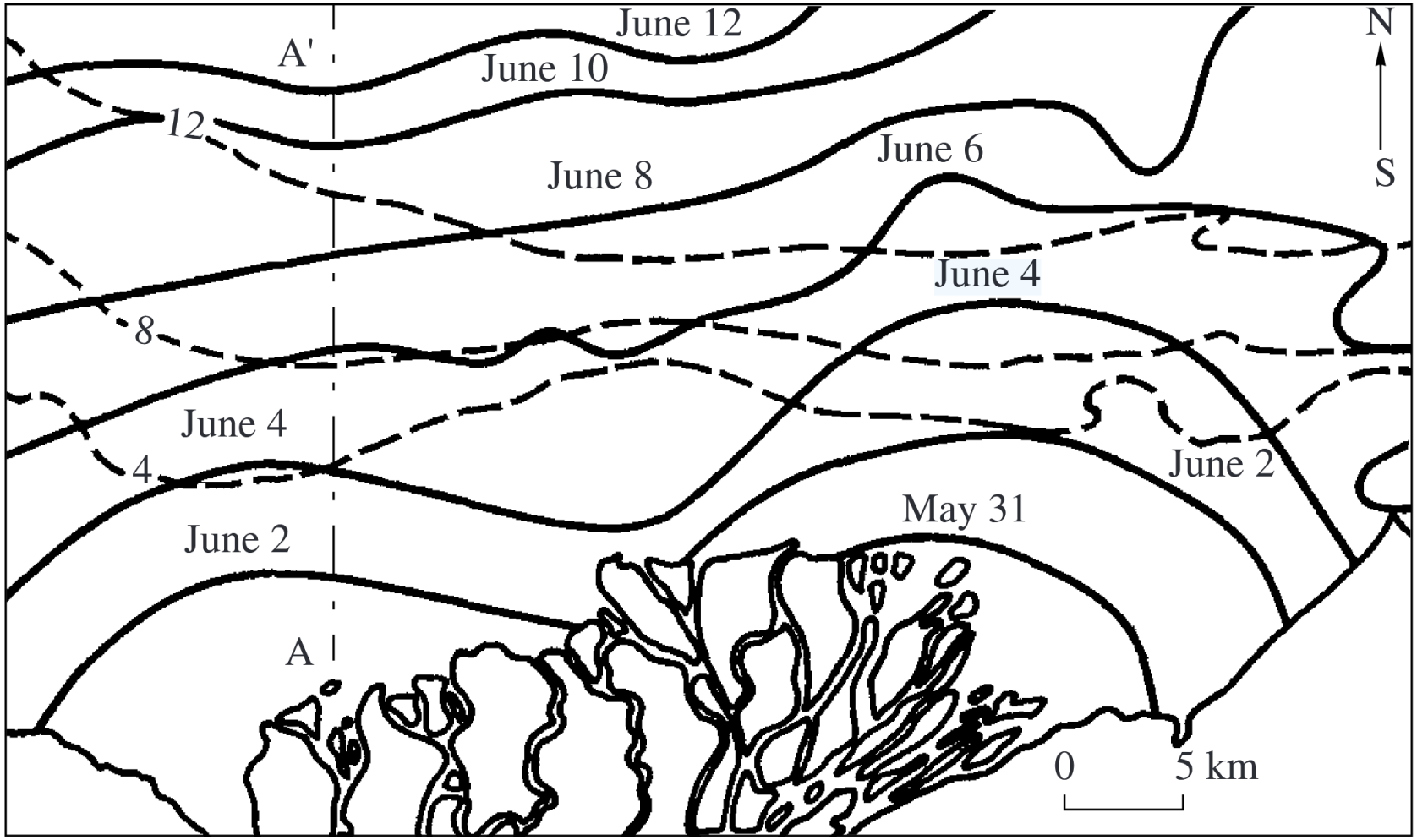

Fig. 7. Isochrones of the front of freshened water wedge under sea ice in early June 1973 according to [32]. The dashed line denotes isobaths, m. A–A' is the section from western channel mouths toward the ocean.

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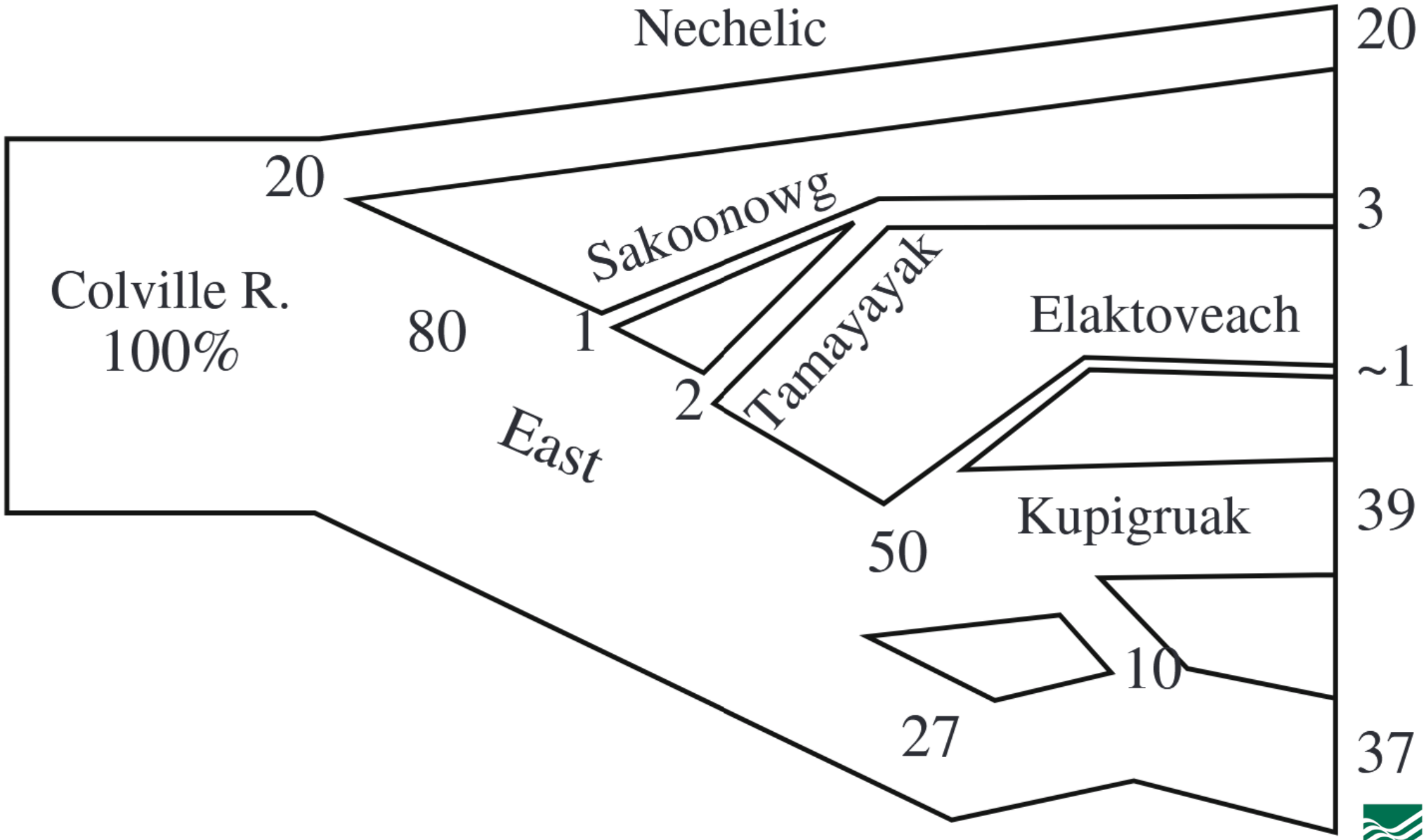
Mikhailova (2009): https://doi.org/10.1134%2FS0097807809010035



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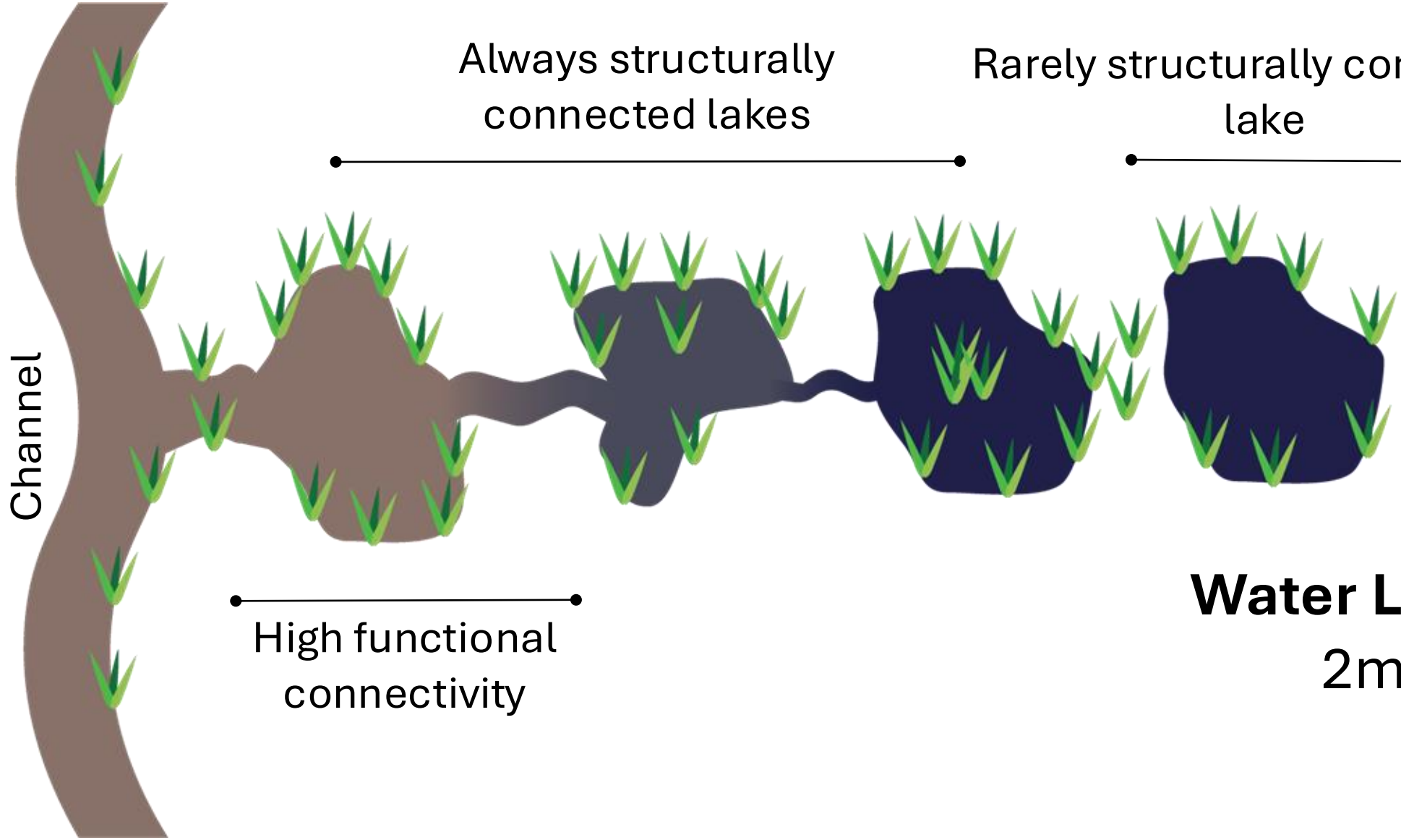
Functional connectivity depends on riverine water levels…



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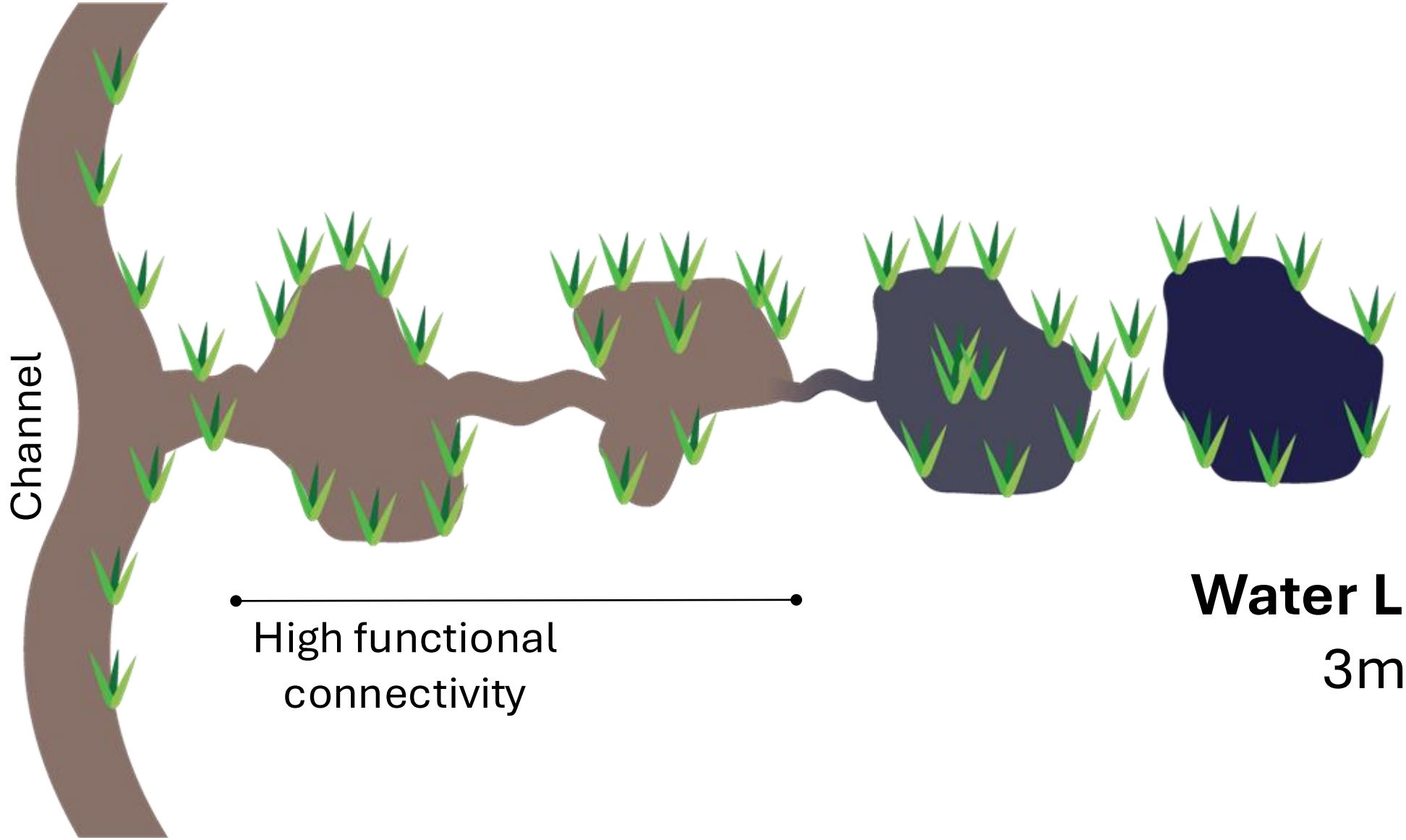
Functional connectivity depends on riverine water levels…



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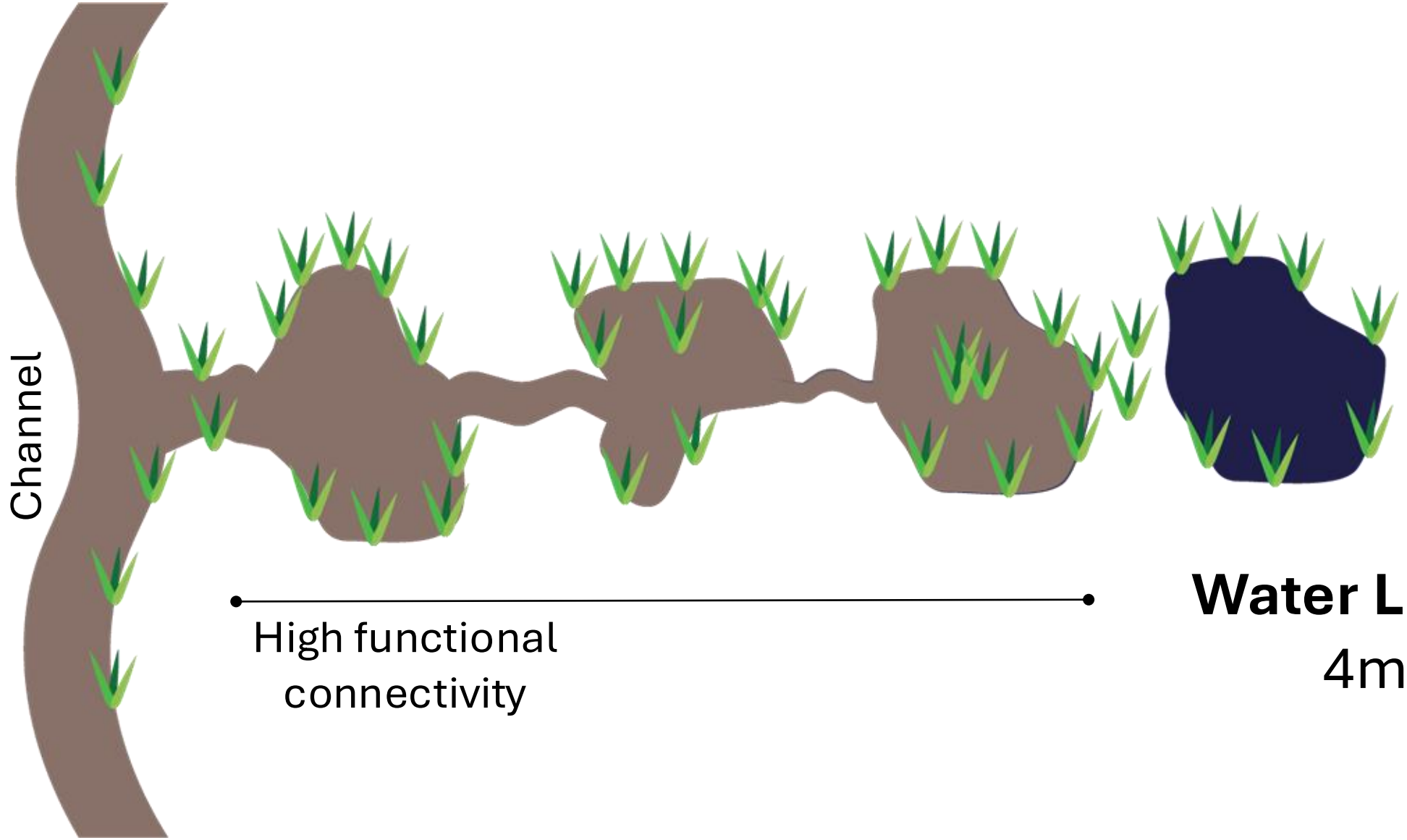

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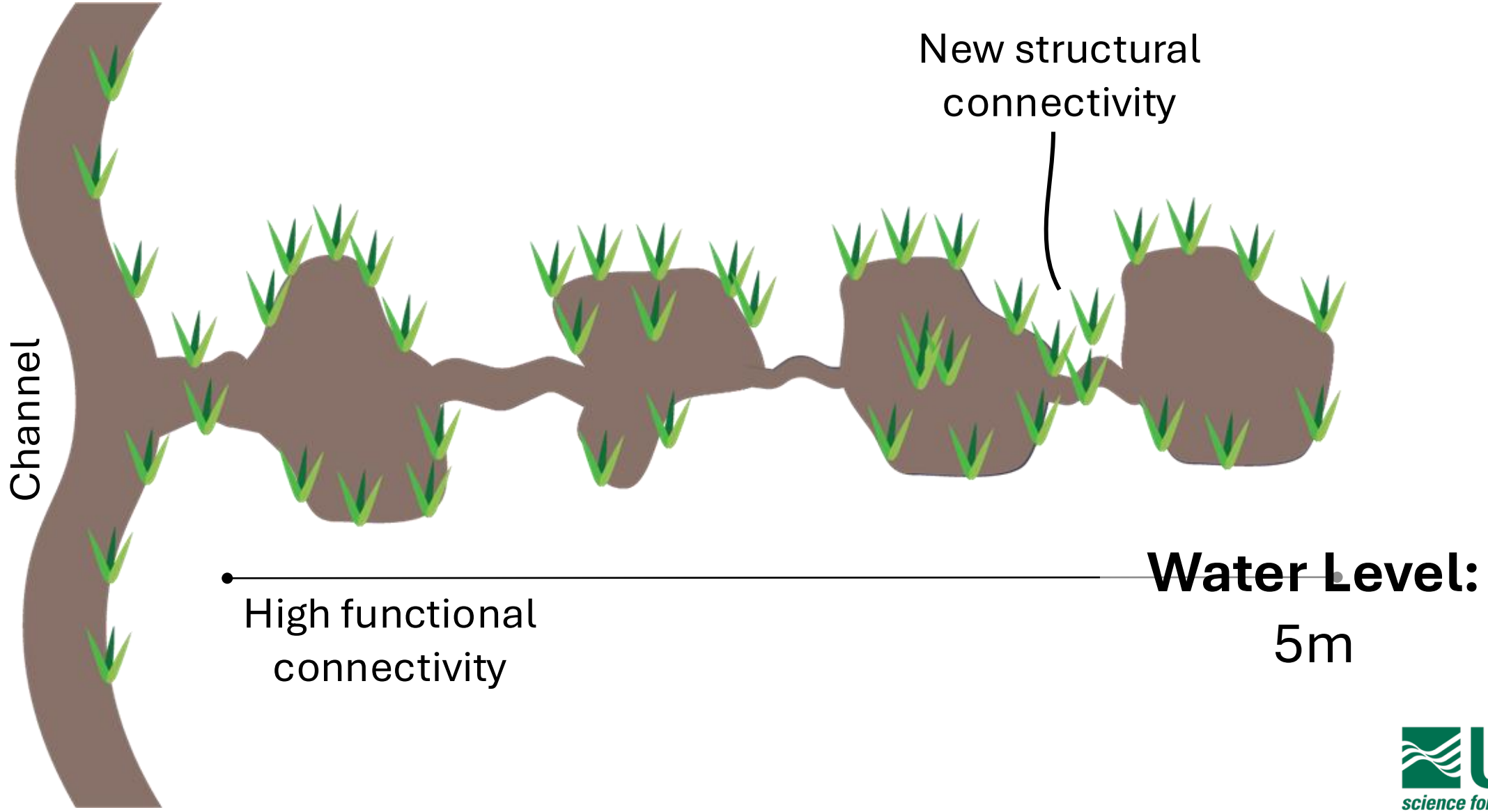

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