What is the chemical composition of silica produced by the marine cyanobacterium *Synechococcus*?

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Background

Synechococcus is a genus of small, unicellular marine cyanobacteria, these organisms are among the most numerous primary producers in the ocean.

It was discovered that **Synechococcus can accumulate measurable amounts of silica** despite lacking silica-based structures like shells (e.g., diatom frustules). **The chemical form of this silica remains unclear** (Ohnemus et al., 2018).

Methods for measuring biogenic silica (i.e., silica from organisms) are tailored to diatoms and **may not fully capture** silica associated with microbes like *Synechococcus* (Brzezinski et al., 2017).

This experiment aims to **characterize the chemical form and solubility** of *Synechococcus*-associated silica using targeted chemical leaching techniques.

Hypothesis & Rationale

We hypothesize that ***Synechococcus*-associated silica includes multiple chemical phases**, such as biogenic silica and metal-oxide bound forms.

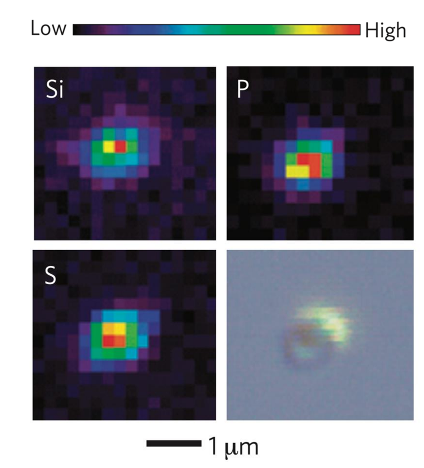
- Different leaching agents target different silica phases

Understanding *Synechococcus*-associated silica is critical for:

- Improving methods for quantifying silica in marine microbes
- Modeling the silica cycle in regions where diatoms do not dominate phytoplankton biomass (e.g., open ocean)

Methods

- Maintained **12 *Synechococcus* clone (CCMP 1334) cultures**.
  - 6 cultures are under moderate light, 6 under low light
  - Monitored pH
- Estimated cell abundance with **in vivo chlorophyll fluorescence.**
- Harvested biomass and subjected it to **3 different chemical leaching treatments** to target different silica phases:
  - 2.5 M hydrofluoric acid (HF) to solubilize all silica content, e.g., mineral, biogenic, metal-oxide (Krause et al., 2017).
  - 0.2 M sodium hydroxide (NaOH) to solubilize amorphous diatom-like biogenic silica (Ohnemus et al., 2016; Krause et al., 2017).
  - 0.1 M hydrochloric acid (HCl) to solubilize silica associated with metal oxides (Pickering et al., 2020). This approach is typically used in marine sediments.
- Quantified solubilized silica using a colorimetric spectrophotometric **dissolved silica analysis.**



Synechococcus cell silicon content (adapted from Baines et al., 2012)

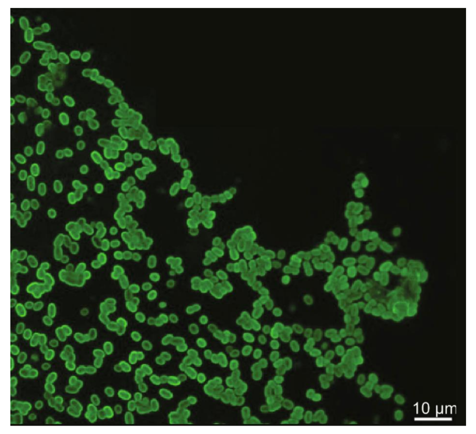
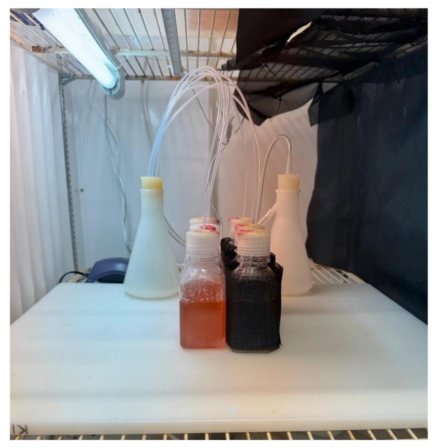


Image of *Synechococcus* cells (adapted from Angulo-Cánovas et al., 2024)



Culturing set up of 6 cultures, 3 moderate light and 3 low light

Results

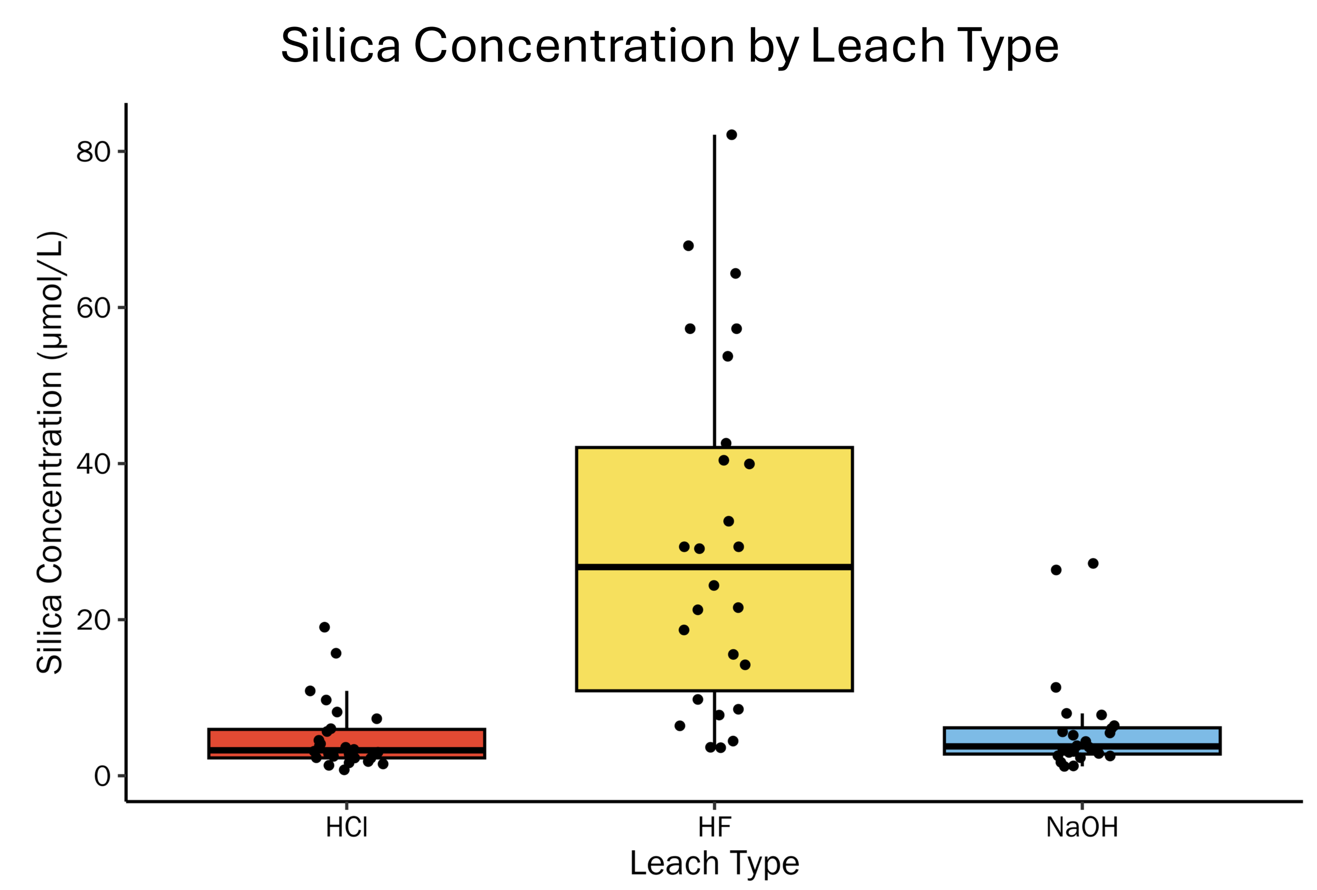


Figure 1 – Box plot showing the concentration of silica (µmol/L) released from *Synechococcus* biomass following three chemical leaching treatments (HCl, HF, NaOH). Kruskal Wallis test indicated significant difference in the median.

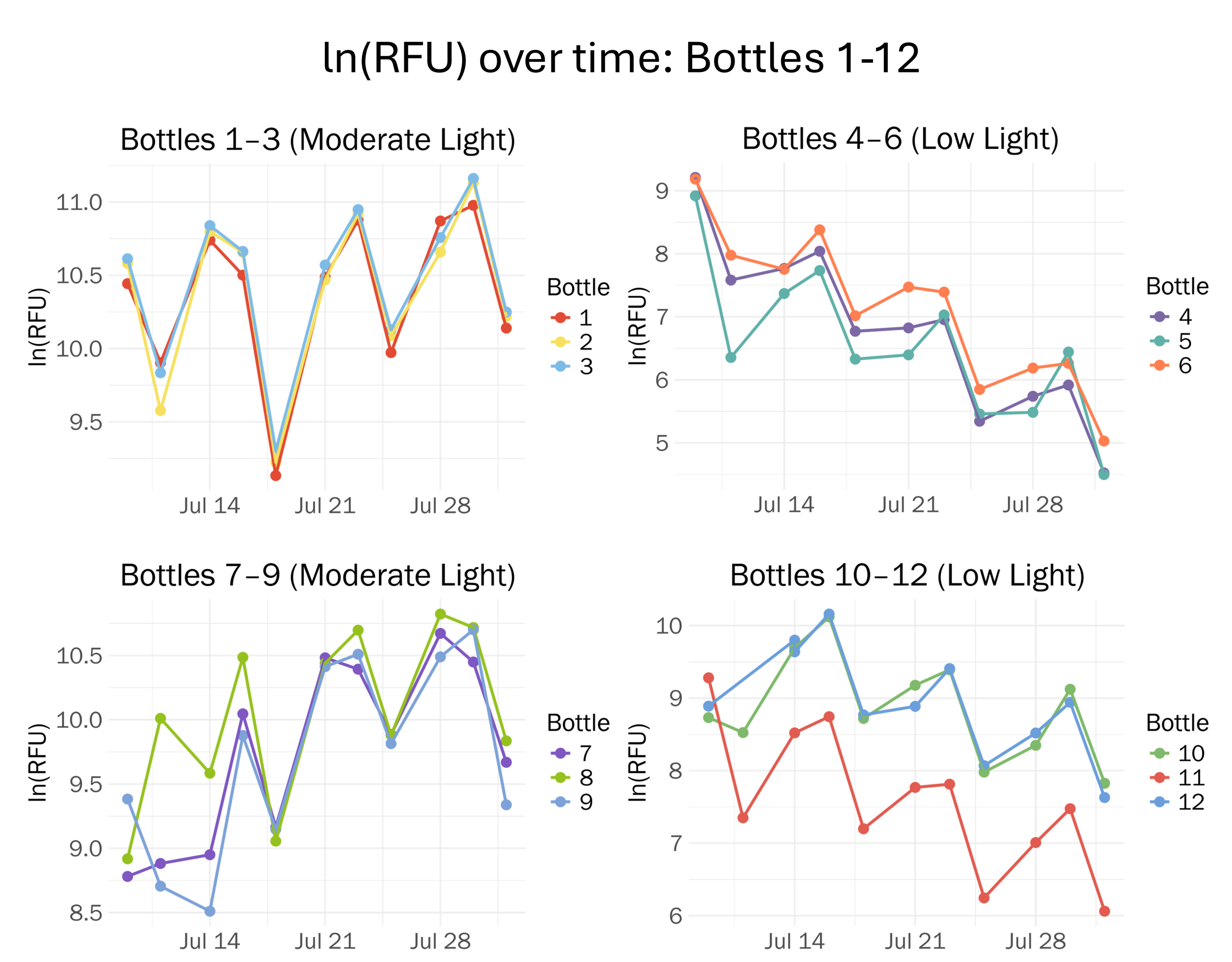


Figure 2 – Line plots showing natural log–transformed in vivo fluorescence (RFU) values across four weeks for all 12 *Synechococcus* cultures (different ranges). Samples were harvested during periods after active growth (peaks) instead of senescence.

Results

pH Summary

Moderate Light		Low Light	
Date	**pH Range**	**Date**	**pH Range**
2025-06-18	8.16 – 8.22	2025-06-18	8.12 – 8.25
2025-06-25	8.20 – 8.27	2025-06-25	8.20 – 8.29
2025-07-02	8.21 – 8.26	2025-07-02	8.19 – 8.31
2025-07-09	8.25 – 9.61	2025-07-09	8.13 – 9.57
2025-07-16	8.19 – 8.39	2025-07-16	8.10 – 8.25
2025-07-23	8.35 – 8.38	2025-07-23	8.10 – 8.19
2025-07-30	8.33 – 8.46	2025-07-30	8.16 – 8.20

Table 1 – pH values for *Synechococcus* cultures across six sampling dates under moderate and low light treatments. Only values >8.5 imply formation of sepiolite (which would be filtered and not discriminated from cells in our analyses); this was only an issue during one sampling (07-09) for a subset of bottles.

Conclusions

These results have **3 implications**:

1) Multiple phases of silica appear to be associated with *Synechococcus.*
2) The phases of silica have different solubilities. One is soluble in base (NaOH) and others are soluble in acid (HCl & HF).
3) Weak HCl associated silica suggests a metal oxide-bound phase (HCl is not strong enough to degrade mineral silica).

These findings suggest that methods for quantifying silica in *Synechococcus* that were designed for diatom-associated silica may not accurately capture silica associated with microbes like *Synechococcus*.

Future directions include expanding leaching experiments to additional *Synechococcus* clones and different leach types.

References

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