Examining the potential interference of Scandium on Iron Uptake Mechanisms in Phytoplankton, through the lens of Nutrient Consumption

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BACKGROUND:

Iron (Fe) is an essential micronutrient, required for growth. However in seawater, it exists at trace levels, and in over ~1/3 of the surface ocean low concentrations of Fe limit primary productivity (Moore et al., 2004). Despite this significant impact on the base of the oceanic food web, the factors impacting Fe availability in the surface ocean are not fully understood and remain under rigorous study by the oceanographic community. One of the challenges is that the biological and chemical cycling of iron in the ocean is very complicated.

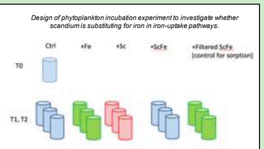
In this work, we investigate the possibility that a simpler chemical analog for Fe could help. Scandium (Sc) is an element with less complex chemistry that shares some aspects of Fe's chemical cycling, including ionic size: it's possible that molecules that bind Fe as part of the Fe uptake process also bind Sc, because Sc would likely fit in those molecules as well. If so, then Sc could be used to study the Fe uptake part of the oceanic Fe cycle.

METHODS:

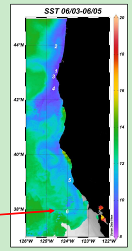
Surface seawater was collected, homogenized, and separated into 30 containers.

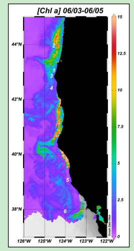
- Five treatments in triplicate, two timepoints
- Let grow for two and three days
- Sampled and measured nutrient concentrations

<u>Hypothesis</u>: the treatments with added Sc will show a greater level of Fe stress, suggesting that Sc interferes with Fe uptake



The sampling site for the incubation was station 6: slightly aged upwelling, which you can see by the plume of colder water moving offshore.

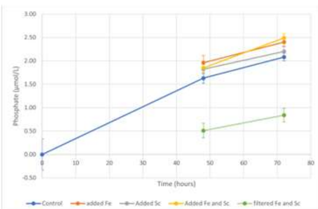


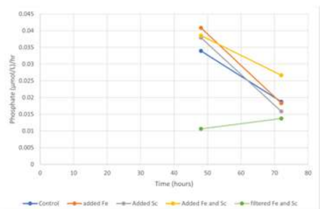


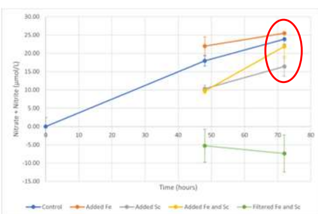
NUTRIENT UPTAKE GRAPHS:

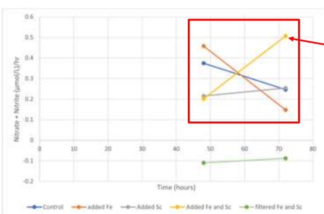
Nutrient Uptake

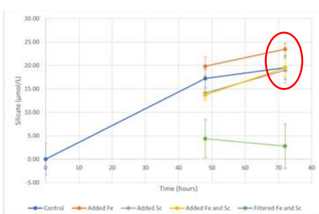
Nutrient Uptake Rates

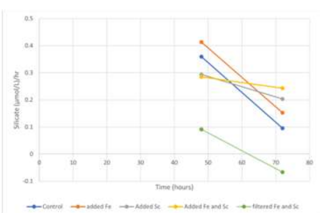








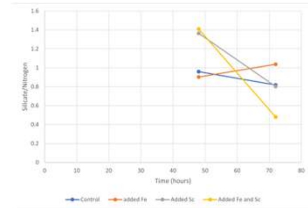


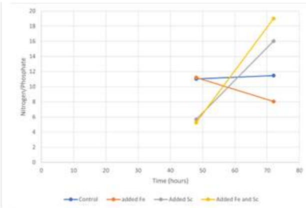


<u>Observations:</u>

- +Fe has the highest total nutrient uptake for all the nutrients
- The rates of consumption decrease over time in the control and added iron treatments for all the nutrients.
- The phosphate data looks very similar across all treatments. More specifically the +Fe and +Fe & Sc seem to align and the control and +Sc match well.
- Sc appears to slow nitrogen uptake. The rate of nitrogen consumption for the non scandium treatments decrease quickly because by t72 they have run out of nitrogen. Contrastingly, the rate of nitrogen consumption rises dramatically for the +Fe & Sc treatment
- There was more nitrate available at t48 in the +Fe & Sc treatment than the control, but by t72, it catches up to the control
- When observing the Si graphs, both +Sc treatments seem to have a slower consumption rate, but eventually they reach the same total consumption as the control group which grew quickly and slowed drastically after t48.

RATIOS:





<u>Important Notes:</u>

In a paper published by Takeda, the silicate:nitrate consumption ratio was found to double in iron limited environments compared to iron rich conditions. In our data we see that the +Sc treatments have much higher Si:N ratios than the Control and +Fe at T48 (circled in red).

- **Suggests that Sc enhances Fe stress**

Looking at T72, we see that the +Sc treatments have a lower Si:N ratio, suggesting that iron stress decreases at this point.

- **Sc could reduce the rate of Fe uptake, rather than permanently blocking it**

In the +Fe treatment, the Fe replete conditions allow the organisms to grow quickly, and uptake nitrate much quicker than the other treatments. Thus the +Fe treatment becomes nitrogen limited before the other treatments, which could explain the elevation in the Si:N ratio.

KEY TAKEAWAYS:

- **Sc may not interfere with the uptake mechanisms of phosphate,** perhaps because iron doesn't have much of an impact on phosphate uptake, and thus Sc cannot interfere with phosphate uptake.
- **Sc may be somehow delaying uptake of nitrate, but not inhibiting it completely.** Could be by reducing the rate of Fe utilization due to Fe's important role in nitrate reduction and absorption.
- **Sc appears to enhance Fe stress,** based on Si:N uptake ratios
- The Si uptake also appeared to be impacted by the presence of Sc

FURTHER QUESTIONS:

- How does Sc interfere with iron absorption?
- Do organisms express genes indicative of Fe stress in the presence of Sc?
- Do organisms take up Sc (perhaps as a substitute for Fe)?
- By what mechanism do organisms uptake iron?
- Does iron impact absorption of phosphorus?
- How can we use Sc as a tool to understand the biogeochemical cycling of iron in the ocean?

ON LIMITING NUTRIENTS:

The seawater samples were taken in regions off the coast of California that are often iron limited, and our data seems to suggest that this was true. The nutrient uptake rates are higher in the +Fe treatments suggesting that adding iron relieved stress, and organisms could grow more.

By 72 hours however, the nitrogen levels in the incubations were nearing zero, suggesting that at the later time points, the organisms were nitrogen limited.

Total concentration of N+N in the seawater samples for each treatment

It is assumed that the initial concentration of all of the nutrients are the same in all treatments at t0, so only the control was measured

NEXT STEPS:

- Fe concentrations
- Gene expression
- X-ray florescence (for association of Sc in organisms)

REFERENCES:

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