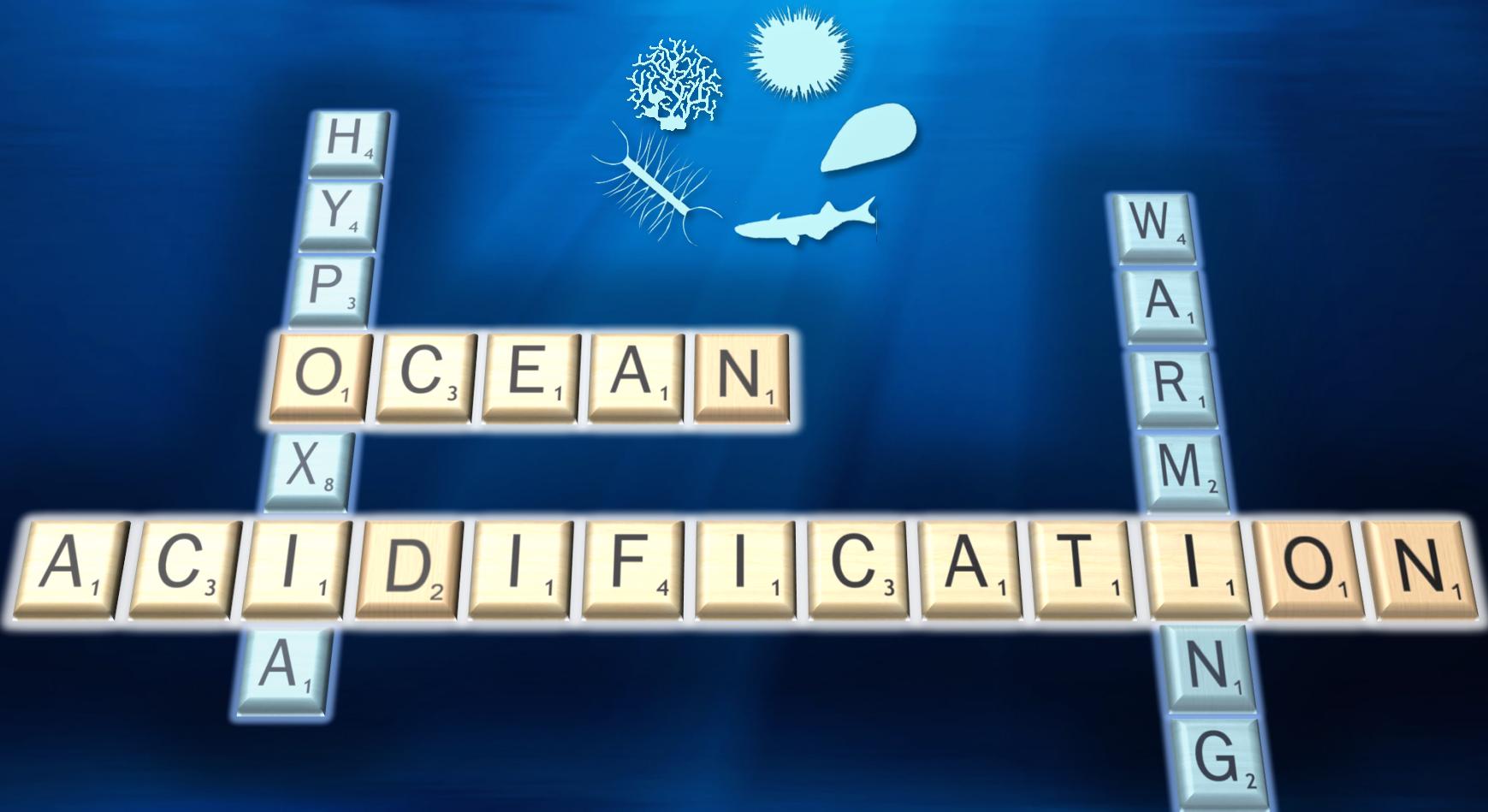


# **Responses of marine organisms to OA and co-stressors**



**Hannes Baumann**  
**University of Connecticut**

**Emily B. Rivest**  
**Virginia Institute of Marine Science**

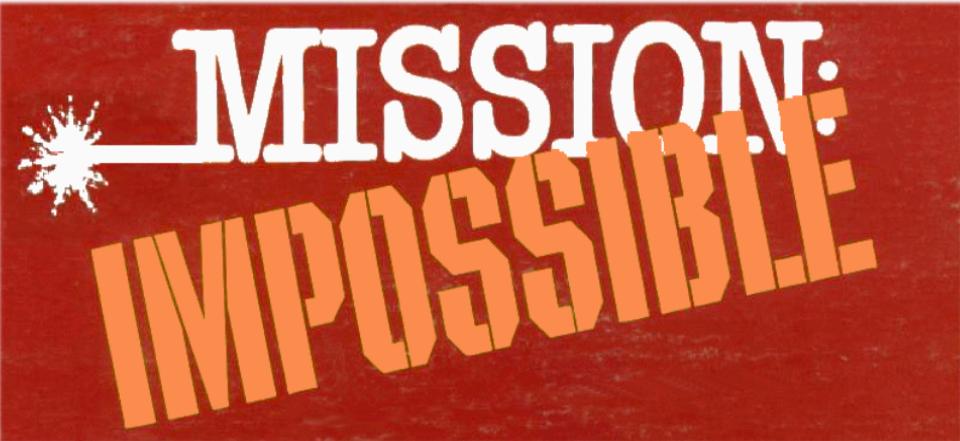


DONT WORRY

All  
is  
lost

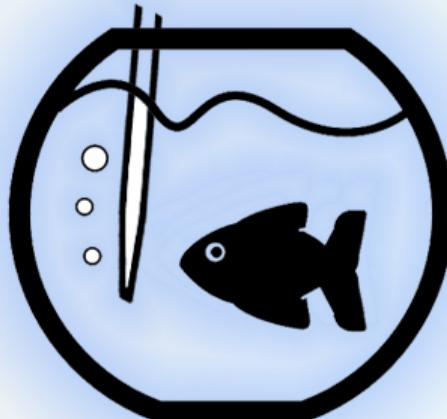


## Three strawmen

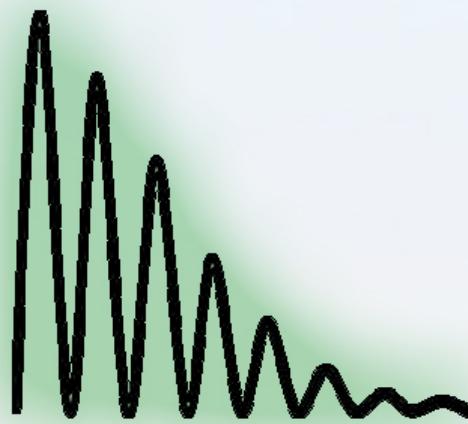


- NOT all is lost.
- There IS reason to worry.
- We HAVE some tools.

**Methods**



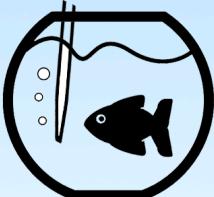
**Multistressors**



**Variability**



**Mechanisms**

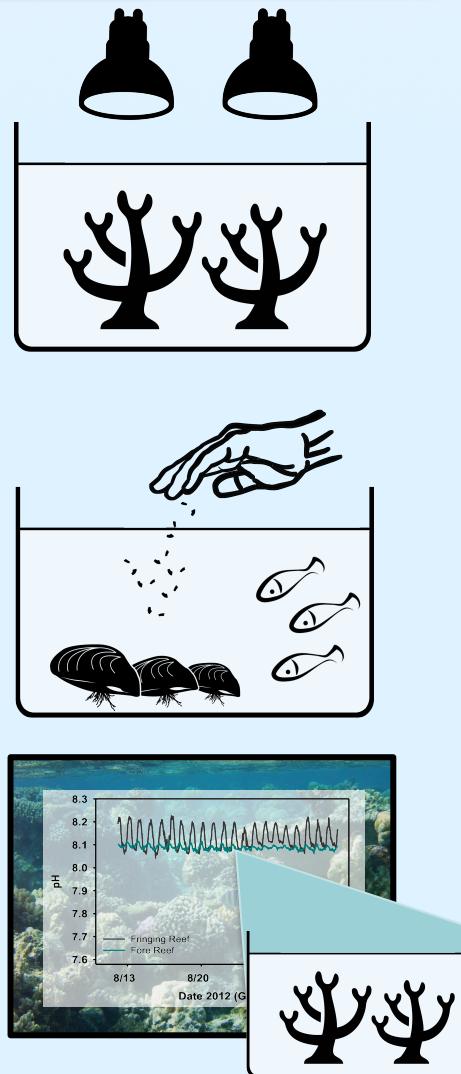


**Experiment(er)s got better.  
Identified co-stressors and  
confounding effects**

**Light alters CO<sub>2</sub>  
sensitivity in corals**

**Food levels alter CO<sub>2</sub>  
sensitivity in mussels  
and fish**

**Environmental context  
is important for  
experimental design**



## **Key papers**

**Randall & Tsui Mar Pol Bull 2002**

**Riebesell et al. Pub Europ Union 2011**

**Seibel et al. PLOS One 2012**

**Suggett et al. Coral Reefs 2013**

**Thomsen et al. Glob Change Biol 2013**

**Kroeker et al. Glob Change Biol 2013**

**McElhany & Busch Mar Biol 2013**

**Cornwall and Hurd ICES J Mar Sci 2015**

**Ramajo et al. Sci Rep 2016**

**Murray et al. ICES JMS 2017**

## Key papers

Hofmann et al. PLOS One 2011

Parker et al. Glob Change Biol 2012

Miller et al. Nat Clim Change 2012

Duarte et al. Est Coasts 2013

Kelly et al. Glob Change Biol 2013

Murray et al. MEPS 2014

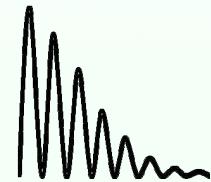
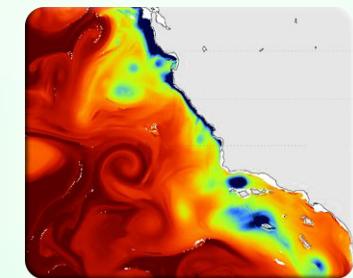
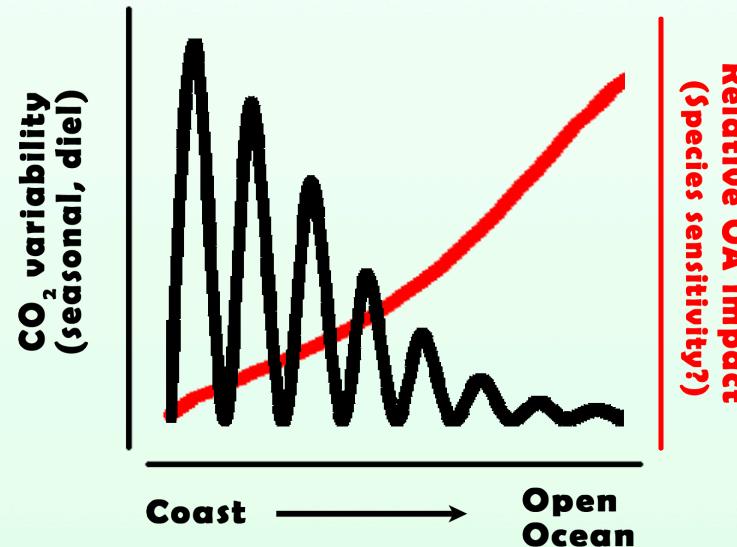
Munday F1000prime Reports 2014

Thor & Dupont Glob Change Biol 2015

Barkley et al. Sci Adv 2015

Rivest et al. Curr Clim Change Rep 2017

## Existing CO<sub>2</sub> variability matters. Winners & losers?



- CO<sub>2</sub> varies naturally in time and space
- Metabolic CO<sub>2</sub> fluctuations important
- Potential for local adaptation, acclimatization
  - intraspecific differences in CO<sub>2</sub> sensitivity
- Transgenerational plasticity likely, hence the parental environment matters



## OA is just one symptom of Marine Climate Change.

- **Warming**
- **Deoxygenation**
- **Acidification**



- **Byrne & Przeslawski: Additive negative effects most common (Temp × CO<sub>2</sub>)**
- **Harvey et al. 2013, Przeslawski et al. 2015: Synergistic interactions are most common (Temp × CO<sub>2</sub>)**
- **Early life stages are most susceptible.**

## Key papers

Pörtner et al J Geophys Res 2005

Darling & Cote Ecol Lett 2008

Harvey et al. Ecol Evol 2013

Byrne & Przeslawski ICB 2013

Kroeker et al. Glob Change Biol 2013

Ban et al. Glob Change Biol 2014

Wallace et al. Est Coast Shelf Sci 2014

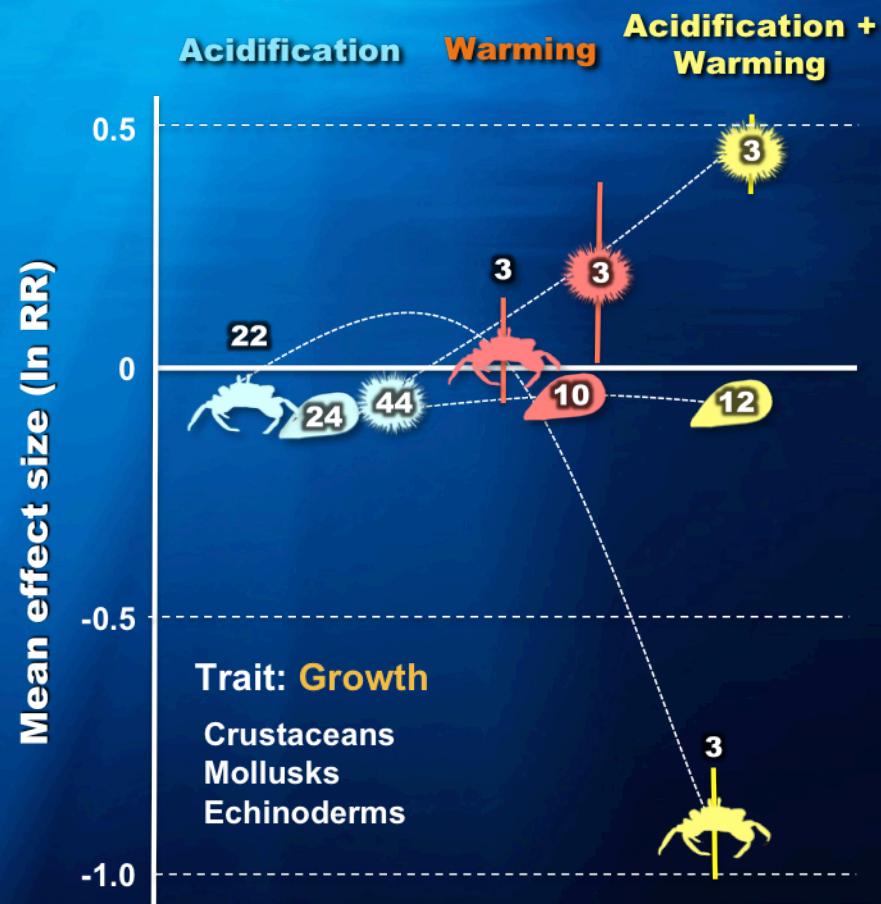
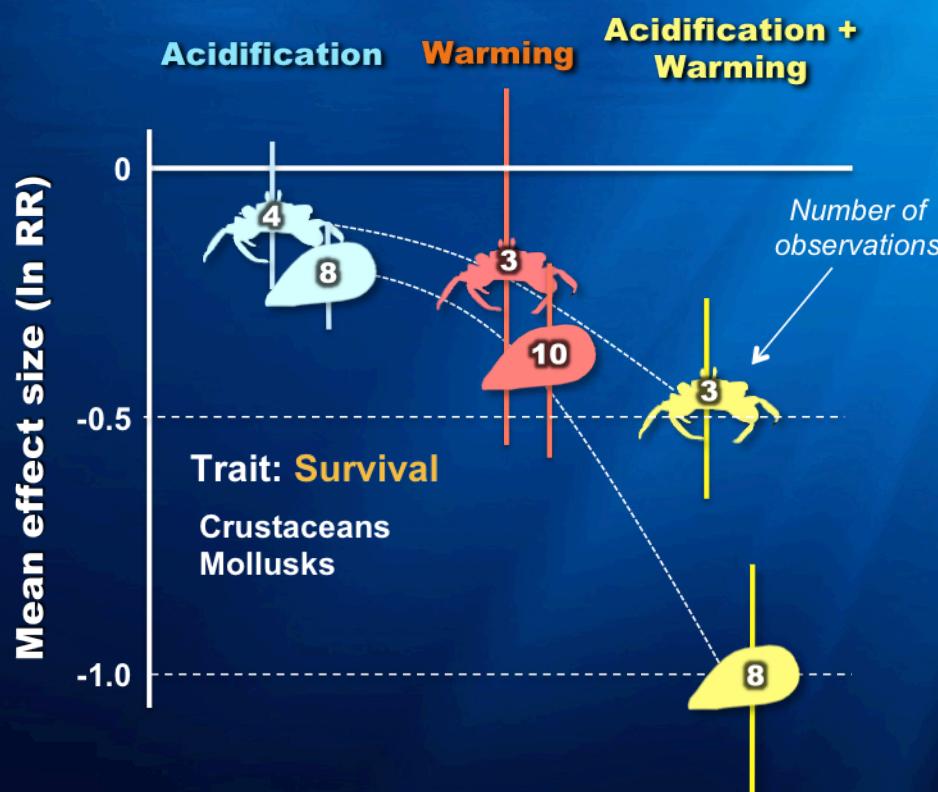
Przeslawski et al. Glob Change Biol 2015

Breitburg et al. Oceanography 2015

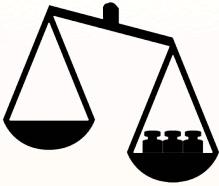
Gobler & Baumann Biol Lett 2016

# $\text{CO}_2 \times \text{temperature}$ : a meta-analysis

## Combining empirical data across studies



- Biological responses vary across taxa, stages, and trophic levels
- Combined stressors generally cause stronger (positive or negative) effects



## OA is just one symptom of Marine Climate Change.

- **Warming**
- **Deoxygenation**
- **Acidification**



- **Byrne & Przeslawski:** Additive negative effects most common ( $\text{Temp} \times \text{CO}_2$ )
- **Harvey et al. 2013, Przeslawski et al. 2015:** Synergistic interactions are most common ( $\text{Temp} \times \text{CO}_2$ )
- **Early life stages are most susceptible.**
- **OA is more stressful to calcifying than non-calcifying larvae**
- **Gobler & Baumann:**  $\text{CO}_2 \times \text{O}_2$  interactions mostly additive, some synergistic effects always found, scarce empirical evidence

## Key papers

**Pörtner et al J Geophys Res 2005**

**Darling & Cote Ecol Lett 2008**

**Harvey et al. Ecol Evol 2013**

**Byrne & Przeslawski ICB 2013**

**Kroeker et al. Glob Change Biol 2013**

**Ban et al. Glob Change Biol 2014**

**Wallace et al. Est Coast Shelf Sci 2014**

**Przeslawski et al. Glob Change Biol 2015**

**Breitburg et al. Oceanography 2015**

**Gobler & Baumann Biol Lett 2016**

## Key papers

Todgham & Hofmann  
JEB 2009

Crawley et al. Glob  
Change Biol 2010

Nilsson et al. Nat Clim  
Change 2012

Pörtner MEPS 2012

Bignami et al. PNAS  
2013

Waldbusser et al.  
Geophys Res Lett 2013

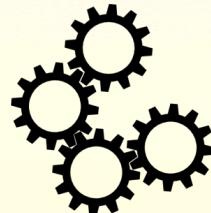
Waldbusser et al. Nat  
Clim Change 2015

Heuer & Grosell Am J  
Phys 2014, Sci Rep  
2016

Ern et al. Biol Lett 2017

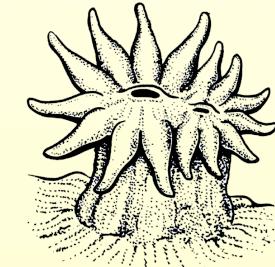
Esbaugh J Comp  
Physiol 2017

What does CO<sub>2</sub> actually do to  
organisms? Many answers.

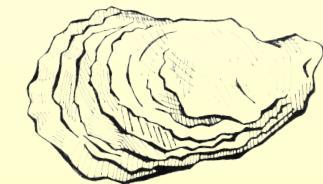


### Physiological frameworks

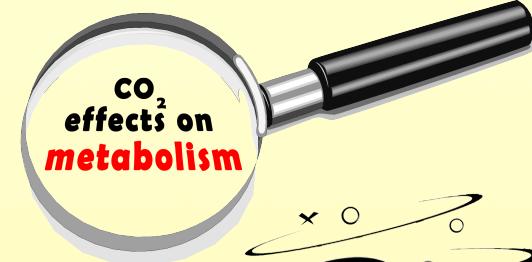
Coral pH up-regulation may  
counter OA effects



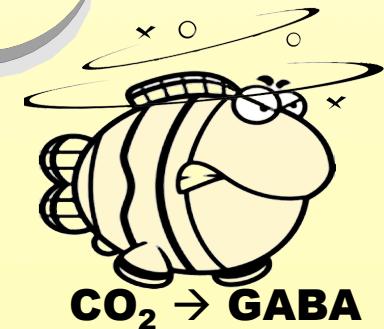
CO<sub>2</sub>? pH? Saturation state?  
What is the actual stressor  
for calcifiers?



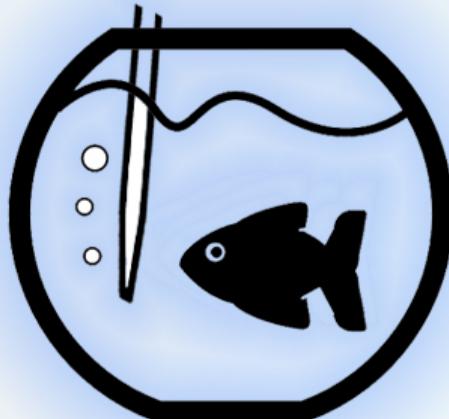
Insights into acid/  
base regulation in  
fish and other marine  
organisms



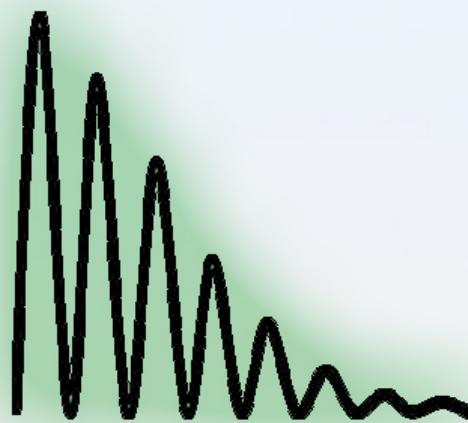
Inhibition of a  
neurotransmitter causes  
behavioral effects in fish



**Methods**



**Multistressors**



**Variability**



**Mechanisms**

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