Sam Dupont
Researcher, Associate Professor
University of Gothenburg

杜邦憲
Assistant Professor
University of Hong Kong

Visiting scholar
University of California, Berkeley

What scenarios shall we test?

GÖTEBORGS UNIVERSITET

Part 2: Experimental design of perturbation experiments

3 Atmospheric CO_2 targets for ocean acidification perturbation experiments

James P. Barry[1], Toby Tyrrell[2], Lina Hansson[3,4], Gian-Kasper Plattner[5] and Jean-Pierre Gattuso[3,4]

[1]Monterey Bay Aquarium Research Institute, USA
[2]National Oceanography Centre, University of Southampton, UK
[3]Laboratoire d'Océanographie, CNRS, France
[4]Observatoire Océanologique, Université Pierre et Marie Curie-Paris 6, France
[5]Climate and Environmental Physics, University of Bern, Switzerland

Table 3.3 Key $p(CO_2)_{atm}$ values (ppm) for ocean acidification studies. These $(CO_2)_{atm}$ levels are useful guidelines for perturbation experiments, and can be supplemented with other values of importance for specific studies, such as higher values for evaluating animal performance, or adjustments to correspond to key carbonate system values (e.g. Ω_a or Ω_c ~1).

# of Treatments	Recommended $p(CO_2)_{atm}$ levels
2	present-day (~385), 750
3	280, present-day, 750
4	280, present-day, 550, 750
6	280, present-day, 550, 650, 750, 1000
8	180, 280, present-day, 450, 550, 650, 750, 1000
>8	Add values (e.g. 350, other) to increase resolution

The only thing constantly changing is change and it comes equipped with a curse

Different source of variability

Sources of acidification and variability

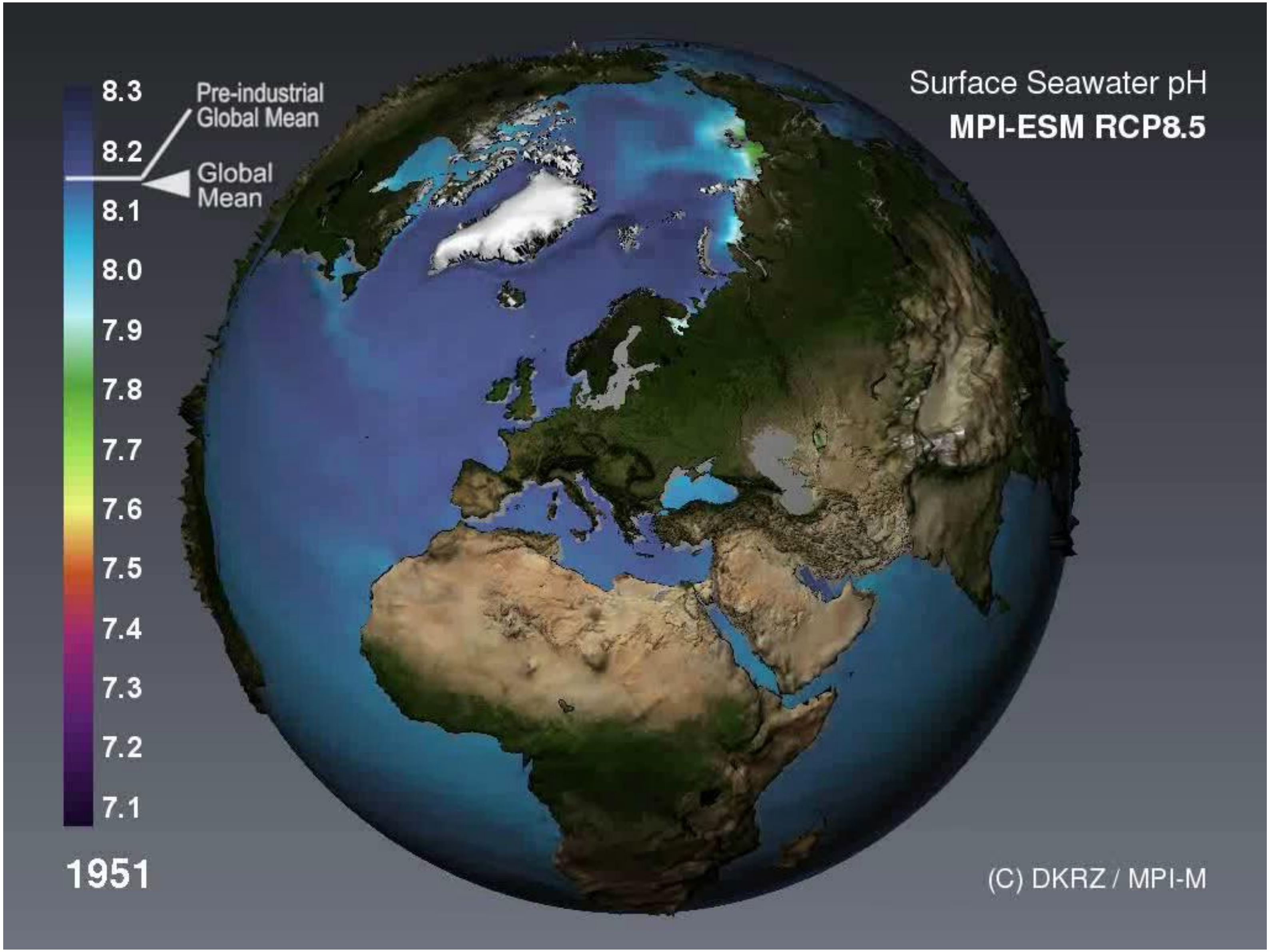
1 - Spatial + microhabitats

2 - Temporal

Sources of acidification and variability

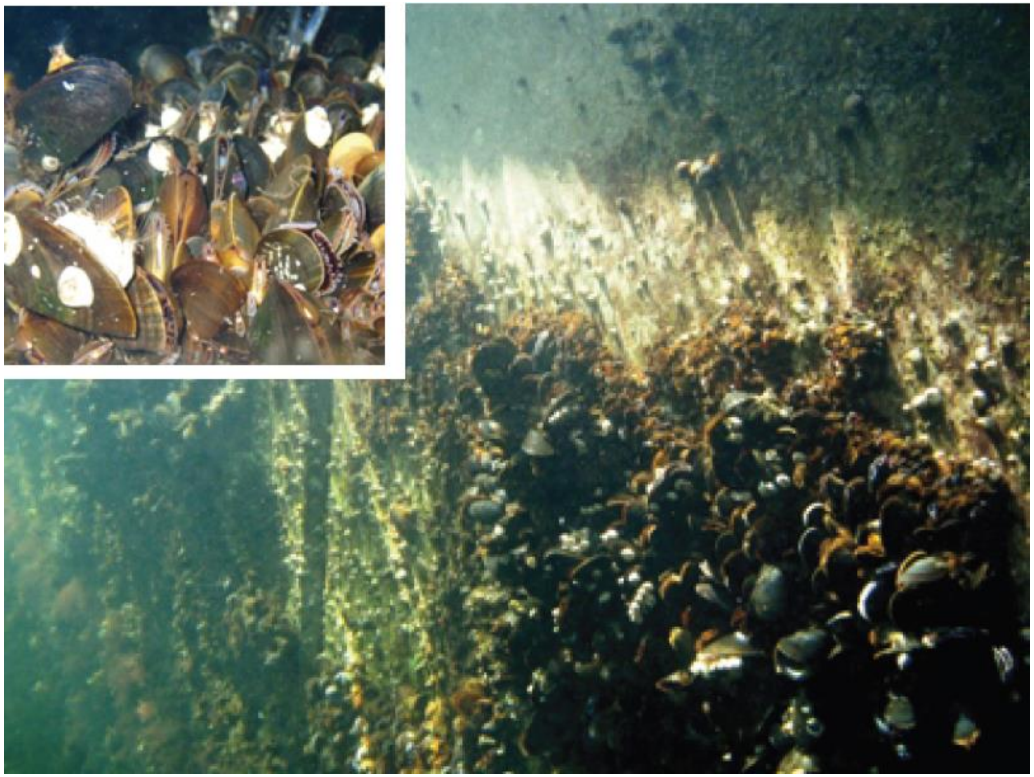
- *Mixing*
- *Biology*
- *Interaction with other parameters (e.g. temperature, salinity)*
- *Other sources (e.g. SOx/NOx)*
- *Etc.*

1. Spatial



8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
Pre-industrial Global Mean
Global Mean
1951
Surface Seawater pH
MPI-ESM RCP8.5
(C) DKRZ / MPI-M

1. Spatial



pH 7.5, Ωara=0.35

(Thomsen et al. 2010)

1. Spatial

pH 5.36, Ωara=0.01

(Tunnicliffe et al. 2009)

GÖTEBORGS UNIVERSITET

1. Microhabitat

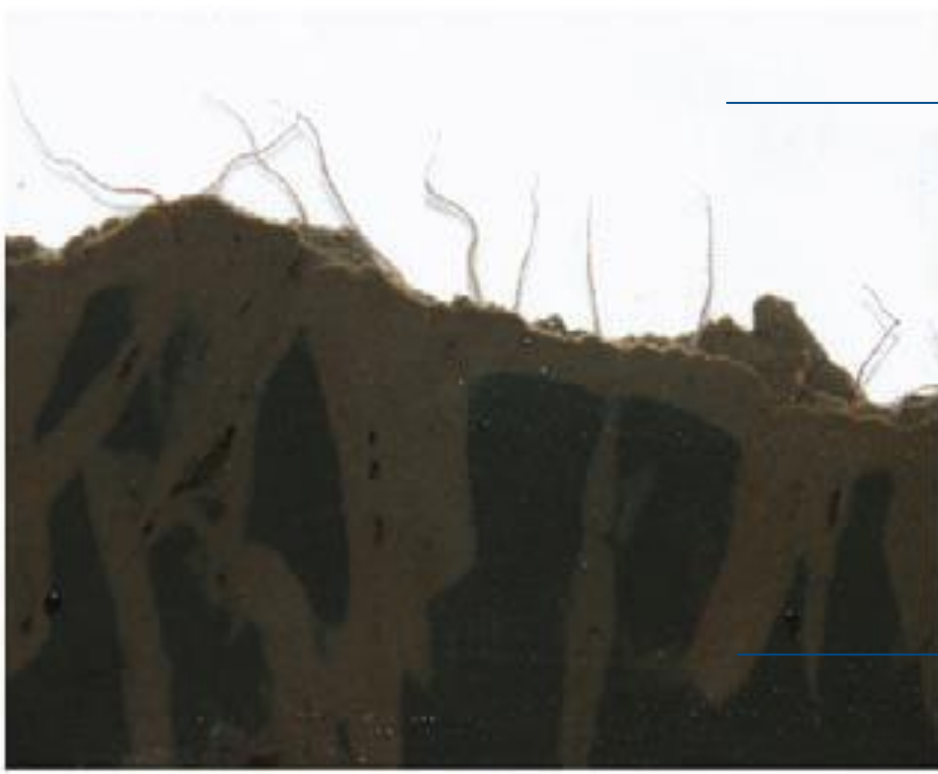
© 2014. Published by The Company of Biologists Ltd | The Journal of Experimental Biology (2014) 217, 2411-2421 doi:10.1242/jeb.100024

THE COMPANY OF Biologists

RESEARCH ARTICLE

Energy metabolism and regeneration are impaired by seawater acidification in the infaunal brittlestar *Amphiura filiformis*

Marian Y. Hu[1,2,*], Isabel Casties[1], Meike Stumpp[1,2], Olga Ortega-Martinez[1] and Sam Dupont[1]



250 mmol O_2
pH 8.00

50 mmol O_2
pH 7.67

“It's evolution, baby
Do the evolution
Come on, come on,
come on”

1. Spatial

Q? What is the impact of GW on bears

<u>Two scenarios</u>:
- present (15C)
- future   (18C)

Conclusion: impact on bears is species-specific

GÖTEBORGS UNIVERSITET

Ocean acidification thresholds

Equilibrium

<u>Temperature</u>

Ice <-> water

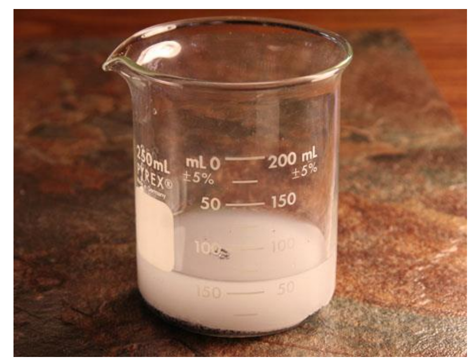
-

+

0° C

<u>Saturation states</u>

$CaCO_3 \leftrightarrow Ca^{++} + CO_3^{--}$



>1 <1

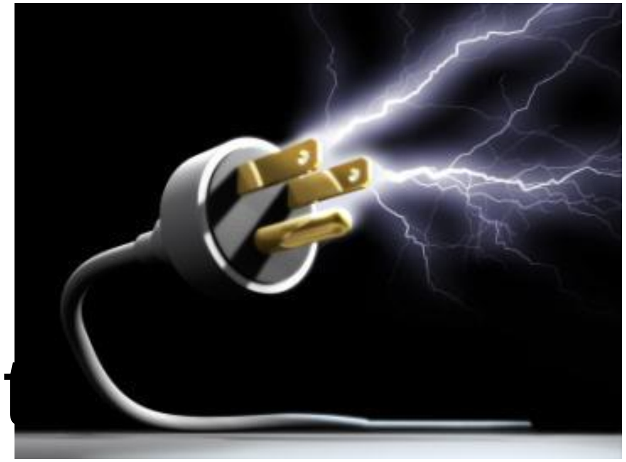
1

GÖTEBORGS UNIVERSITET

How to make ice at > 0° C?

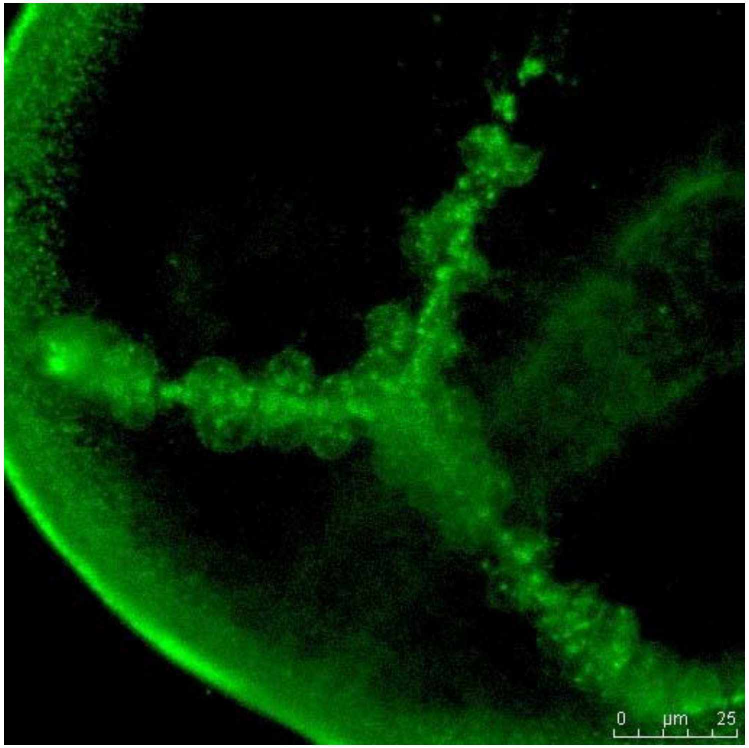
A freezer

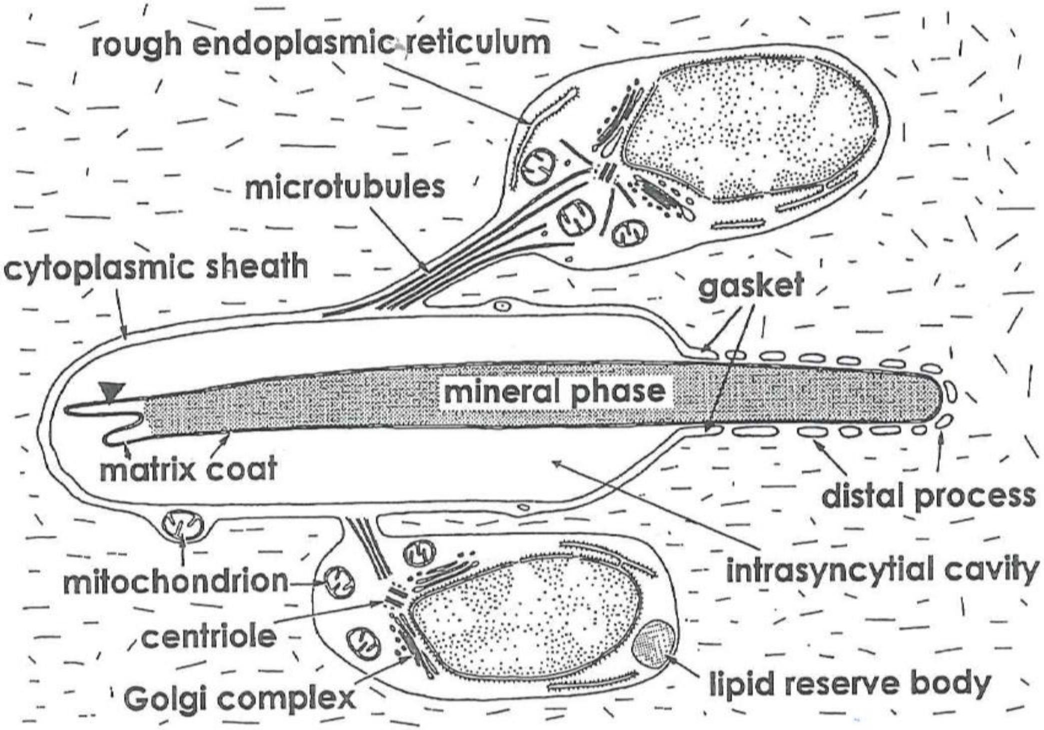
Energy cost



How to make $CaCO_3$ at Ω<1

Ω>1 at the calcification site





(Markel et al. 1986)

GÖTEBORGS UNIVERSITET

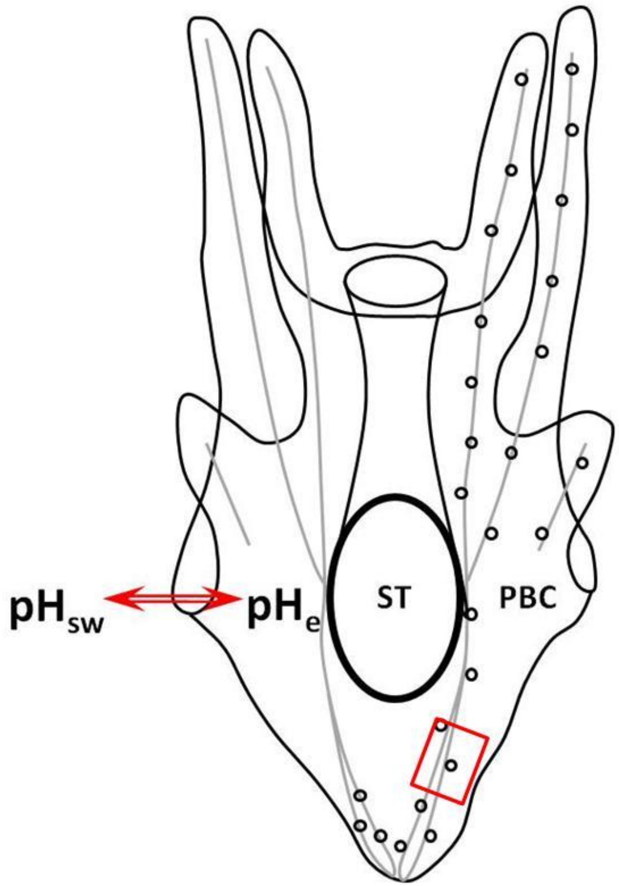
PNAS

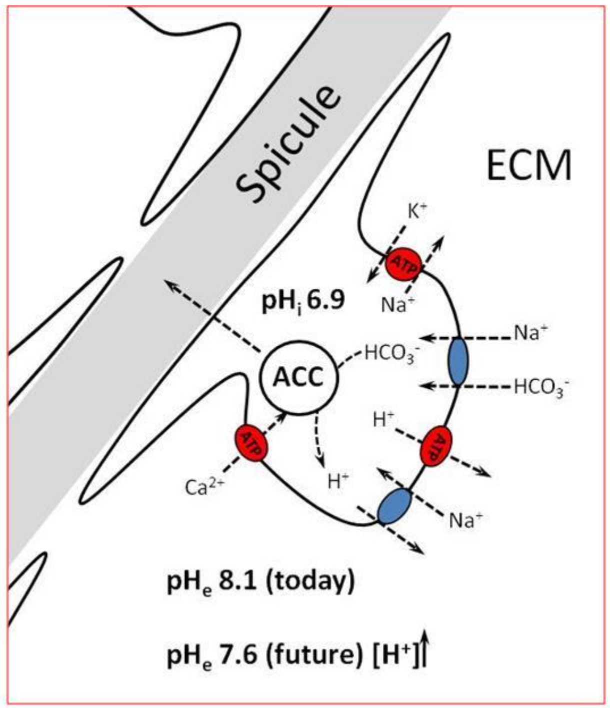
Acidified seawater impacts sea urchin larvae pH regulatory systems relevant for calcification

Meike Stumpp[a,b,c,1], Marian Y. Hu[a,b,c,1], Frank Melzner[b], Magdalena A. Gutowska[a,b], Narimane Dorey[c], Nina Himmerkus[a], Wiebke C. Holtmann[a], Sam T. Dupont[c], Michael C. Thorndyke[c], and Markus Bleich[a,2]

[a]Institute of Physiology, Christian Albrechts University Kiel, 24098 Kiel, Germany; [b]Helmholtz Centre for Ocean Research Kiel (GEOMAR), 24105 Kiel, Germany; and [c]Department of Biological and Environmental Sciences, The Sven Lovén Centre for Marine Science, University of Gothenburg, Kristineberg, 45178 Fiskebäckskil, Sweden

Edited by George N. Somero, Stanford University, Pacific Grove, CA, and approved September 19, 2012 (received for review June 22, 2012)





<u>pH 7.6 vs. pH 8.1</u>

↑ Energetic costs

↓ Energy for growth and development

↓ Juvenile energy reserves

- **No pHe regulation**
- **pHi regulation**
- **Role of HCO3$^-$, H$^+$-pumps**
- **Extra costs**

PERGAMON

Energy Conversion and Management 43 (2002) 845–854

ENERGY CONVERSION & MANAGEMENT

www.elsevier.com/locate/enconman

Role of ambient temperature, door opening, thermostat setting position and their combined effect on refrigerator-freezer energy consumption

R. Saidur *, H.H. Masjuki, I.A. Choudhury

Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

Received 24 October 2000; accepted 19 March 2001

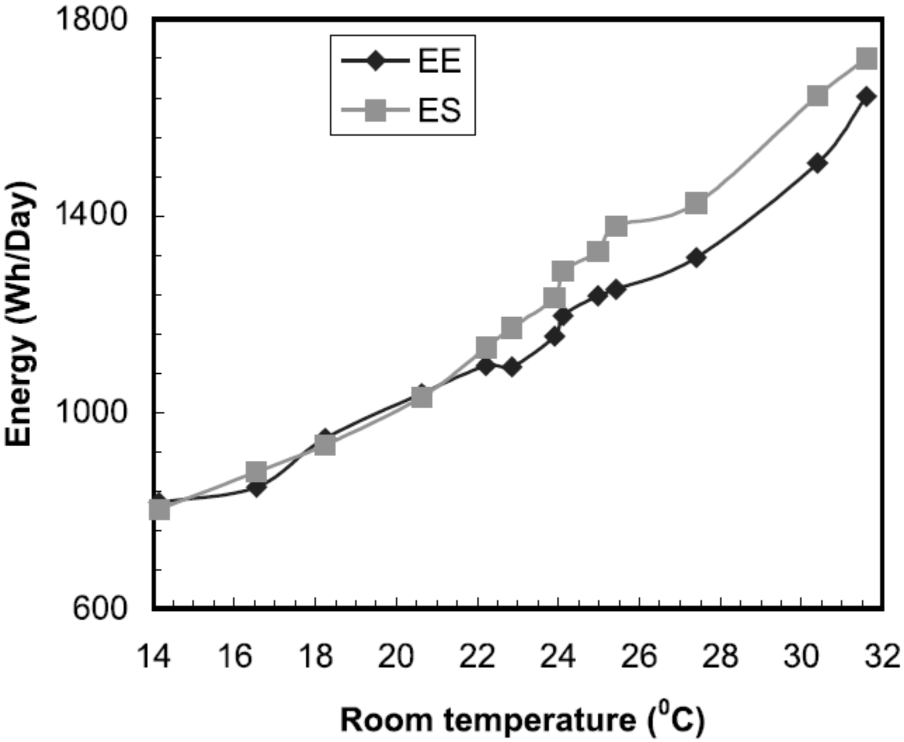
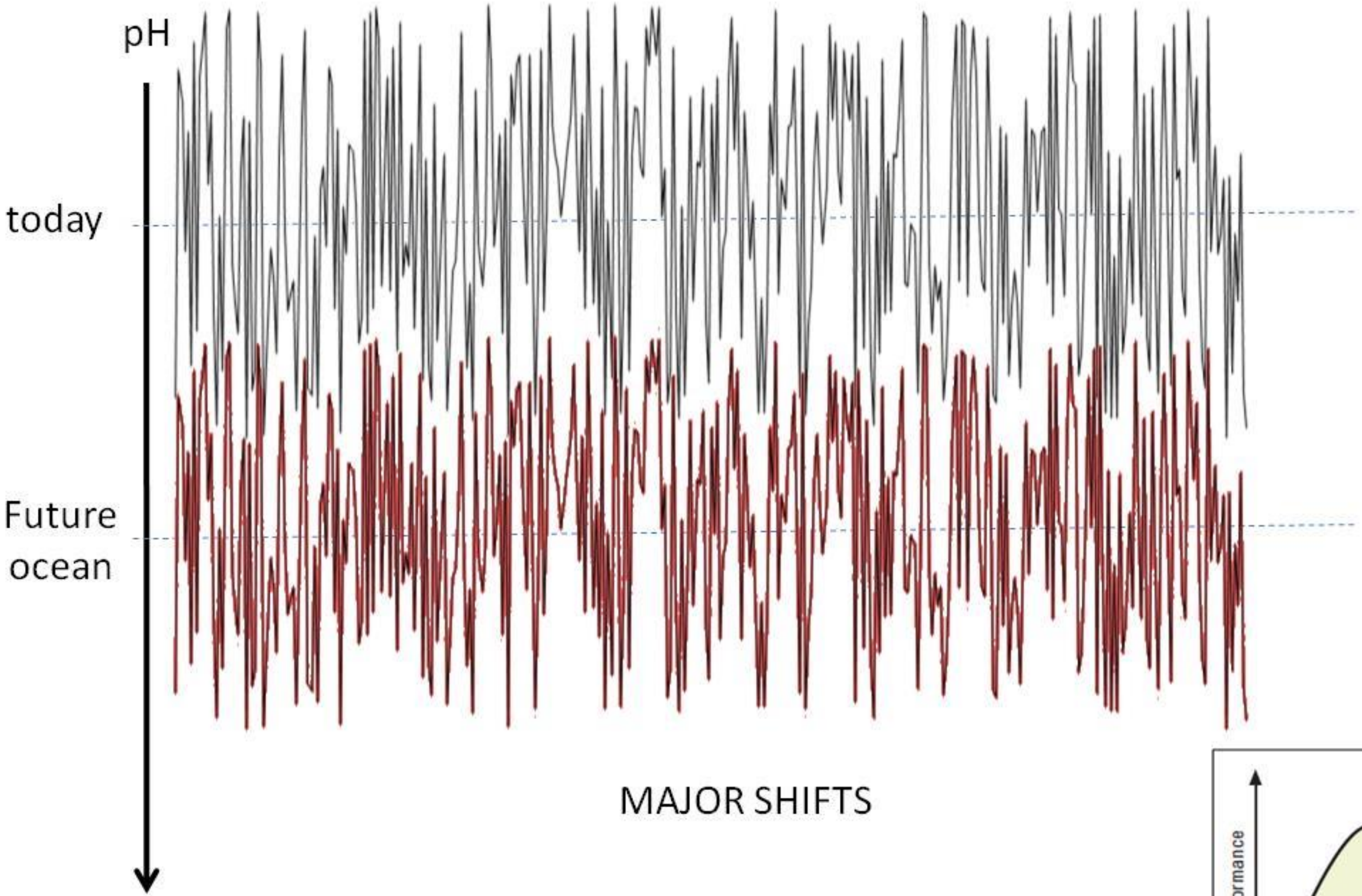
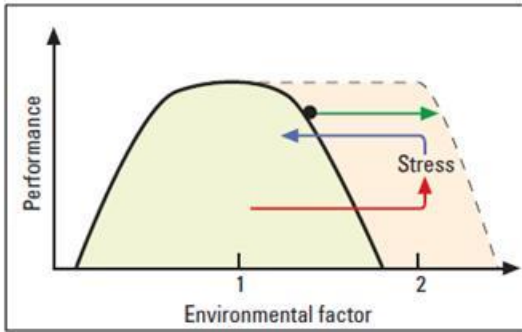


Fig. 1. Variation of energy consumption with room temperature.

Higher temperature = higher cost

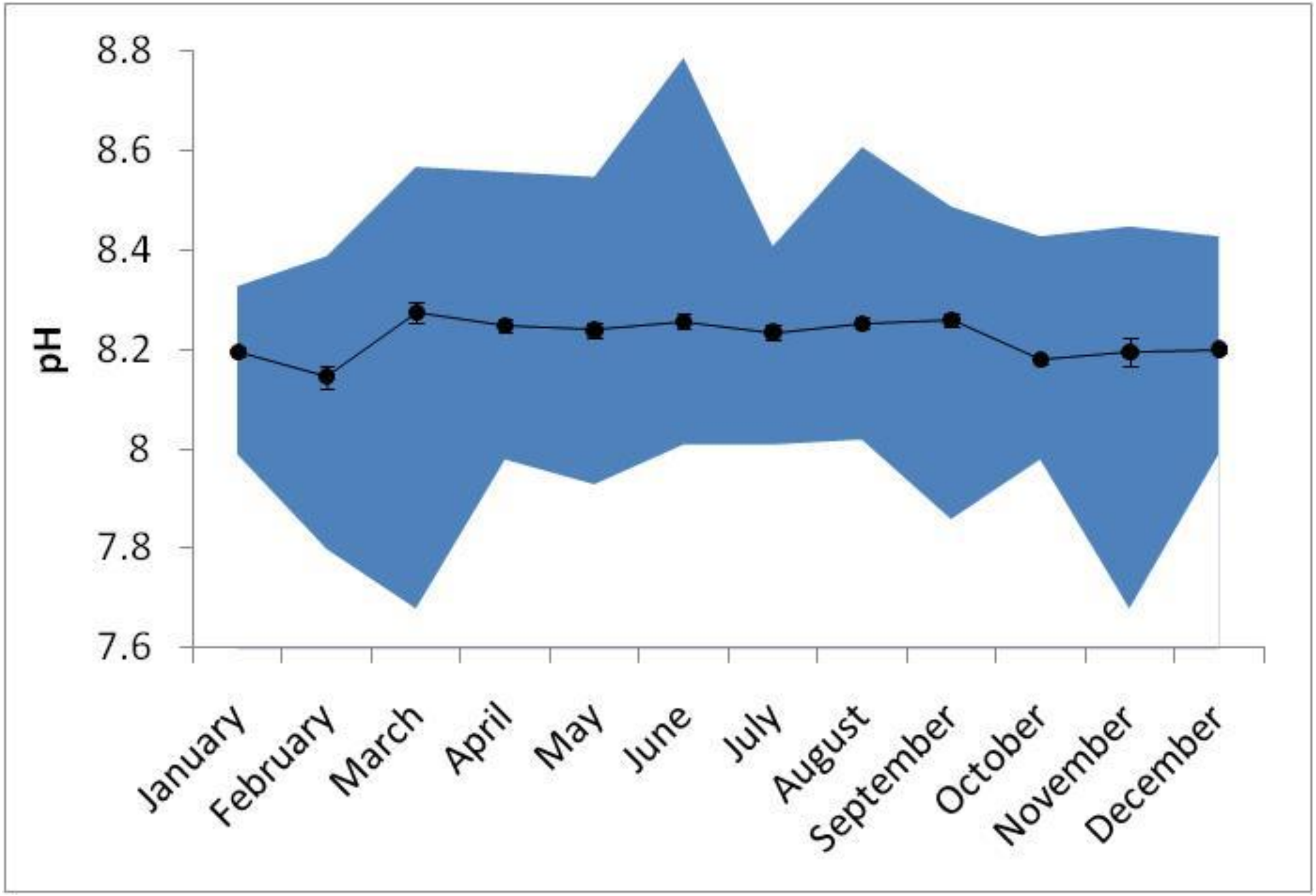
2. Temporal





Not 1 control and 1 scenario

pH variability – in time

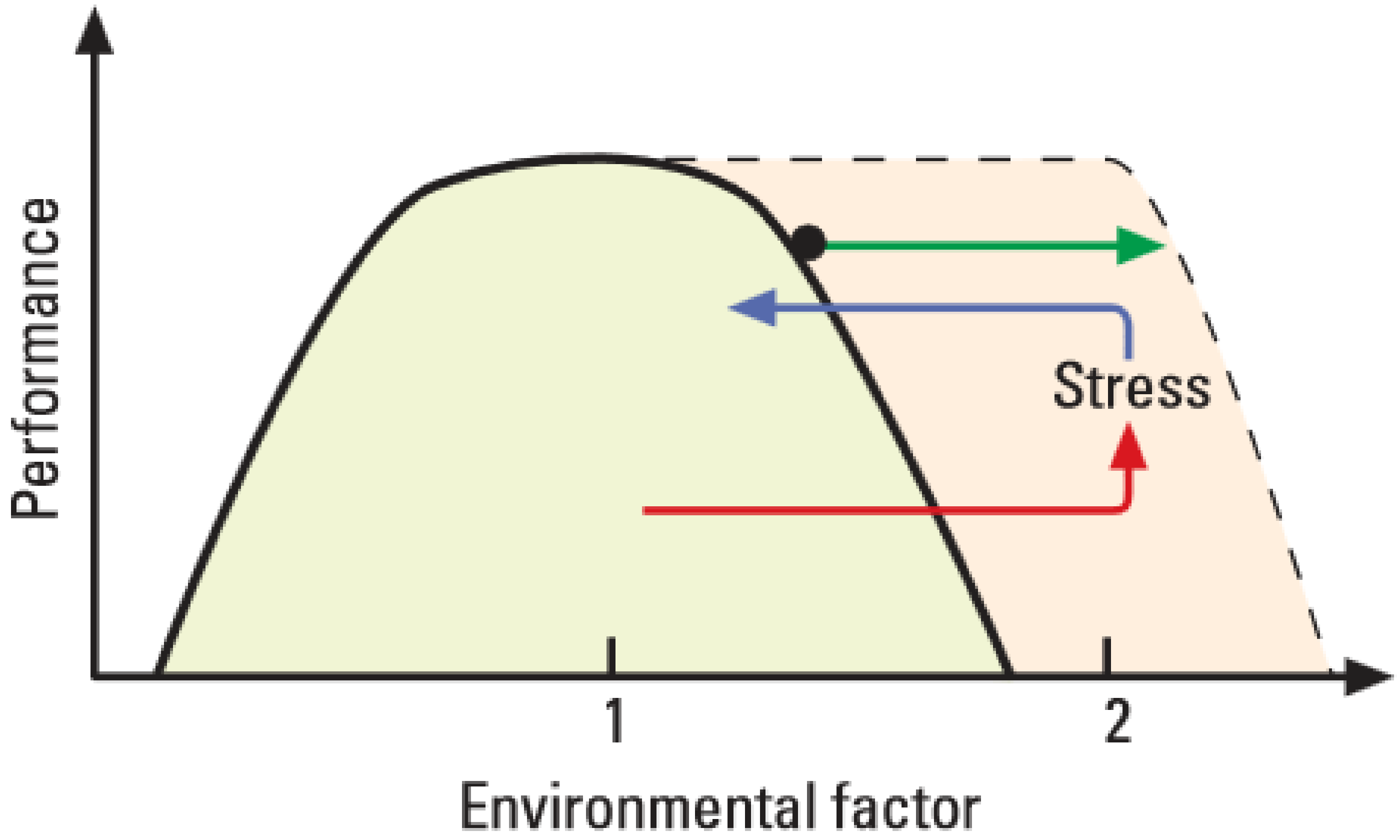


(Dorey et al. 2013)

GÖTEBORGS UNIVERSITET

“It's evolution, baby
Do the evolution
Come on, come on, come on”

Stress ecology



(Van Straalen 2007)

Need to understand the biology of your species

Plasticity vs stress

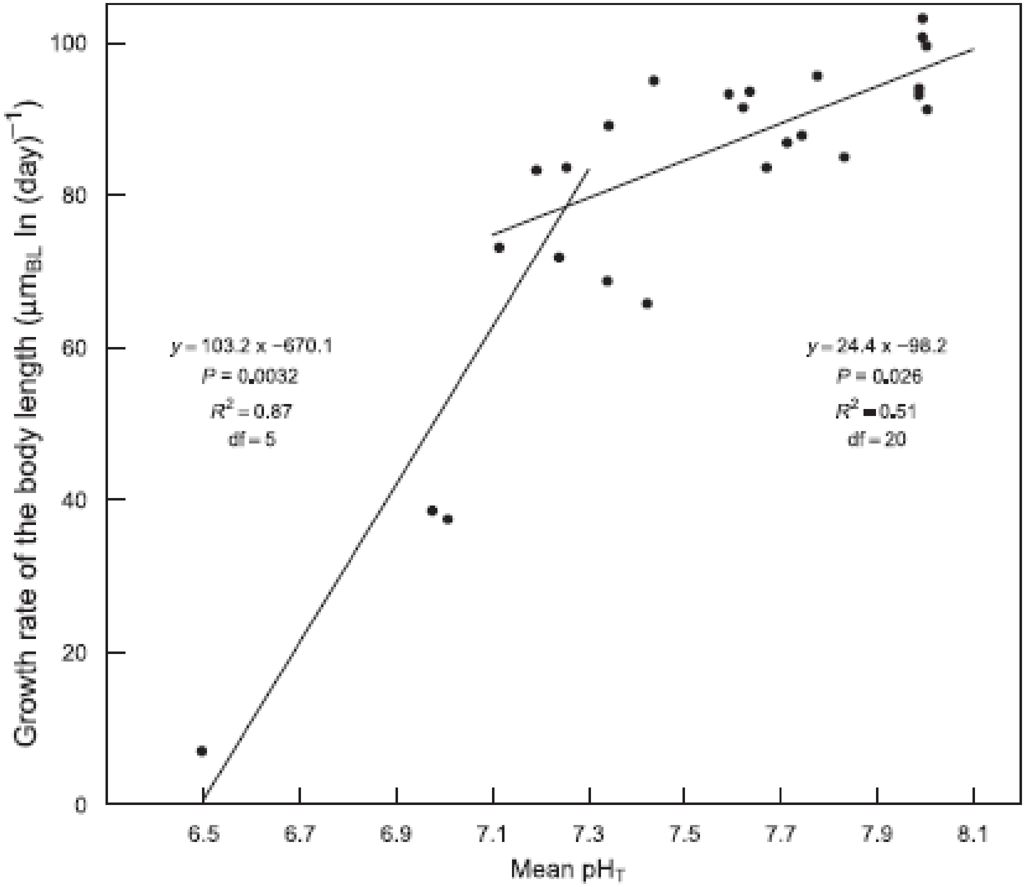
Global Change Biology

Global Change Biology (2013), doi: 10.1111/gcb.12276

Assessing physiological tipping point of sea urchin larvae exposed to a broad range of pH

NARIMANE DOREY*, PAULINE LANÇON*, MIKE THORNDYKE† and SAM DUPONT*

*Department of Biological and Environmental Sciences, The Sven Lovén Centre for Marine Sciences – Kristineberg, University of Gothenburg, Fiskebäckskil 45178, Sweden, †The Royal Swedish Academy of Sciences, The Sven Lovén Centre for Marine Sciences – Kristineberg, Fiskebäckskil 45178, Sweden



Physiological tipping point reached when out of present range of variability

Plasticity vs stress

GÖTEBORGS UNIVERSITET

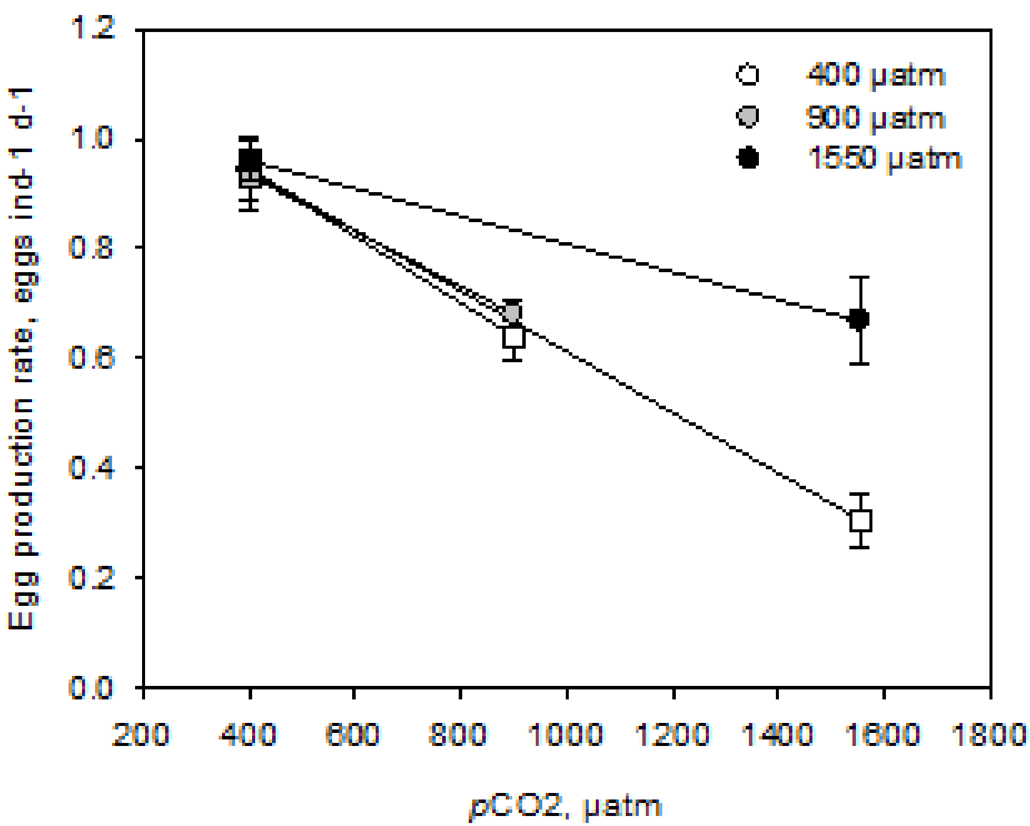
Global Change Biology

Global Change Biology (2015), doi: 10.1111/gcb.12815

Transgenerational effects alleviate severe fecundity loss during ocean acidification in a ubiquitous planktonic copepod

PETER THOR[1] and SAM DUPONT[2]

[1]Norwegian Polar Institute, Fram Centre, 9296 Tromsø, Norway, [2]Department of Biological and Environmental Sciences, University of Gothenburg, 566 Kristineberg, 45178 Fiskebäckskil, Sweden

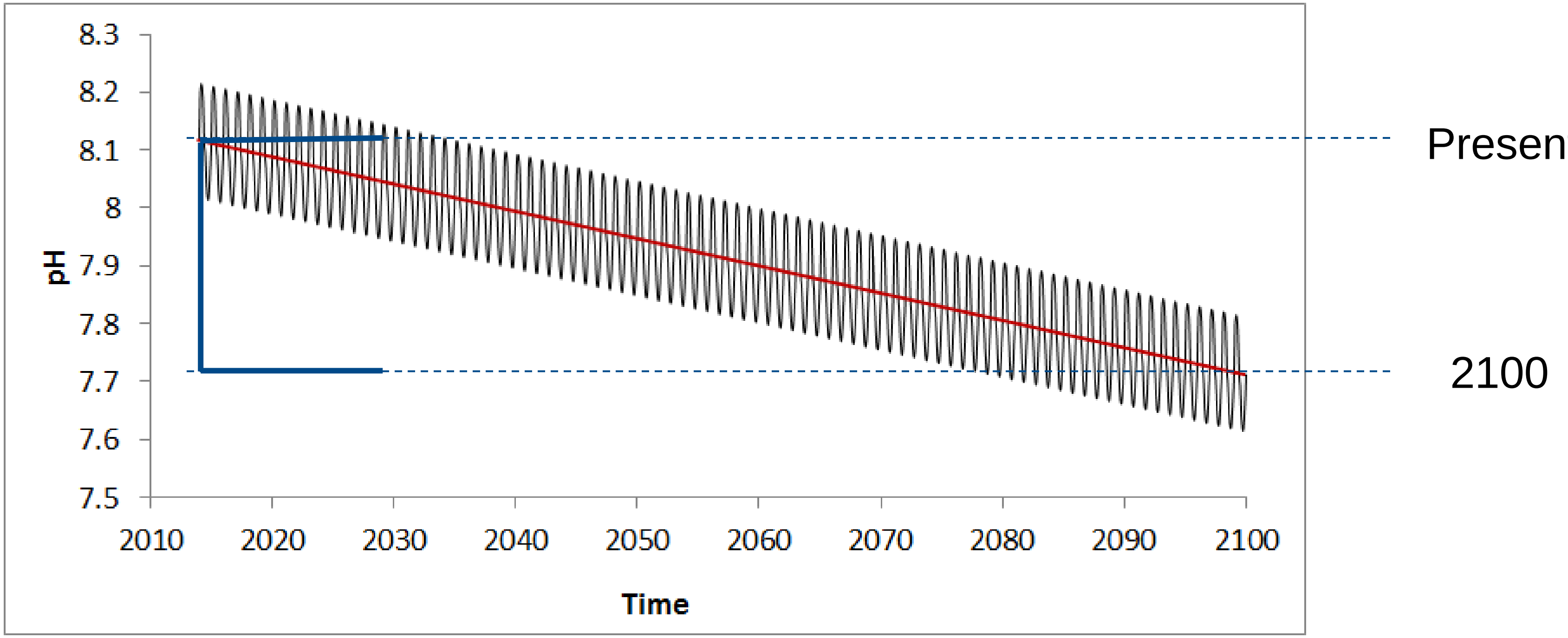


Present range -> plasticity

Out of present range -> evolution (buffering)

GÖTEBORGS UNIVERSITET

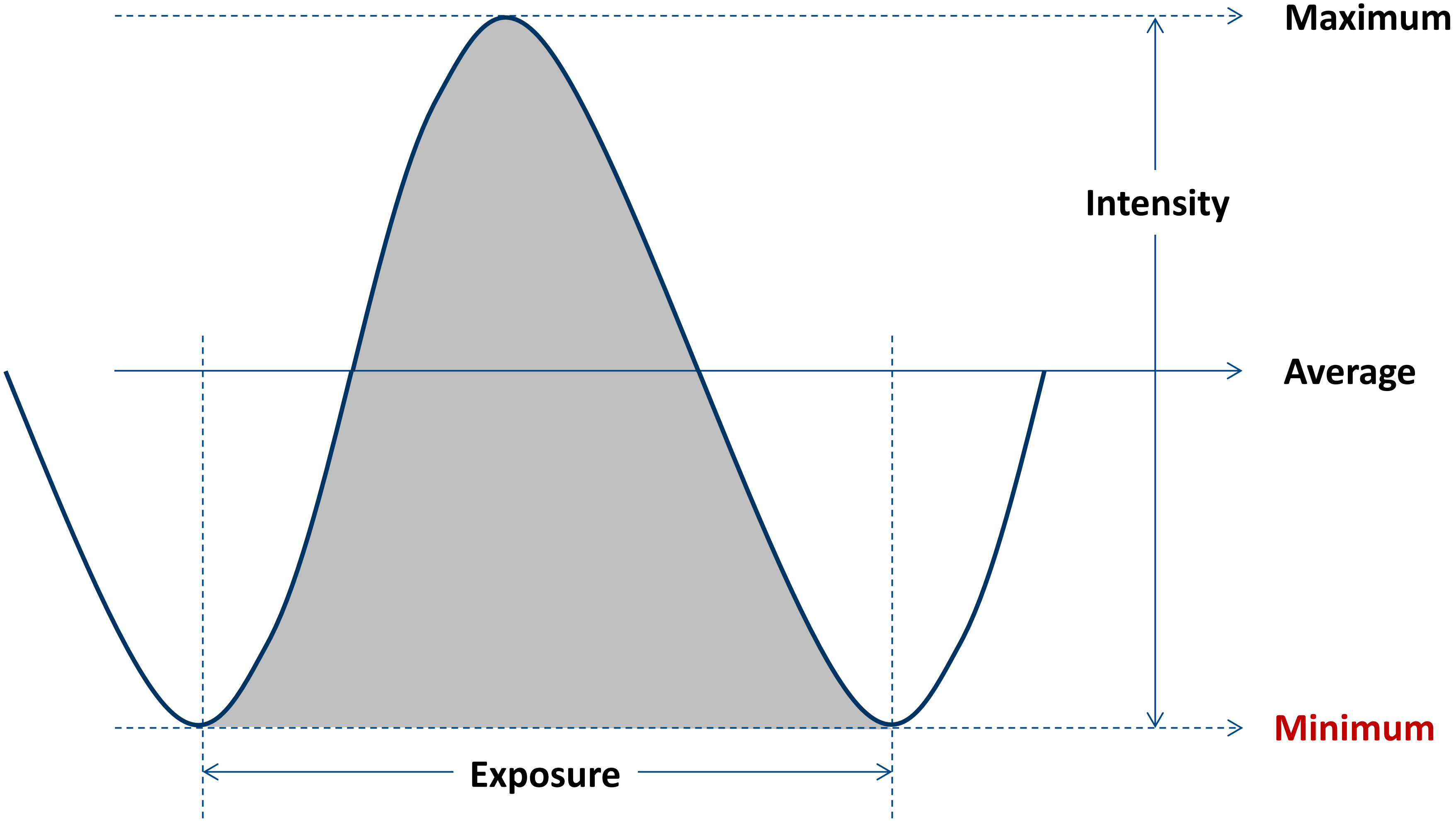
Other important aspects



Abrupt vs. Gradual changes

Soft vs hard selection

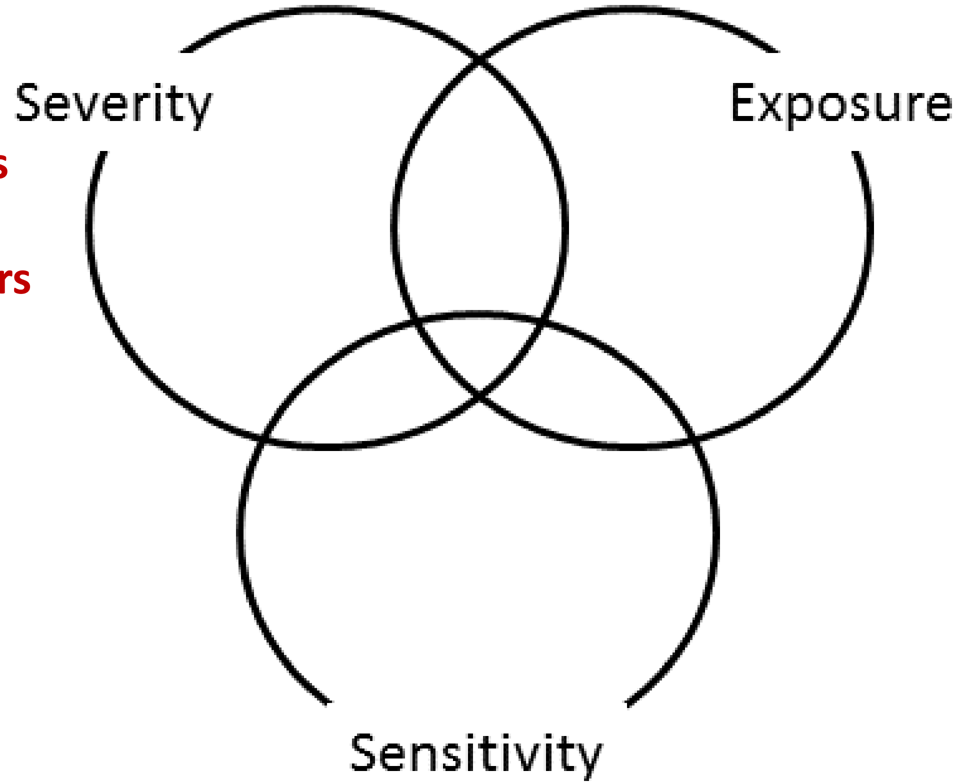
Variability as a selective force



What does matter?

GÖTEBORGS UNIVERSITET

What is a stress(or)?



Local differences
Multistressor
Modulating factors

A fluctuating environment

Each species is different

All species have a tipping point…

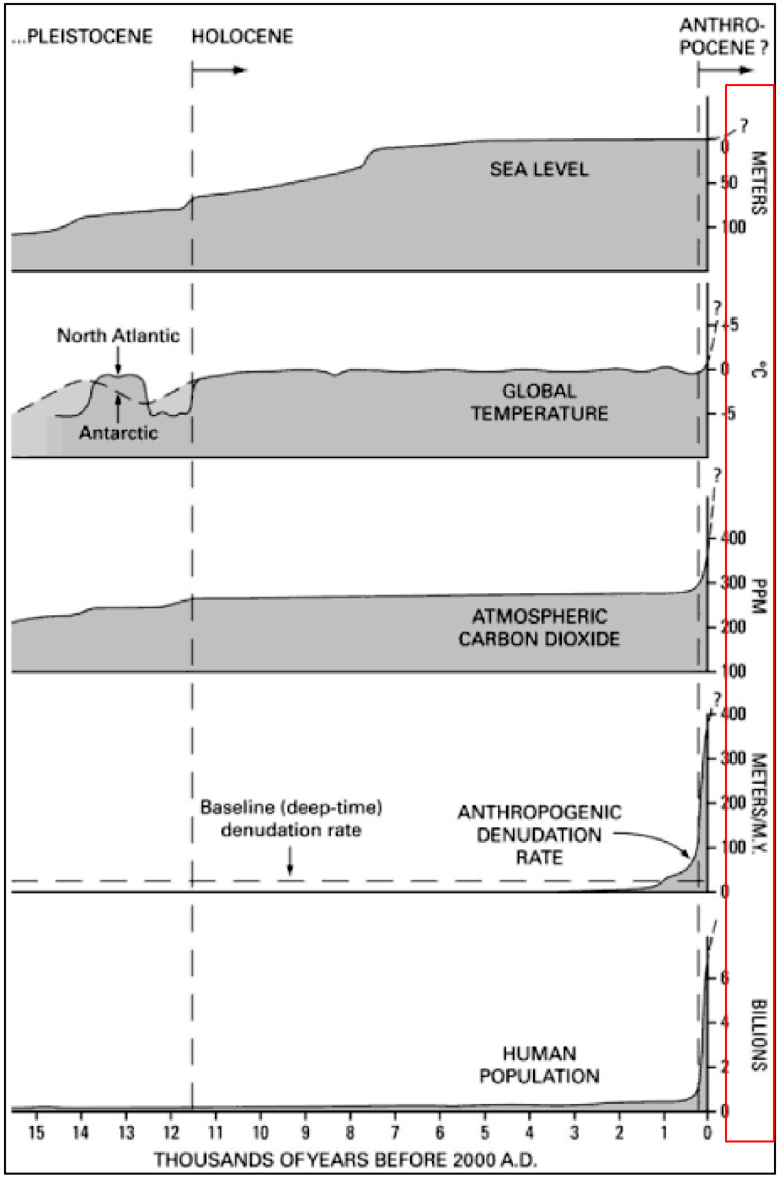
Different source of variability

NEVER 1 control vs 1 treatment

Take species niche & variability into your thinking

Be creative with your design to focus on your question

Global and local changes



Global increase of human population and a high CO_2 world

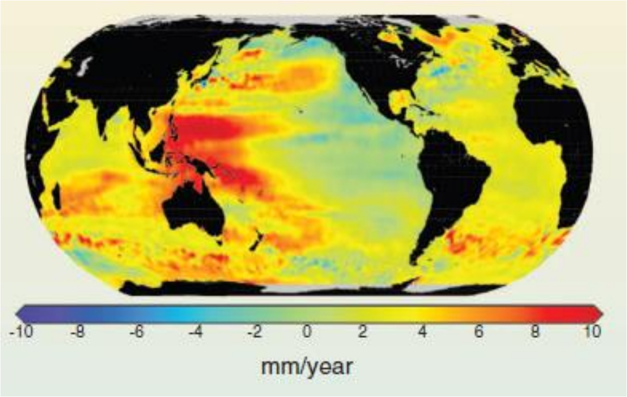
- Global warming
- Ocean acidification
- Hypoxia
- Increased precipitation
- Increased catastrophic events

Local impacts including:

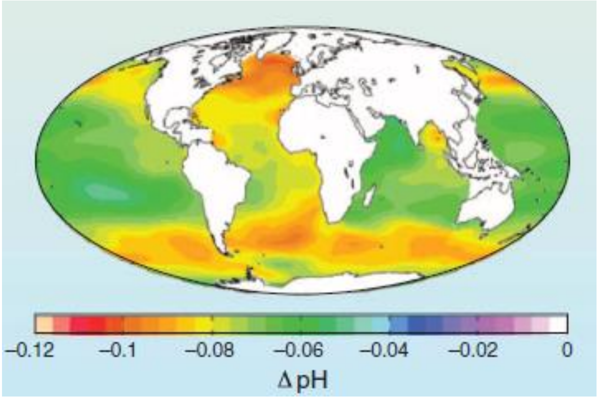
- habitat destruction
- over-exploitation of resources
- local pollution
- Introduction of species
- etc.

Zalasiewicz et al. 2008

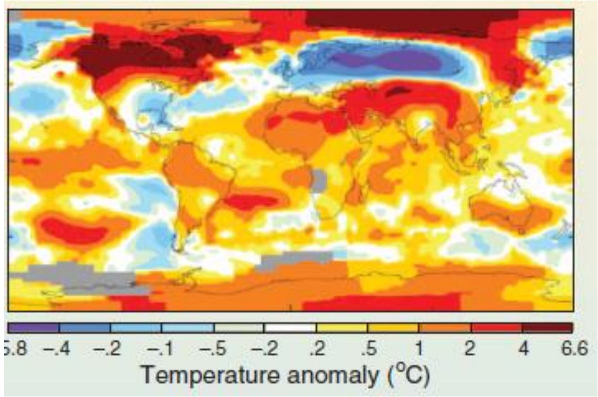
Not only pH…



Sea level rise



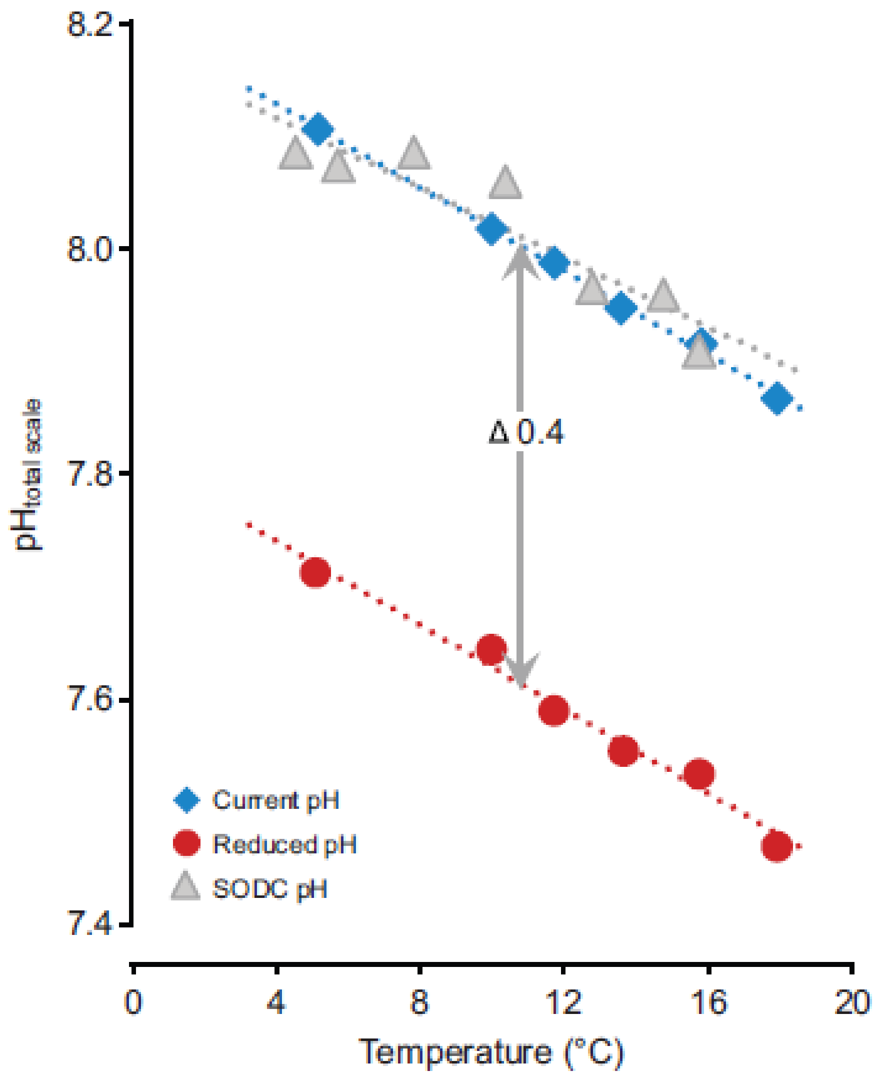
pH



Temperature

Hoegh-Guldberg & Bruno 2010 Science

Not only pH



(Grans et al. 2014)

GÖTEBORGS UNIVERSITET

TO BE CONTINUED...

Next episode:

How can we do that???