Corals and Halimeda

Calcification, respiration and photosynthesis measured by microsensors.

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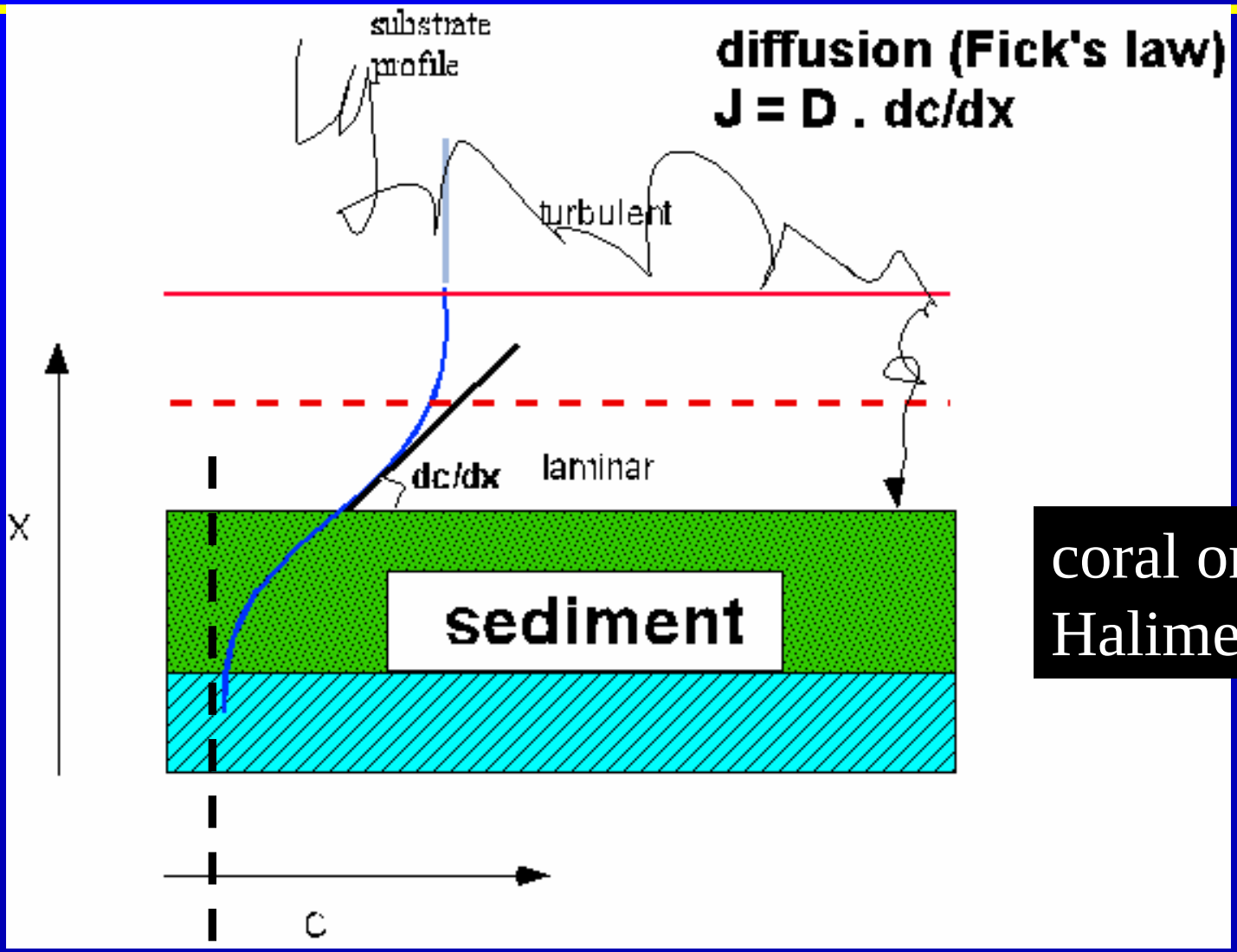
Microsensors

- O_2 Photosynthesis/respiration
- pH Photosynthesis/physiology
- CO_2 Photosynthesis
- Ca^{2+} Calcification

Process analysis

- process state (steady or transient state)
- transport: diffusion - Fick’s law (1-D)
- mass balance and process rates
- mechanisms: microbiology/physiology

Interfacial flux (1-D transport)



coral or Halimeda

Calcifying phototrophs: Main processes

photosynthesis: $CO_2 + H_2O \rightarrow CH_2O + O_2$

$\uparrow\downarrow$

$H_3O^+ + HCO_3^-$

respiration: $CH_2O + O_2 \rightarrow CO_2 + H_2O$

$\uparrow\downarrow$

$H_3O^+ + HCO_3^-$

calcification: $2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + CO_2 + H_3O^+$

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combined: $2HCO_3^- + Ca^{2+} \rightarrow CH_2O + O_2 + CaCO_3$

net photosynthesis:calcification = 1:1 then dH^+ and $dCO_2 = 0$

actually ratio lower (1:0.1-0.5)

calcification is stimulated by photosynthesis

Coral measurements (Favia)

measured:

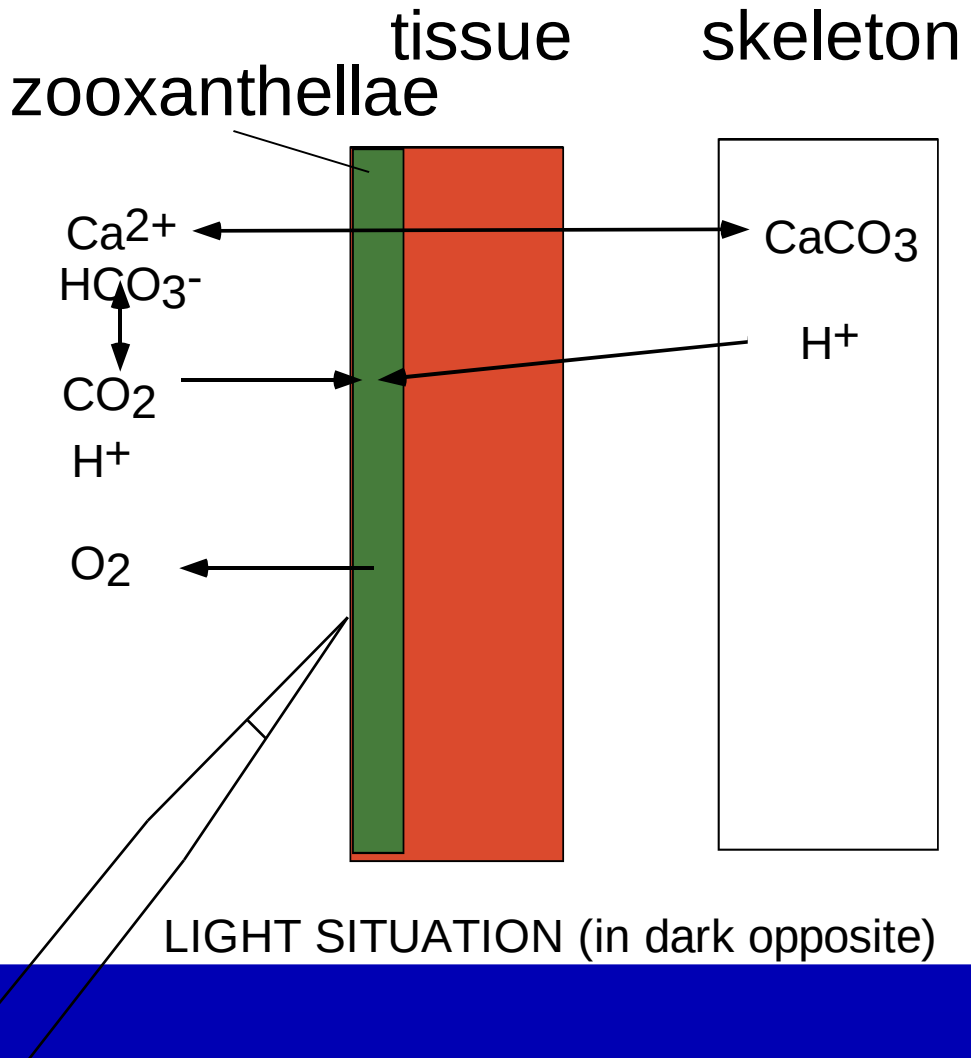
- ***effect of light and inhibitors on***
- ***1) concentration profiles in boundary layer***
- ***2) surface concentration dynamics***

expected:

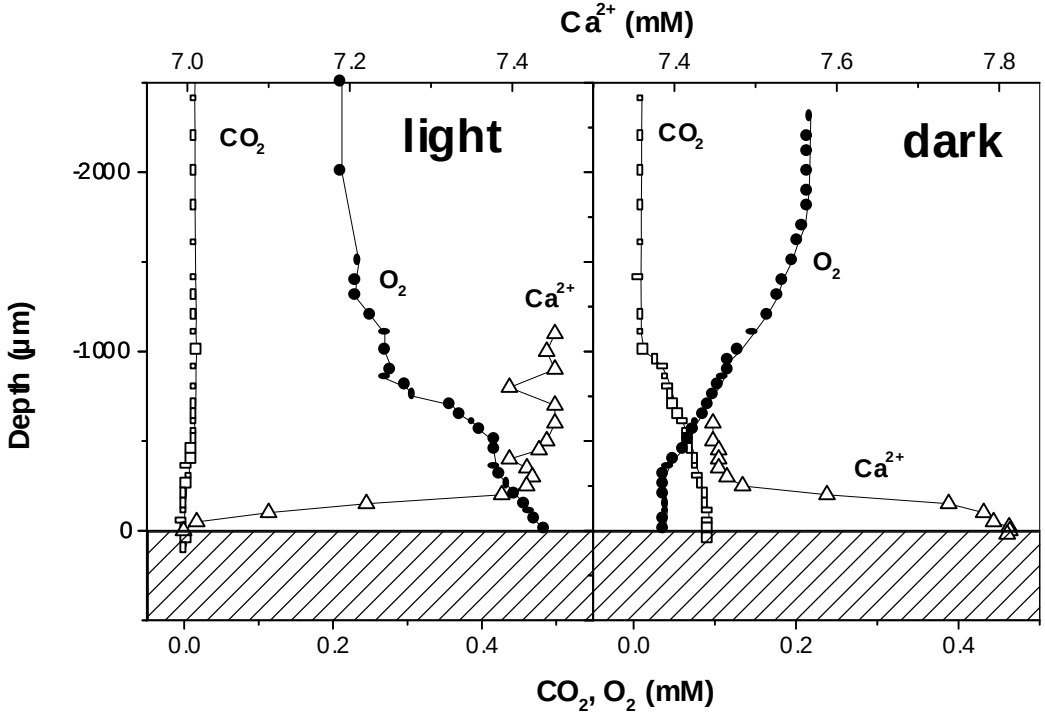
- **concentration of all measurable compounds depends on light intensity**
- **transients of photosynthesis reactants fast (H^+, CO_2, O_2)**
- **transients of calcification reactants slow (Ca^{2+}, H^+, CO_2)**

- **effect inhibitors: DCMU fast on O_2, slow on Ca^{2+}**

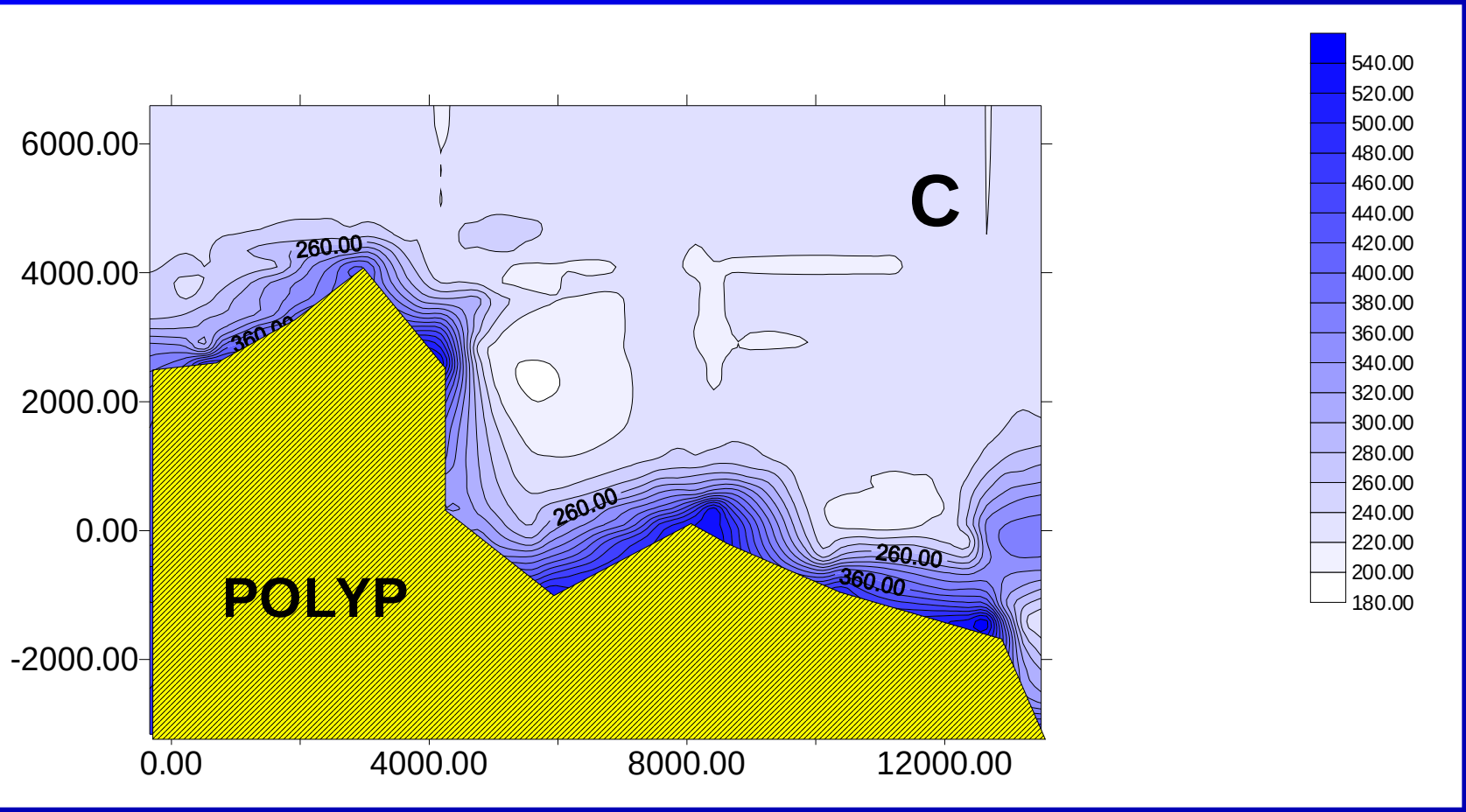
Coral structure



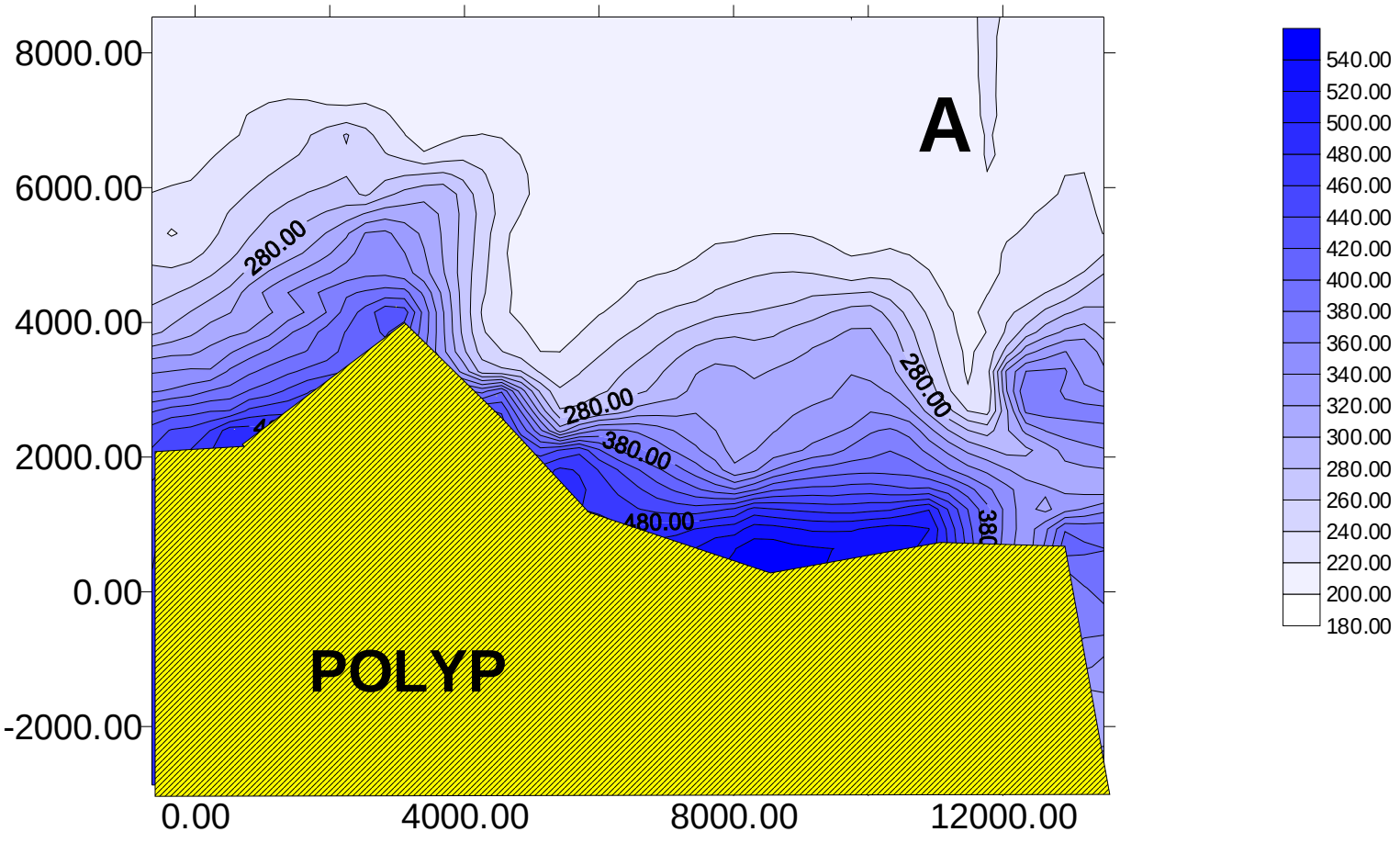
Light and dark profiles Favia



O_2 distribution (flow 10 cm/s)

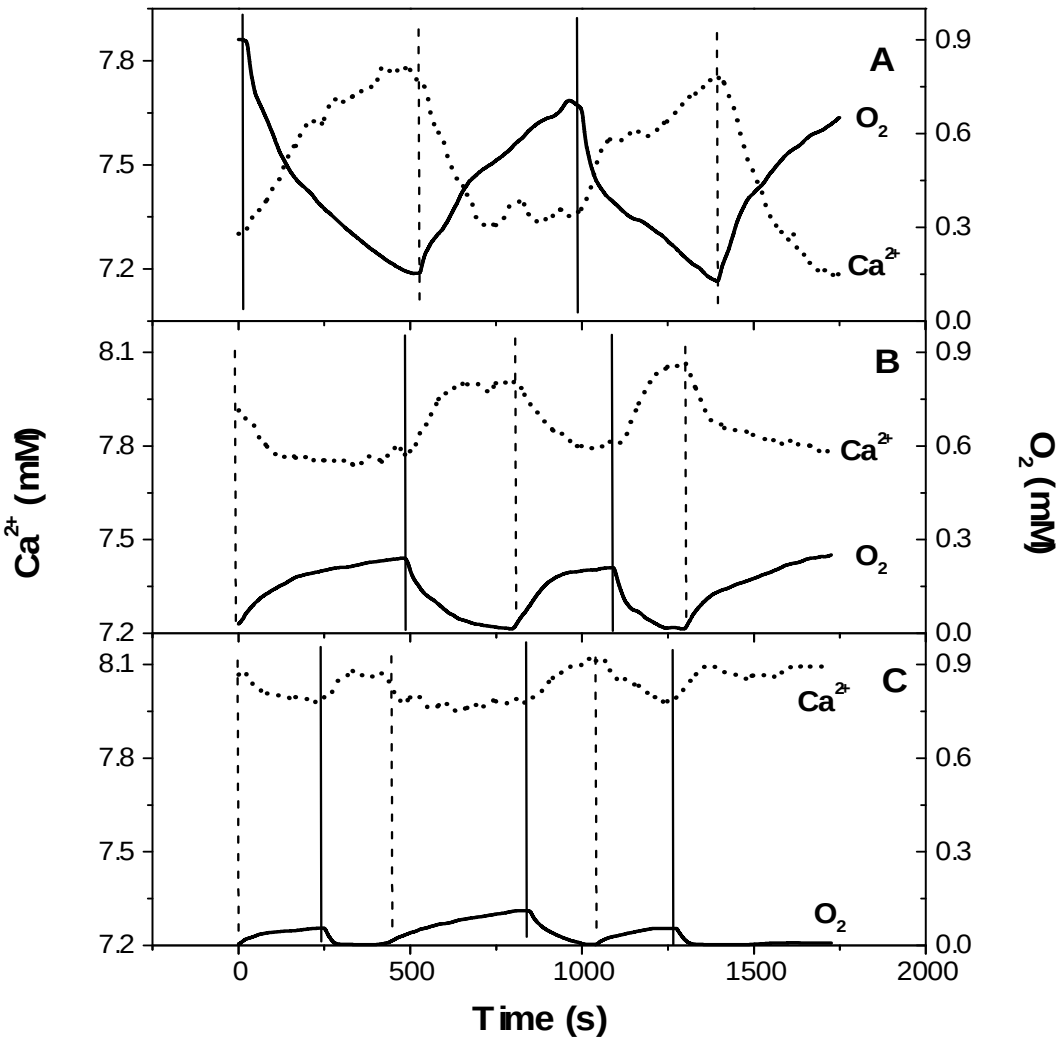


O_2 distribution (flow 1 cm/s)

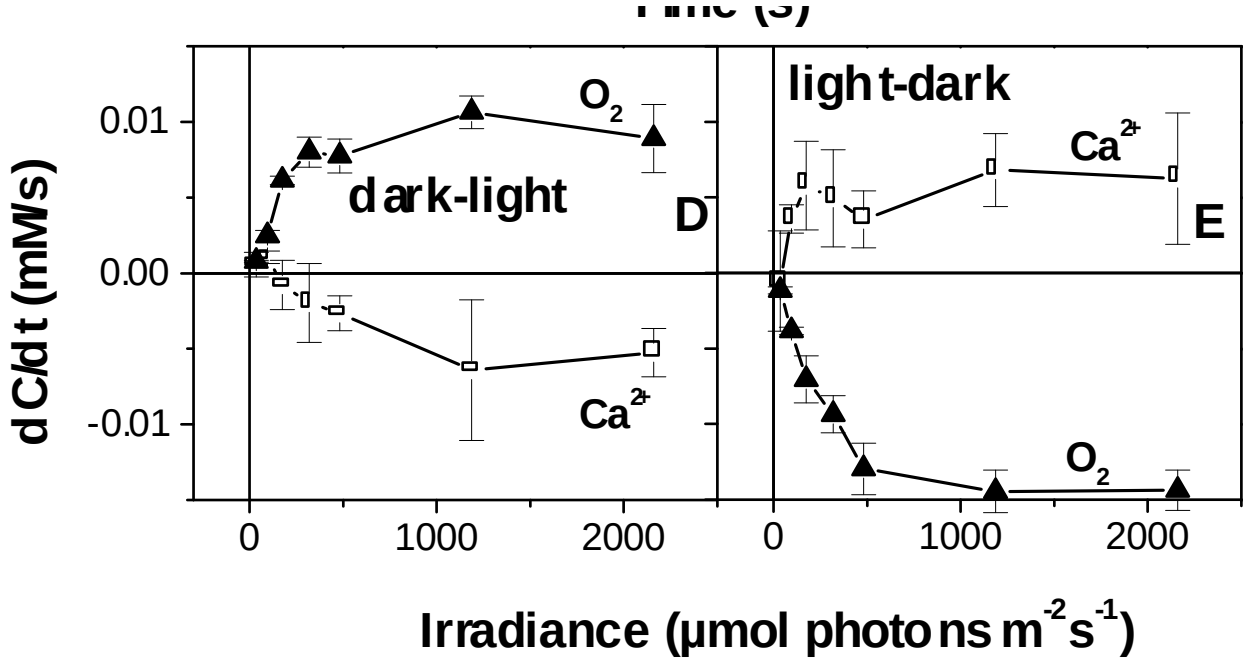


- coral not 1-D

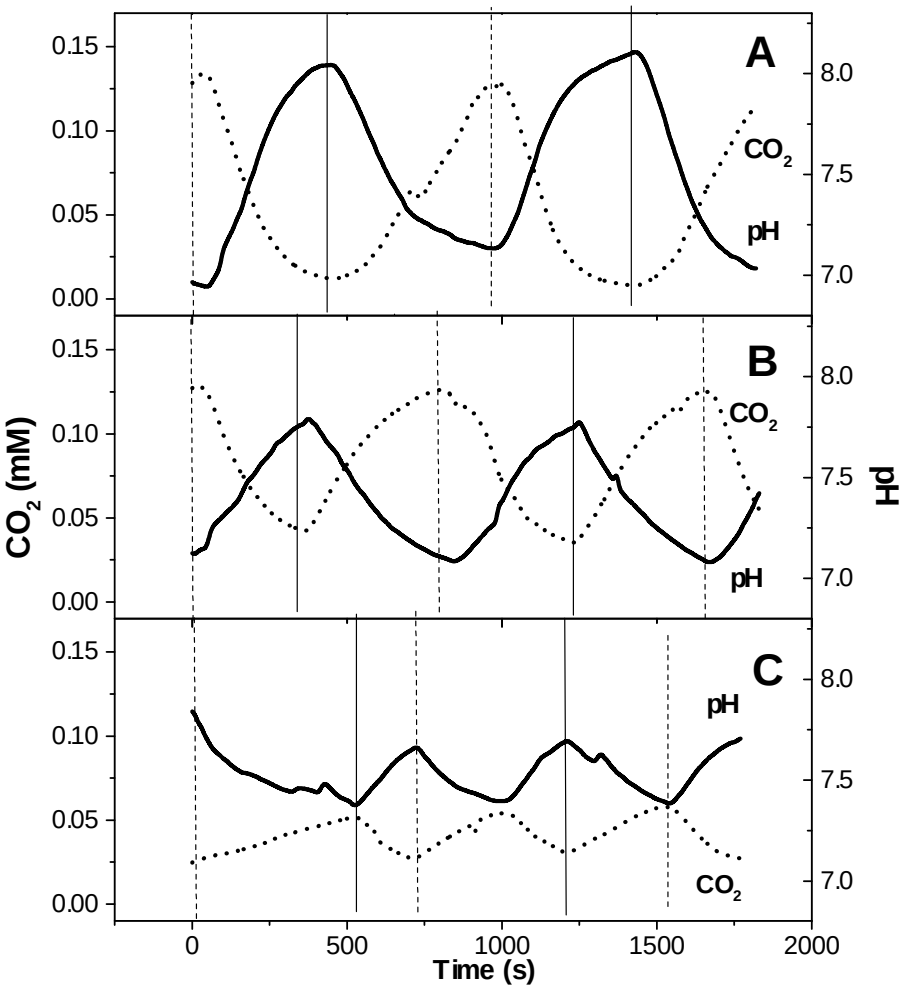
Ca and O_2 coral surface dynamics



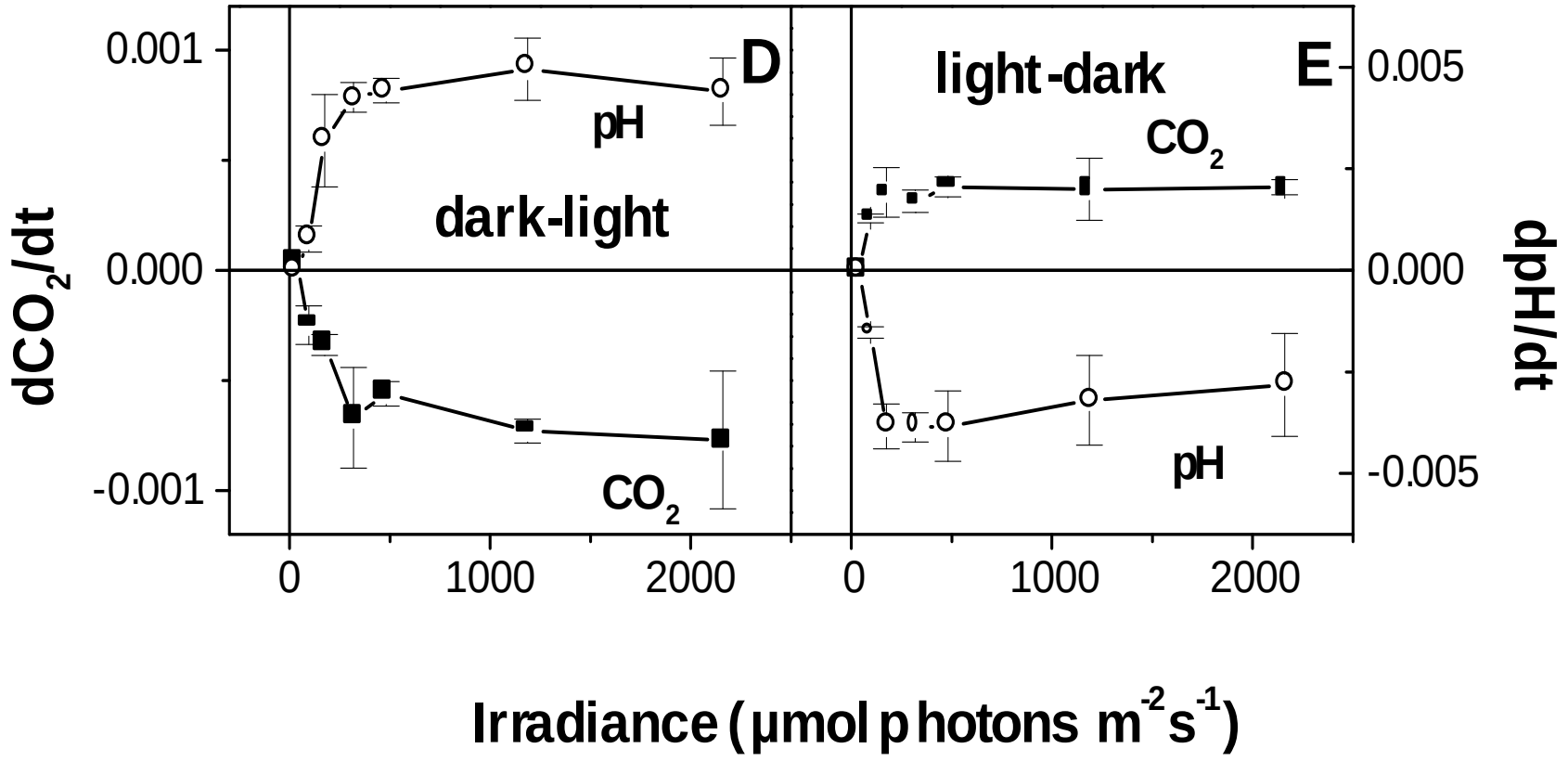
PI curve Ca and O_2 dynamics (initial rates)



CO_2 and pH coral surface dynamics



PI curves CO_2 and pH dynamics (highest rates)



$Ca + O_2$ versus CO_2 + pH dynamics

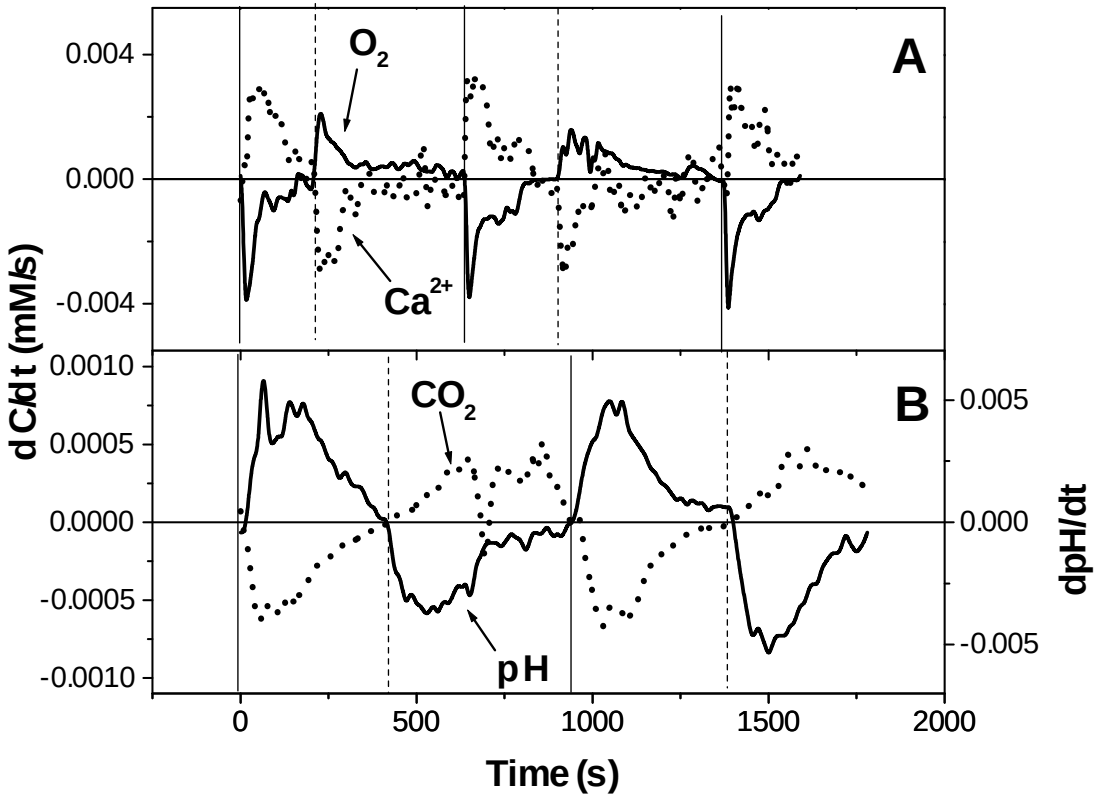
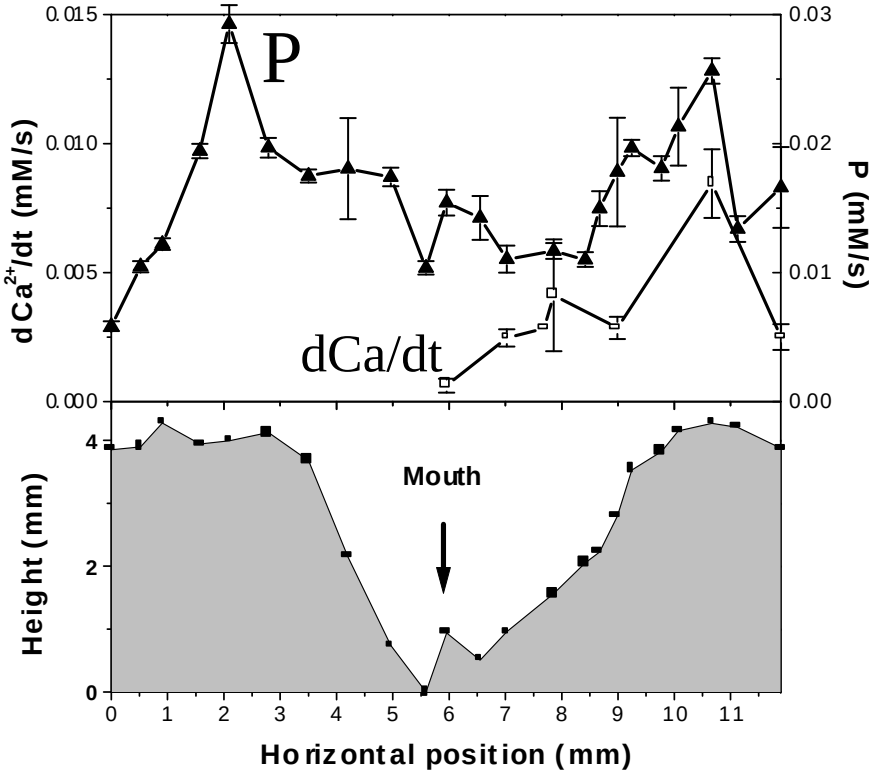
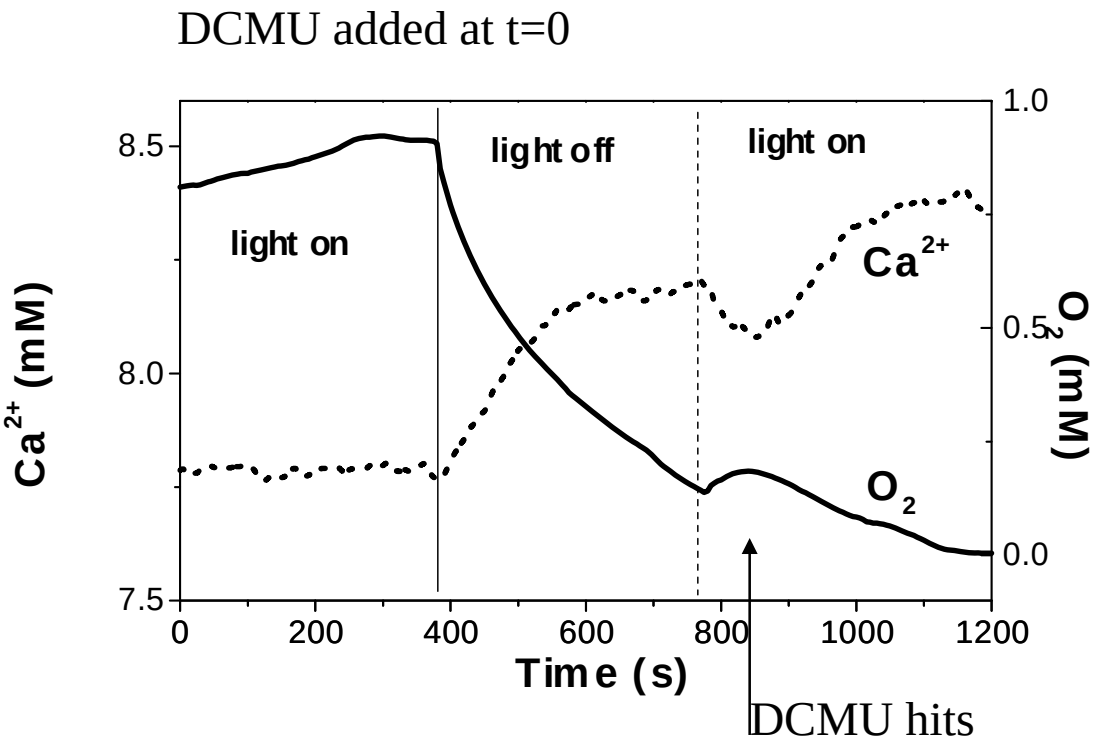


Fig. 5

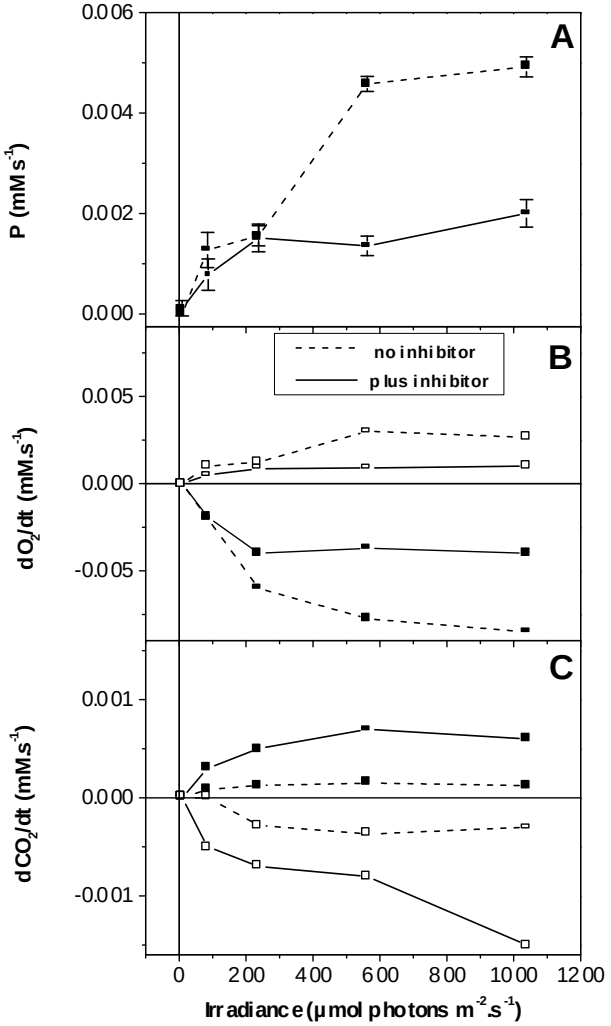
Distribution gross photosynthesis and Ca dynamics



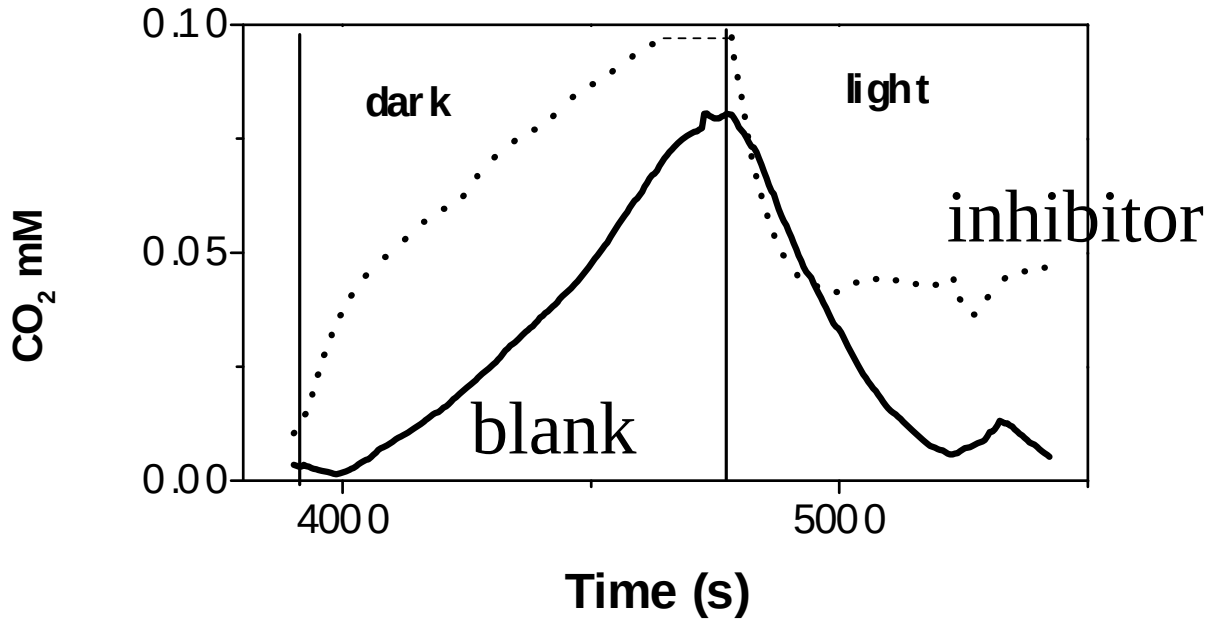
Effect DCMU


DCMU added at t=0
light on
light off
light on
Ca^{2+}
O_2
Ca^{2+} (mM)
O_2 (mM)
8.5
8.0
7.5
1.0
0.5
0.0
0
200
400
600
800
1000
1200
Time (s)
DCMU hits

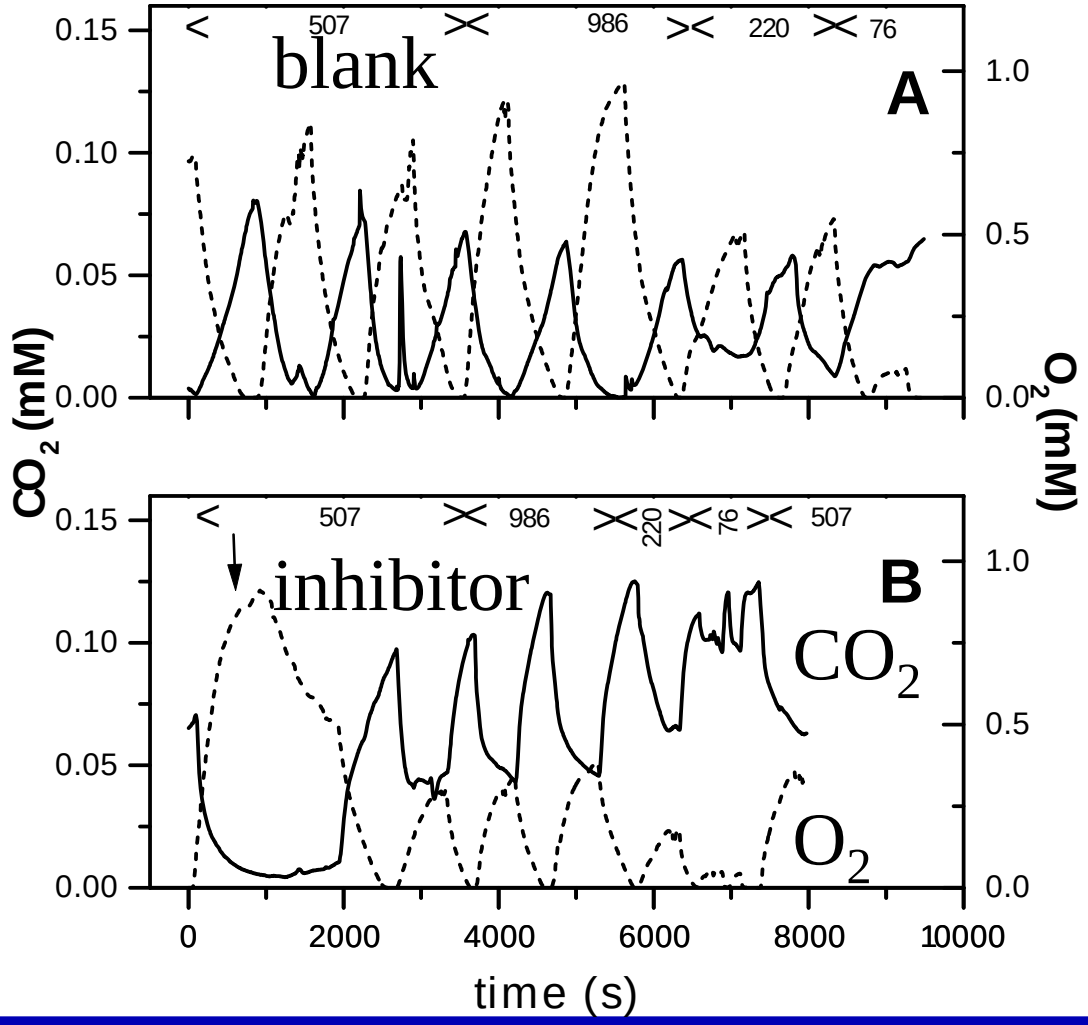
Effect CA inhibitor



Effect CA inhibitor on CO_2 dynamics



Effect of CA inhibitor



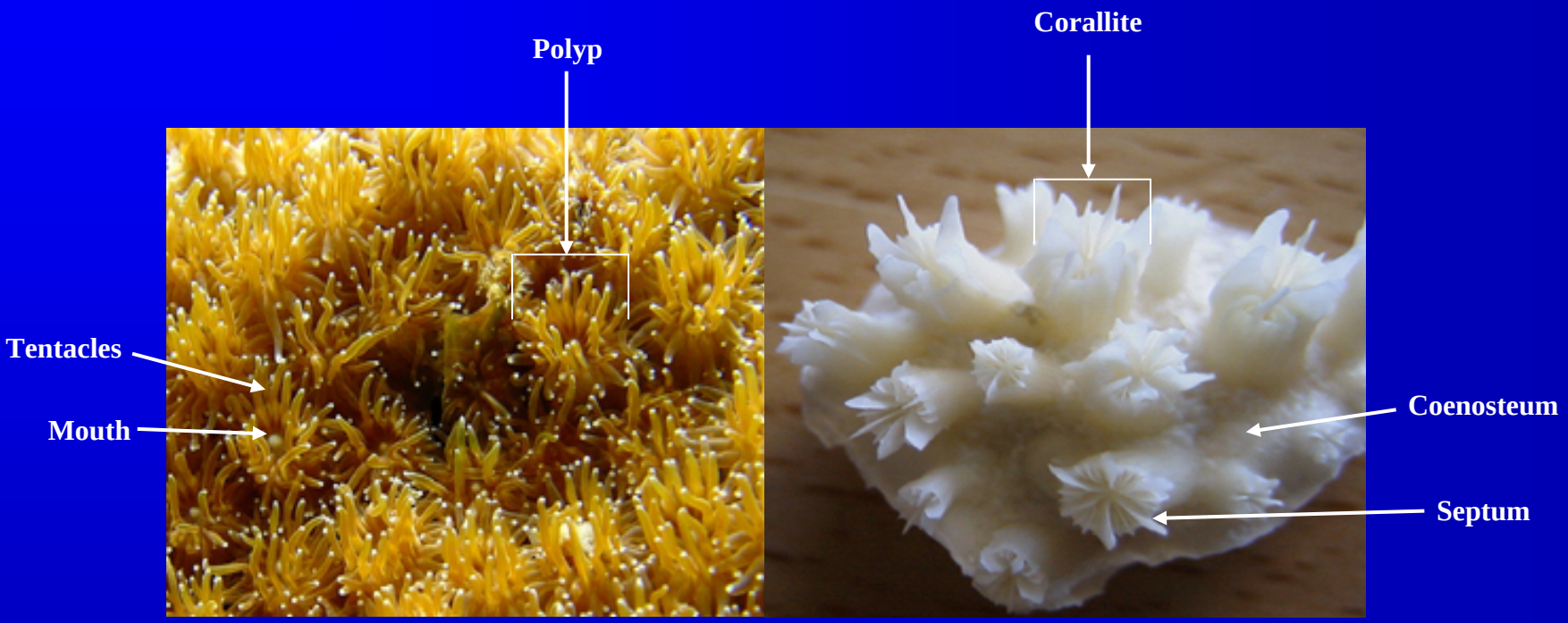
Summary corals

- Ca^{2+} and O_2 dynamics simultaneous and of same order of magnitude
- distribution over polyp similar
- simultaneous response to DCMU
- pH/CO_2 dynamics much slower than Ca^{2+}
- CA inhibitor reduces photosynthesis and increases CO_2

conclusions

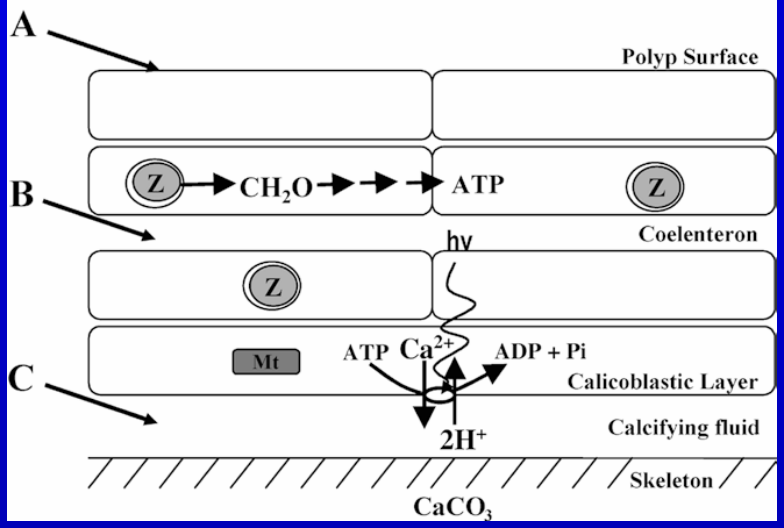
- Ca^{2+} surface dynamics actively regulated, governed by photosynthesis
- Ca^{2+} uptake/efflux not tightly coupled to pH
- calcification is not an important CO_2 source for photosynthesis (CO_2 is not taken up fast)
- calcification pH buffer?

Galaxea (Fuad Al-Horani)

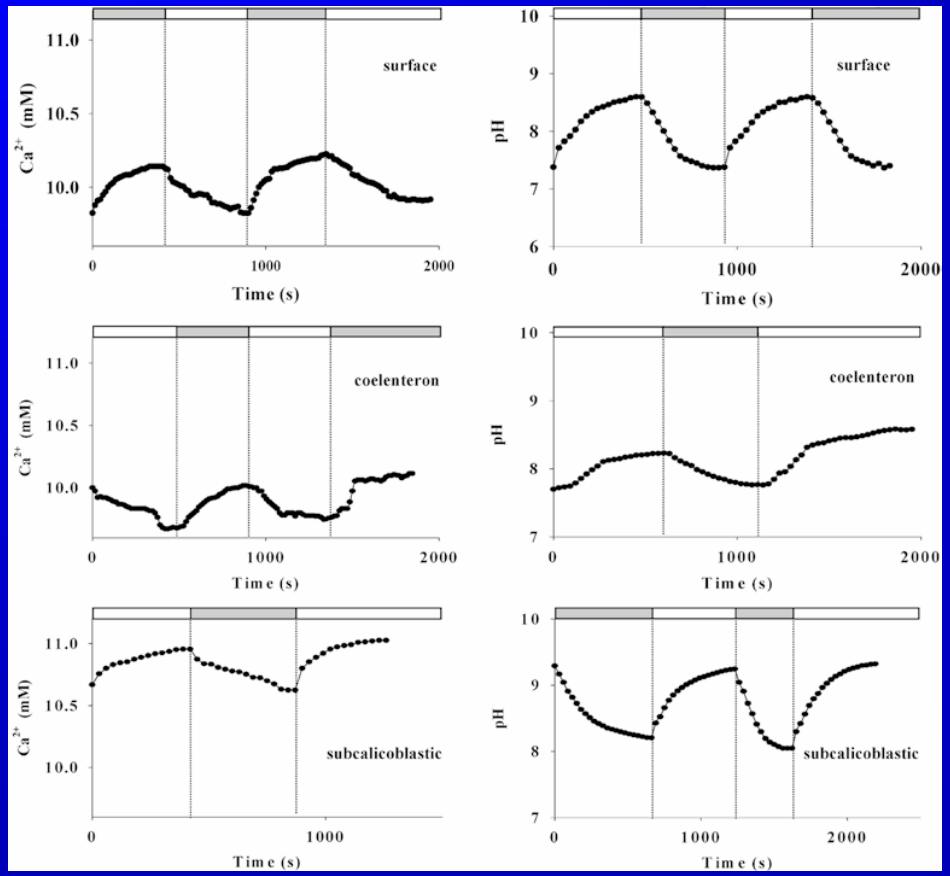


Galaxea (Fuad Al-Horani)

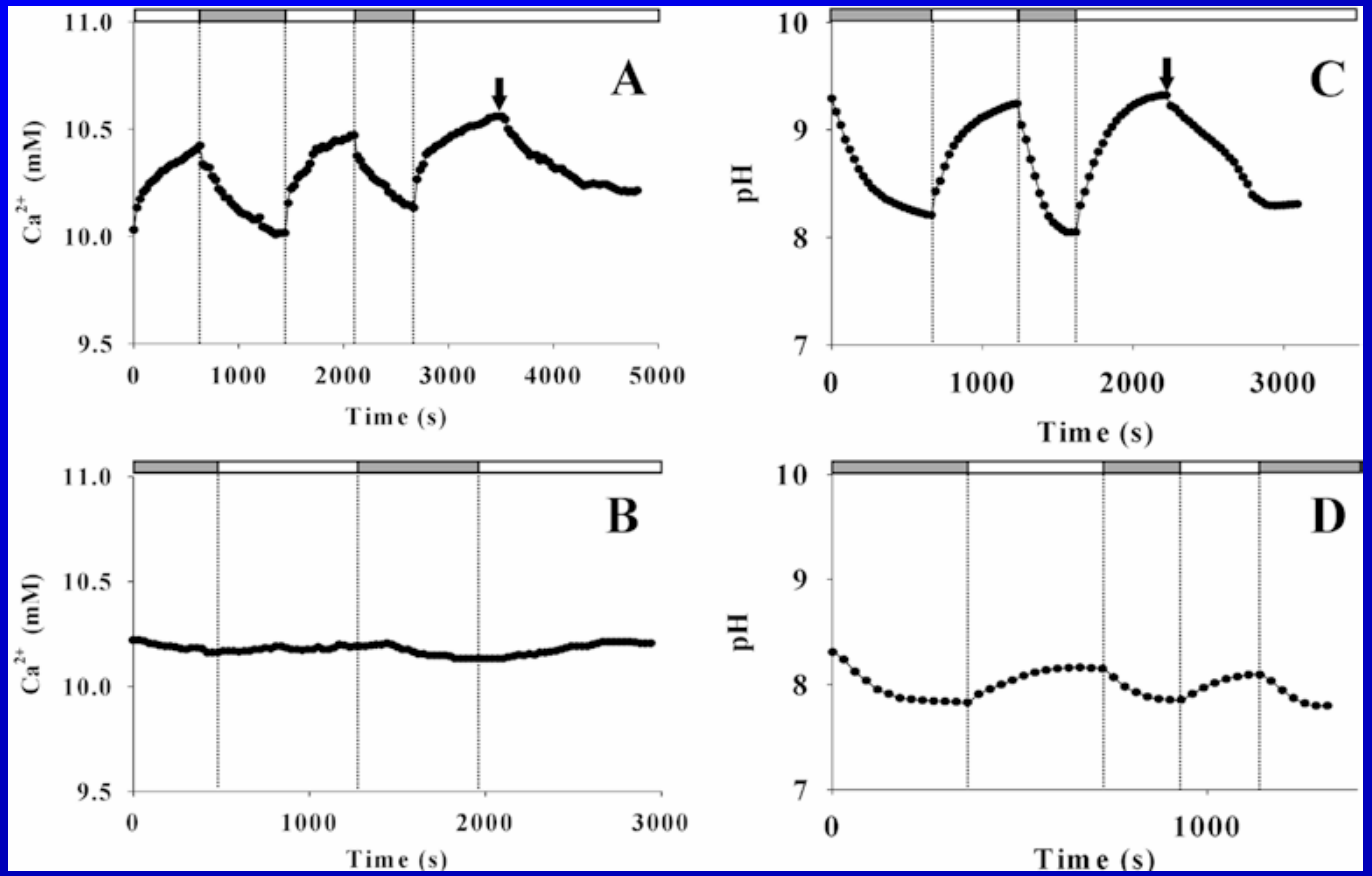
	pH	Ca^{2+} (mM)	saturation state
Seawater	ca. 8.2	ca. 10.0	ca. 4
Polyp surface	8.49 ± 0.25 (light) 7.60 ± 0.22 (dark)	9.82 ± 0.06 (light) 10.04 ± 0.06 (dark)	
Coelenteron	8.19 ± 0.20 (light) 7.61 ± 0.19 (dark)	9.76 ± 0.05 (light) 9.94 ± 0.13 (dark)	
Calcifying Fluid	9.28 ± 0.03 (light) 8.13 ± 0.08 (dark)	10.58 ± 0.29 (light) 10.21 ± 0.25 (dark)	ca. 25 (light) ca. 3.2 (dark)



Galaxea (Fuad Al-Horani)



Ca and pH dynamics under calicoblastic layer



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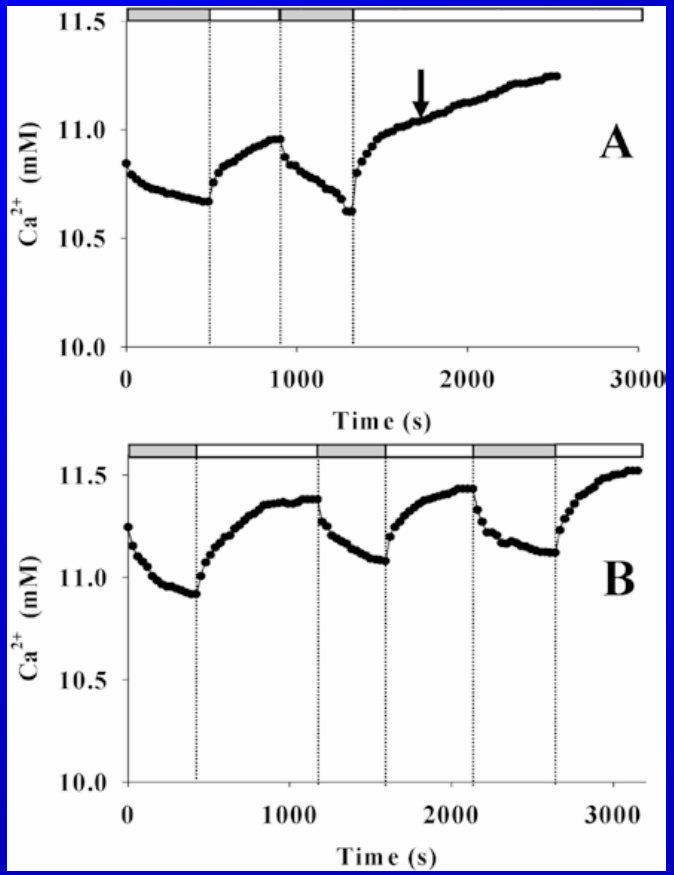
Ruthenium Red
Ca-H-ATPase inhibitor

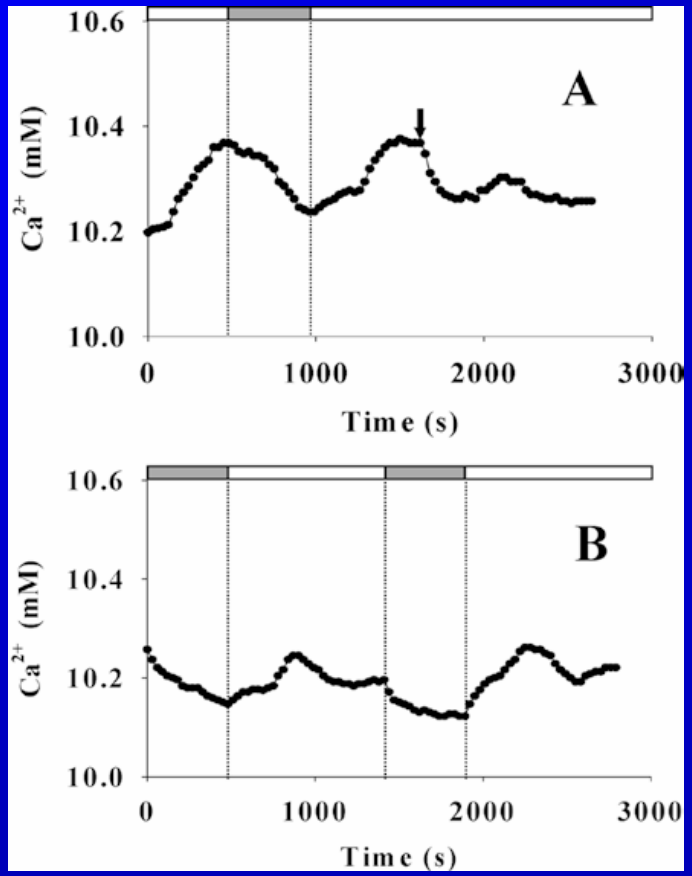
Effect AZ (CA-inhibitor)

under
calicoblast

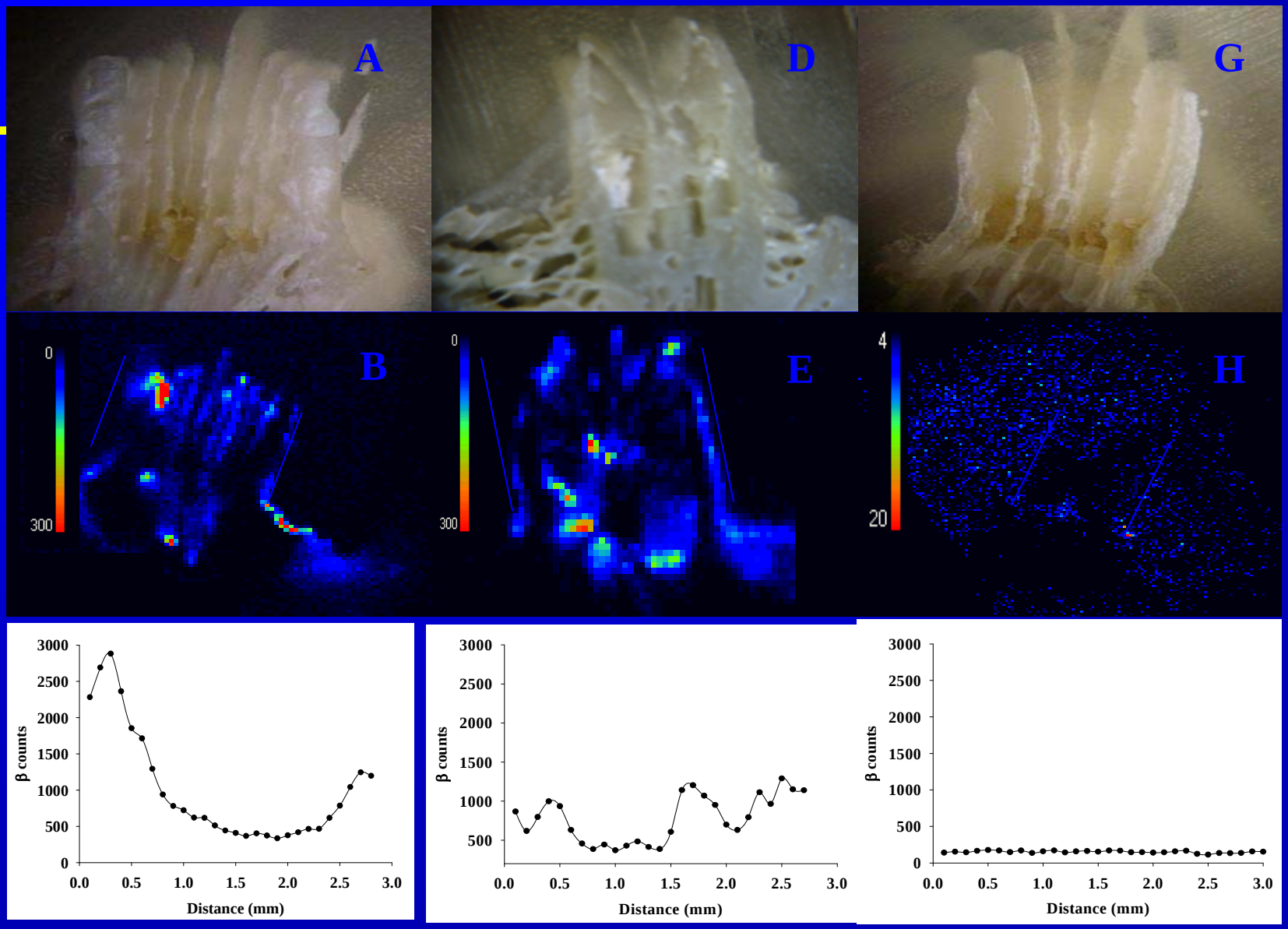


arrow:
addition AZ

Effect DCMU (PSII inhibitor)



Ca dynamics not directly controlled by photosynthesis

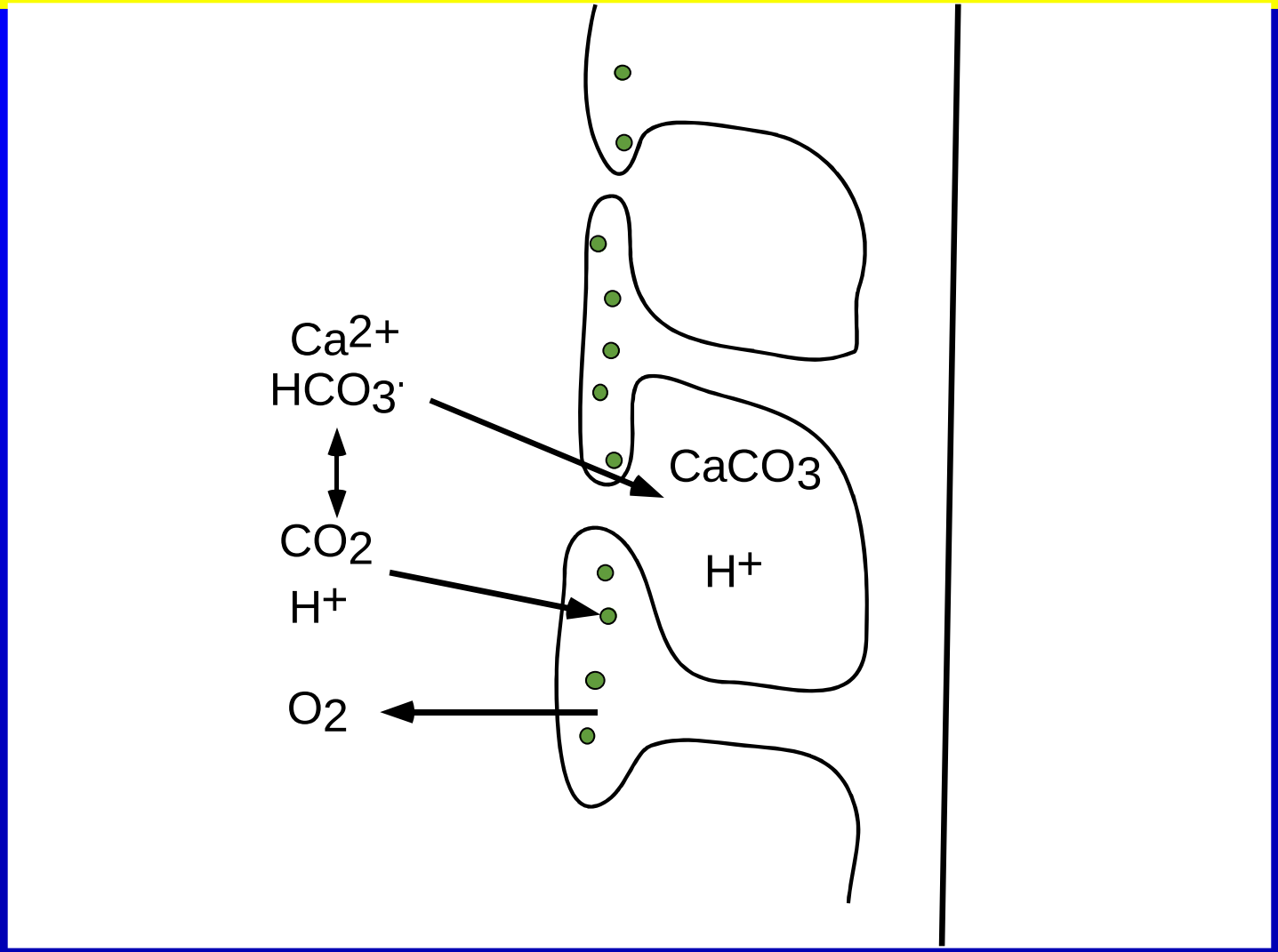


Calcification is a highly organized process

- Ca and H+ transport from SW to calicoblastic membrane diffusional
- photosynthesis supplies ATP for Ca-H trans-calicoblastic pump to skeleton (calcifying site)
- After ~3 hours of PSII inhibition calcification stops
- Ca—H pump in calicoblast directly activated by light

Halimeda discoidea

Halimeda structure



Calcifying algae measurements (Halimeda)

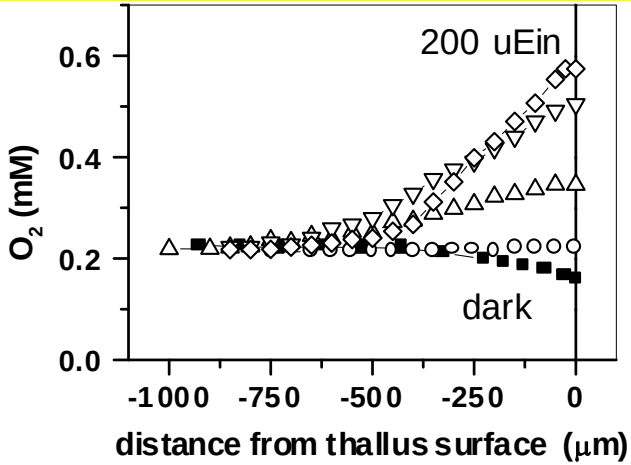
measured:

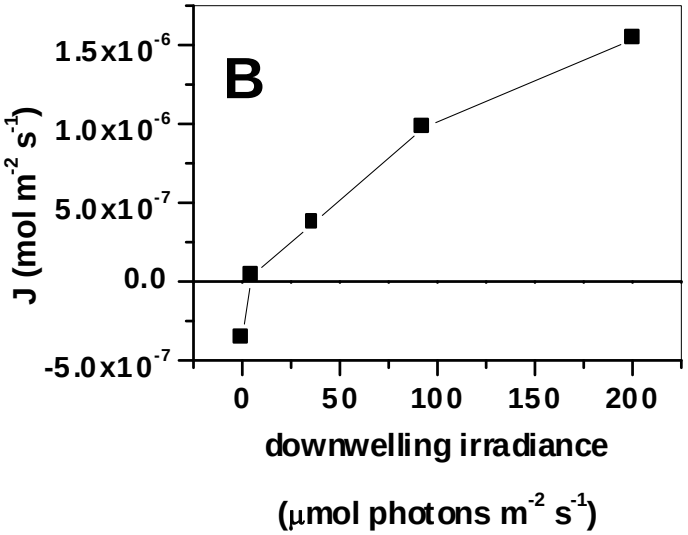
- ***effect of light and inhibitors on***
- ***1) concentration profiles in boundary layer***
- ***2) surface concentration dynamics***

expected:

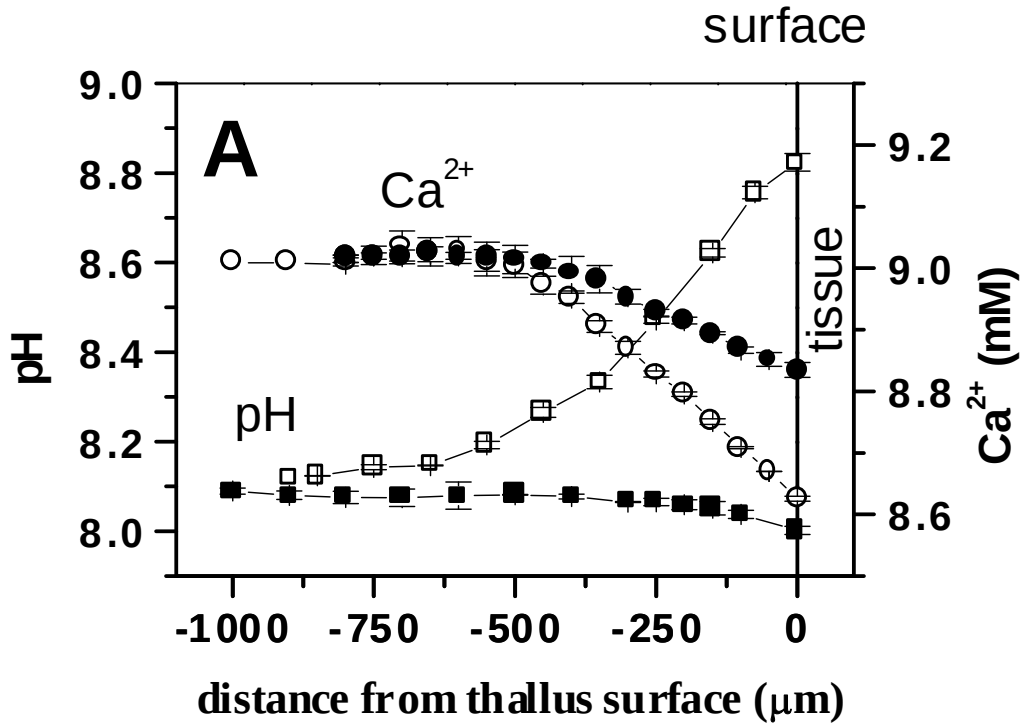
- **concentration of all measurable compounds depends on light intensity**
- **transients of photosynthesis reactants fast (H^+, O_2)**
- **transients of calcification reactants slow (Ca^{2+}, H^+)**

O_2 profiles, PI curve net photosynthesis





Ca^{2+} and pH profiles



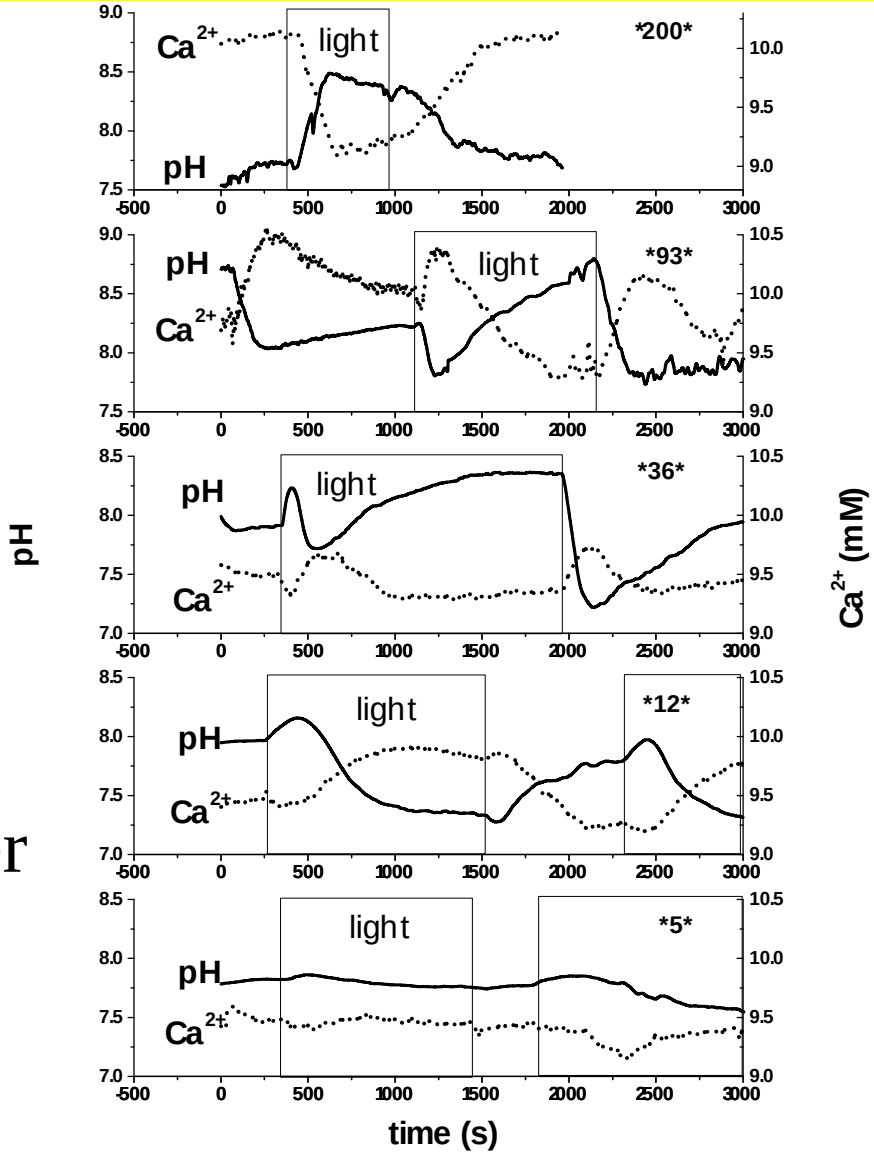
200 uEin:

Ca^{2+}:O_2 flux = 0.5

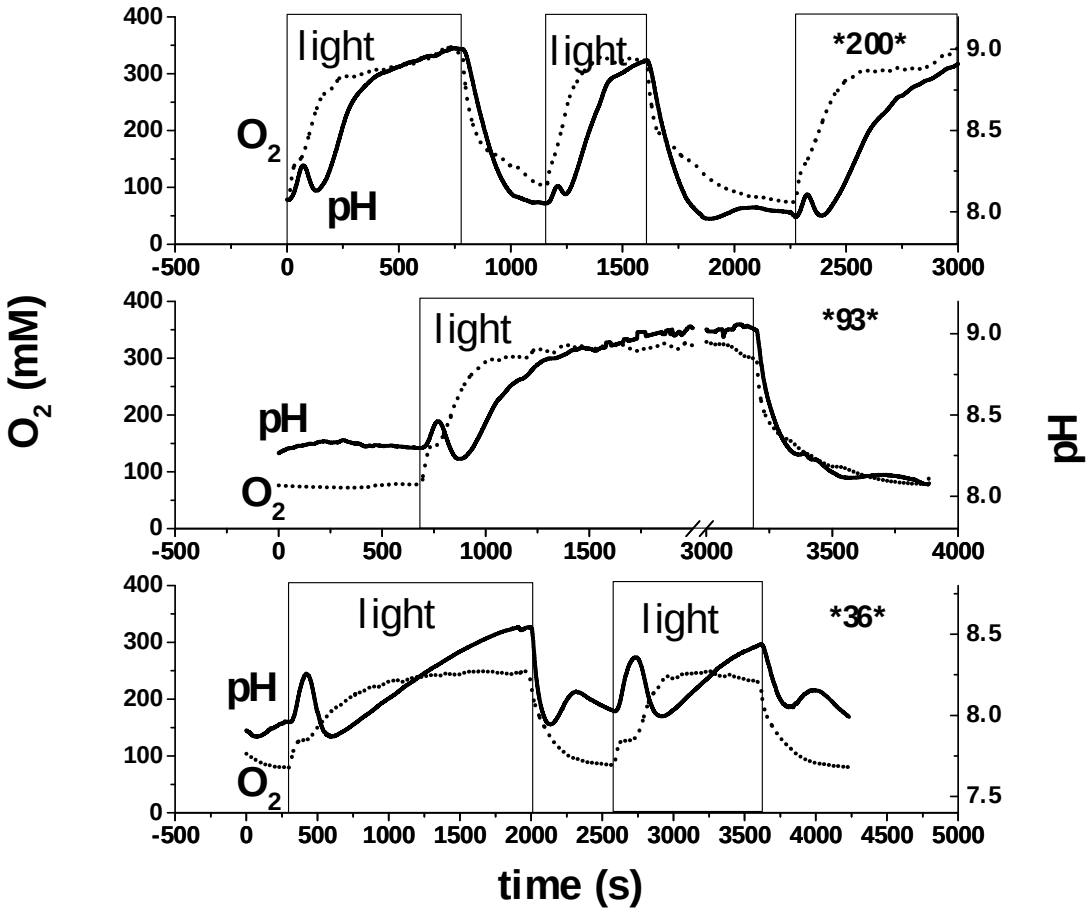
Ca^{2+} and pH dynamics Halimeda

pH<seawater

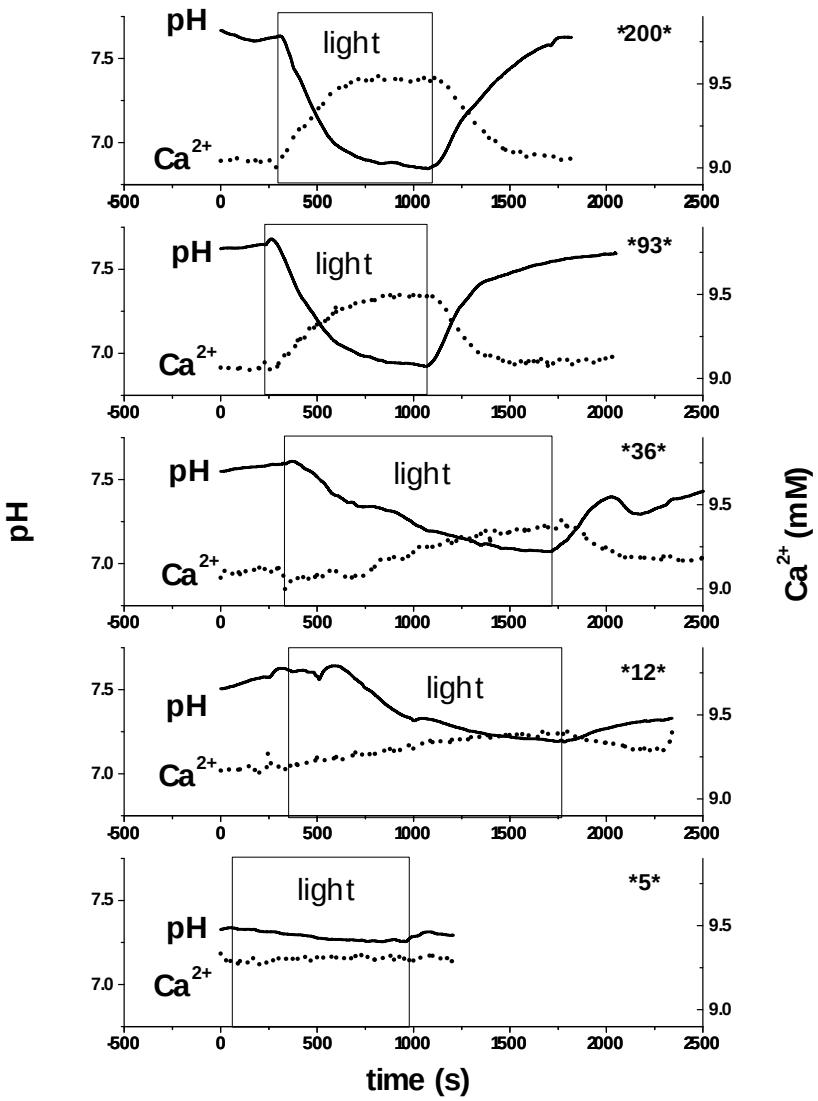
Ca^{2+}>seawater



O_2 and pH dynamics at Halimeda surface



Ca^{2+} and pH dynamics Halimeda plus DCMU



Effect DCMU on Ca and pH

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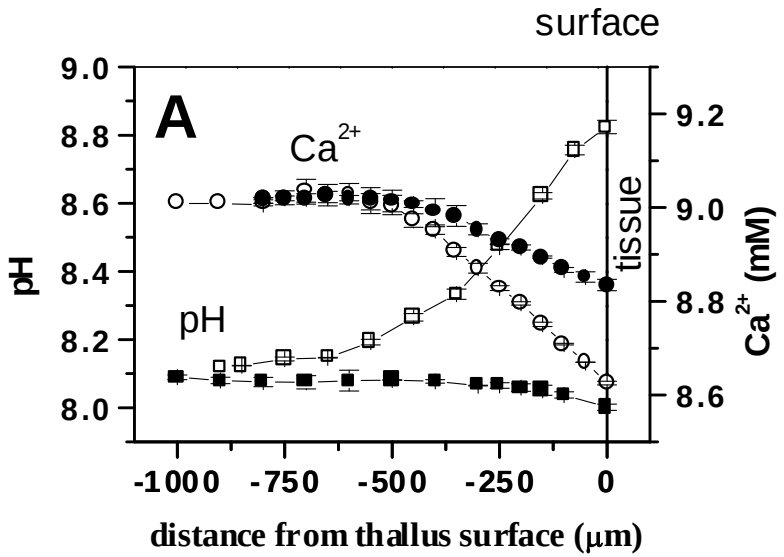
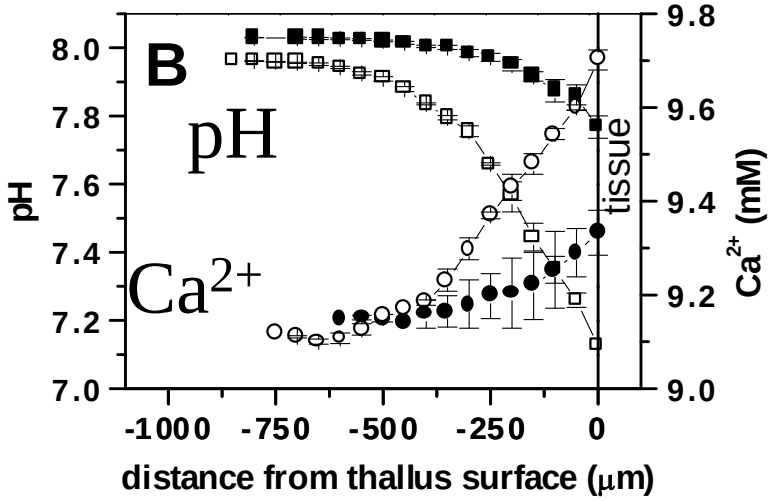
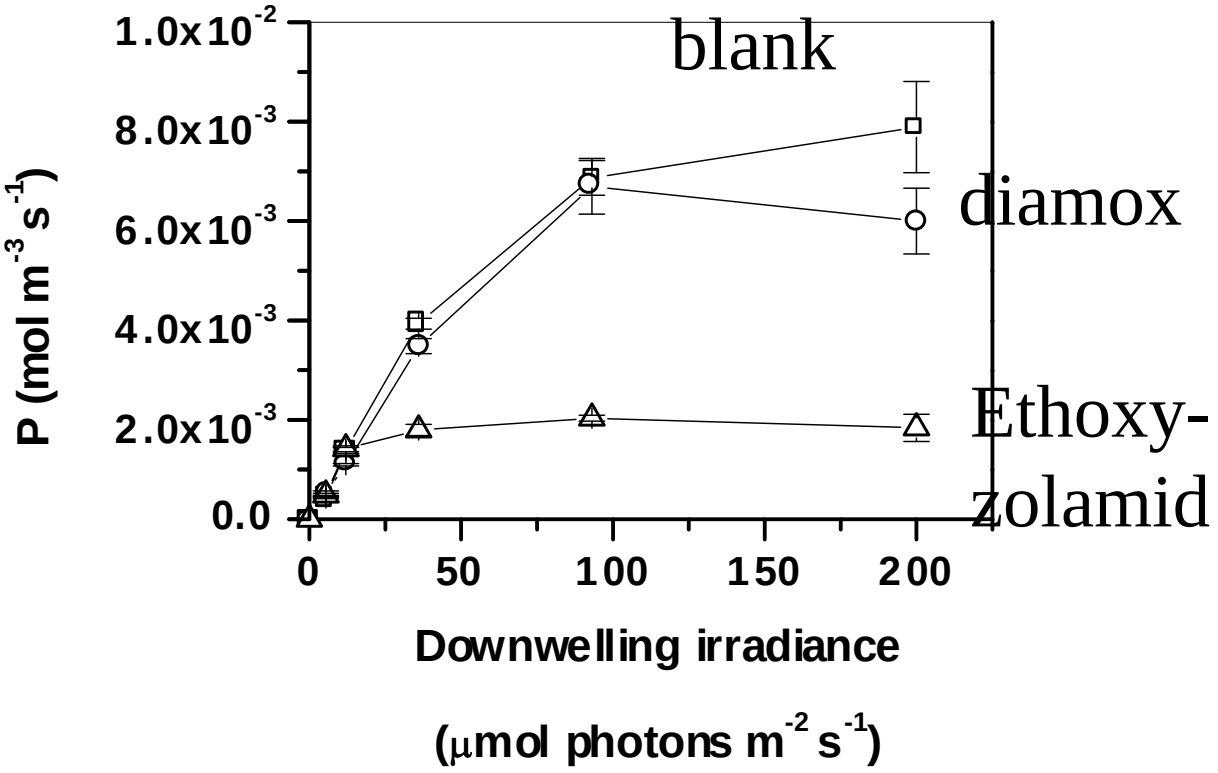


DCMU



DCMU increased dark respiration

Effect CA inhibitor



Summary

- pH and Ca^{2+} dynamics synchronous
- O_2 and Ca^{2+}/pH dynamics not synchronous
- two processes affect pH: photosynthesis and H^+ pump
- at low light decalcification, in dark and high light calcification

Conclusions

- Calcification only determined by pH
- Calcification not significant for CO_2 supply, $\rightarrow HCO_3^-$
- Halimeda can regulate calcification by a proton pump

Why calcification?

- Structure building
- Protection against grazing (?)
- pH buffering

- Side effect of photosynthesis

Thanks

- Michael Kuehl, Noga Stambler, Lior Vaki, Zvy Dubinsky, Tony Larkum, Gaby Eickert, Anja Eggers, Inez Schroeder, Vera Hubner, Fuad Al-Horani
- staff HIRS, MLA and IUI