GÖTEBORGS UNIVERSITET

Harmful Algal Blooms and Climate Change
Symposium 2015

Trichodesmium under ocean acidification
- A close-up on colony microenvironments -

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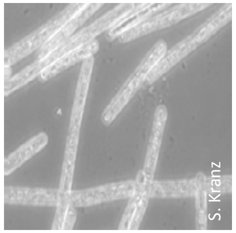
Alexander von Humboldt Stiftung/Foundation

center for microbial oceanography: research and education
C-MORE linking genomes to biomes

Stockholms universitet

Trichodesmium
Background

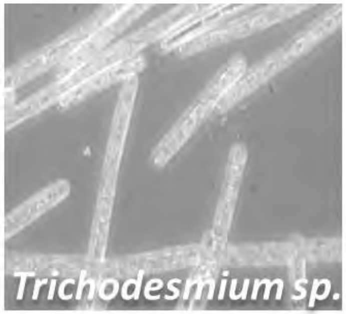
- **Filamentous, colony**-forming cyanobacteria
- Forms **extensive blooms** in subtropical and tropical, oligotrophic oceans
- Important **N_2 fixer**
- Diverse range of **associated organisms**
- Various **toxic effects** reported
(e.g. ciguatoxin-related toxins)

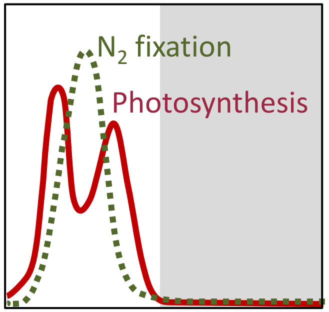


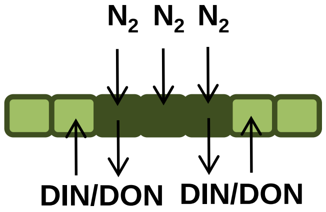
Trichodesmium
Cellular N- and C-fluxes

- N_2 fixation has a high energy demand & is impeded by O_2

→ *Separation of N_2 fixation and photosynthesis in time (diurnal cycle) and space (diazocytes)*

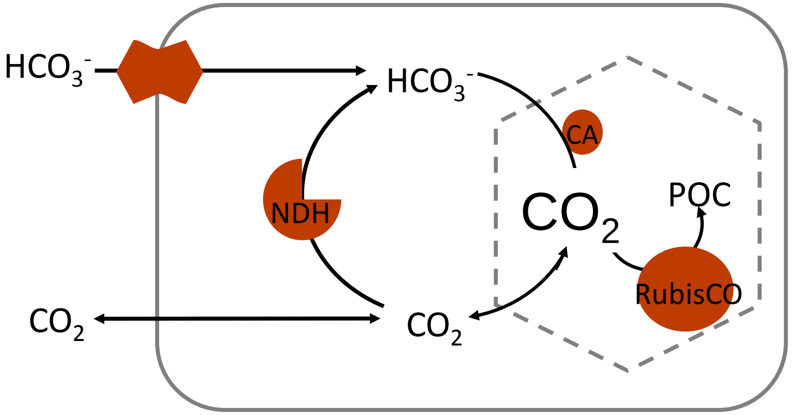




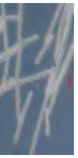


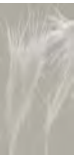
- RubisCO has a low CO_2 affinity & is competitively inhibited by O_2

→ *Operation of Carbon Concentrating Mechanisms (CCM)*



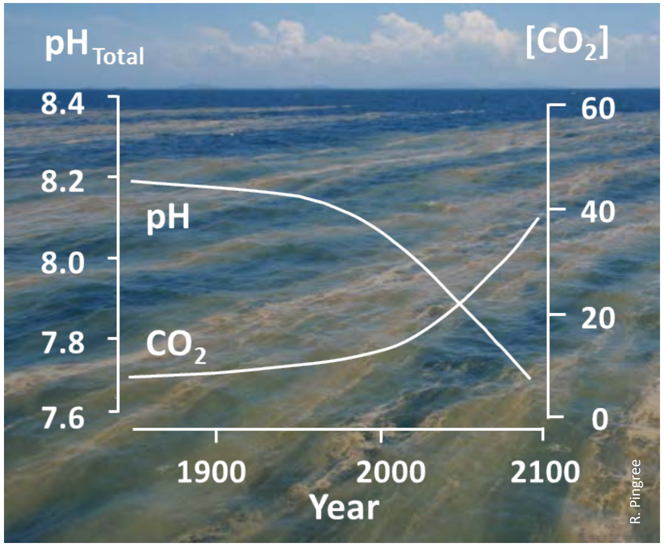
Trichodesmium and OA
Previous results





- In **lab** studies *Trichodesmium* responded **sensitively to OA**, increasing growth, N_2 fixation and POC & PON production
  (e.g. Hutchins et al. 2007, Kranz et al. 2009)

- **Energy reallocation** from the **CCM to N_2 fixation** suggested as a key driver behind OA responses
  (e.g. Kranz et al. 2011, Eichner et al. 2014)

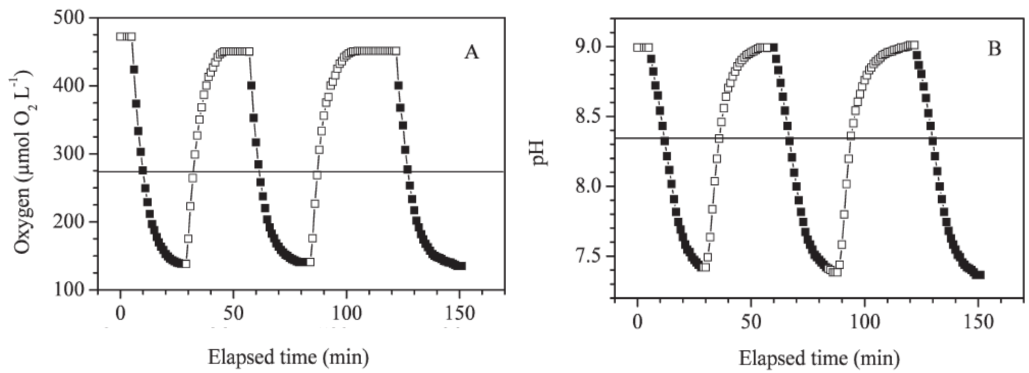


- **Field** experiments with N_2-fixing communities found **no OA effects**
  (e.g. Böttjer et al. 2014, Gradoville et al. 2014)

Microenvironments of colonies
Previous results



- Conditions in colonies can differ strongly from the bulk with respect to e.g. $[O_2]$ & pH
(e.g. Paerl & Bebout 1988, Ploug 2008)

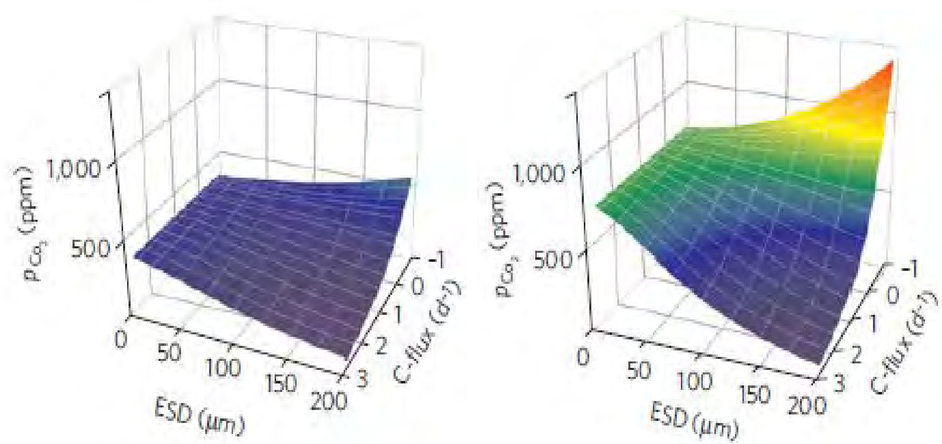


Ploug 2008

- Variability in pCO_2 depends on size and bulk pCO_2
(e.g. Flynn et al. 2012)

current

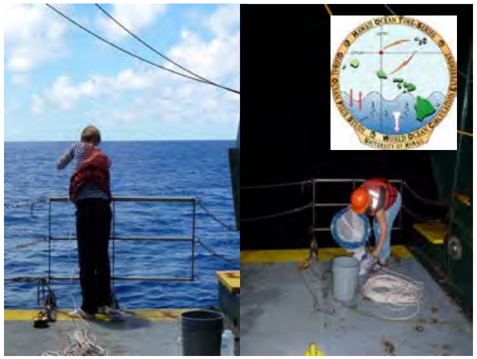
future



Flynn et al. 2012

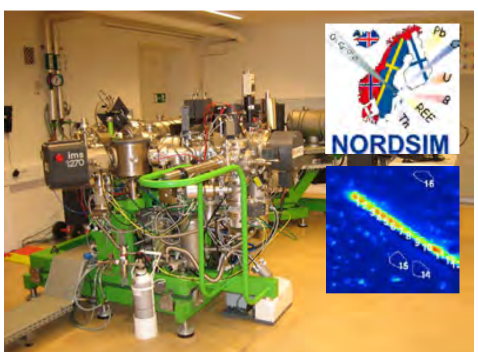
→ *Requirements for the CCM differ between colonies and single filaments*

Microenvironments under OA
Methods



- *Trichodesmium* colonies
  500 vs. 1000 µatm pCO_2

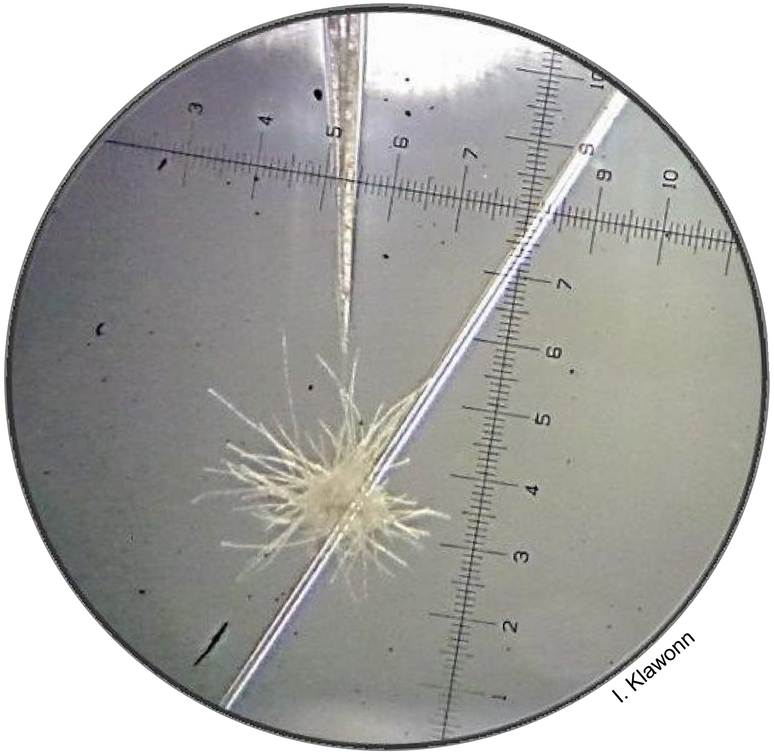
- Microsensor measurements:
  O_2 & pH



- Stable isotope incubations:
  $^{15}N_2$ & ^{13}C; SIMS analysis

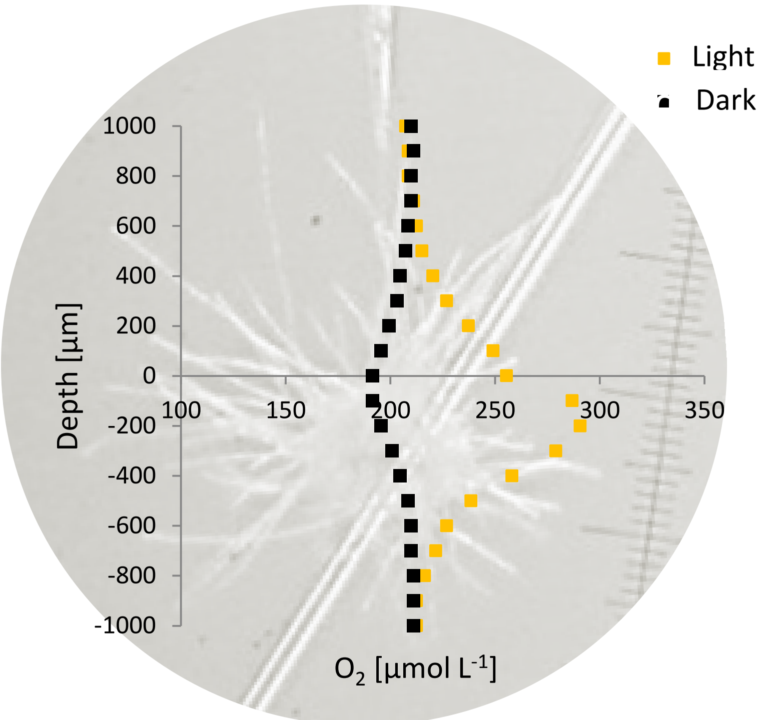
Microenvironments under OA
Colony characteristics





- Diameter from 0.4 to 1 mm
- 400 to 15,000 cells colony^{-1}
- Different types of filaments
(70% á ~10 µm, 30% á ~20 µm width)

Microenvironments under OA
O_2 profiles



- [O_2] in the center of colonies

  <u>Light</u>: 146 ± 35 % air saturation

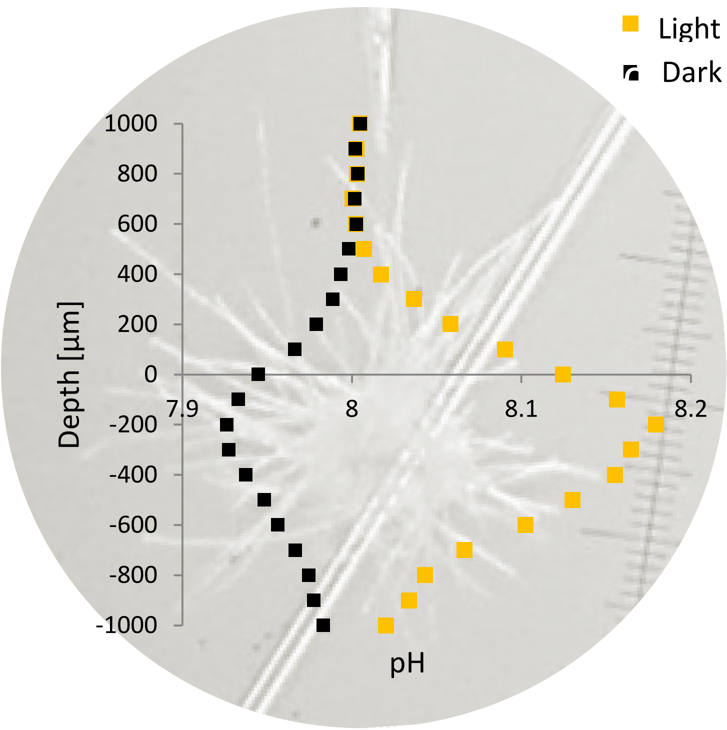
  <u>Dark</u>: 78 ± 8 % air saturation

  - Total range 61 % to 203 % air sat.

- Diurnal variation in photosynthesis

- No CO_2 effects

Microenvironments under OA
pH profiles



- pH in the center of colonies

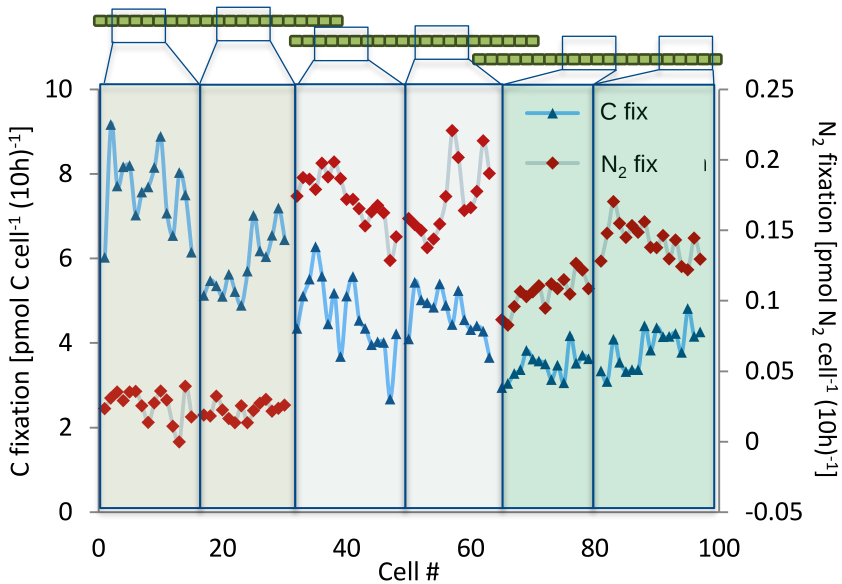
	@ 8.1 bulk	@ 7.8 bulk
Light:	8.3 ± 0.5	7.8 ± 0.5
Dark:	7.8 ± 0.2	7.4 ± 0.3

  - Total range 7.1 to 8.6

- Larger variability in $[H^+]$ at high pCO_2
  - @ 8.1 bulk: $\Delta[H^+]$ = 12 nmol L^{-1}
  - @ 7.8 bulk: $\Delta[H^+]$ = 20 nmol L^{-1}

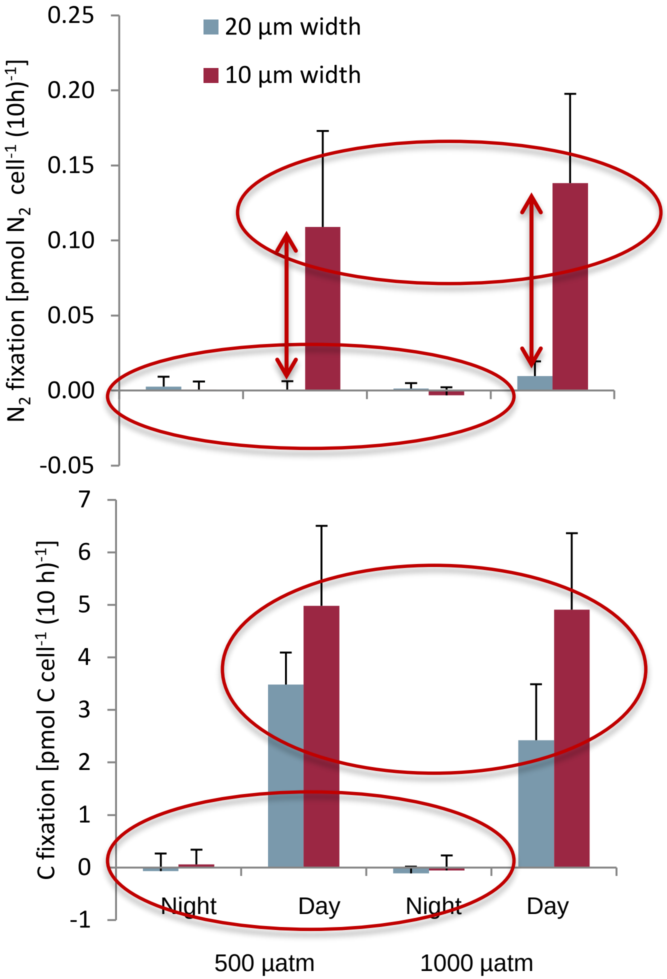
Microenvironments under OA

Single cell C- and N-fluxes



- High variability between filaments but not between cells within filaments

Microenvironments under OA
Single cell C- and N-fluxes



- High C- and N_2-fixation rates during the day
- ’Wide filaments’ are non-diazotrophs
- No CO_2 effects

Microenvironments under OA
Conclusions & Implications



Conclusions

- Highly variable $[O_2]$ and pH
- Increasing variability in $[H^+]$ with pCO_2

→ *Demand for high flexibility in pH-dependent processes, incl. CCMs*

- High N_2 fixation + high $[O_2]$

→ *Demand for efficient protection/repair of nitrogenase*

- High C fixation + high pH

→ *Demand for highly active CCM*

Variability

Energy demand

To be continued…

→ *Low OA sensitivity due to adaptation to high variability?*

→ *Can flexibility be increased to match future pH-variability?*

→ *Do high energy demands enforce positive OA responses (mediated by energy re-allocation)?*

Thank you for your attention

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