S5 From genes to ecosystems: genetic and physiological responses to climate change

Ocean acidification The quest for unifying principles

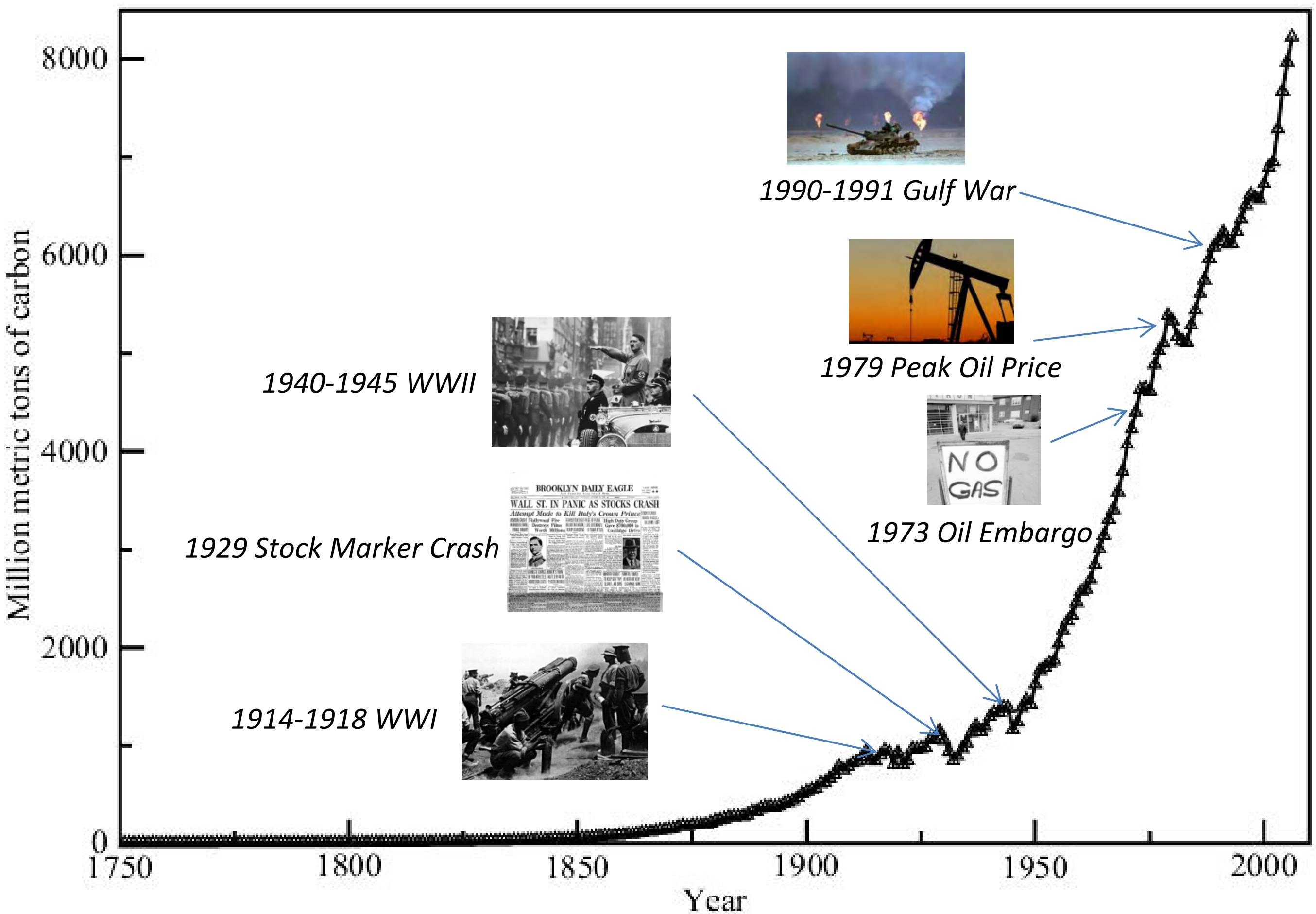
Sam Dupont & Mike Thorndyke
[sam.dupont@marecol.gu.se]

UNIVERSITY OF GOTHENBURG
CENTRE FOR MARINE EVOLUTIONARY BIOLOGY

Department of Biological and Environmental Sciences
Gothenburg University
The Sven Lovén Centre for Marine Sciences
Kristineberg

Oceans in a high CO_2 world

Global Fossil-Fuel CO_2 Emissions

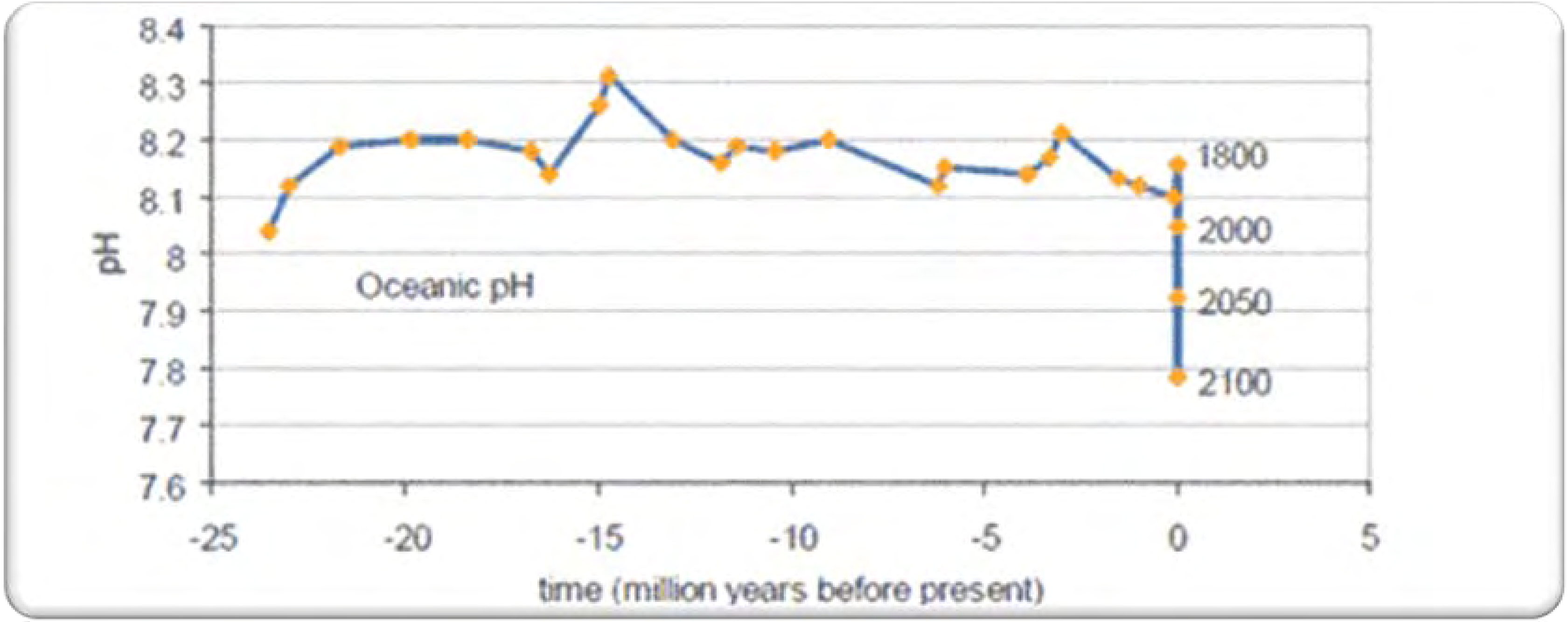


26% absorbed by the oceans

The other CO_2 problem

Ocean acidification

$CO_2 + H_2O = HCO_3^- + H^+$ → pH decrease



(Turley et al. 2006)

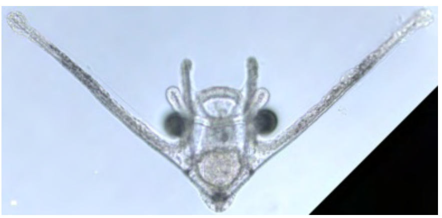
What we need to know ?

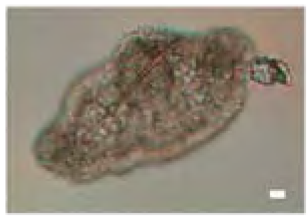
©Robin Paris (1994)

Ocean in a high CO_2 world:
What will be the consequence on marine species / population / ecosystems ?

Urgent need to predict (?)

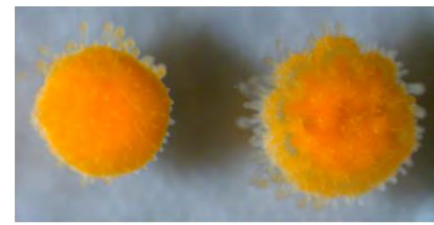
Impact of OA is species-specific





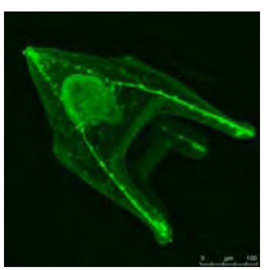
Ophiothrix fragilis:
100% mortality in 8 days
pH=-0.2 units
(Dupont et al. 2008)

Difference in life-history strategy



Crossaster papposus:
Increased growth
pH=-0.4 units
(Dupont et al. 2010)

Same life-history strategy



Paracentrotus lividus:
Normal development (but delayed & molecular plasticity)
pH=-1.2 (7.0)
(Martin et al. 2011)

ECHINODERMS

Abyssocucumis sp.
Amphiura filiformis
Arbarcia drufresnei
Arbarcia punctulata
Asterias rubens
Crossaster papposus
Cystechinus sp.
Denstraster excentric
Echinocardium corda
Echinometra mathae
Eucidaris tribuloides
Evechinus chloroticus
Heliocidaris erythrog
Hemicentrotus pulch
Lytechinus pictus
Ophiothrix fragilis
Ophiura ophiura
Par
Pisa
Psa
Pse
Ste
Stro
Stro
Trip

MOLLUSKS

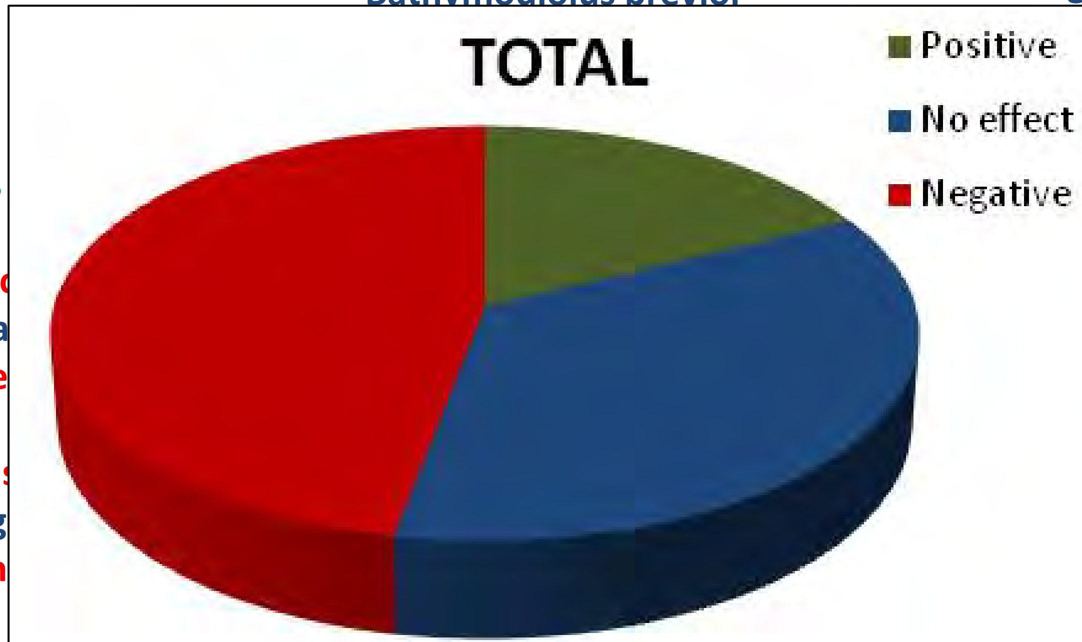
Argopecten irradians
Bathymodiolus brevior

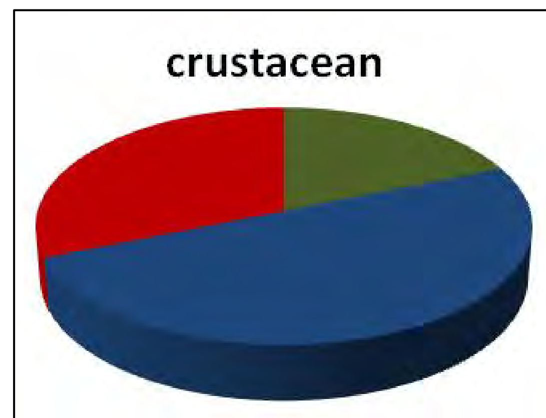
Patella vulgata
Rudipates decussatus

Ciona intestinalis
Oikopleura dioicea

CRUSTACEANS

Callinectes sapidus
Echinogammarus marinus
modestus
modestus
a superba
rus locusta
s lodo
s americanus
neus
uber
on elegans
on pacificus
on serratus
plebejus
era knabeni
Semibalanus balanoides





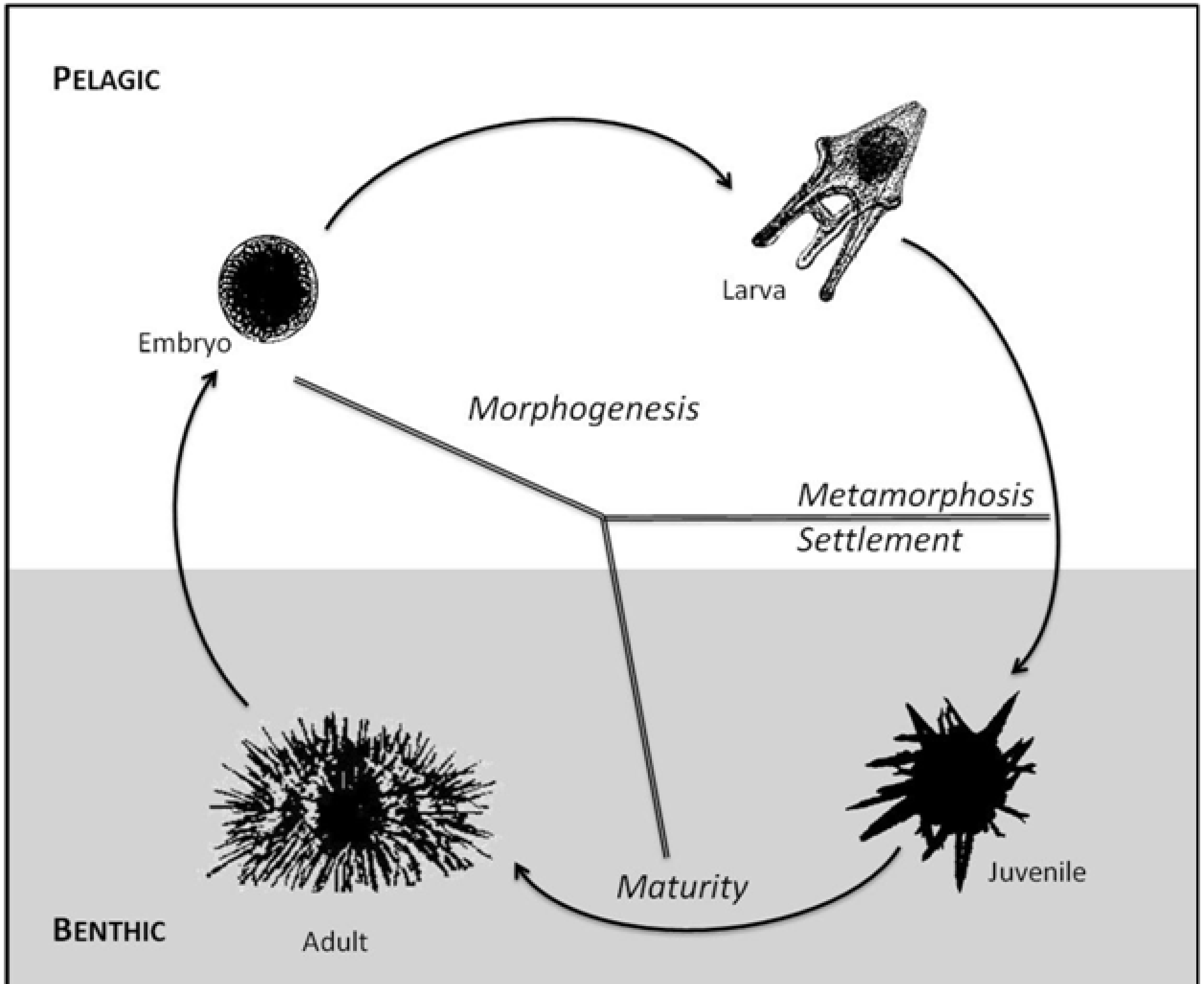
BRYOZOANS

Myriapora truncata

A good model

Sea urchin - Strongylocentrotus spp.

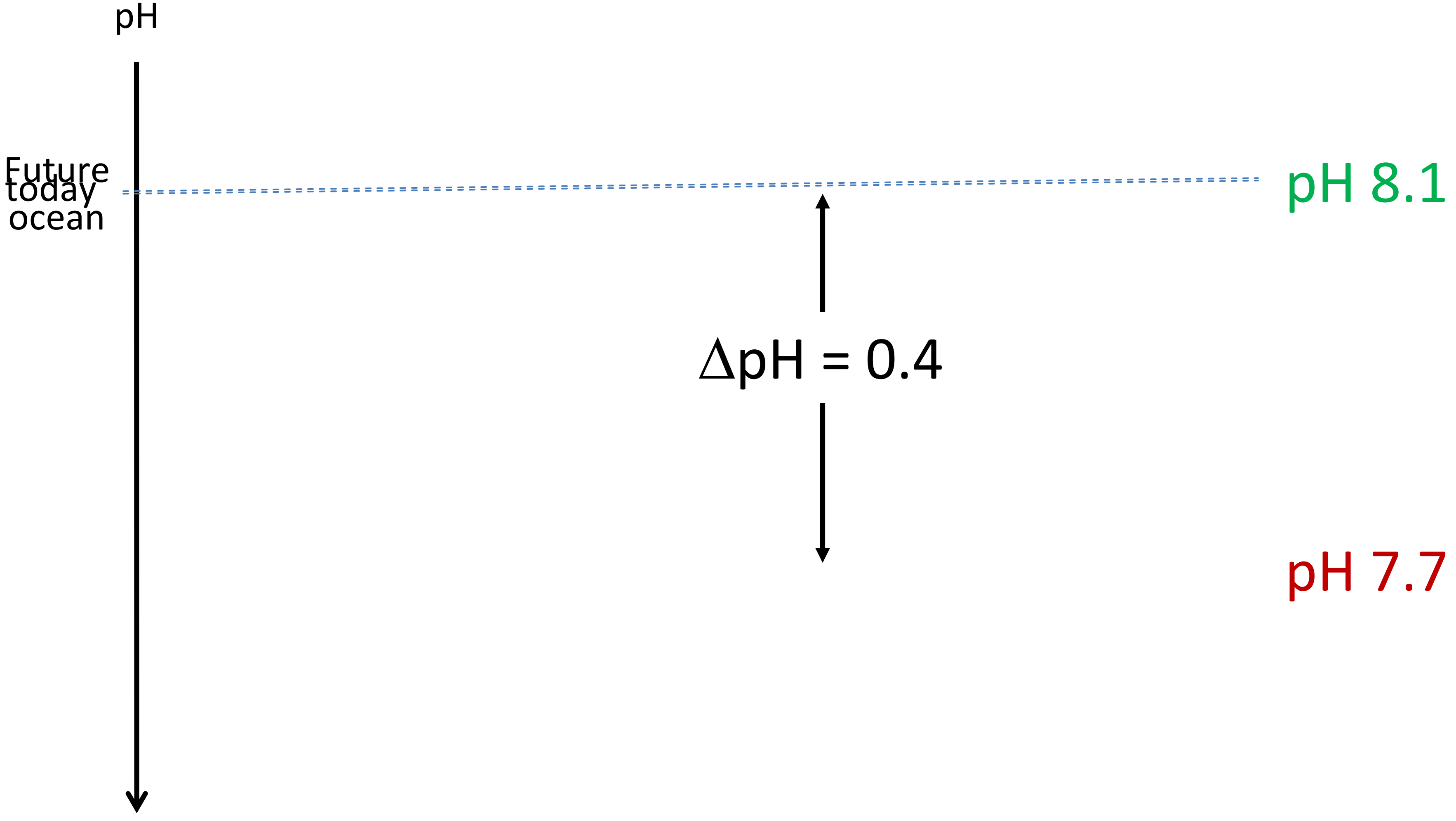
A good model



Different life stages
Different habitats
Transitions

(Dupont et al. 2012, Marine Biology)

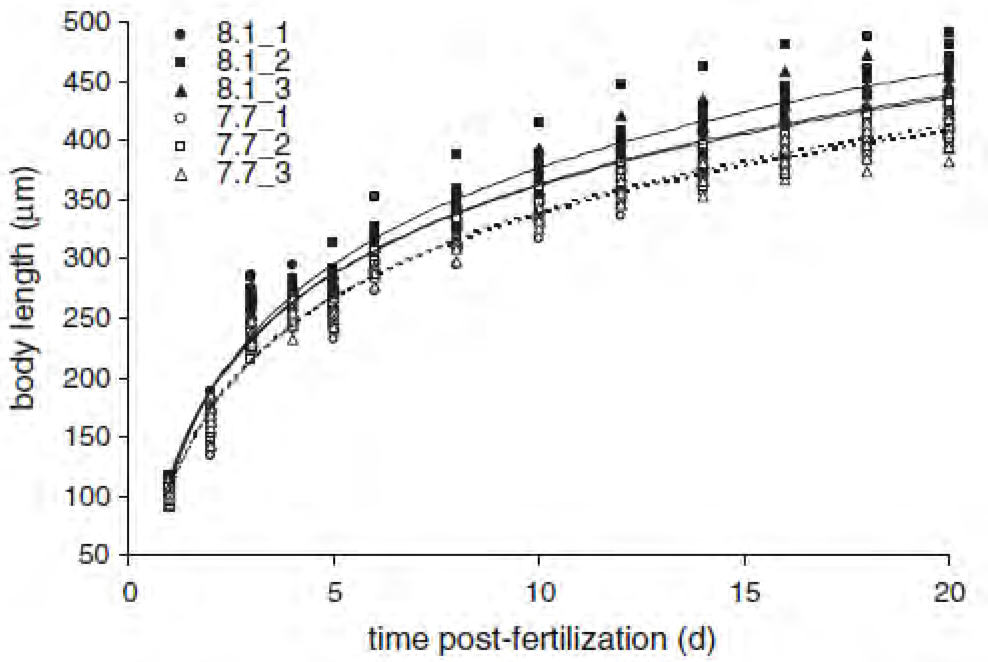
1. Testing scenarios



Two scenarios: TODAY vs NEAR-FUTURE (e.g. ΔpH=0.4)

REM: no need to cross with temperature (temperature is the spawning signal)

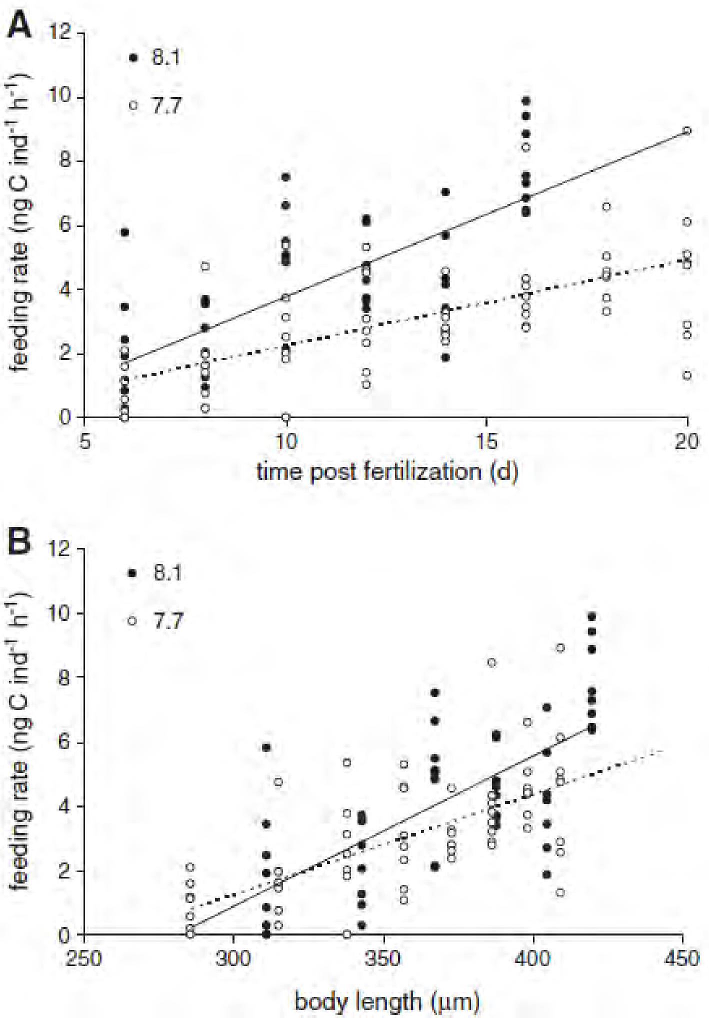
Impact of elevated pCO2 on sea urchin larvae

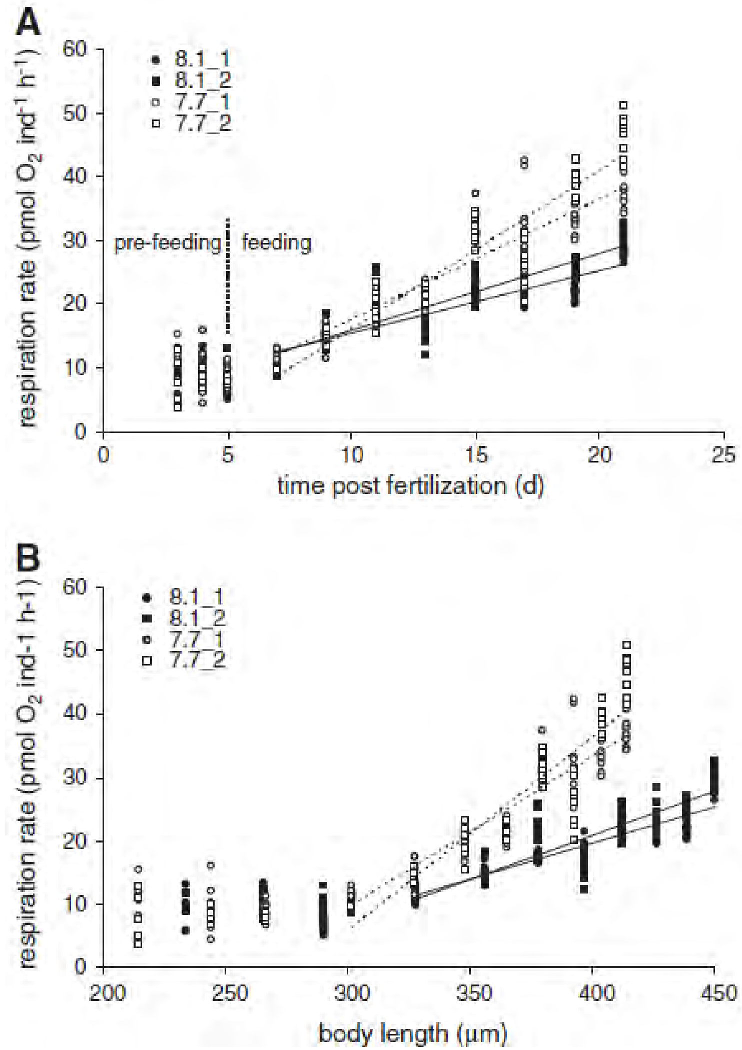


Delay in development

e.g. Martin et al. (2011) JEB; Stumpp et al. (2011a,b) CBP

Dissecting energy budget





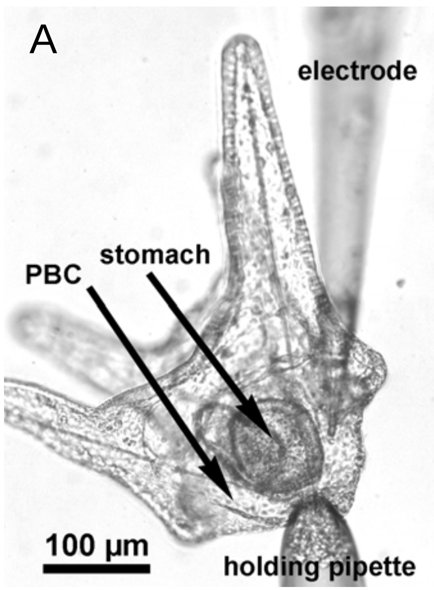
Same feeding ***Increased respiration***

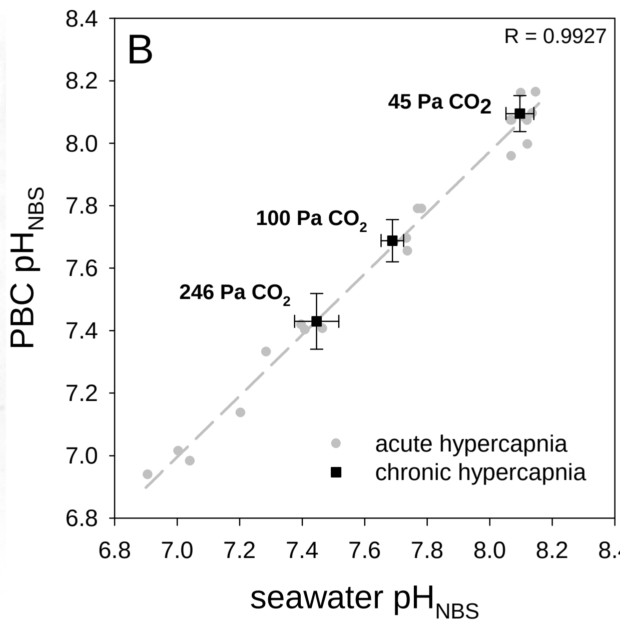
Stumpp et al. (2011a,b) CBP

pH regulation

No pHe regulation

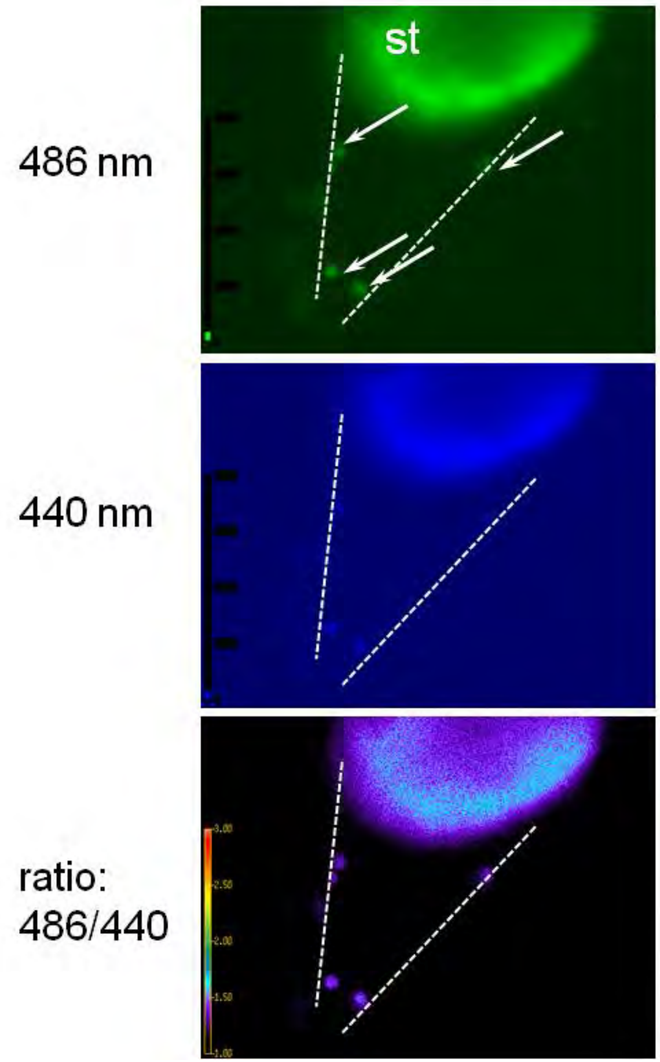
Micro-electrodes





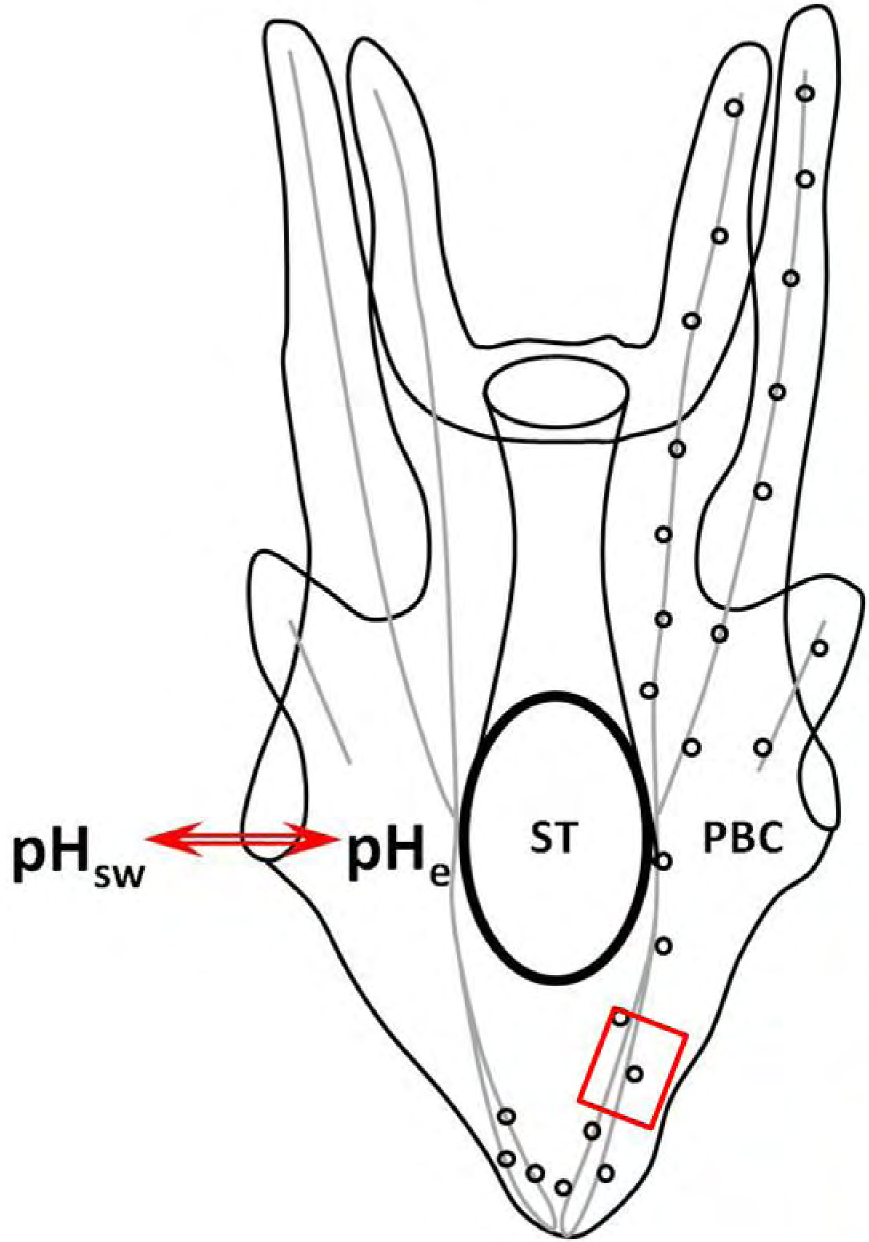
BCECF

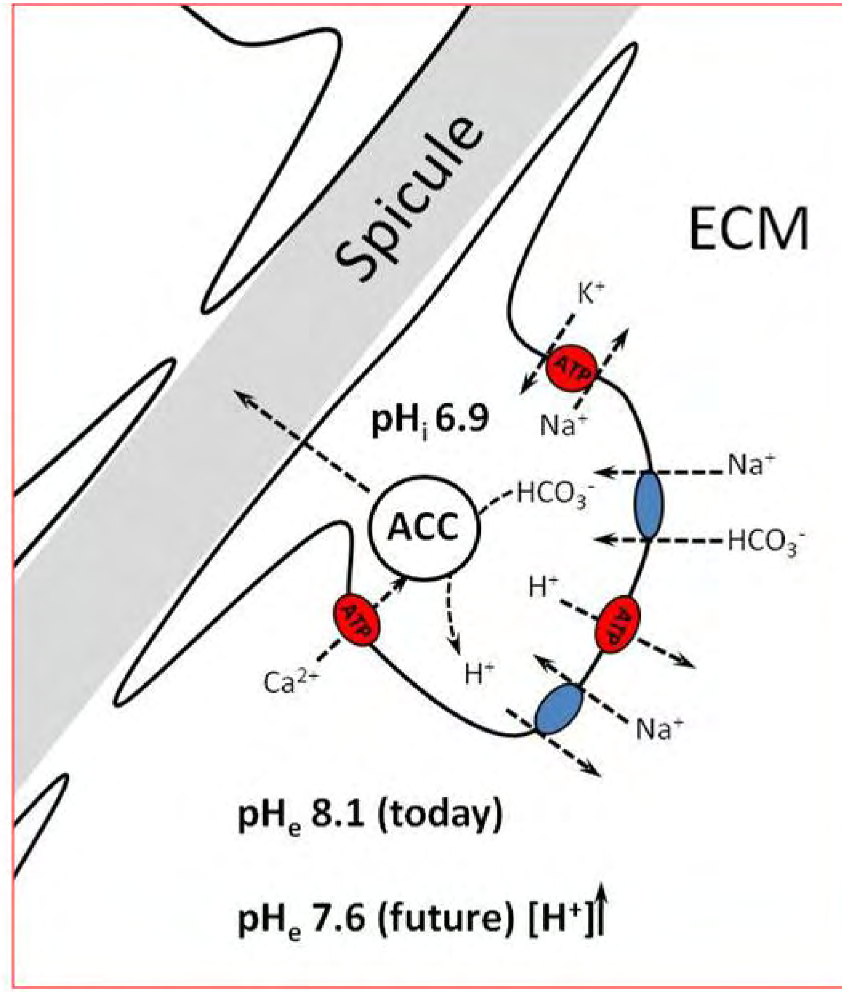
control (pH_i 6.9)



pHi regulation
[HCO3-, H^+-pumps]

Stumpp et al. (subm.)





pH 7.6 vs. pH 8.1

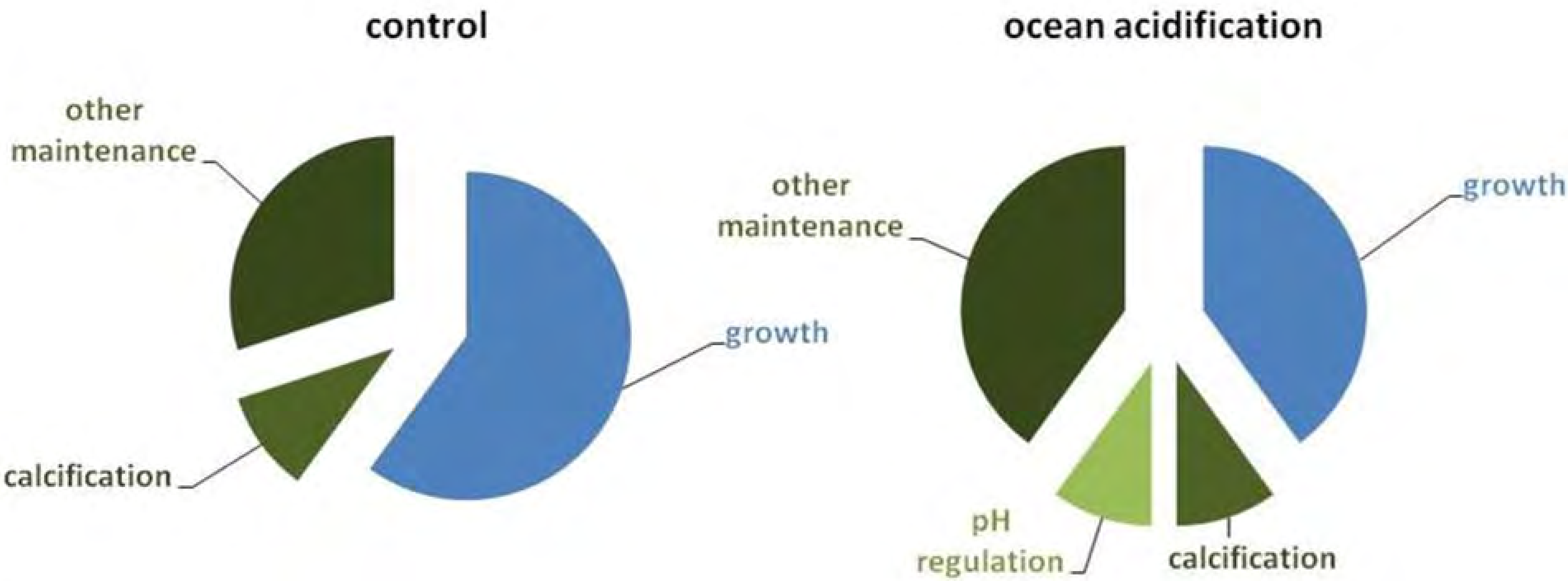
↑ Energetic costs

↓ Energy for growth and development

↓ Juvenile energy reserves

Stumpp et al. (subm.)

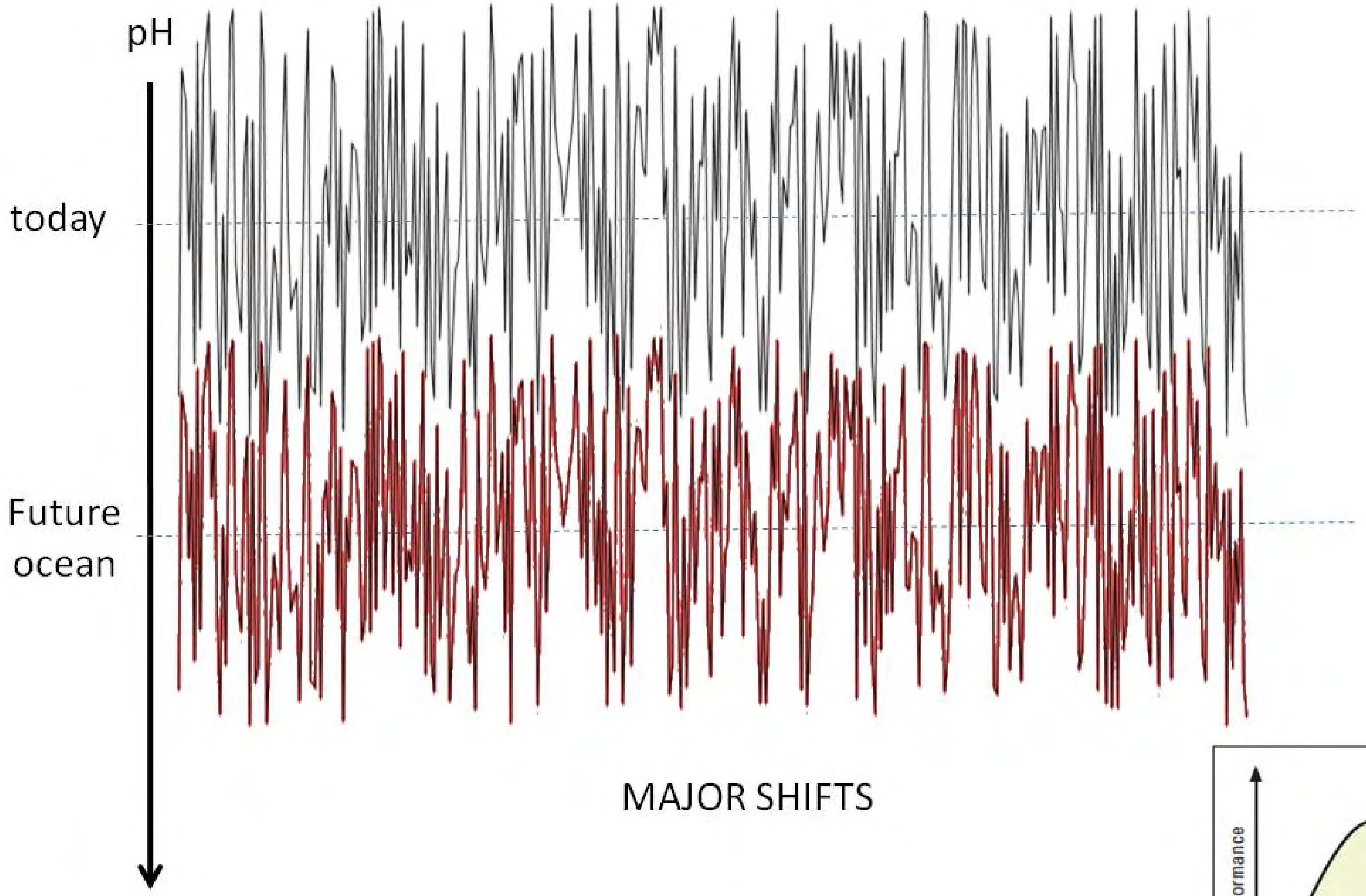
Shift in energy budget



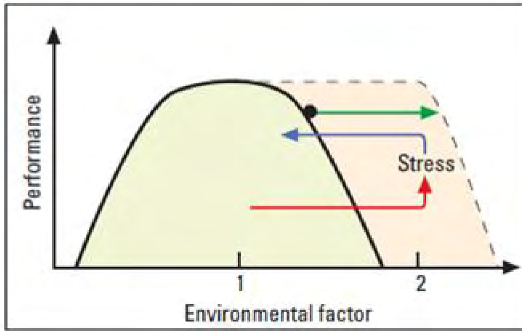
CONCLUSION: Better than expected BUT ecological costs (**Dupont et al. (2010) ECSS**)

2. An always-changing world

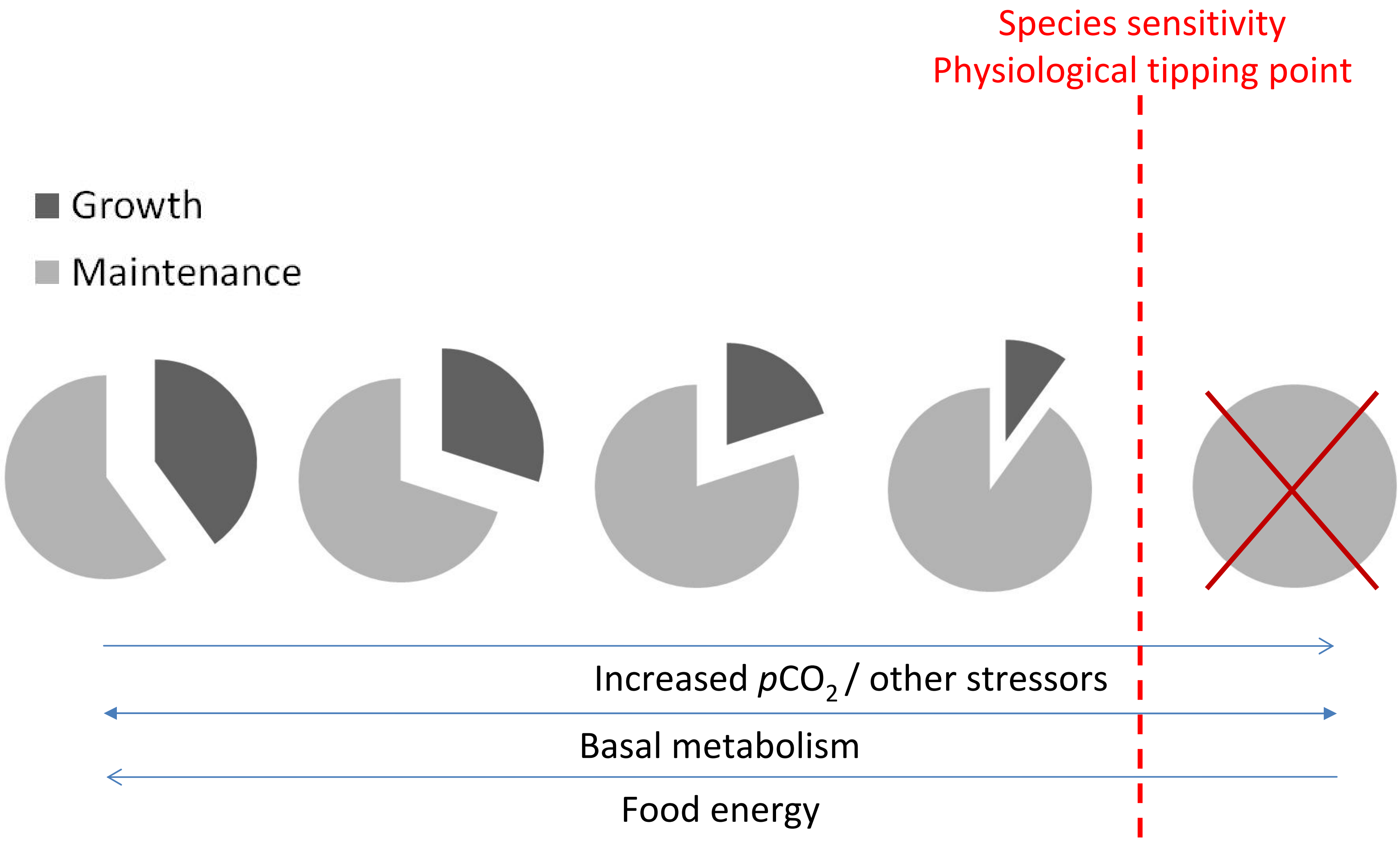
What is a relevant scenario?



MAJOR SHIFTS



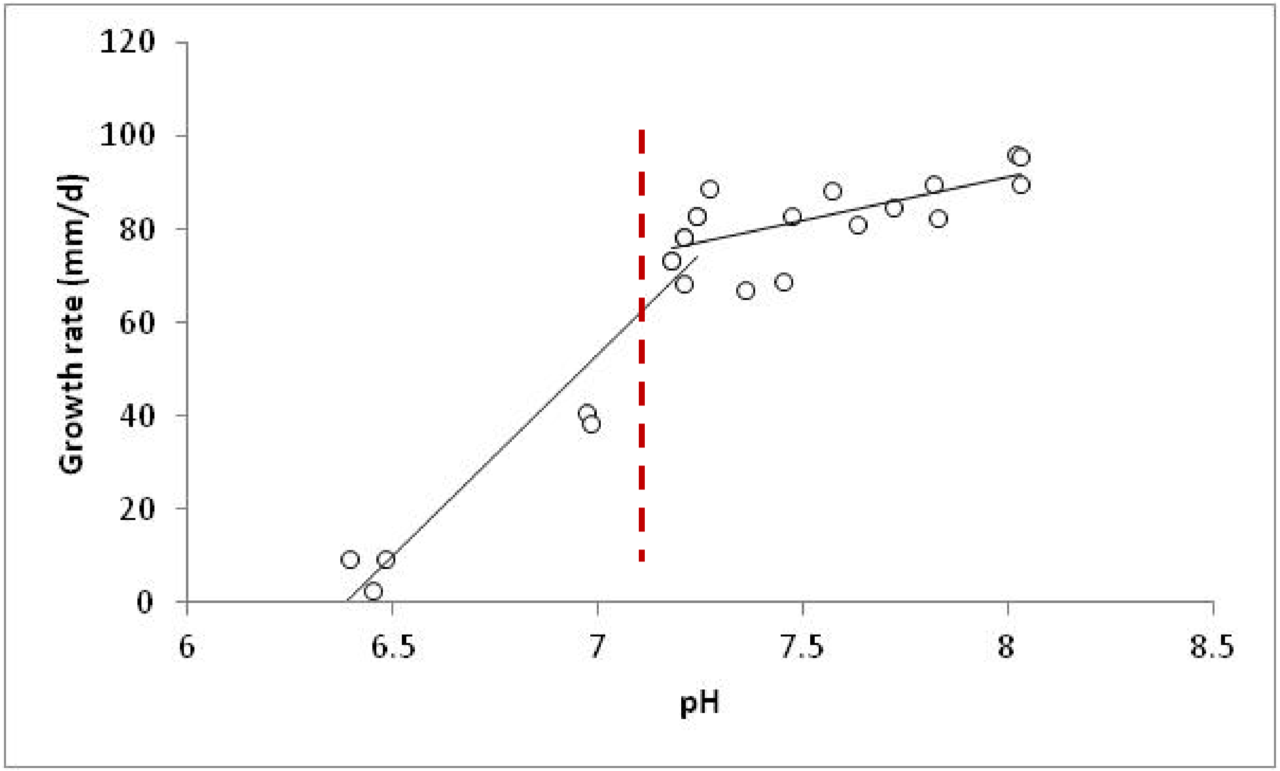
Working hypothesis – trade-off

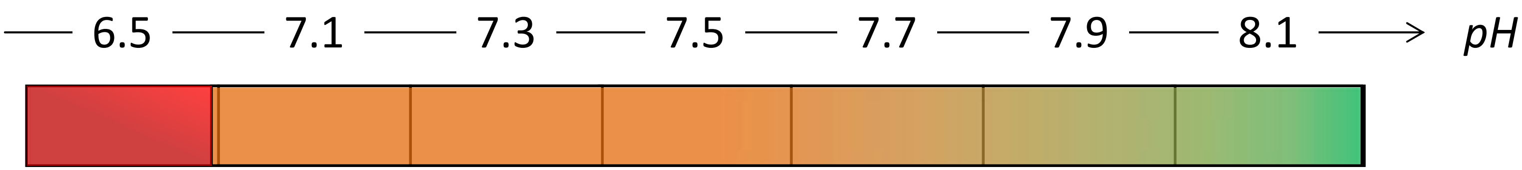


Hypothesis:

-Energy partition is directly linked to metabolism / food availability

Impact on growth

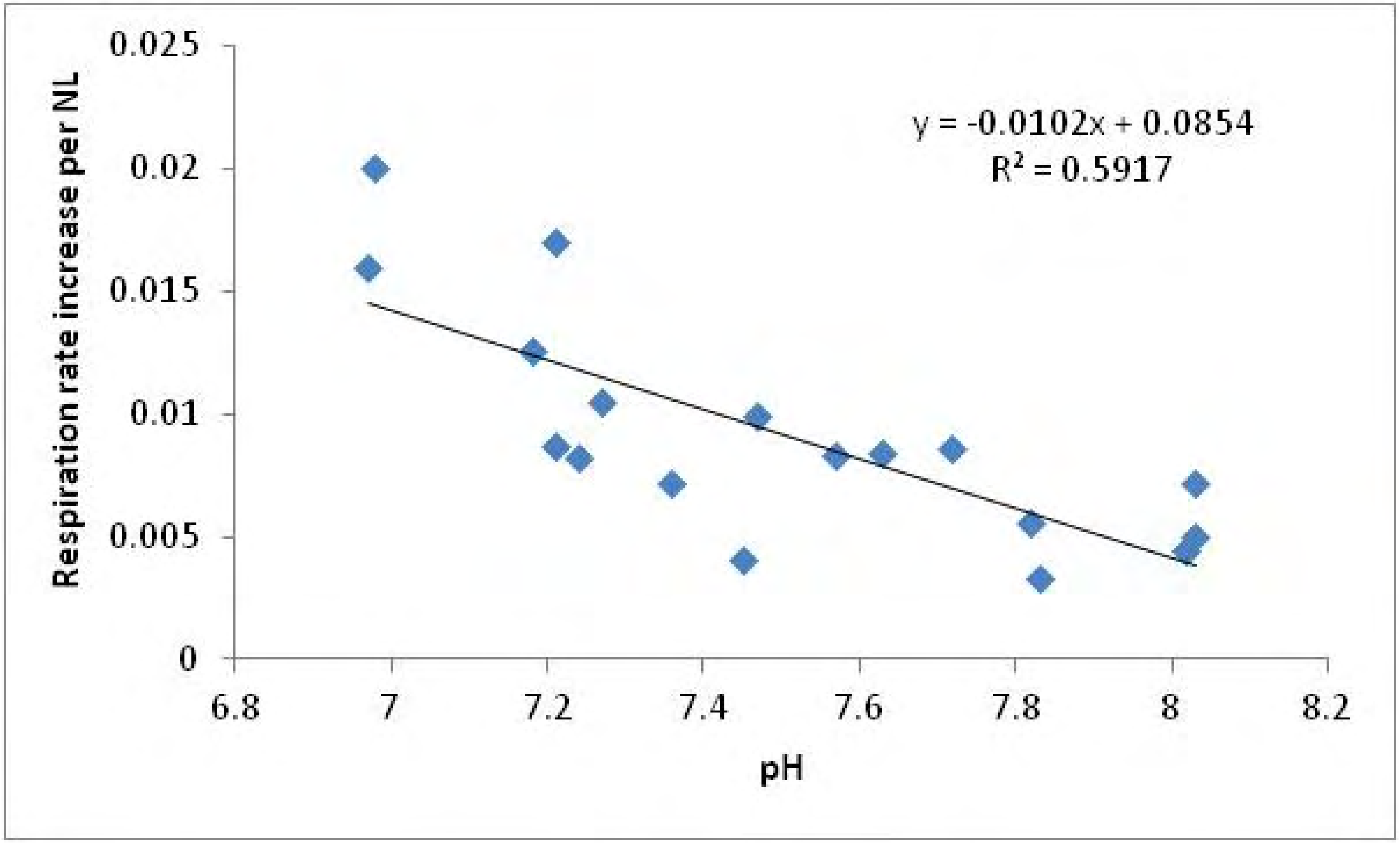




Grow slower at low pH (tip point pH<7.3)

Dorey et al. (in prep)

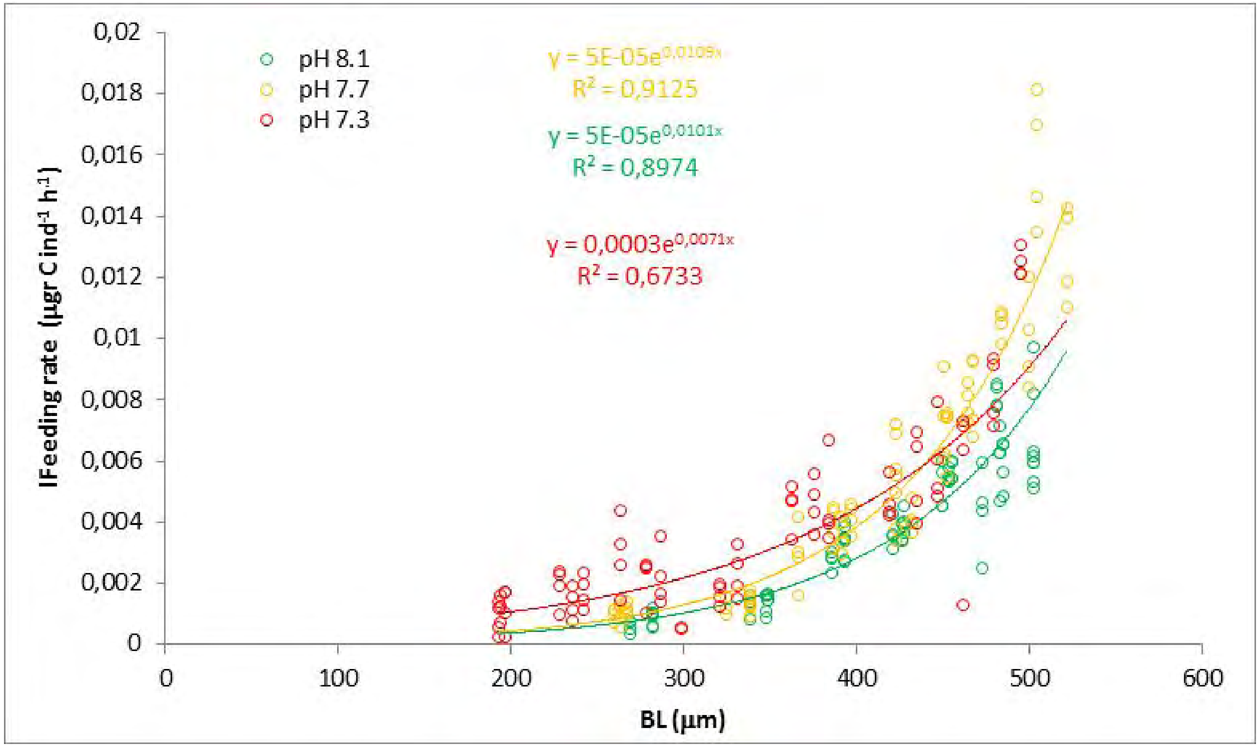
Impact on respiration



Increased respiration with decreasing pH

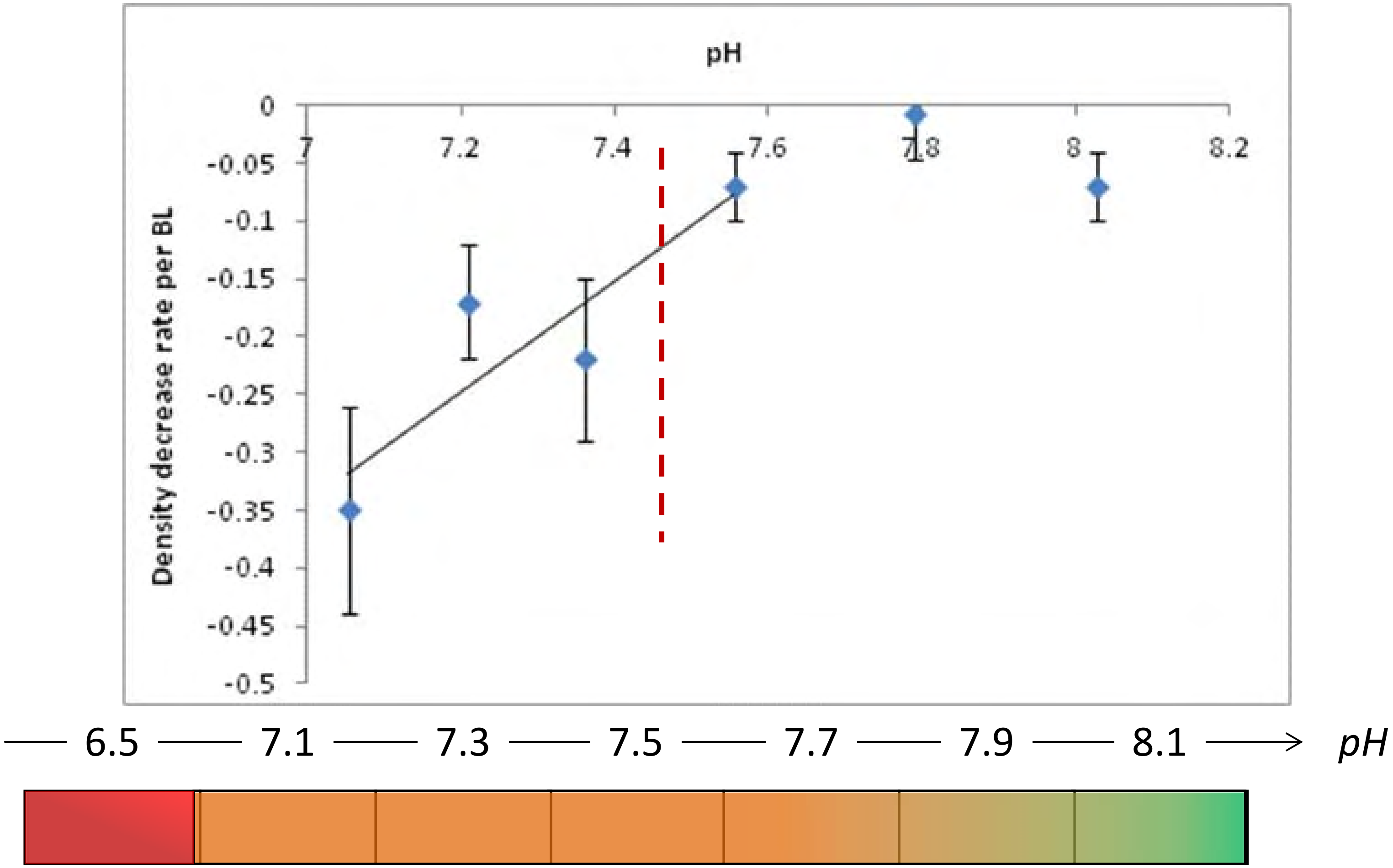
Dorey et al. (in prep)

Impact on feeding



(small) Increased feeding with decreasing pH

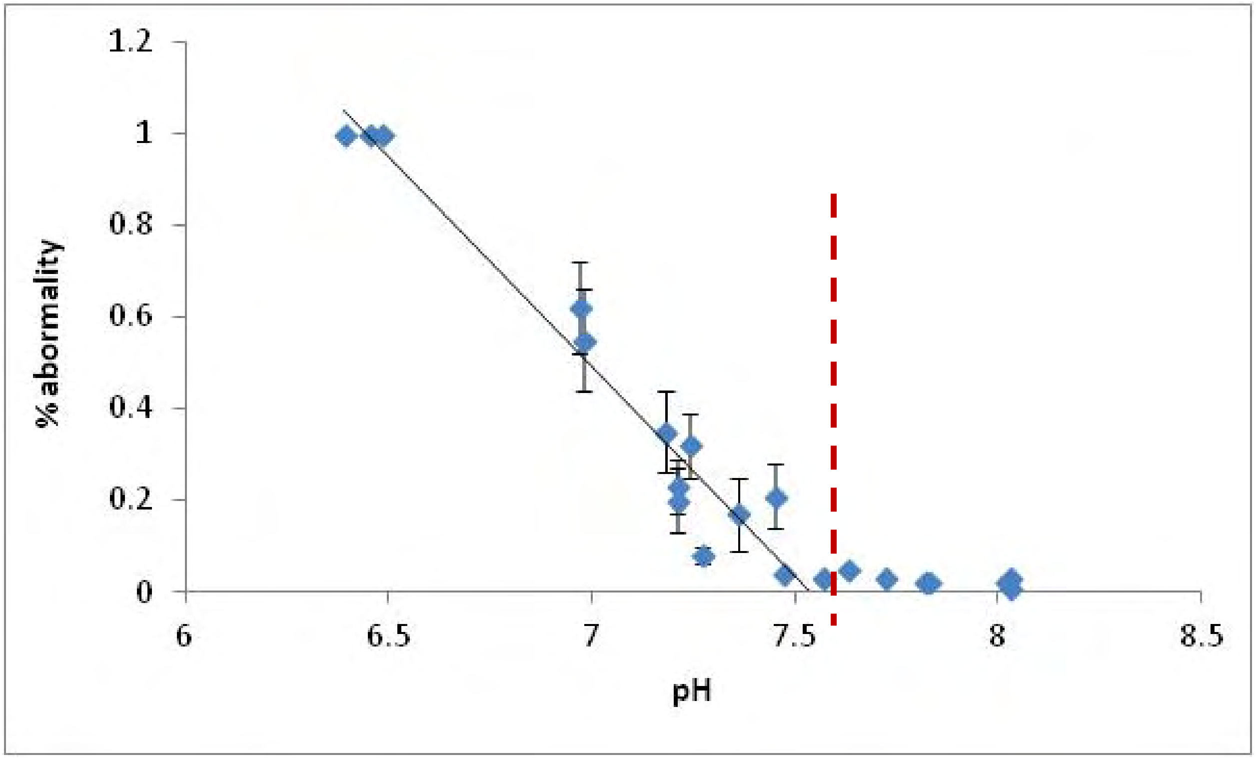
Impact on survival



Increased mortality at low pH (<7.5)

Dorey et al. (in prep)

Impact on development

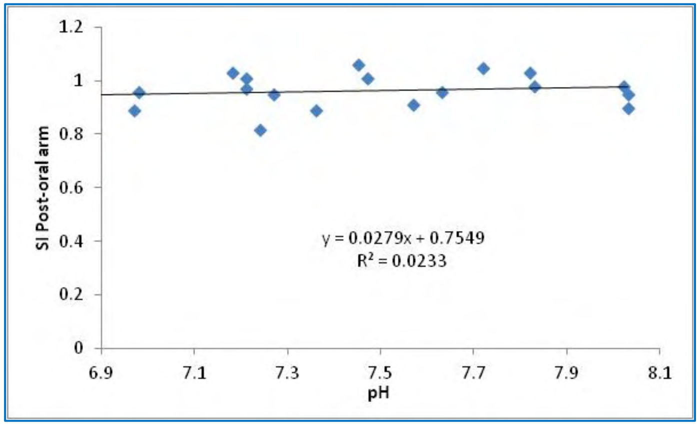


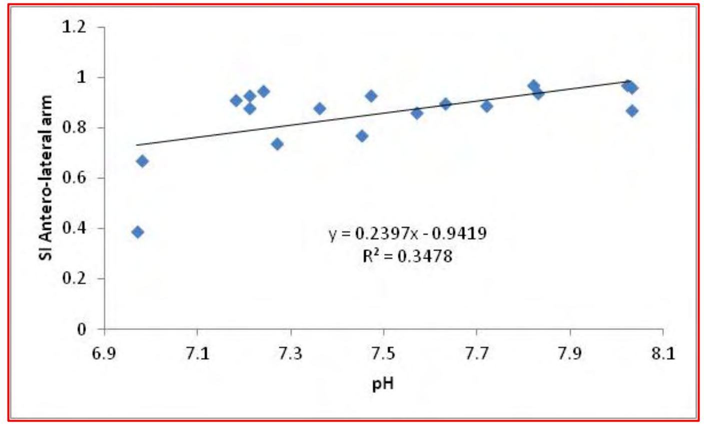
6.5 — 7.1 — 7.3 — 7.5 — 7.7 — 7.9 — 8.1 → *pH*

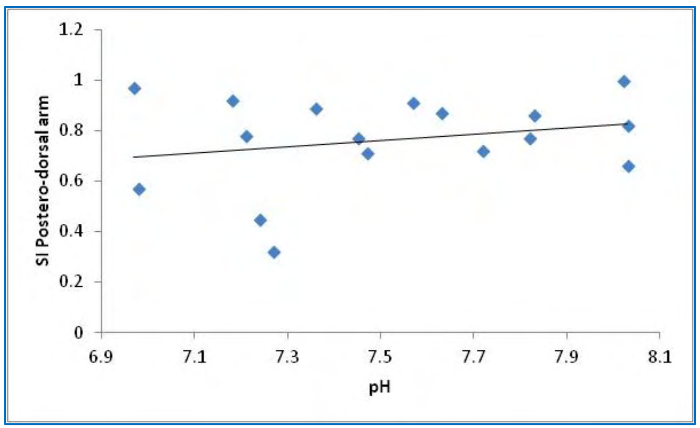
Increased abnormality at low pH (<7.5)

Dorey et al. (in prep)

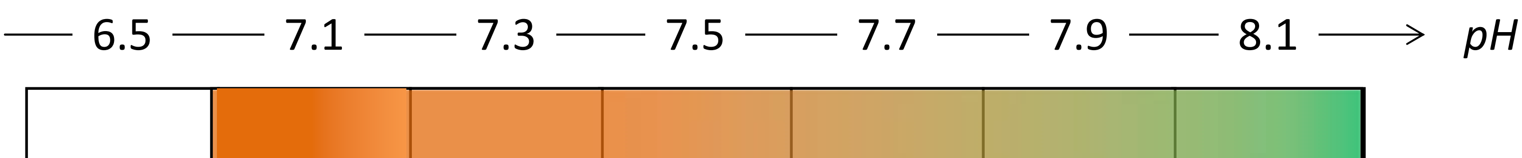
Impact on symmetry



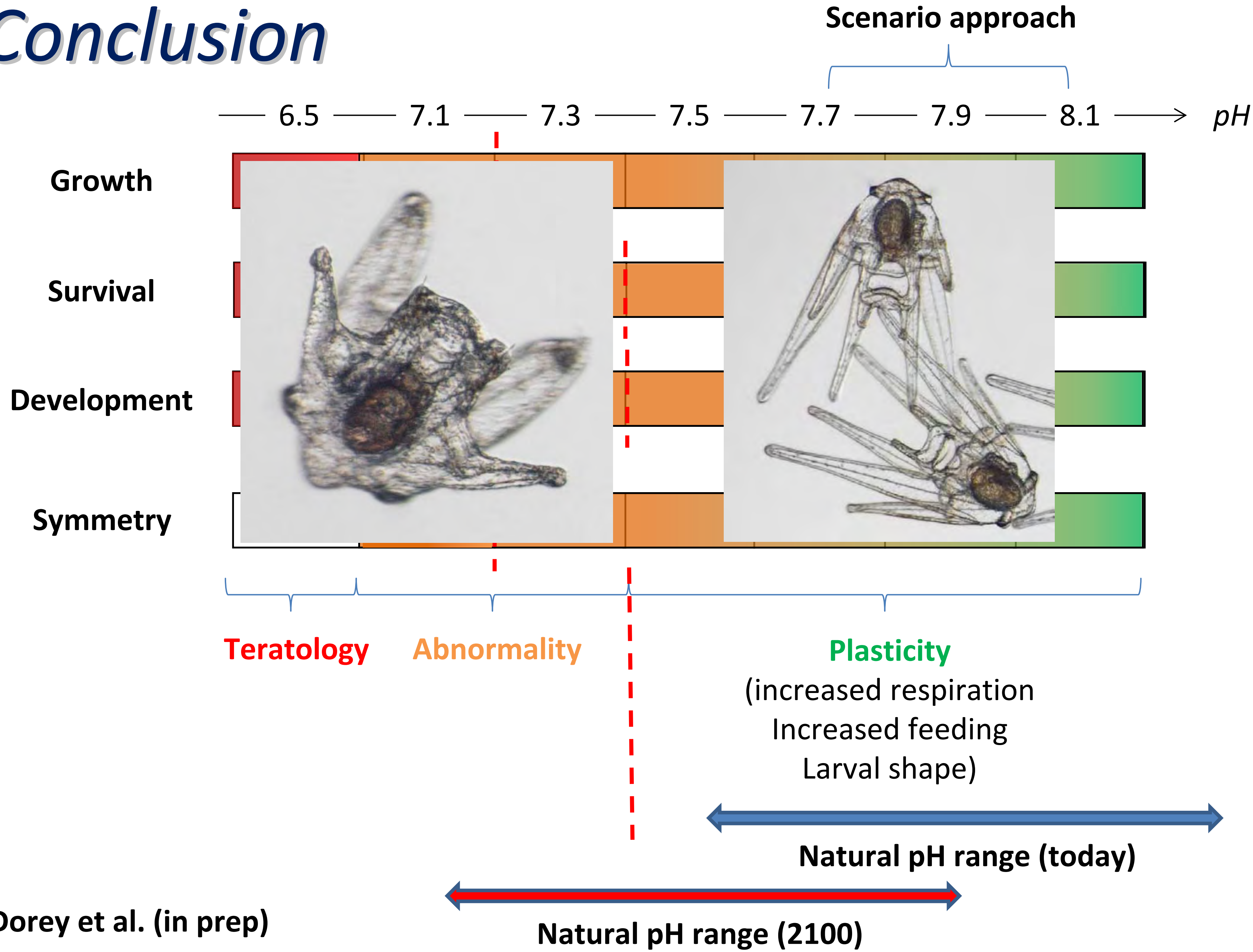




Asymmetry of the ALM at lowest pH



Conclusion



Dorey et al. (in prep)

Conclusion

PNAS

PERSPECTIVE

Embryo stability and vulnerability in an always changing world

Amro Hamdoun and David Epel
Hopkins Marine Station of Stanford University, Pacific Grove, CA 93950

Edited by Ryuzo Yanagimachi, University of Hawaii, Honolulu, HI, and approved December 2, 2006 (received for review November 14, 2006)

Contrary to the view that embryos and larvae are the most fragile stages of life, development is stable under real-world conditions. Early cleavage embryos are prepared for environmental vagaries by having high levels of cellular defenses already present in the egg before fertilization. Later in development, adaptive responses to the environment either buffer stress or produce alternative developmental phenotypes. These buffers, defenses, and alternative pathways set physiological limits for development under expected conditions; teratology occurs when embryos encounter unexpected environmental changes and when stress exceeds these limits. Of concern is that rapid anthropogenic changes to the environment are beyond the range of these protective mechanisms.

Larvae are tough…

… but have limits…

… and do not like the unexpected