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A persistent mid-water column hypoxic zone with low pH and CaCO3 saturation state in Toba Inlet

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A persistent mid-water column hypoxic zone with low pH and $CaCO_3$ saturation state in Toba Inlet.

Hakai
Science on the Coastal Margin

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Introduction

- Oxygen concentrations in many coastal areas have declined over the last several decades, increasing the prevalence of low oxygen zones and hypoxia ($[O_2] < 2$ ml L^{-1}) [1].
- This trend is driven by warming temperatures that decrease oxygen solubility and increase biological metabolism and ocean stratification, as well as by anthropogenic nutrient loading [2, 3].
- Here, we identify and characterize a mid-water column hypoxic zone with very low pH and $CaCO_3$ saturation state in Toba Inlet, and evaluate the processes controlling this feature.
- **The key findings from our research will improve our understanding of the presence and formation of hypoxia in coastal waters**

Methods

- Monthly paired marine and river surveys of Toba Inlet and Toba River from Jan 2021 to June 2022 (fieldwork currently ongoing).
- Marine stations (5): standard hydrographic suite of CTD measurements coupled with bottle samples of nutrients, POC, chlorophyll, phytoplankton, and pCO_2/TCO_2.
- River station (1): nutrients, POC, PON, $\delta^{18}O$, $\delta^{13}C$, temperature, oxygen, pH, alkalinity

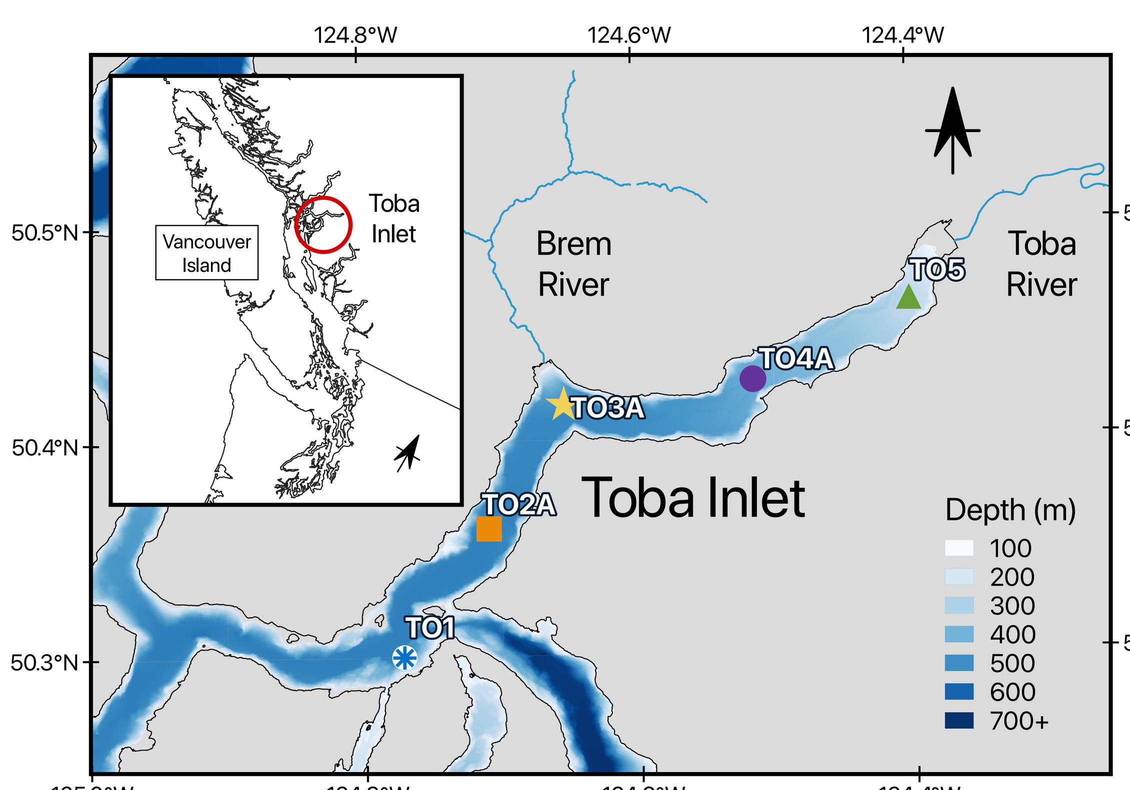

Figure 1. Map of Toba Inlet with marine sampling locations and bathymetry. Note that Toba does not have a sill. Station symbols correspond to Fig. 3.

Acknowledgements

Toba Inlet is located in the traditional territories of the Klahoose First Nation, and we gratefully acknowledge the ongoing assistance of members of the Klahoose First Nation with this project.

Results

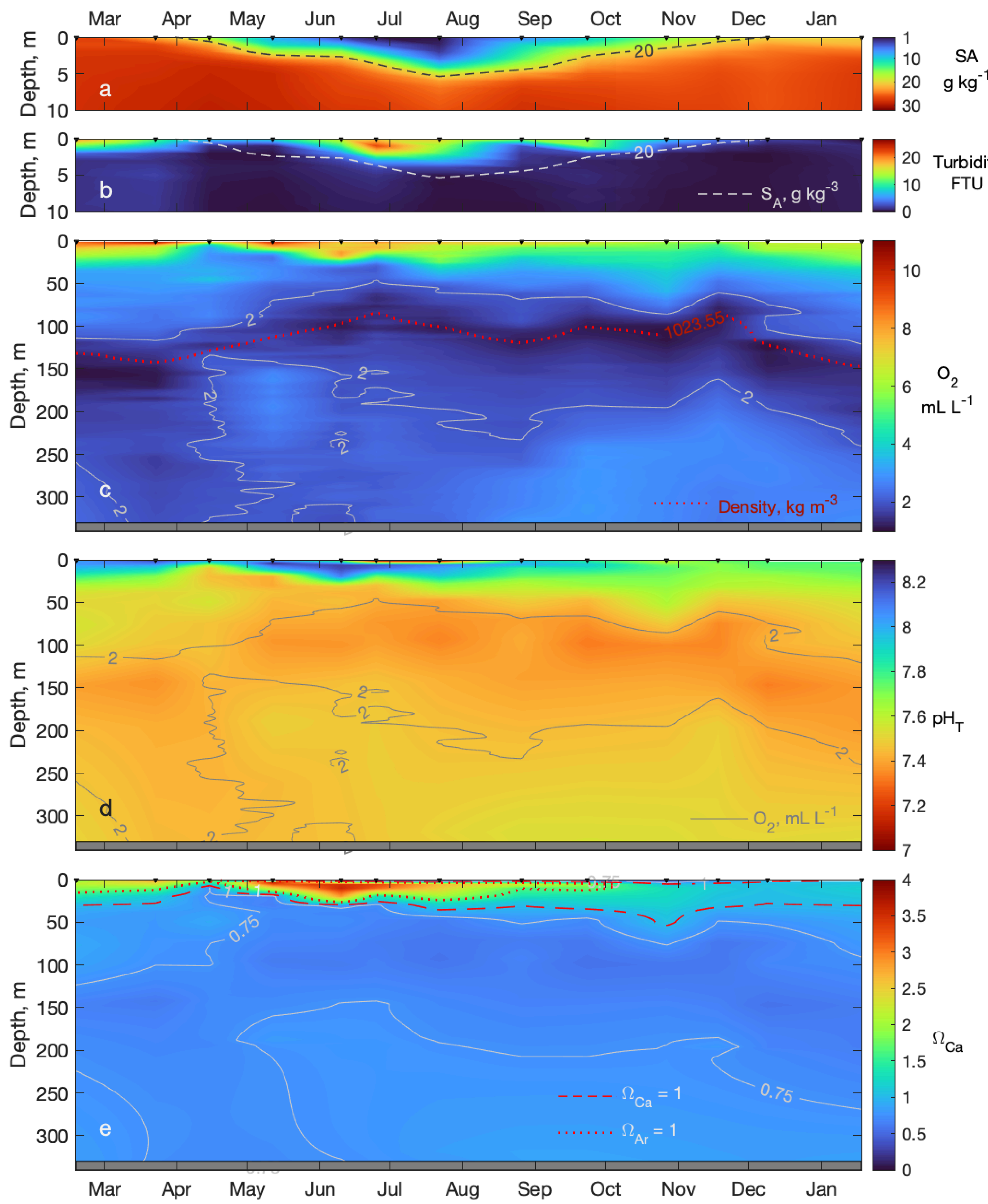

Figure 2. Time series of water column properties at station TO4A. (a) Absolute Salinity, (b) Turbidity, (c) Oxygen, (d) pH, (e) Calcite saturation state (Ω). Isolines overlaid on panels correspond to coloured parameter except where indicated by panel legends. Isopycnal in panel (c), (1023.55), corresponds to approximate depth of minimum hypoxic value measured across all stations in Fig. 3, panel (b).

Key findings, Figure 2:

(1) Hypoxia was present in the mid-water column of Toba Inlet throughout the entire year 2021, and centred roughly along the 1023.55 kg m³ isopycnal

(2) Hypoxia in Toba Inlet was associated with the lowest pH and Ω, but was not required for undersaturated Ω conditions, which existed throughout the year at roughly all depths > 30 m, for both calcite and aragonite (ΩAr).

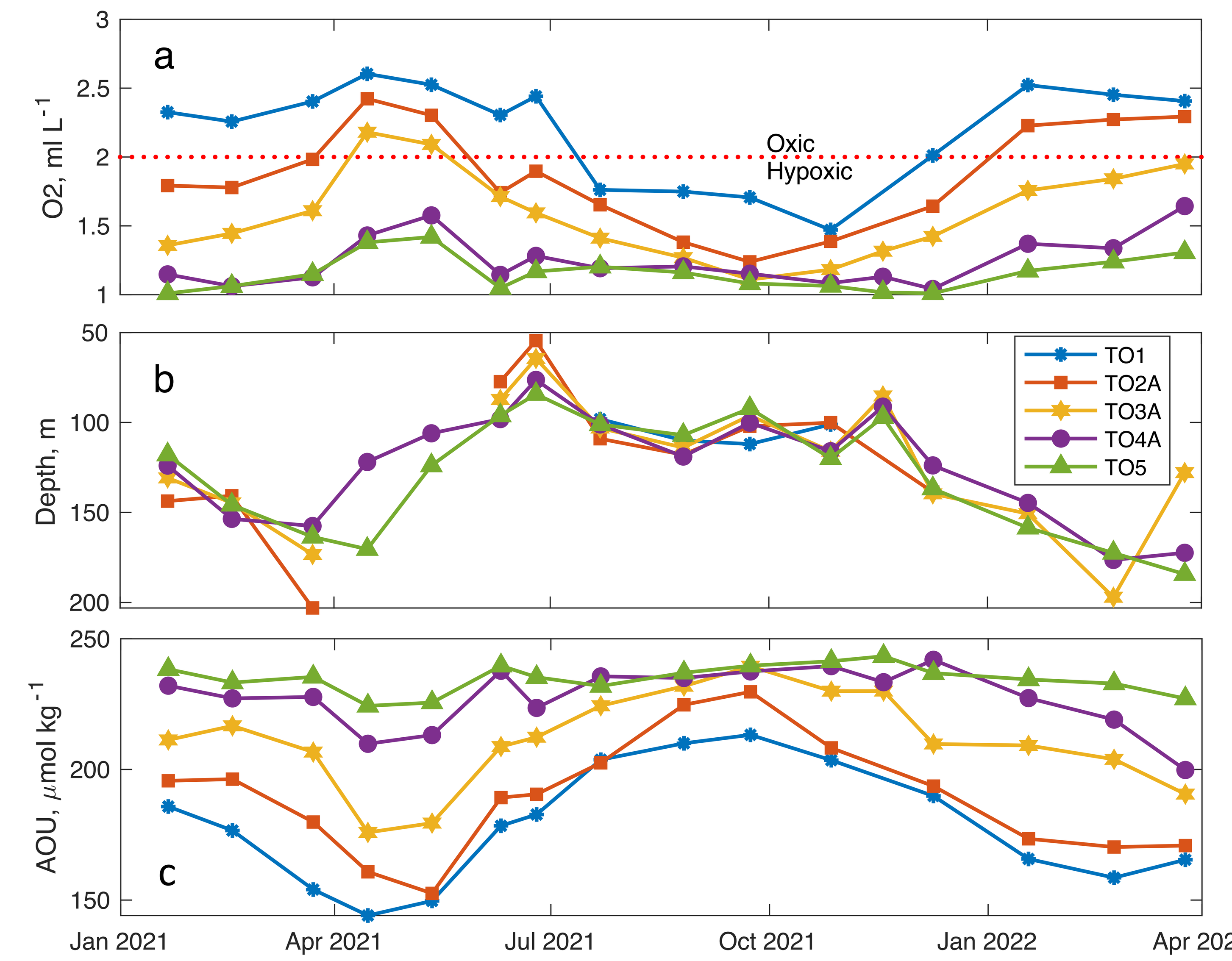

Figure 3. Comparison of oxygen characteristics across all Toba Inlet stations. (a) Minimum $[O_2]$ measured in water column, (b) depth of minimum hypoxic $[O_2]$, (c) Apparent Oxygen Utilization (AOU) at approximate density of depths in panel (b) (1023.55 kg/m³). Legend in panel (b) applies to all panels.

Key findings, Figure 3:

(1) Re-oxygenation of the water column at lowest $[O_2]$ occurred concurrently at all stations in spring and again in winter

(2) A consistent spatial gradient of minimum $[O_2]$ was present year-round, with higher concentrations near the fjord mouth, and lower concentrations near the head.

(3) However, the depth of the hypoxic water, estimated by the minimum hypoxic $[O_2]$, was roughly equal at all stations, year-round.

(4) AOU was highest and most stable at the fjord head, and steadily declined in magnitude and increased in variability, towards the fjord mouth.

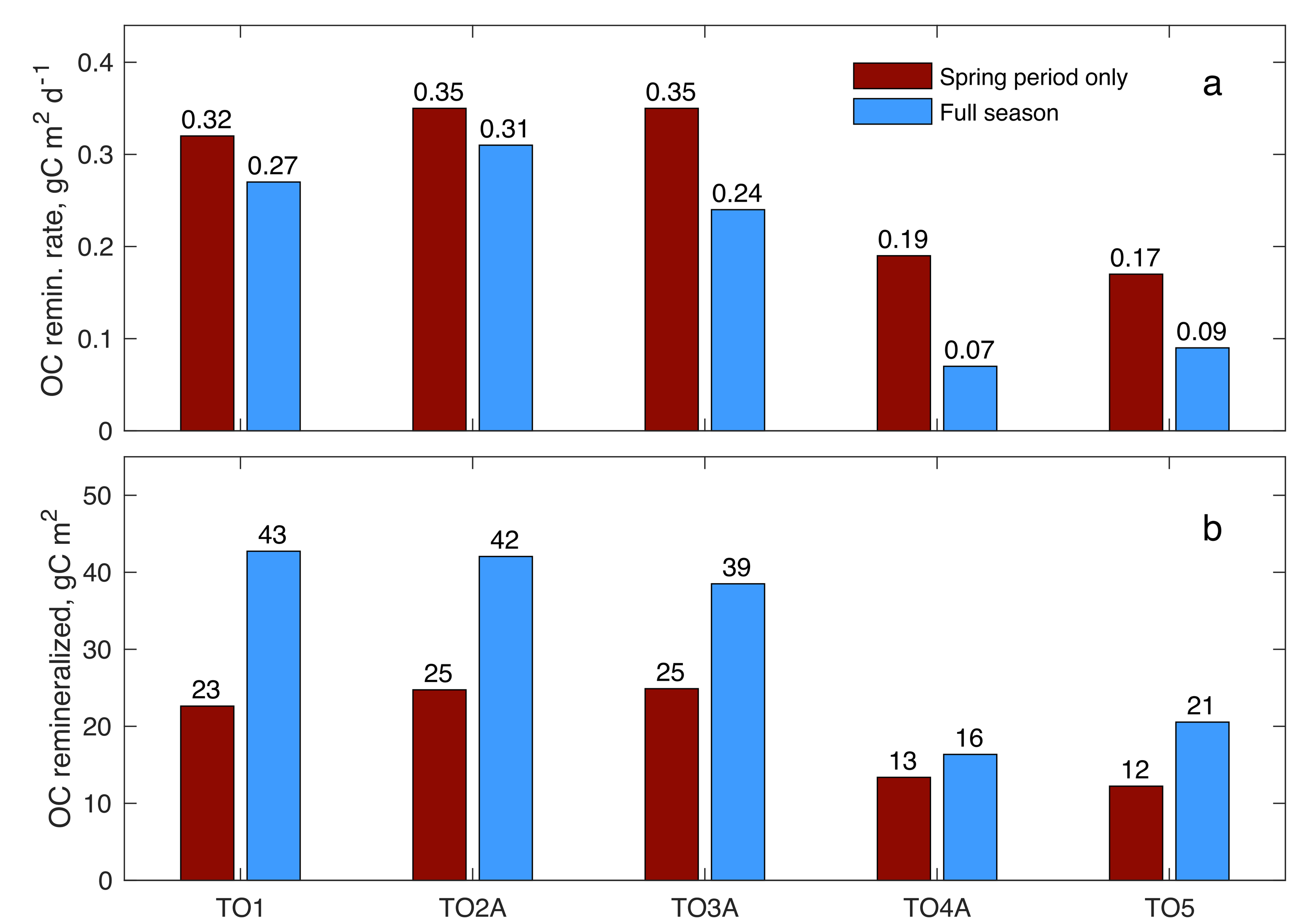

Figure 4. Organic carbon (OC) remineralization (remin.) estimated from O_2 loss in the hypoxic layer. (a) rates, (b) mass. OC loss (amount of OC converted to CO_2) was determined from mean ΔAOU between 75 m and 150 m, and a Redfield ratio of 138 O: 106 C. Spring period is April 15 to June 25. Full season represents the maximum observed change in AOU during the spring to winter seasons in year 2021.

Key findings, Figure 4:

(1) OC remineralization rates and loss were highest at the outer fjord stations

(2) These calculations suggest that OC remineralization at the fjord head is not greater than at the mouth, despite more intense hypoxia near the fjord head

Ongoing research questions

- What processes control the seasonal shoaling and deepening of the hypoxic layer?
- How much autochthonous and allochthonous OC are delivered to the fjord head, and what happens to it?

References:

[1] Breitburg et al., Science 359, 46 (2018)

[2] Diaz and Rosenberg, Science 321, 5891 (2008)

[3] Schmidtko et al. Nature 542, 335–339 (2017).