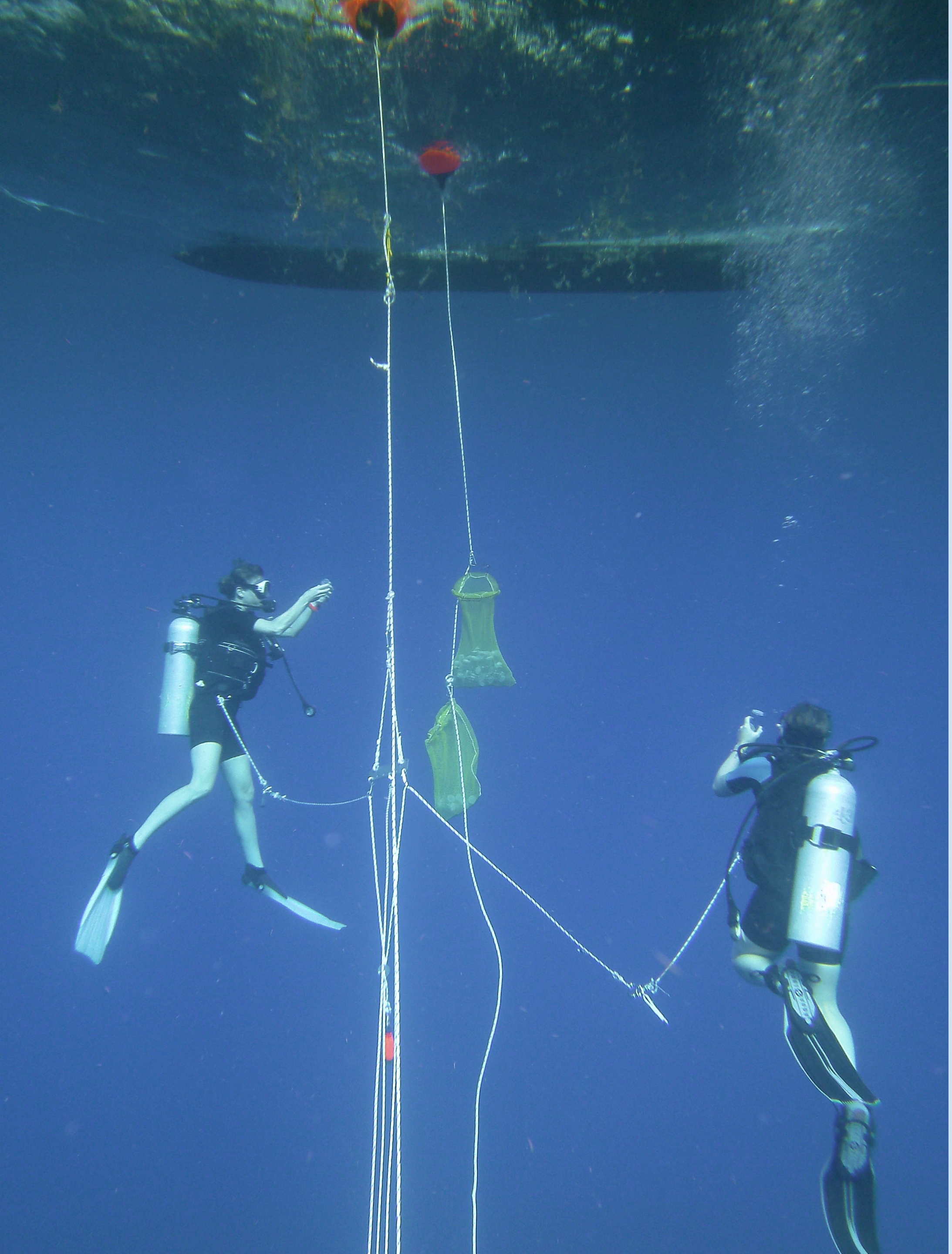


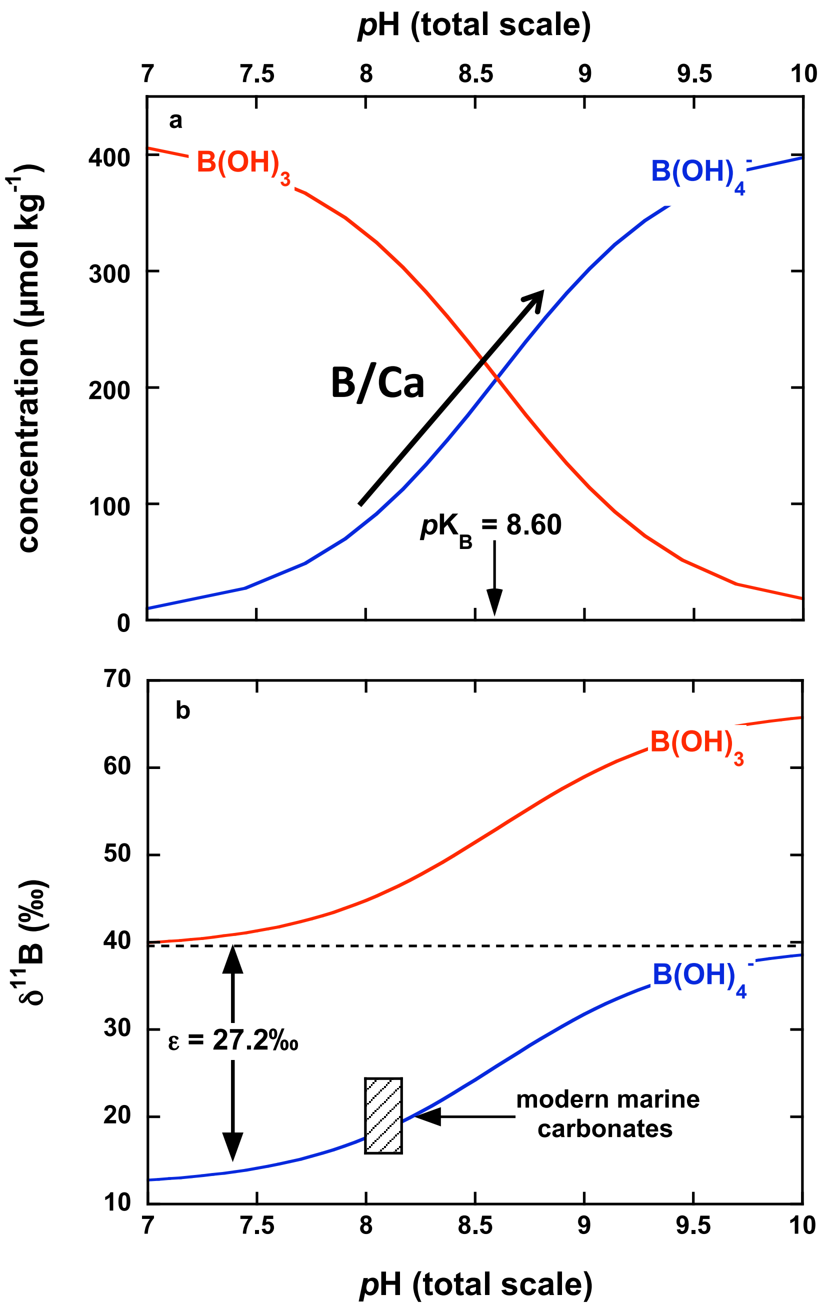
Can we infer organismal physiology from geochemical proxies?

Bärbel Hönisch

with much help from
Carina Fish
Sam Phelps
Joaquim Goes
Tetsu Fujiki
Laura Haynes
Kate Holland
Steve Eggins

Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

Proxies are stand-ins for environmental parameters that can no longer be measured directly.



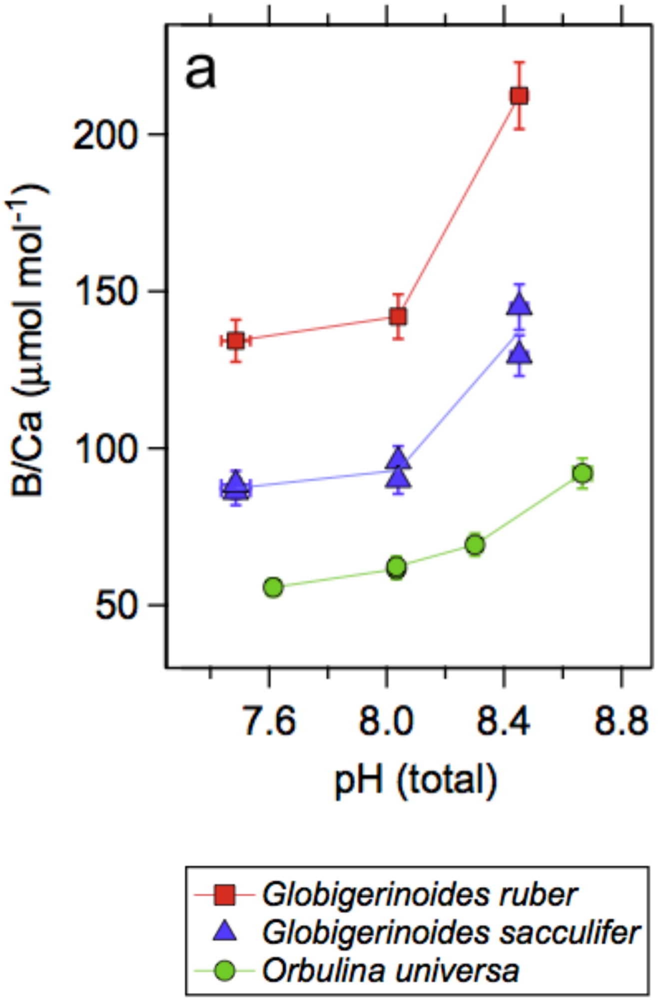
Hemming & Hanson, GCA, 1992

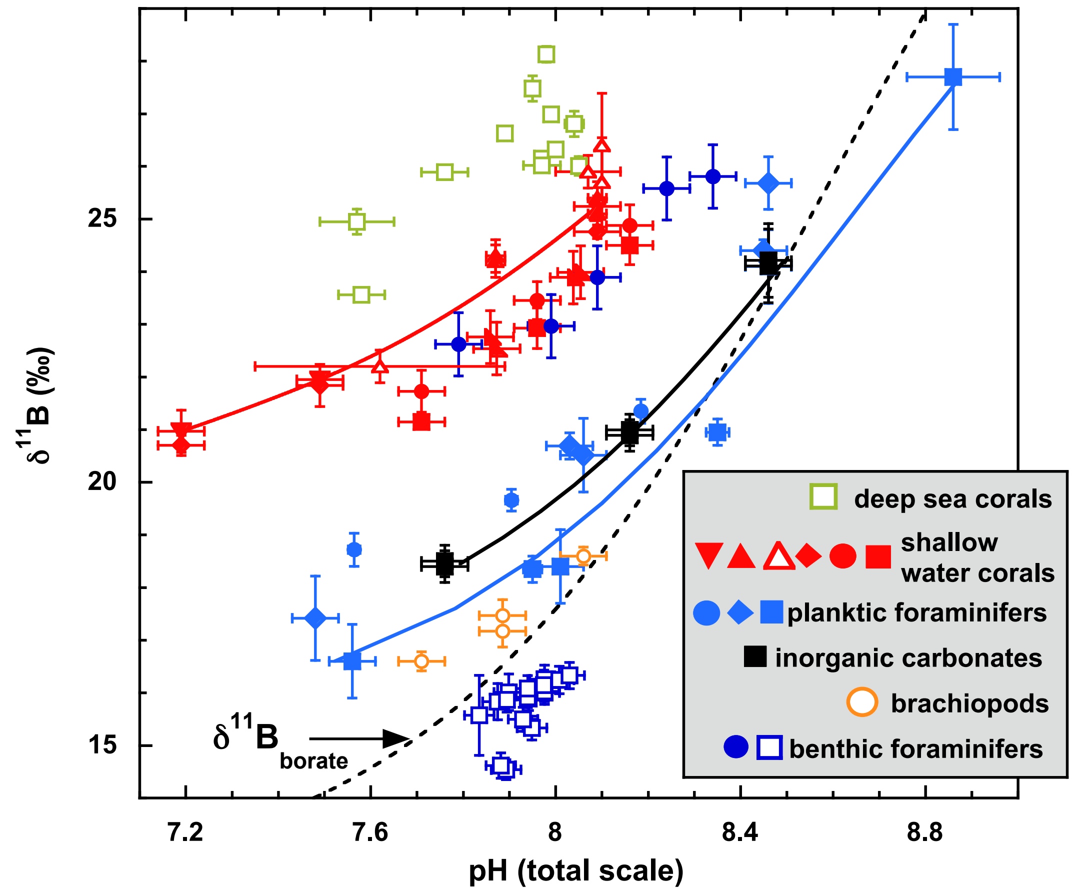
The B/Ca proxy for past seawater-pH or $[B(OH)_4^-]/[HCO_3^-]$

$CaCO_3 + B(OH)_4^- \leftrightarrow Ca(HBO_3) + HCO_3^- + H_2O$

The boron isotope proxy for past seawater-pH

B/Ca and boron isotope proxies for reconstructing past seawater-pH

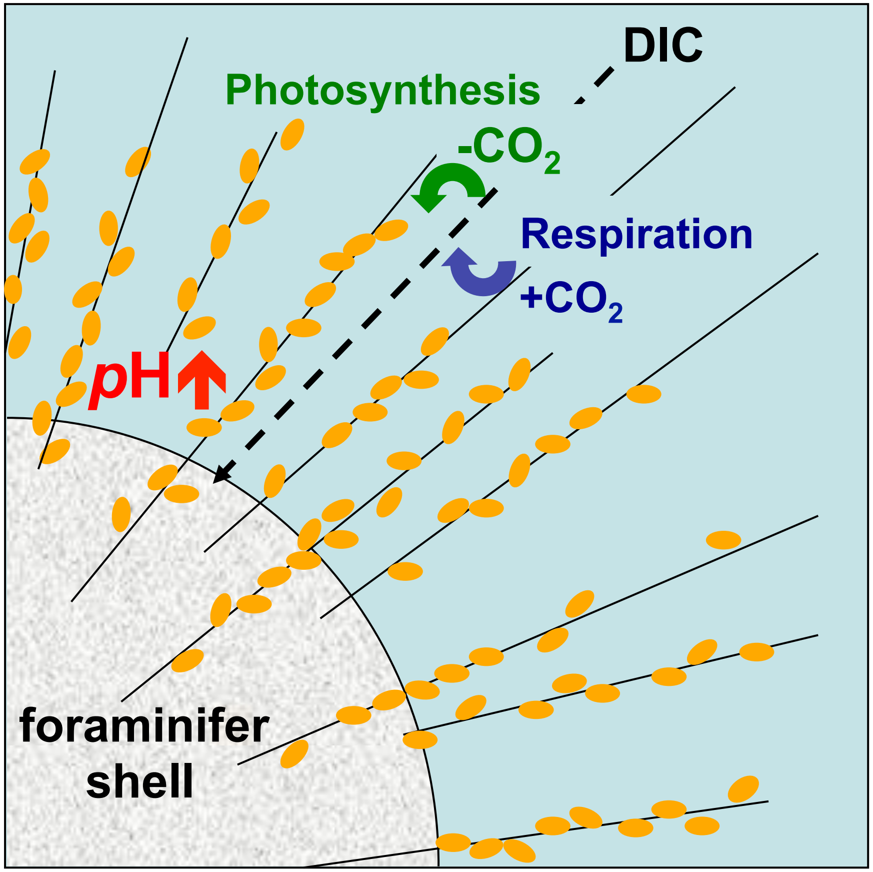


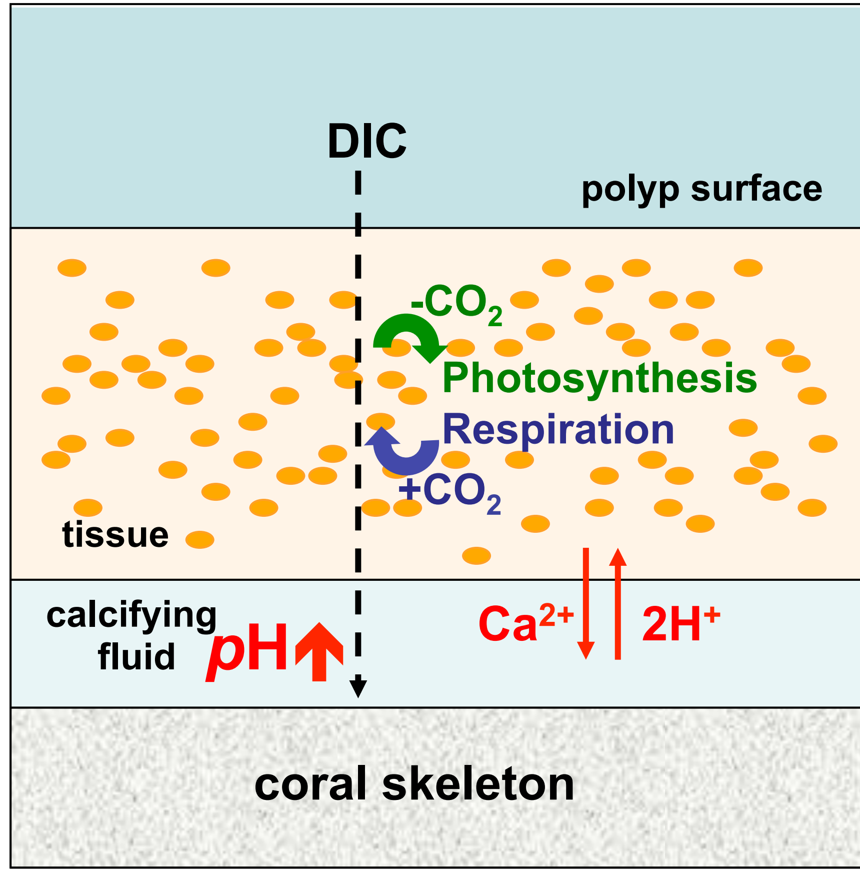


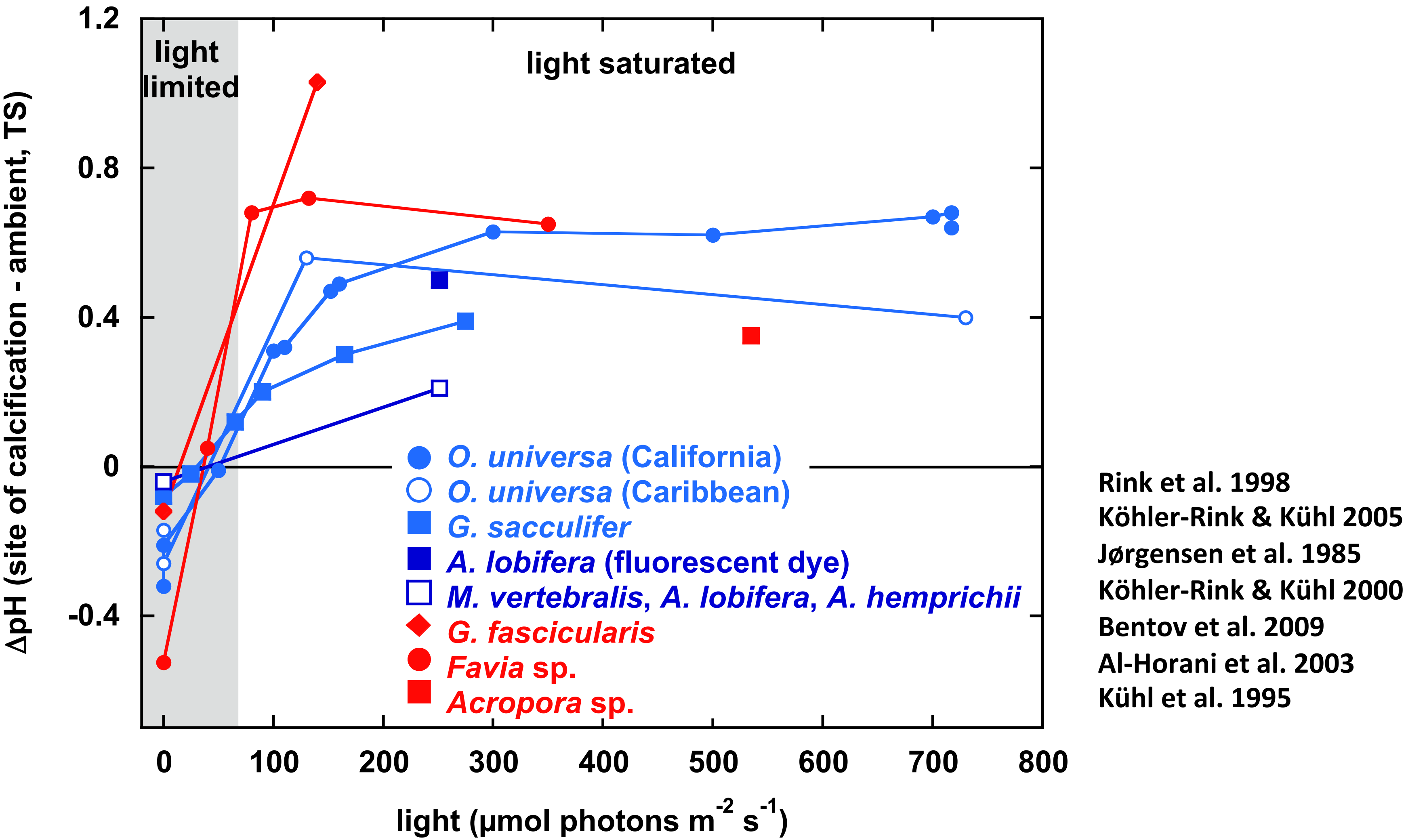
Allen et al. (2011)

(too many to list)

pH modification in response to physiological processes: photosynthesis, respiration, calcification

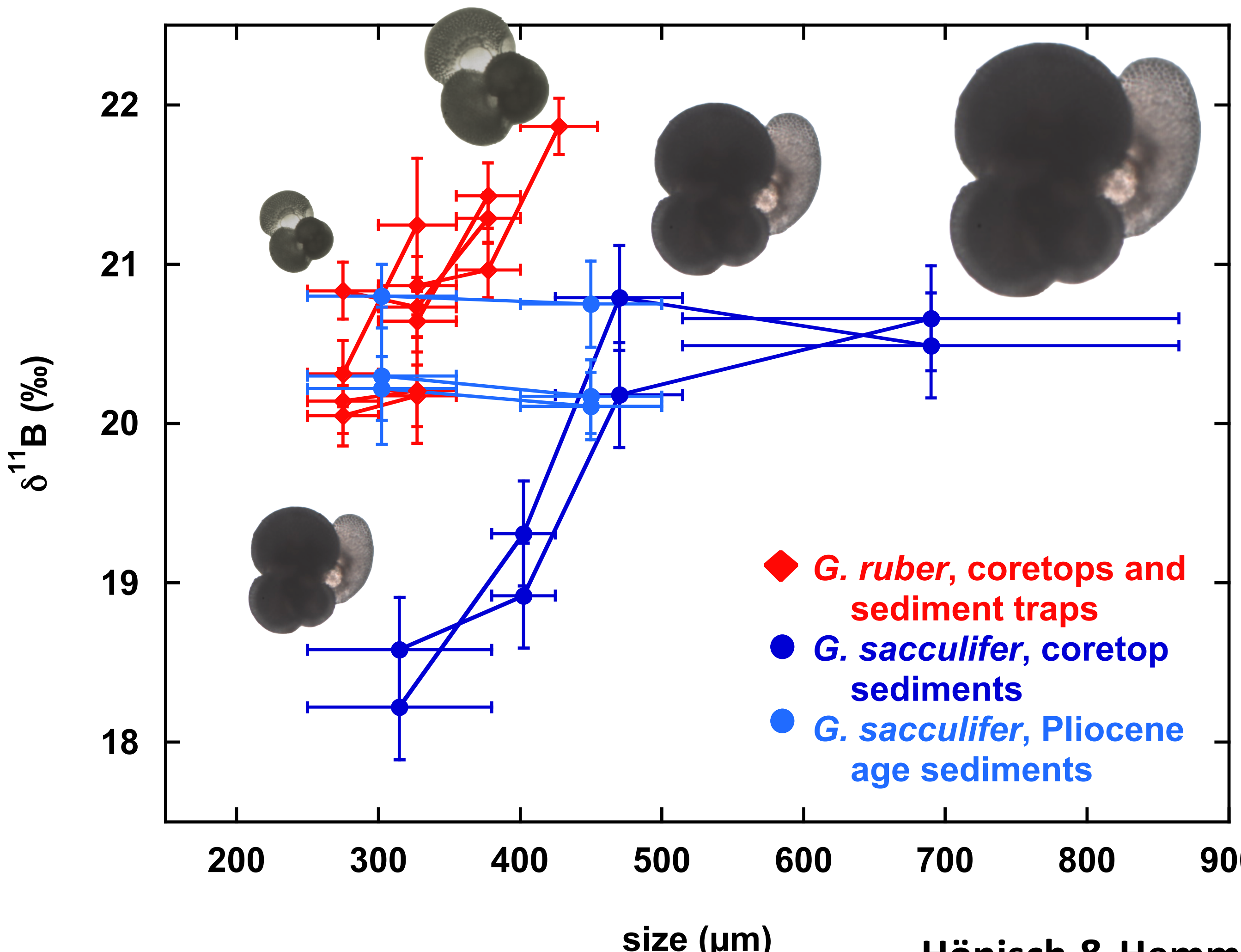






light limited
light saturated
ΔpH (site of calcification - ambient, TS)
1.2
0.8
0.4
0
-0.4
0
100
200
300
400
500
600
700
800
light (μmol photons m-2 s-1)
O. universa (California)
O. universa (Caribbean)
G. sacculifer
A. lobifera (fluorescent dye)
M. vertebralis, A. lobifera, A. hemprichii
G. fascicularis
Favia sp.
Acropora sp.
Rink et al. 1998
Köhler-Rink & Kühl 2005
Jørgensen et al. 1985
Köhler-Rink & Kühl 2000
Bentov et al. 2009
Al-Horani et al. 2003
Kühl et al. 1995

Larger symbiont-bearing foraminifers often record higher $\delta^{11}B$ - i.e. greater pH elevation

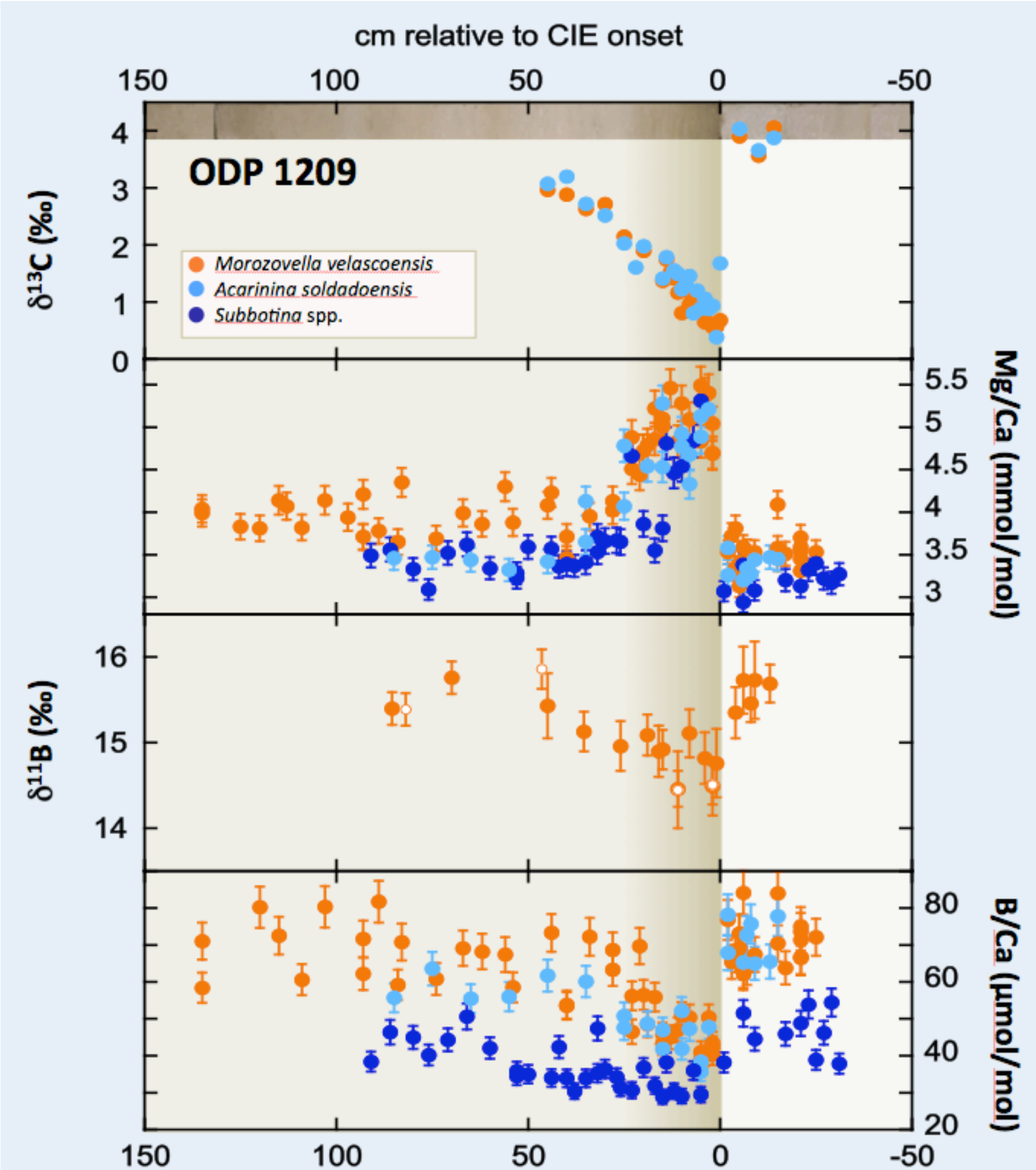


Hönisch & Hemming, 2004

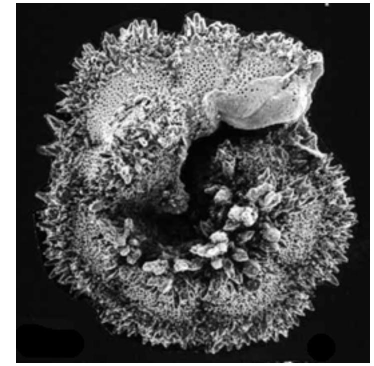
Bartoli et al., 2011

Henehan et al., 2013

Ocean acidification at the PETM (56 million years ago)

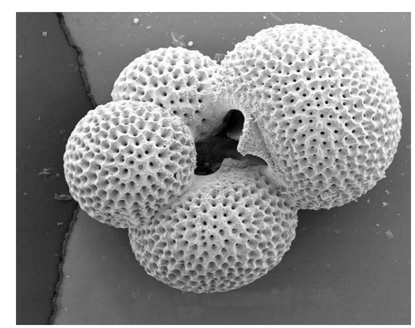


Penman et al., Paleoceanography, 2014



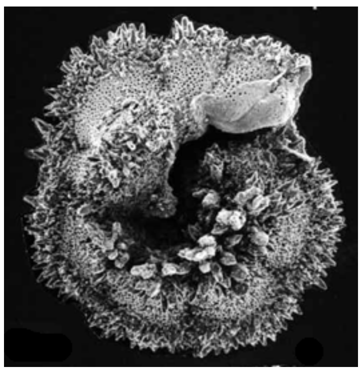
Morozovella velascoensis

Acarinina soldadoensis

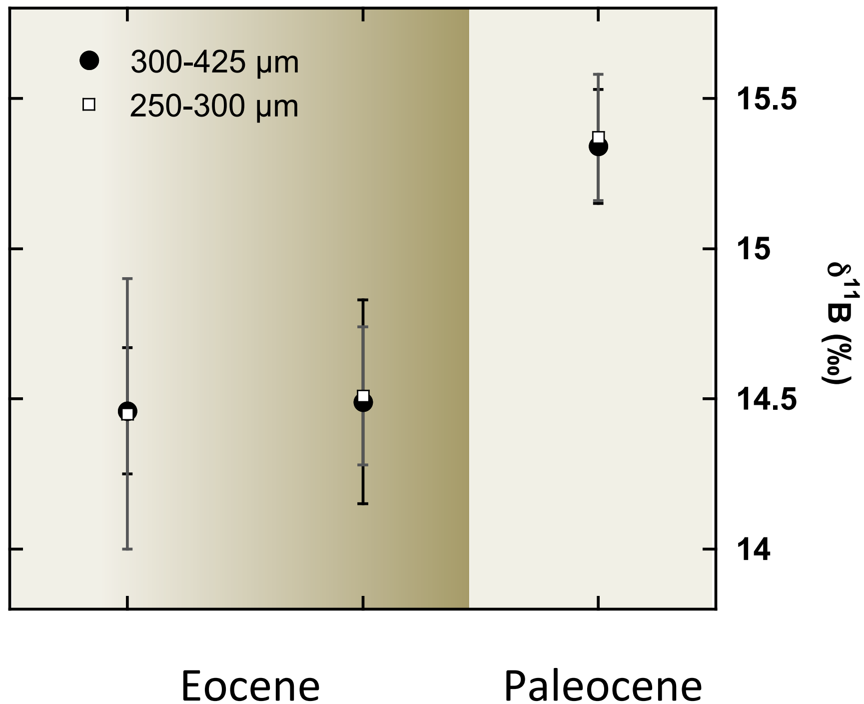


Subbotina spp.

No apparent effect of symbiont-bleaching on the $\delta^{11}B$ record at the PETM

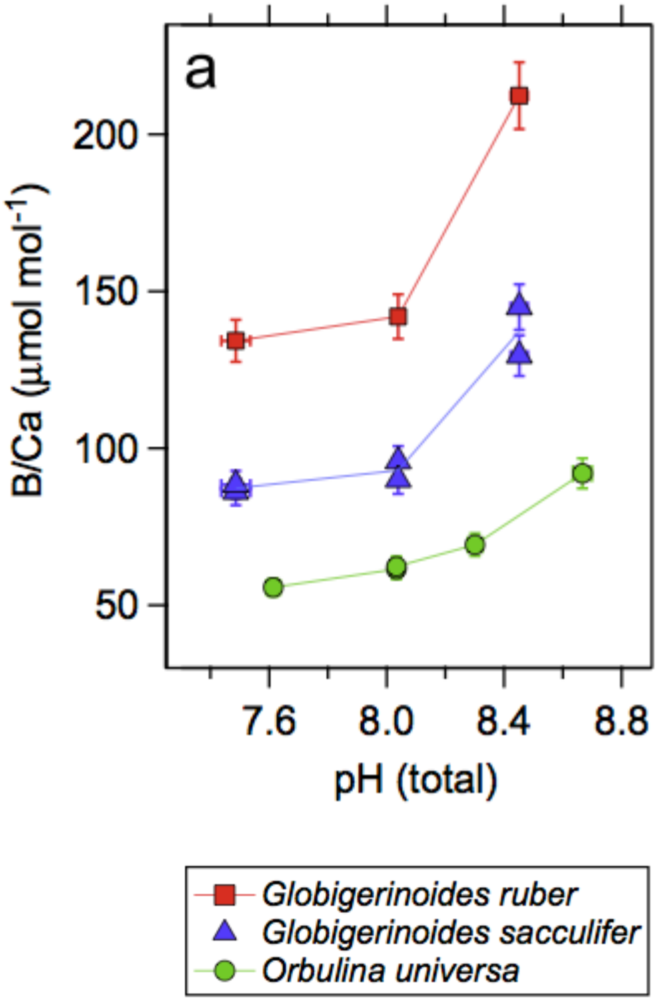


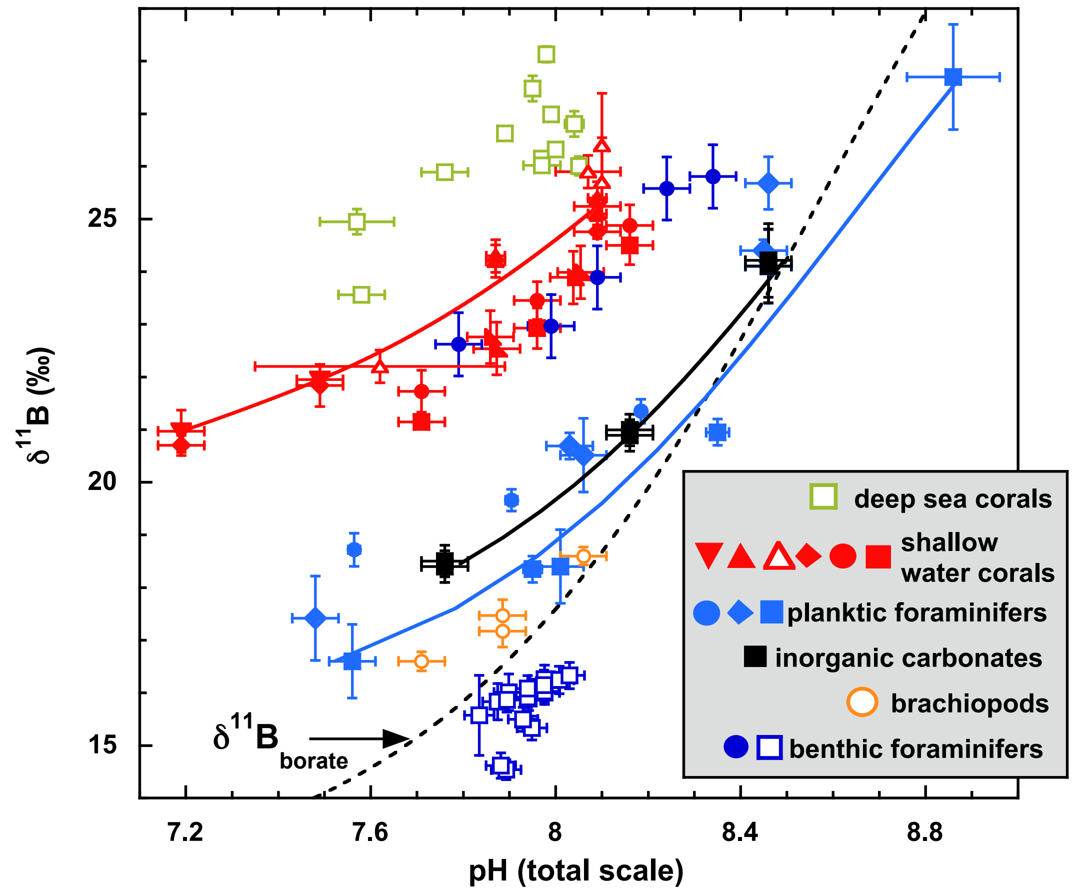
Morozovella velascoensis



Penman et al. (EPSL, 2014)

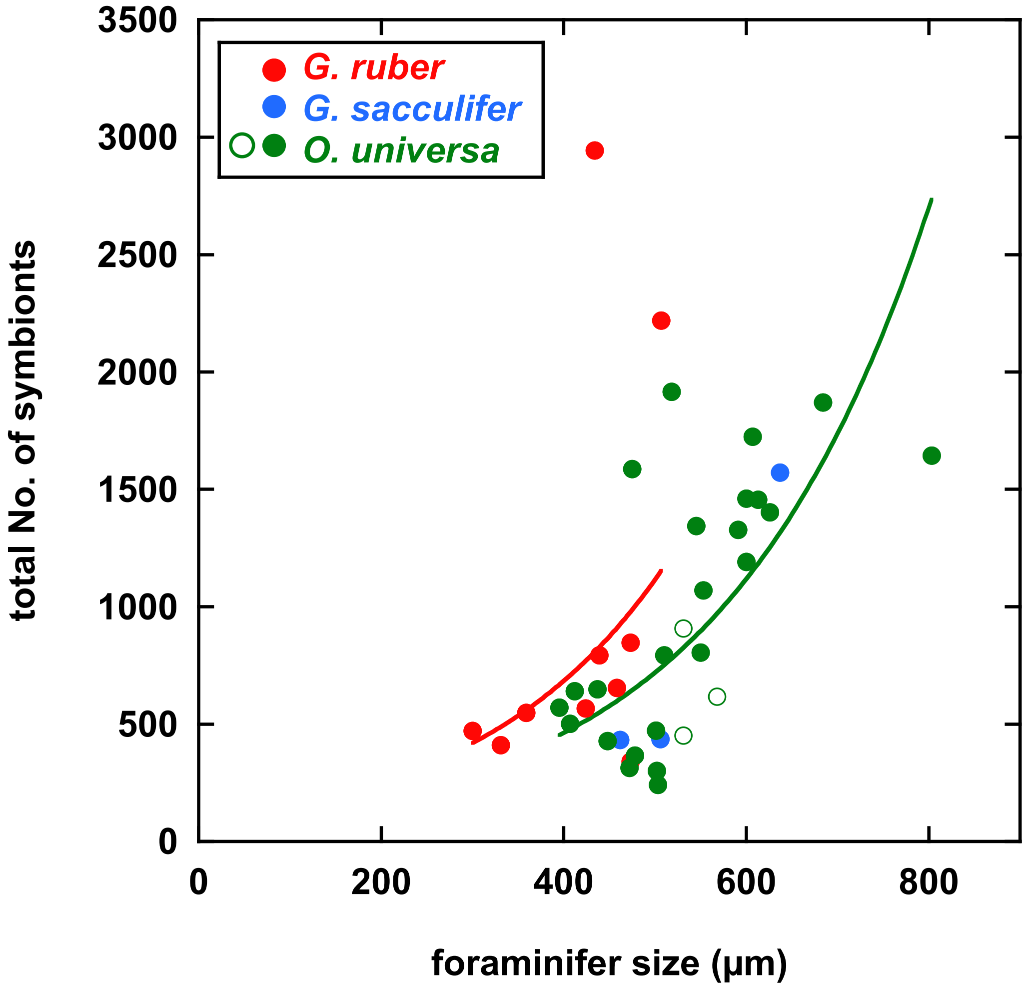
But what about pH-elevation differences between species?

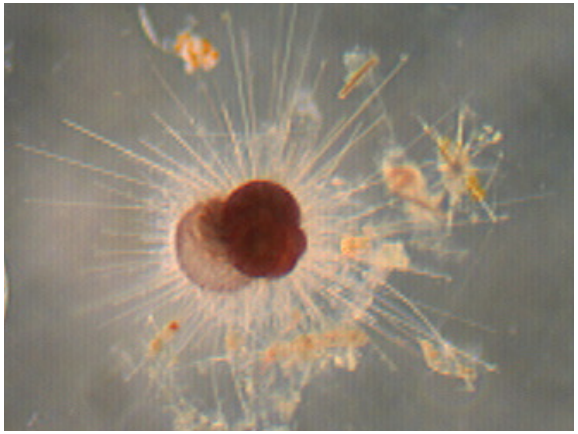


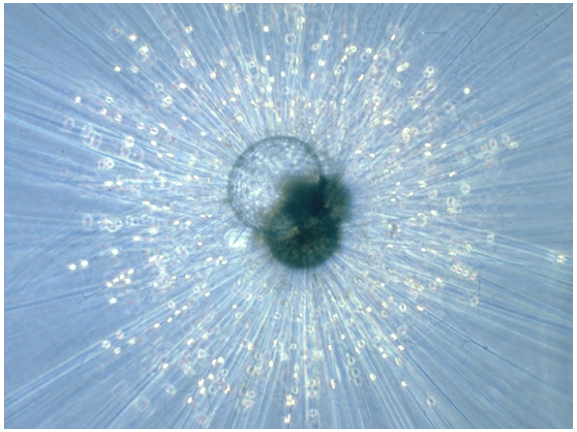


Allen et al. (2011)

(too many to list)

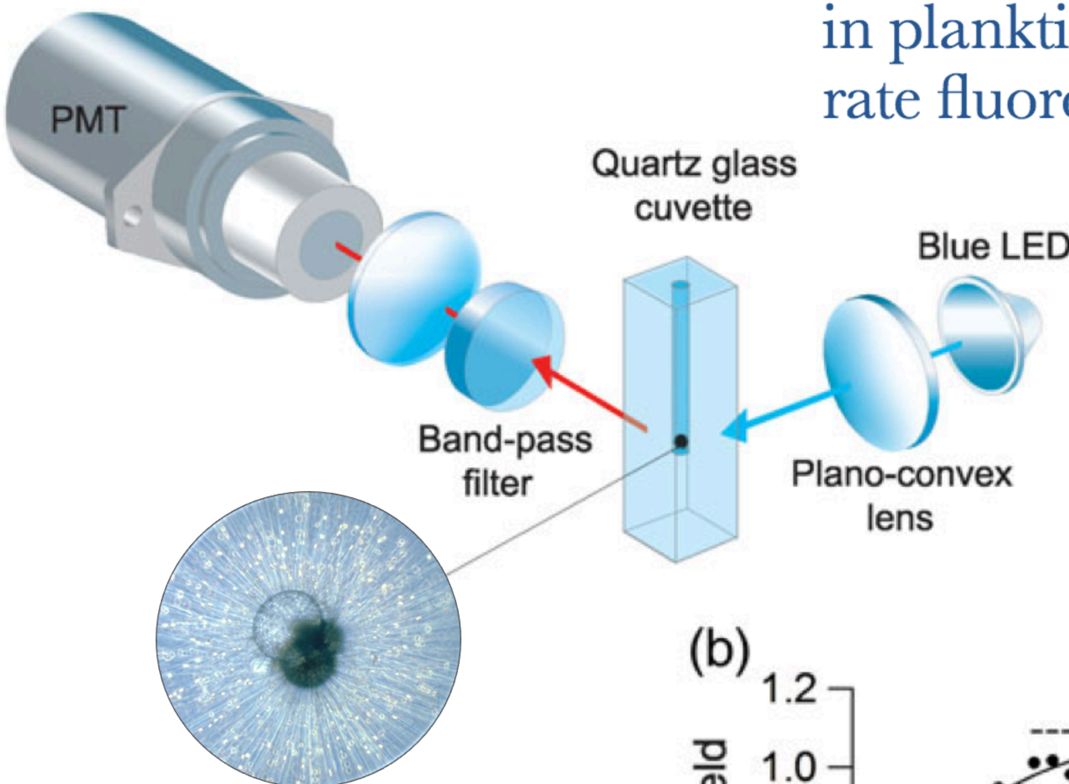


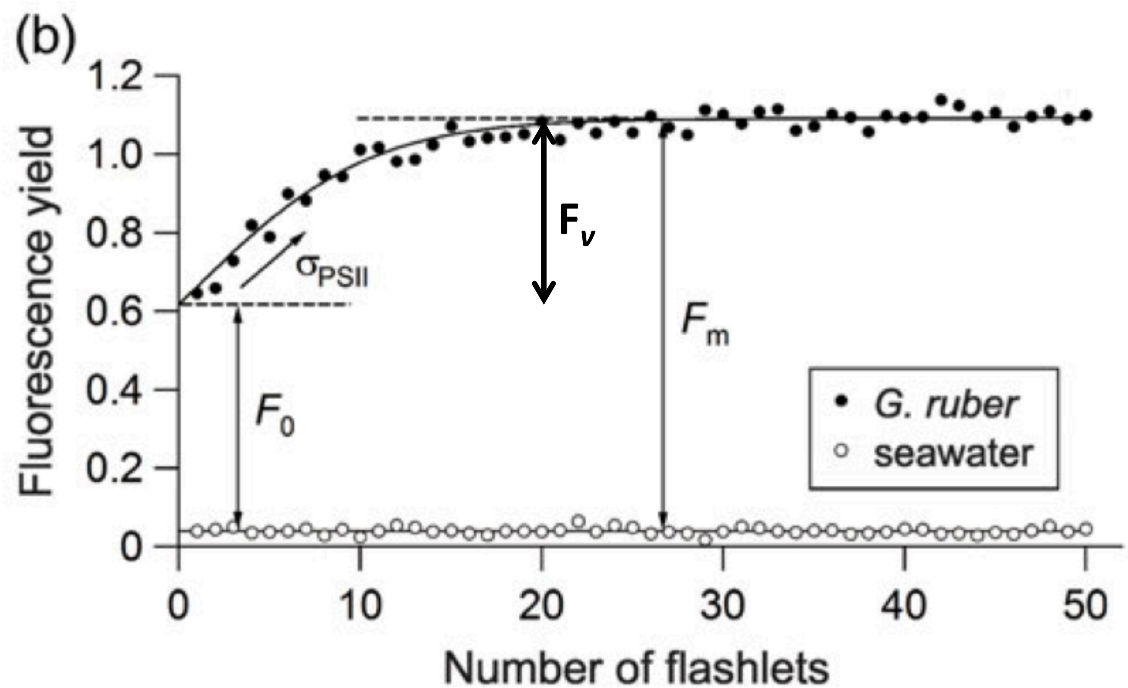




Dyez & Hönisch, unpubl.

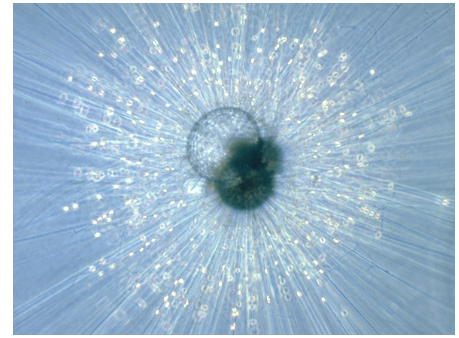
Assessment of algal photosynthesis in planktic foraminifers by fast repetition rate fluorometry

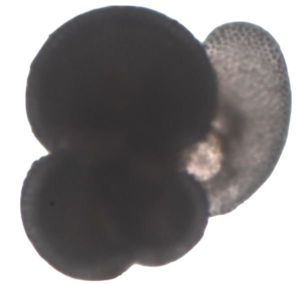


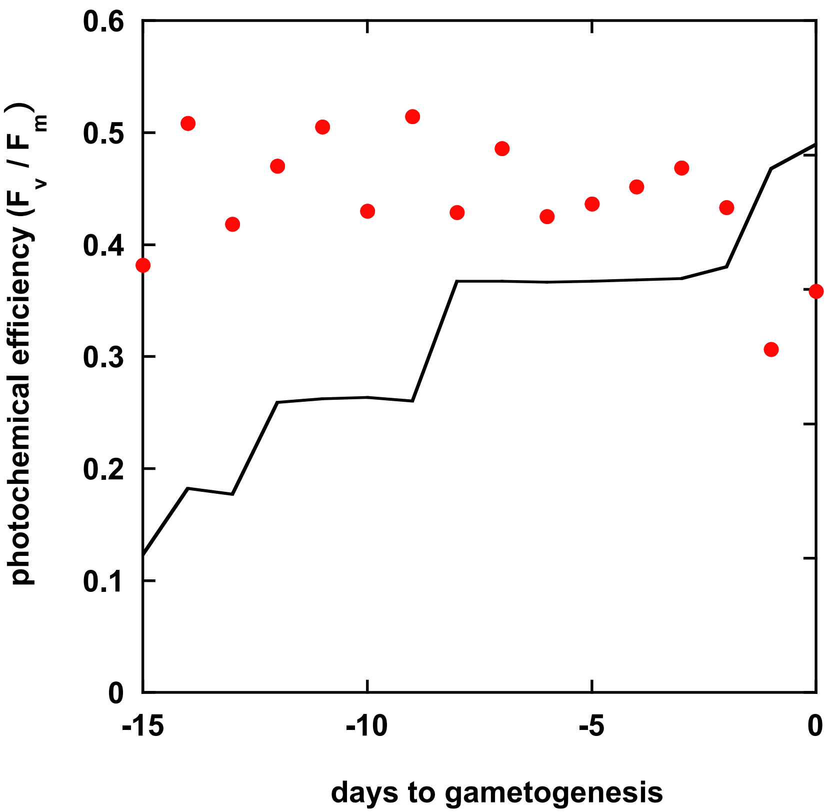


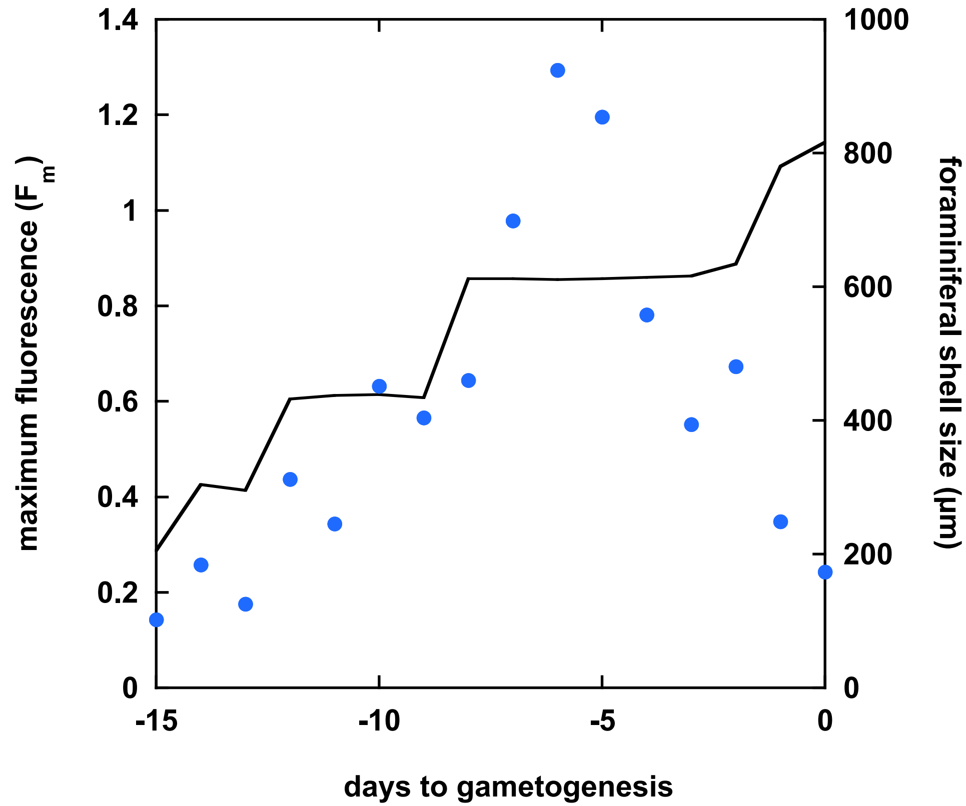
Fujiki et al. (2014)

Globigerinoides sacculifer



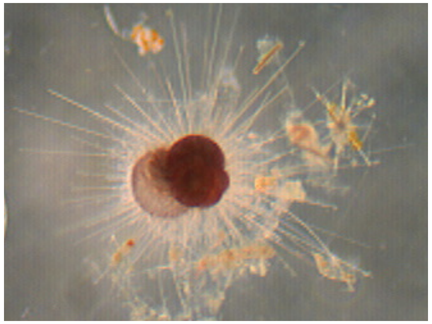


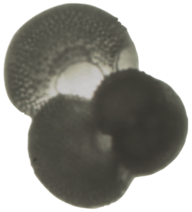


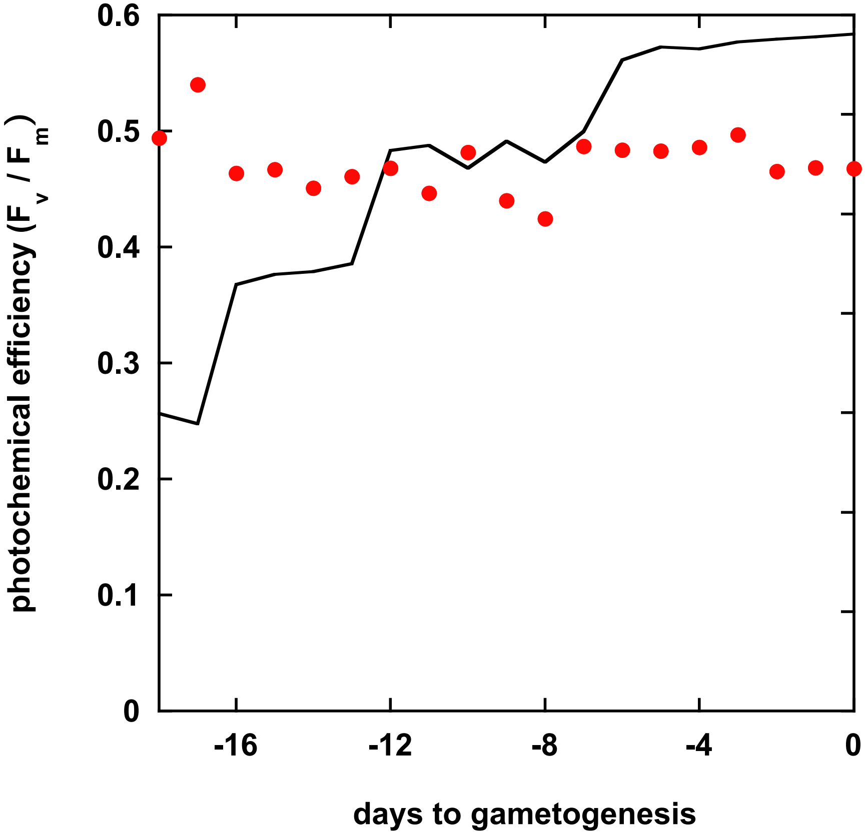


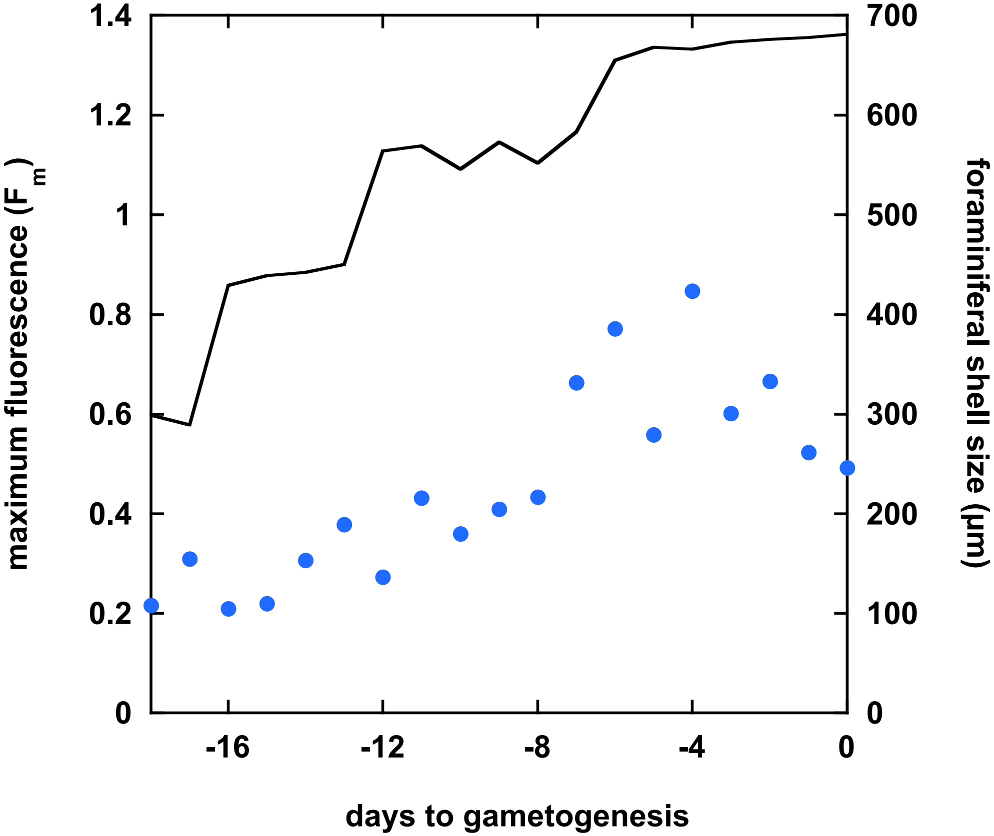
Fish et al., unpubl.

Globigerinoides ruber



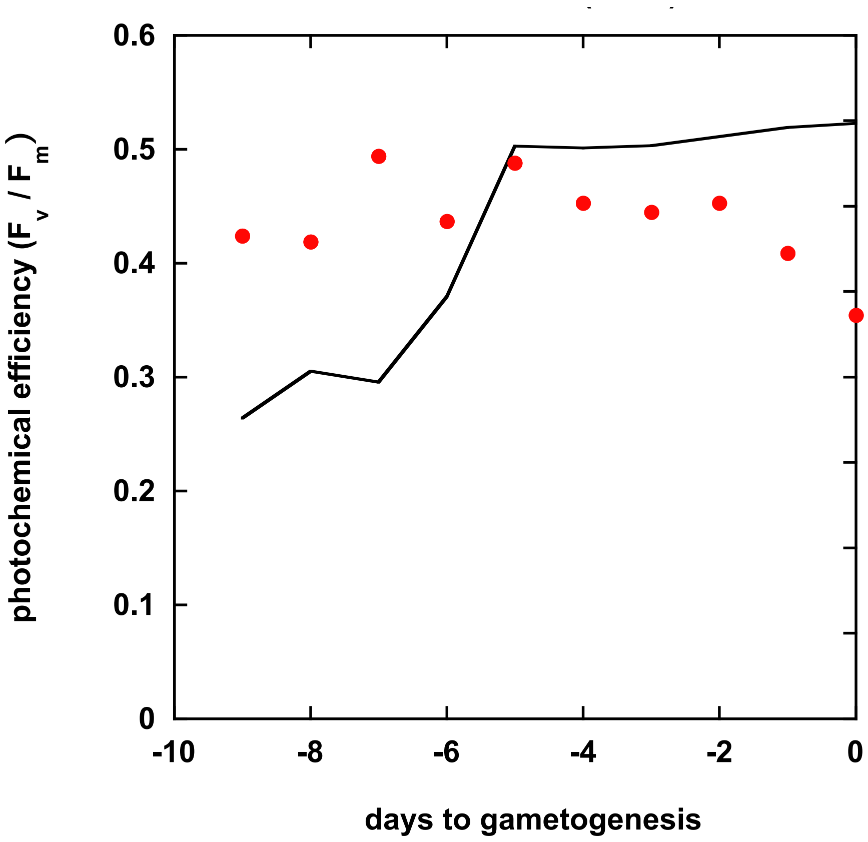


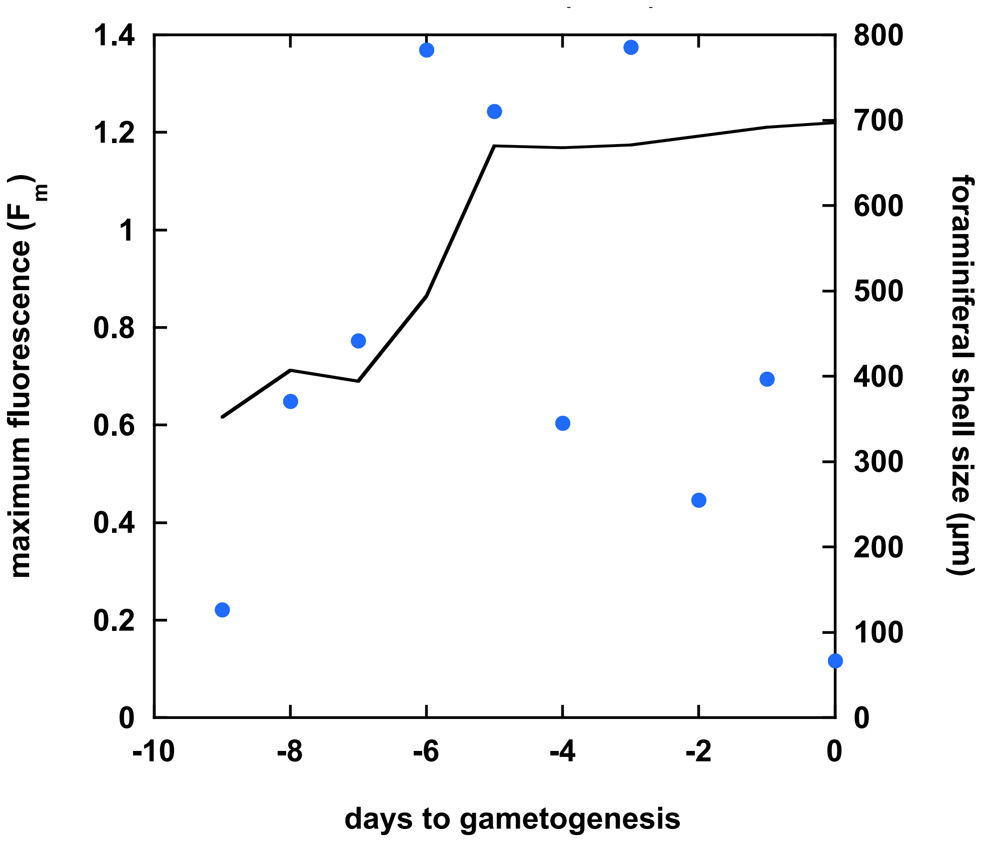




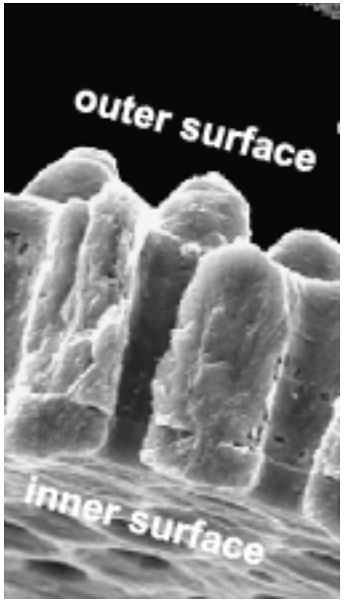
Fish et al., unpubl.

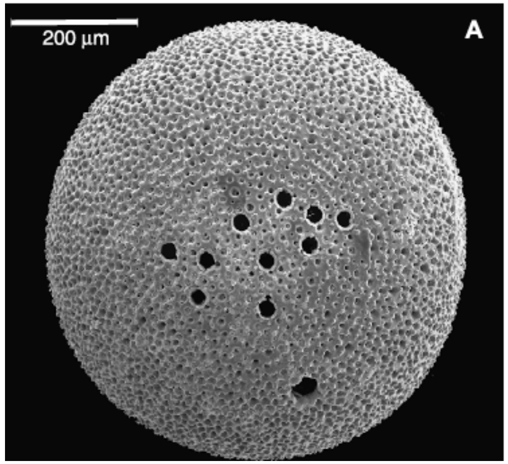
Orbulina universa



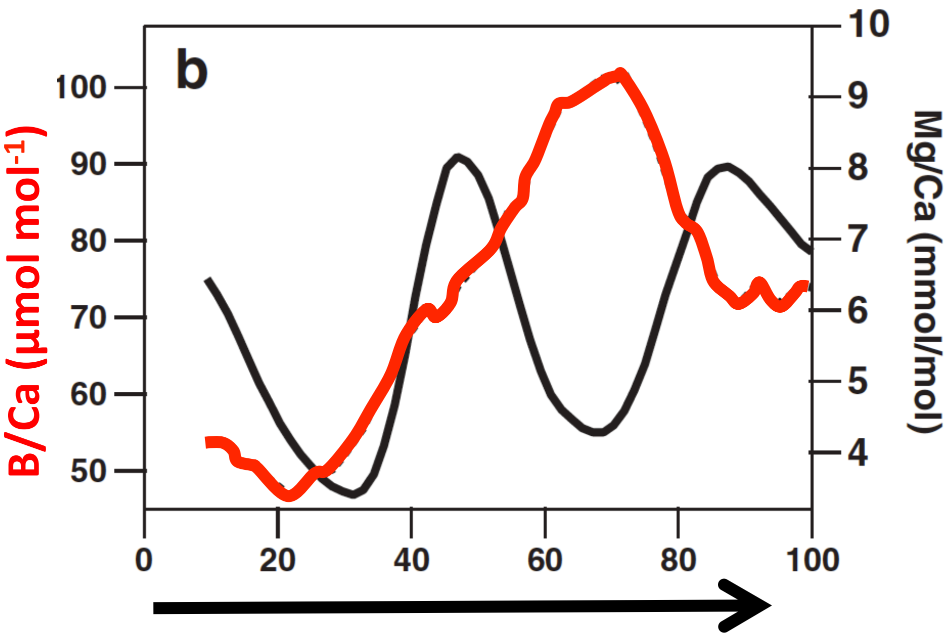


Fish et al., unpubl.



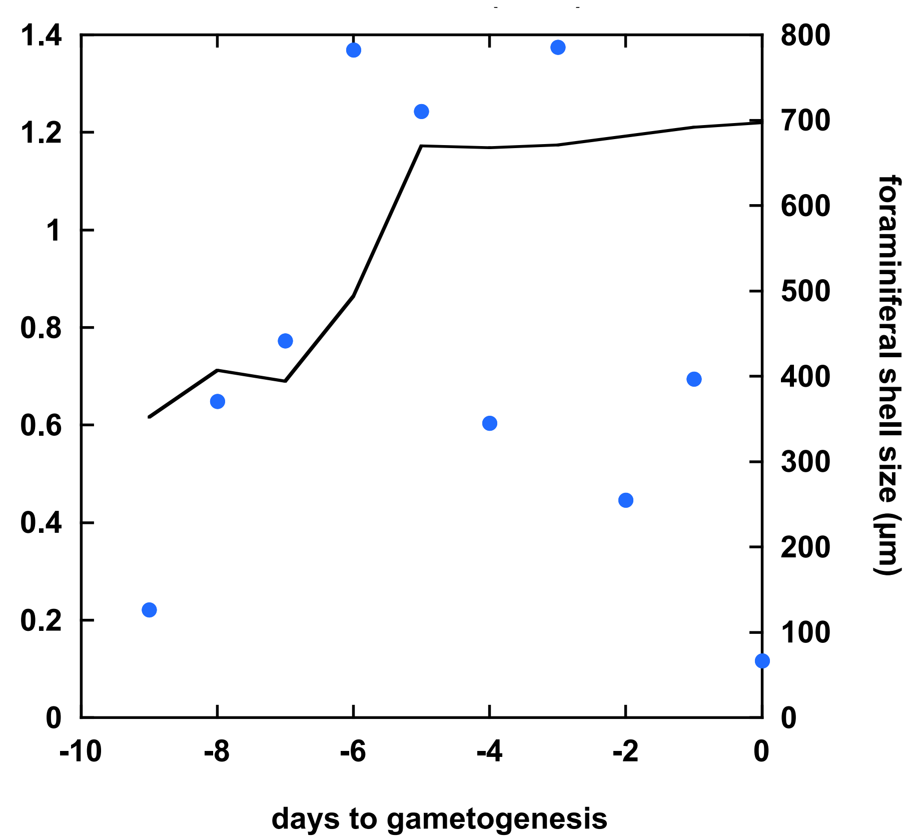


Orbulina universa

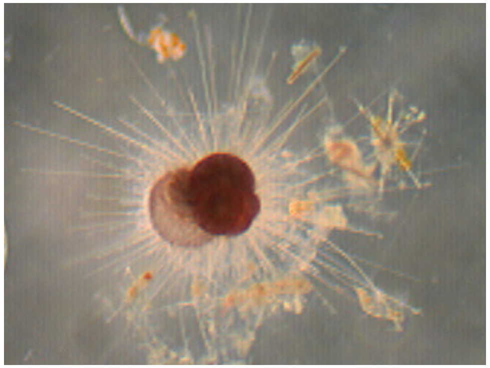
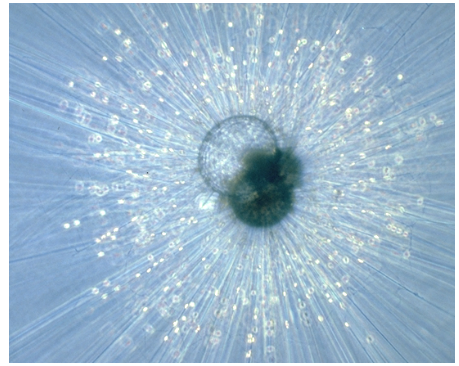


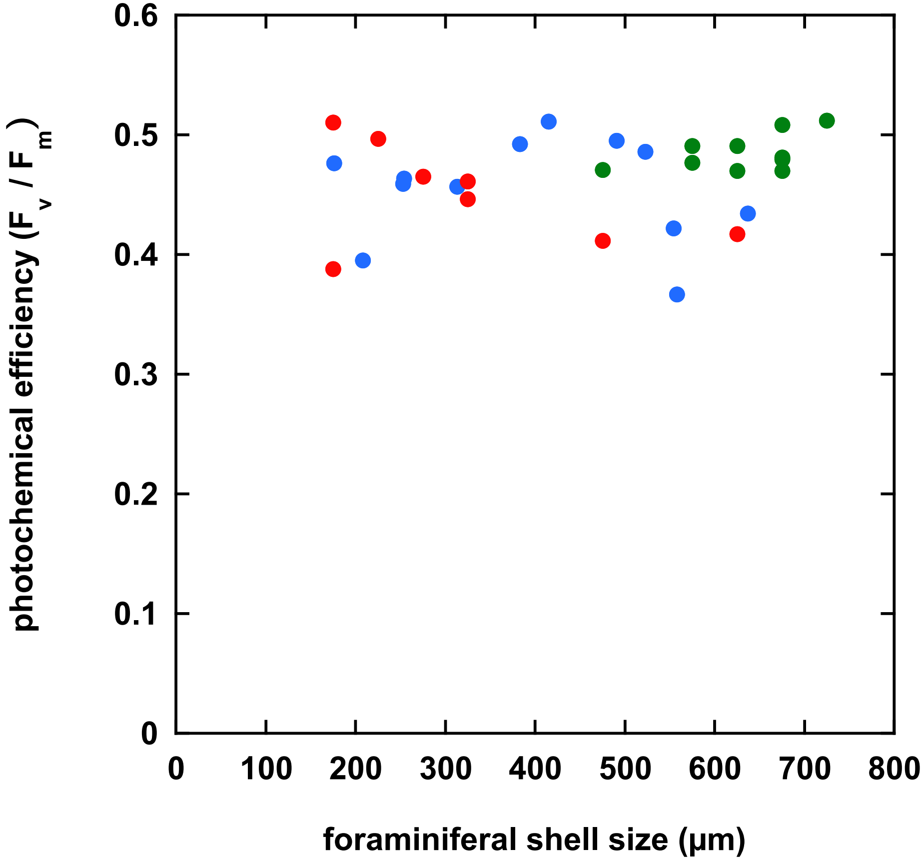
distance (%) from inside to outside of shell wall

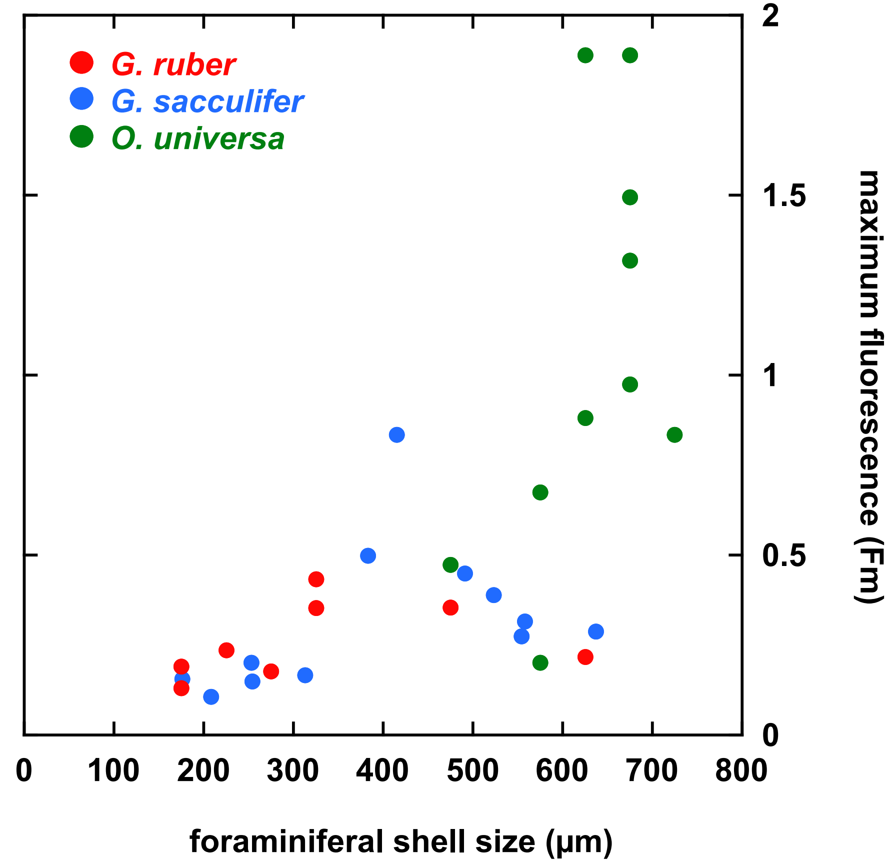
Allen et al., 2011



Fish et al., unpubl.

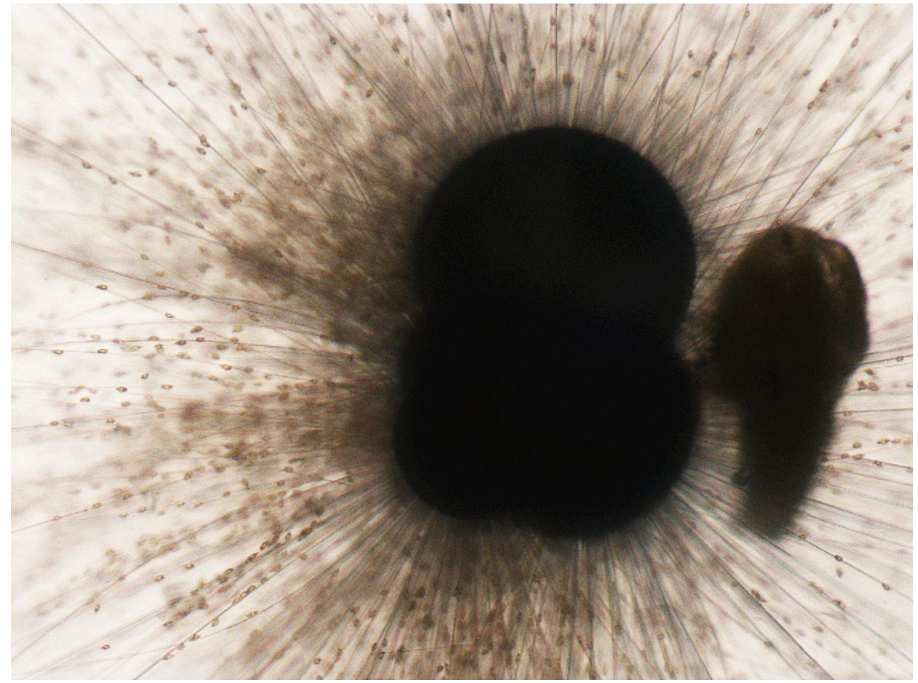





Fish et al., in prep.

Physiological processes – photosynthesis, respiration and calcification – modify pH in the microenvironment of foraminifers.

Taking B/Ca and boron isotope values at face value, pH-elevation due to symbiont photosynthetic activity and/or depth range in the water column should rank *G. ruber* > *G. sacculifer* > *O. universa.*

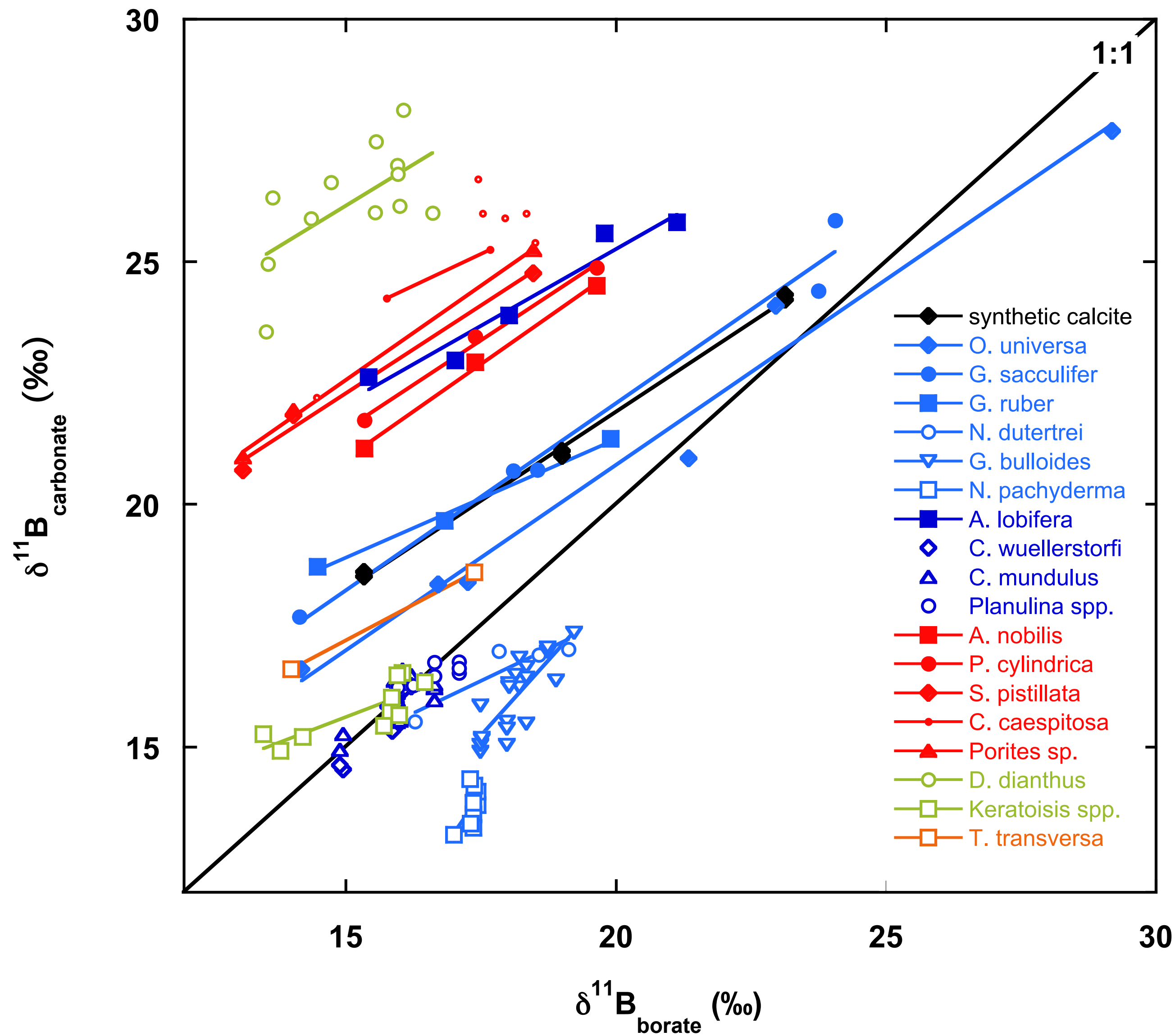


This prediction is not verified by symbiont density and fluorescence measurements, which are similar for all species, if not even highest for *O. universa.*

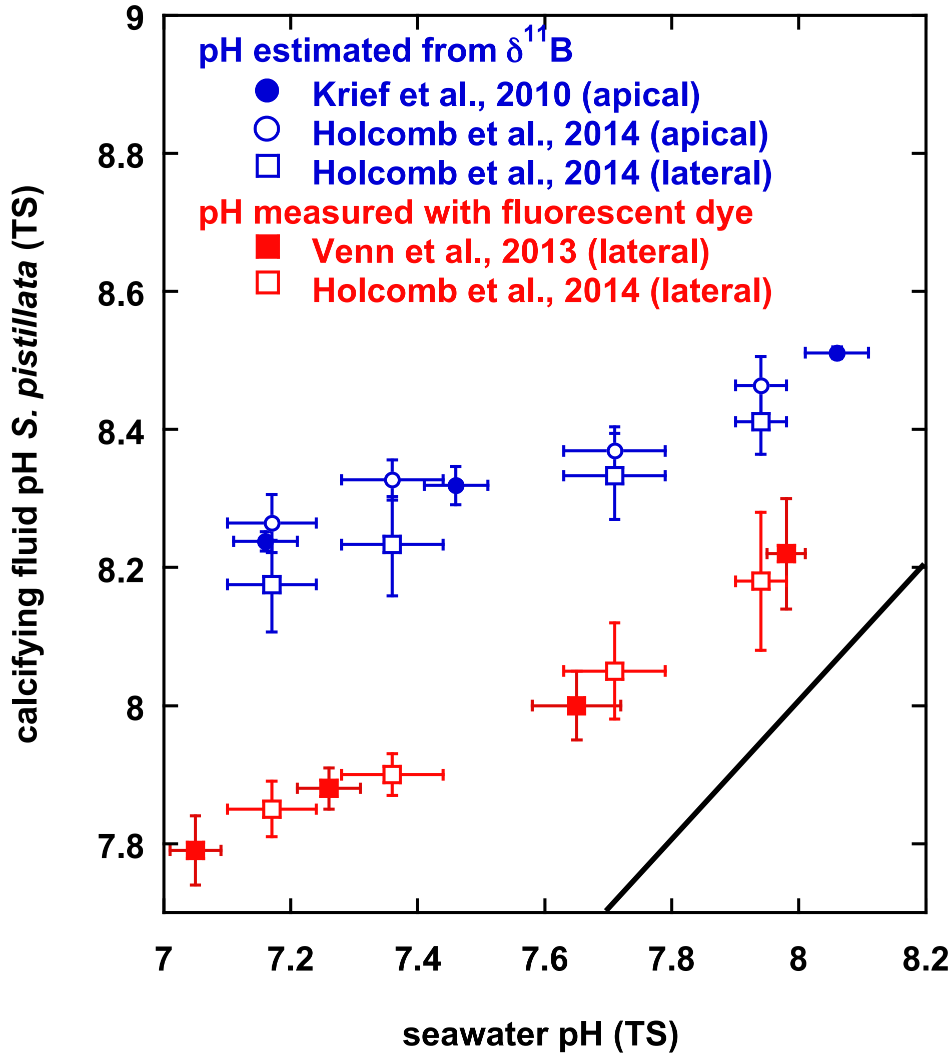
Alternative processes must be responsible for the difference in shell geochemistry, most likely including the biomineralization process and related ion transport.

Inferring physiological processes from geochemical proxies may be misleading, unless all details of the organismal biology are known.

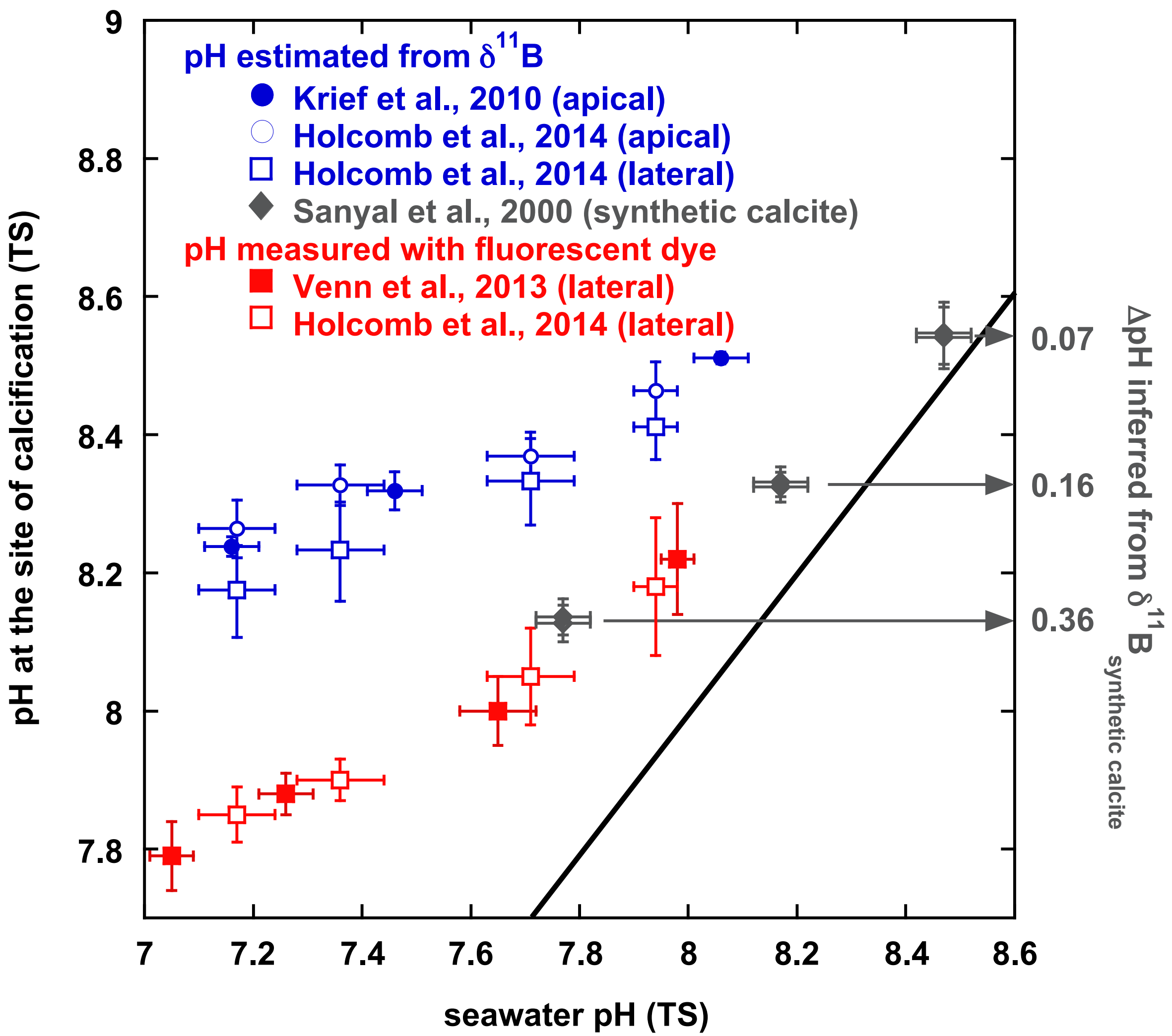
Coral resilience to ocean acidification and global warming through pH up-regulation?



Coral resilience to ocean acidification and global warming through pH up-regulation ?



Coral resilience to ocean acidification and global warming through pH up-regulation ?



pH up-regulation has been measured directly and via $\delta^{11}B$ in *S. pistillata* follow a similar pH-slope. This may indicate greater resilience to ocean acidification.

$\delta^{11}B$ in all marine carbonate calibrated over a wide pH range show lesser sensitivity to pH than predicted from $\delta^{11}B$ in aqueous borate, including synthetic calcite.

Biology is not involved in synthetic calcite precipitation, suggesting that the $\delta^{11}B$ vs. pH sensitivity of marine carbonates may not be due to active pH up-regulation, but instead reflect an incomplete understanding of the boron isotope proxy systematics.

Unless proxy systematics are understood in their entirety, interpretations of deviations from theory should be approached with caution.

Inorganic $CaCO_3$ precipitation experiments should be replicated to confirm or revise the calibration.

Thanks!