Responses of marine organisms to OA and co-stressors

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All is lost

Three strawmen

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

Multistressors

Variability

Mechanisms
Experiment(ers) got better. Identified co-stressors and confounding effects

Light alters CO$_2$ sensitivity in corals

Food levels alter CO$_2$ 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
- Murray et al. ICES JMS 2017
Key papers

Hofmann et al. PLOS One 2011
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 CO₂ variability matters. Winners & losers?

- CO₂ varies naturally in time and space
- Metabolic CO₂ fluctuations important
- Potential for local adaptation, acclimatization
  - intraspecific differences in CO₂ 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 × CO₂)
- Harvey et al. 2013, Przeslawski et al. 2015: Synergistic interactions are most common (Temp × CO₂)
- 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
- Wallace et al. Est Coast Shelf Sci 2014
- Breitburg et al. Oceanography 2015
- Gobler & Baumann Biol Lett 2016
Biological responses vary across taxa, stages, and trophic levels.

Combined stressors generally cause stronger (positive or negative) effects.
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- Byrne & Przeslawski: Additive negative effects most common (Temp × CO₂)
- Harvey et al. 2013, Przeslawski et al. 2015: Synergistic interactions are most common (Temp × CO₂)
- Early life stages are most susceptible.
- OA is more stressful to calcifying than non-calcifying larvae
- Gobler & Baumann: CO₂ × O₂ 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
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Key papers

Todgham & Hofmann JEB 2009
Crawley et al. Glob Change Biol 2010
Pörtner MEPS 2012
Bignami et al. PNAS 2013
Waldbusser et al. Nat Clim Change 2015
Ern et al. Biol Lett 2017
Esbaugh J Comp Physiol 2017

What does CO$_2$ actually do to organisms? Many answers.

Physiological frameworks

Coral pH up-regulation may counter OA effects

CO$_2$? 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


References


