Enhancement of nitrogen fixation rates by unicellular diazotrophs versus *Trichodesmium* after a dust deposition event in the Canary Islands

Mar Benavides
• Reduction of atmospheric nitrogen to ammonium \[ \text{N}_2 \rightarrow \text{NH}_4^+ \]

• Diazotrophic organisms (diazo = nitrogen, trophykos = nutrition)

  Cyanobacteria, Bacteria, Archaea

  \[ \text{N}_2 \text{ fixation fuels up to 50\% of open ocean primary production (Capone et al., 2005)} \]

  Nitrogenase \( \rightarrow \) \textit{nifH} gene

  Diazotrophs limited by Fe and P

\textit{Introduction}

Unicellular cyanobacteria

\textit{Eg. Cyanothece} sp.

Symbiotic cyanobacteria

\textit{Eg. Richelia intracellularis}

Colonial cyanobacteria

\textit{Eg. Trichodesmium thiebautii}

\[ \text{Riemann et al., 2010} \]
The importance of unicellular diazotrophs

- *Trichodesmium* only appears in tropical and subtropical areas
- Wide distribution of the *nifH* gene but…
- Lack of N$_2$ fixation data

Moisander et al., 2010
Canary Current

• Strong surface heating throughout the year
• Quasi-permanent thermocline → oligotrophic waters
• Mixing January-March → 'late winter bloom'
• Dust deposition → P and Fe
Objectives

• Short-term variability of N$_2$ fixation activity in Canary Current waters
• Influence of Saharan dust deposition on diazotrophic activity and diversity
N\textsubscript{2} fixation

• Acetylene Reduction Assay (ARA) (Stal, 1988)

\[ \text{H–C} \equiv \text{C–H} \rightarrow \text{N} \equiv \text{N} \quad \text{Conversion factor } C\textsubscript{2}H\textsubscript{2}:N\textsubscript{2} = 4:1 \]

• Surface water (Niskin 30 L)

• On-deck incubations (light/dark)

Abundance of *Trichodesmium sp.*

• Plankton net 50 \( \mu \text{m} \)

• Vertical casts to 100 m

• ARA >50 \( \mu \text{m} \)

\( >50 \mu \text{m} \text{ N}_2 \text{ fixation rates} = \textbf{Trichodesmium} \text{ N}_2 \text{ fixation rates} \)

• Correlations between >50 \( \mu \text{m} \) N\textsubscript{2} fixation rates and *Trichodesmium* abundance

\[ r^2 = 0.86 \text{ (light)} \quad r^2 = 0.69 \text{ (dark)} \quad p < 0.05 \]

Surface seawater N\textsubscript{2} fixation rates = Unicellular diazotroph N\textsubscript{2} fixation rates

• Low probability of catching *Trichodesmium* with Niskin bottles when its abundance is low (Chang, 2000)
Unicellular diazotroph abundance

Tyramide Signal Amplification – Fluorescent In Situ Hybridization (TSA-FISH)

- Filtrate seawater on PC filters
- Probe Nitro821 → nifH gene
- Classification

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 µm</td>
<td>Small Free-living</td>
</tr>
<tr>
<td>&gt;1 - &lt;3 µm</td>
<td>Medium Attached to organic matter</td>
</tr>
<tr>
<td>&gt;3 µm</td>
<td>Large Symbiont</td>
</tr>
</tbody>
</table>

Methods

Leica DM 2500

Size

Type

Washing

Hybridized cells

FISH analysis

Fluorescent oligonucleotide probes
Methods

Dust deposition and composition

• Aerosol Optical Depth → Giovanni NASA
• PM$_{10}$, PM$_{2.5}$ → Gobierno de Canarias Calidad del Aire
• Metal analysis

Hydrography and Chl a

• CTD SBE 25
• Turner AU-10 Fluorometer
Results & Discussion

Temperature, MLD, Chl $a$, nutrients

- Higher temperatures than previous years
- Stratification
- Lower Chl $a$
- Low nutrient concentrations

→ No clear ‘late winter bloom’
Results & Discussion

Dust deposition

Dust composition

Metal concentration (μg m⁻³)

Date

Fe
Zn
Al

Cu
Mn
Ni
Pb
Results & Discussion

- Trichodesmium $N_2$ fixation rates decrease after the dust deposition event
- Unicellular diazotrophs’ $N_2$ fixation rates increase after the dust deposition event
Unicellular diazotrophs complexed to organic matter particles

Barbeau, 2006
Results & Discussion

- *Trichodesmium* N₂ fixation rates decrease after the dust deposition event.
Results & Discussion

- *Trichodesmium* colonies can take advantage of dust particles
- Free *Trichodesmium* filaments cannot
• Dust deposition enhances unicellular diazotrophs’ \( N_2 \) fixation rates when they are attached to organic matter particles

• Free *Trichodesmium* filaments do not seem to be able to uptake the Fe in atmospheric dust

• \( N_2 \) fixation rates may change greatly in short-term periods: importance of monitoring programmes
Gracias!