Ocean acidification: knowns, unknowns and perspectives

Lessons learned from ocean acidification research

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Further information and acknowledgements

ipcc
INTERGOVERNMENTAL PANEL ON climate change

OA
Ocean Acidification

Jean-Pierre Gattuso (France), Peter Brewer (USA), Ove Hoegh-Guldberg (Australia), Joan A. Kleypas (USA), Hans-Otto Pörtner (Germany), Daniela Schmidt (UK)

Gattuso J.-P., Kirkwood W., Barry J. P., Cox E., Gazeau F., Hansson L., Hendriks I., Kline D. I., Mahacek P., Martin S., McElhany P., Peltzer E. T., Reeve J., Roberts D., Saderne V., Tait K., Widdicombe S. & Brewer P. G., 2014. Free-ocean CO_2 enrichment (FOCE) systems: present status and future developments. *Biogeosciences* 11:4057-4075.

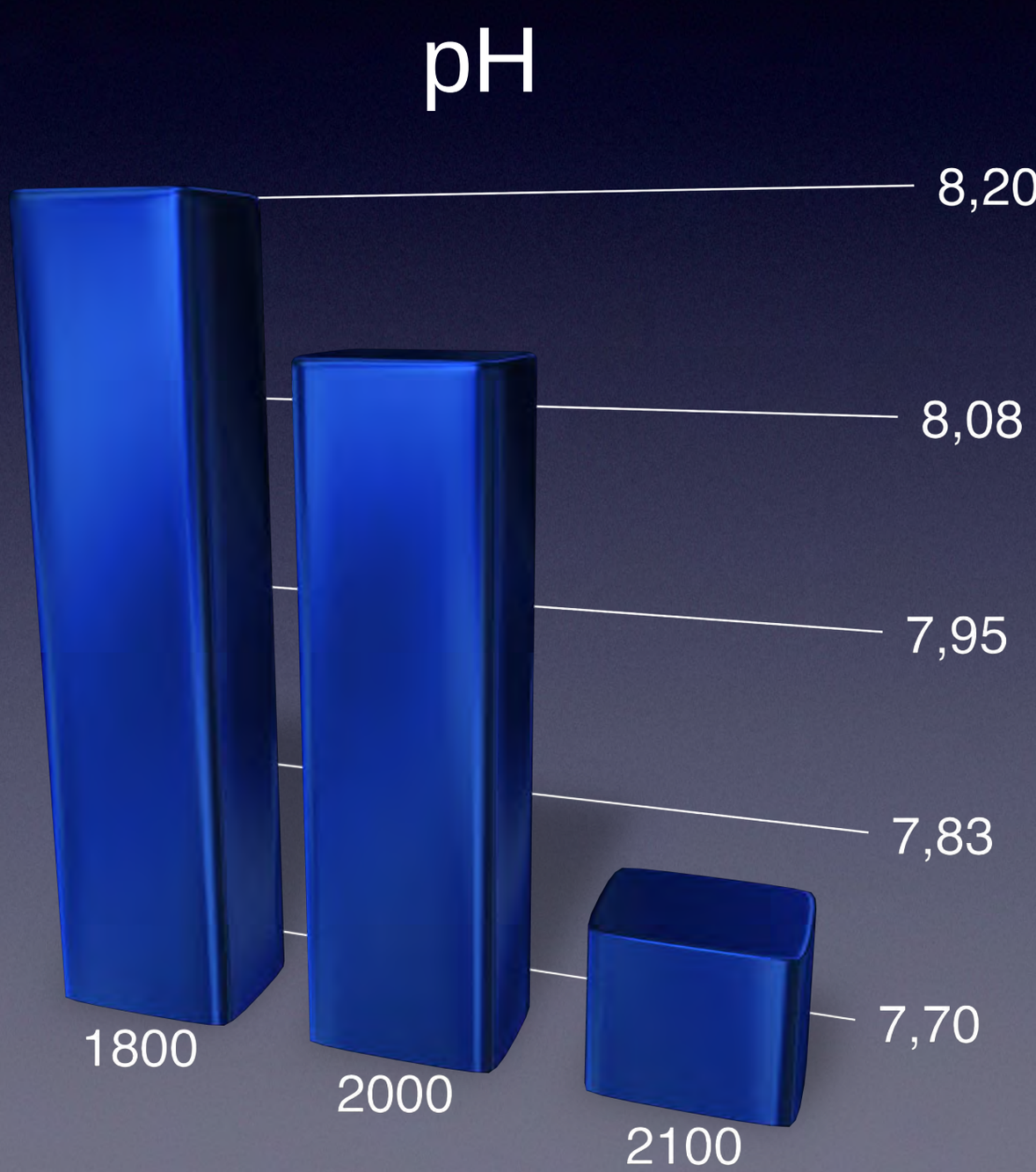
nature climate change

Riebesell U. & Gattuso J.-P., 2015. Lessons learned from ocean acidification research. *Nature Climate Change* 5:12-14.

Climate-related variables

Unpublished figure deleted

pH and acidity



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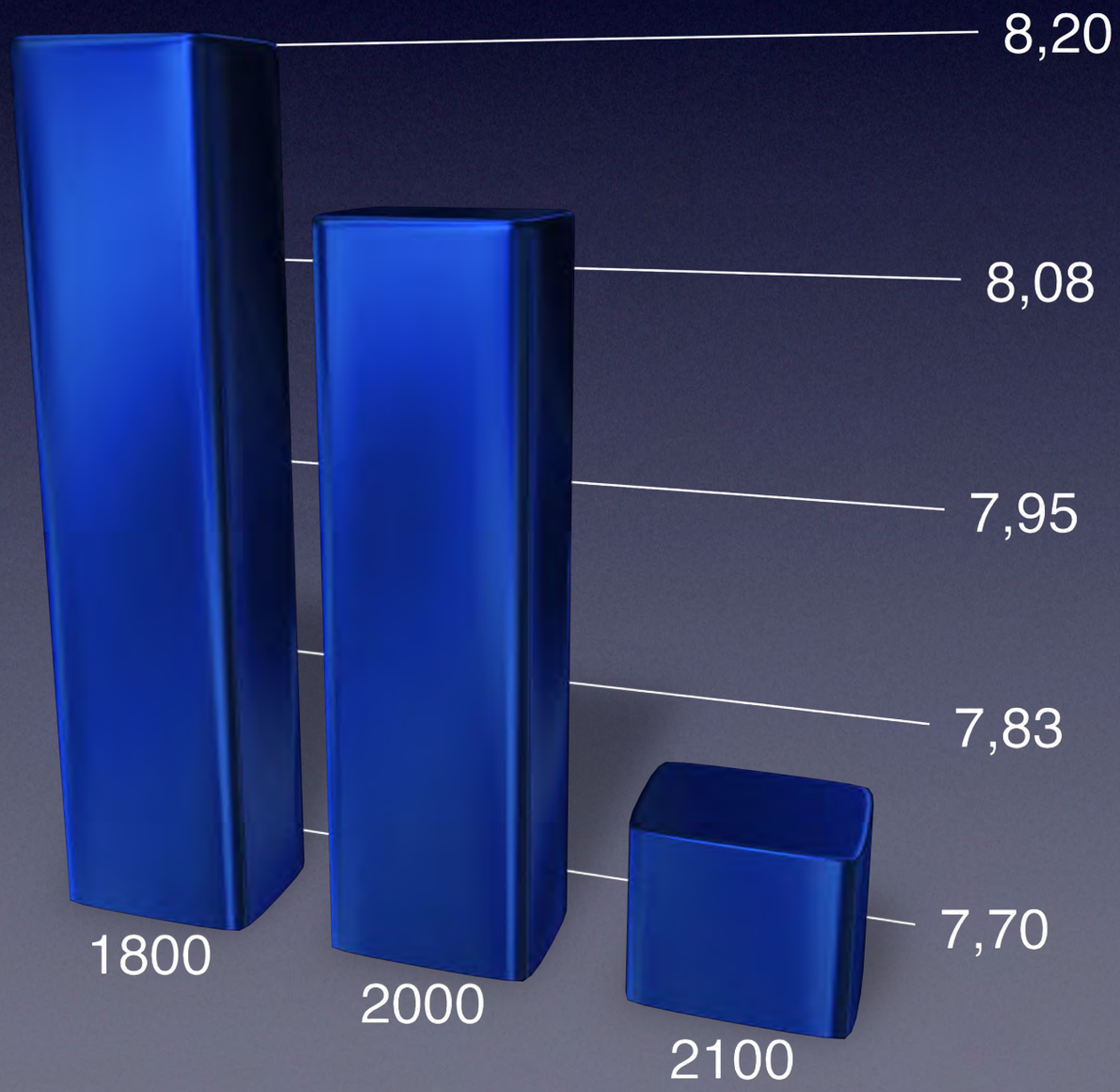
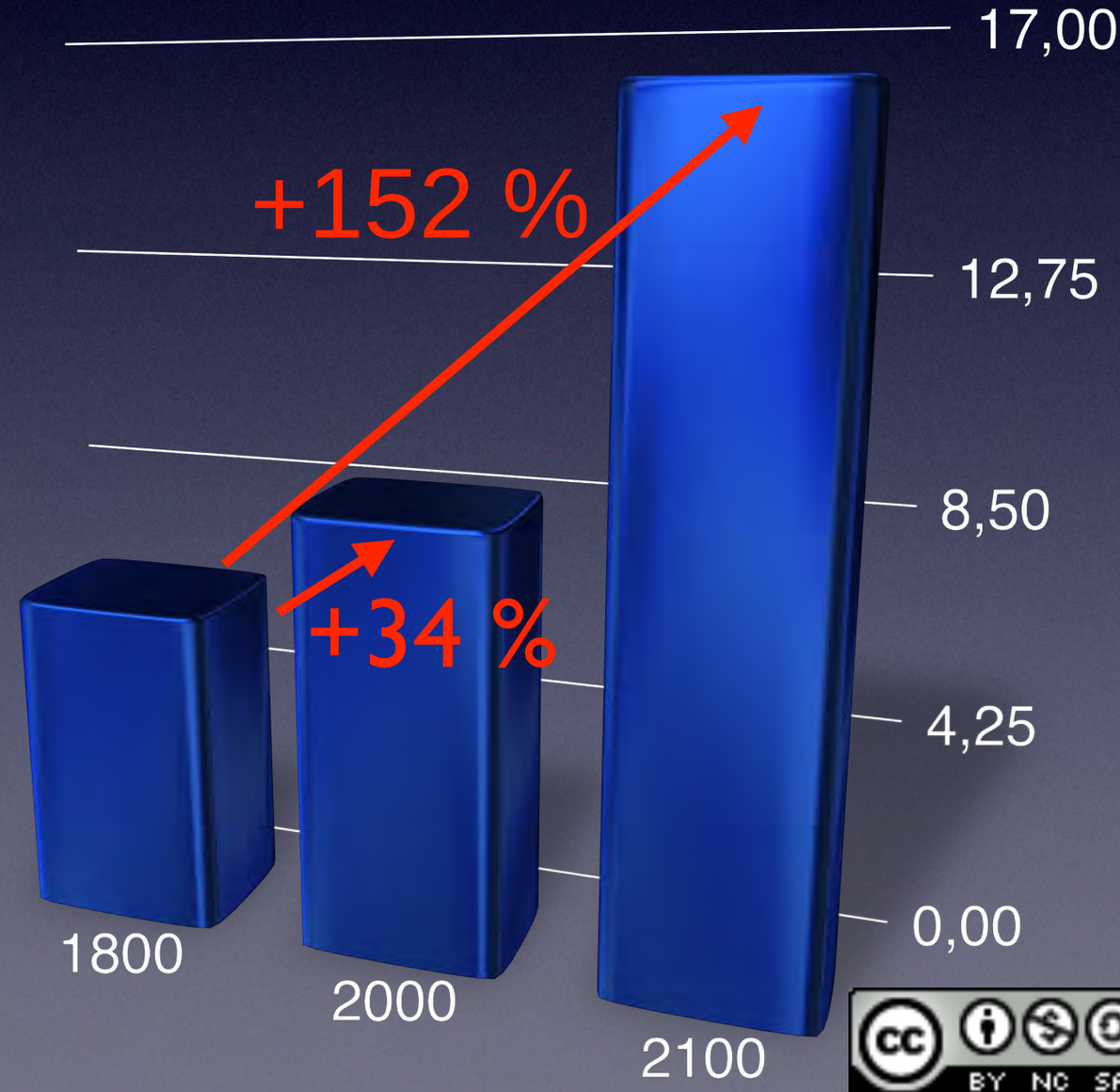
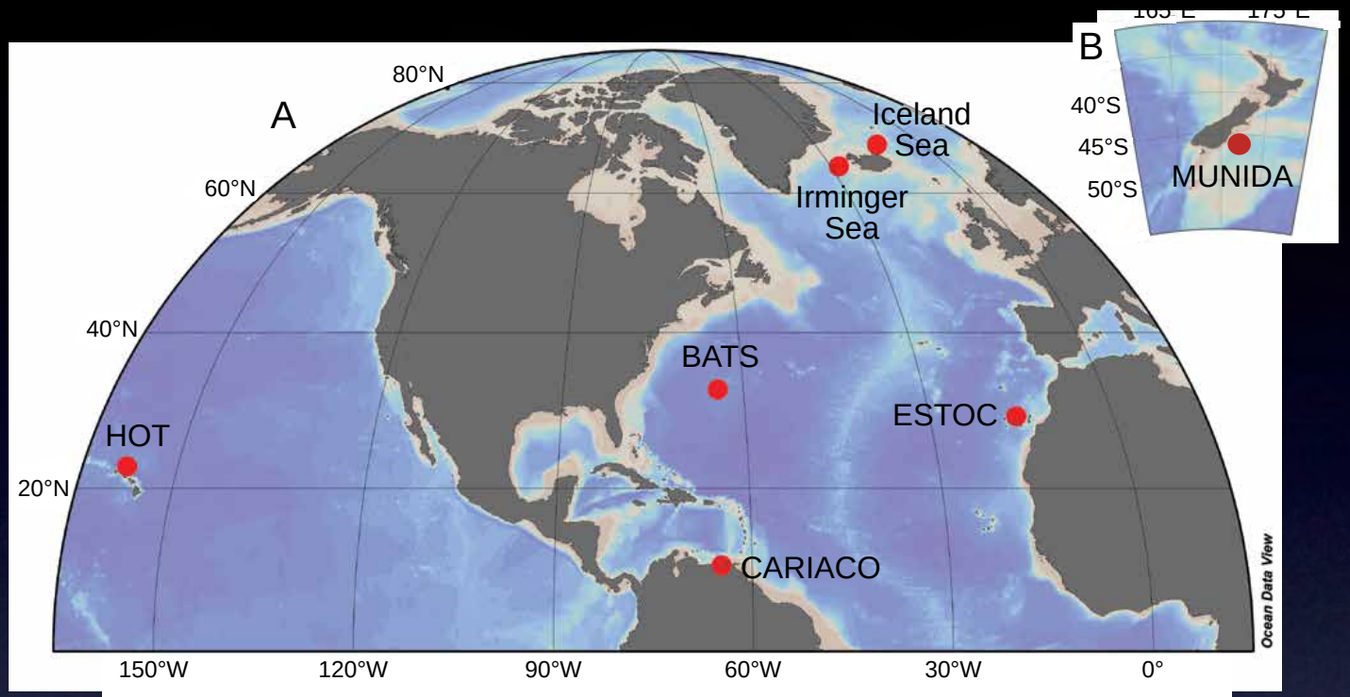




Ocean acidification can be measured



Bates et al. (2014)

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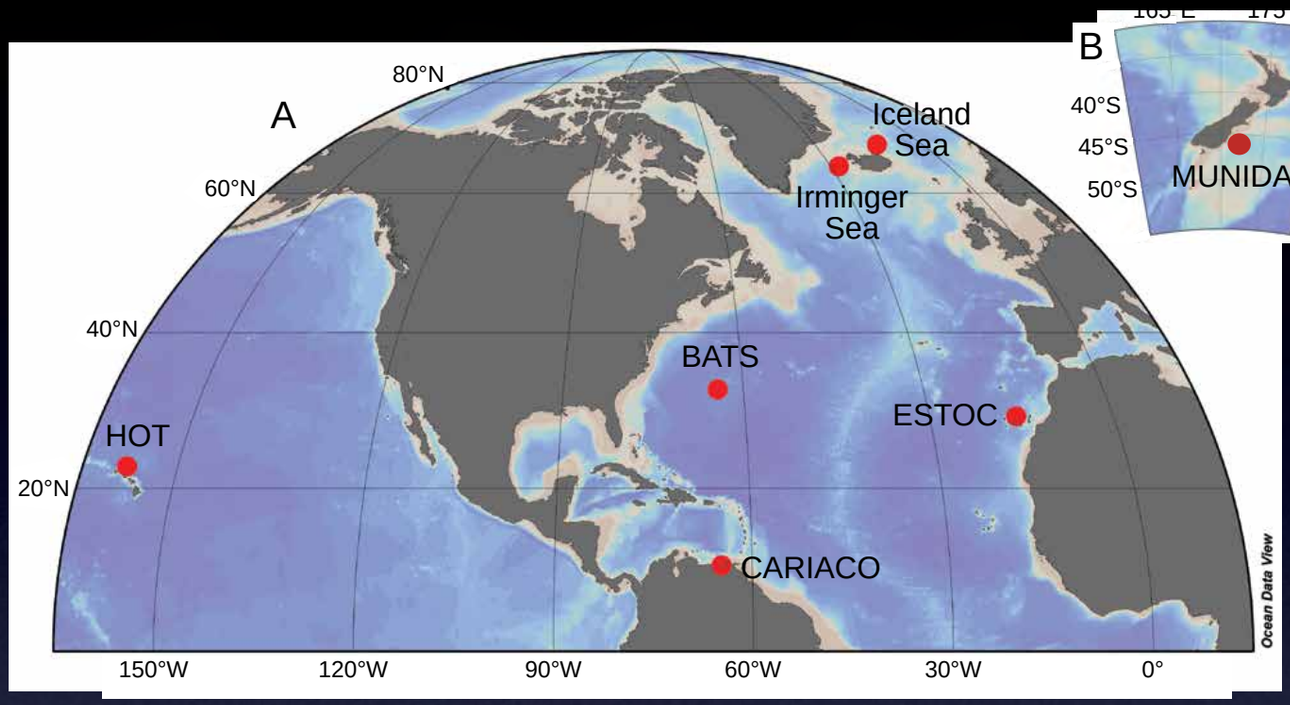
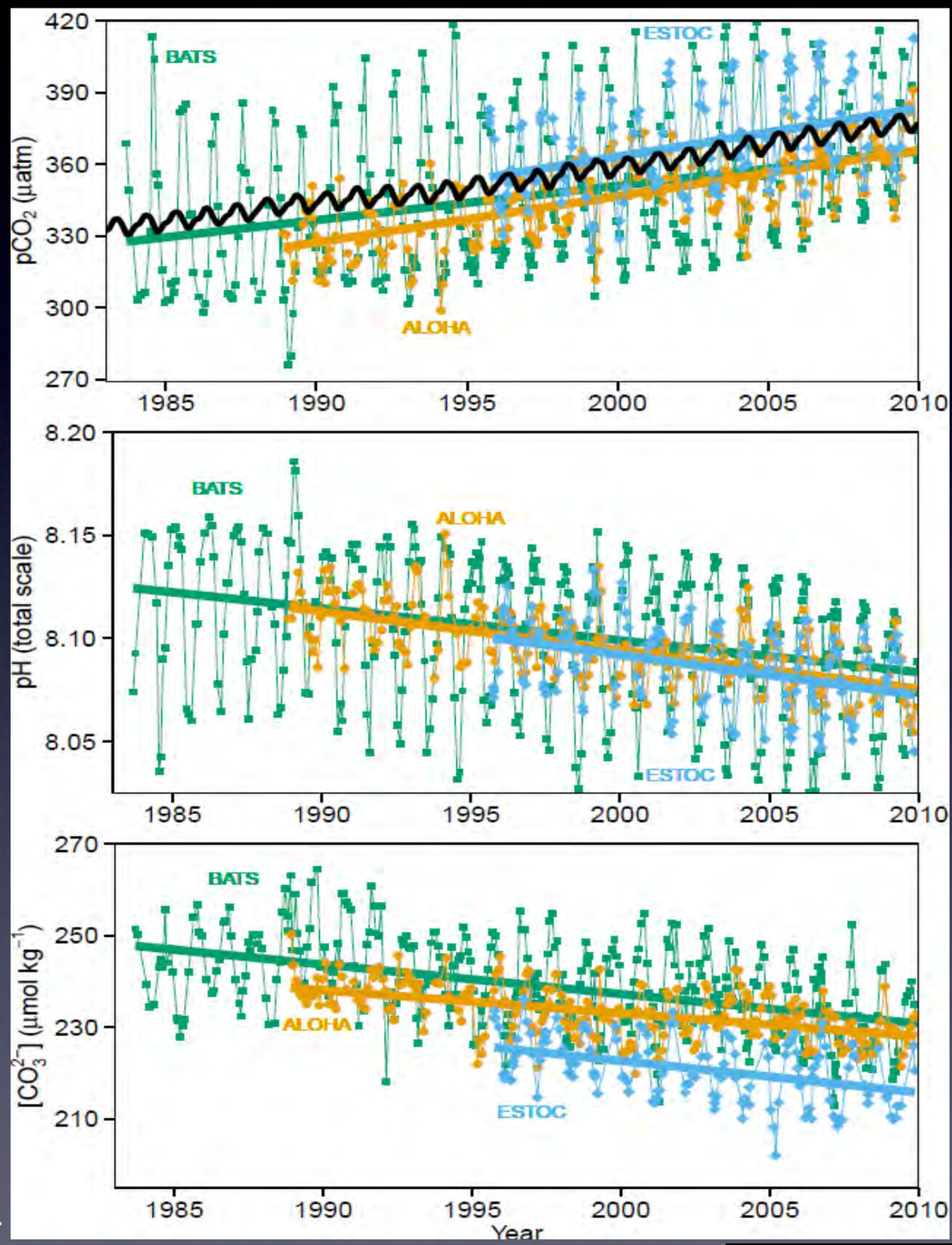


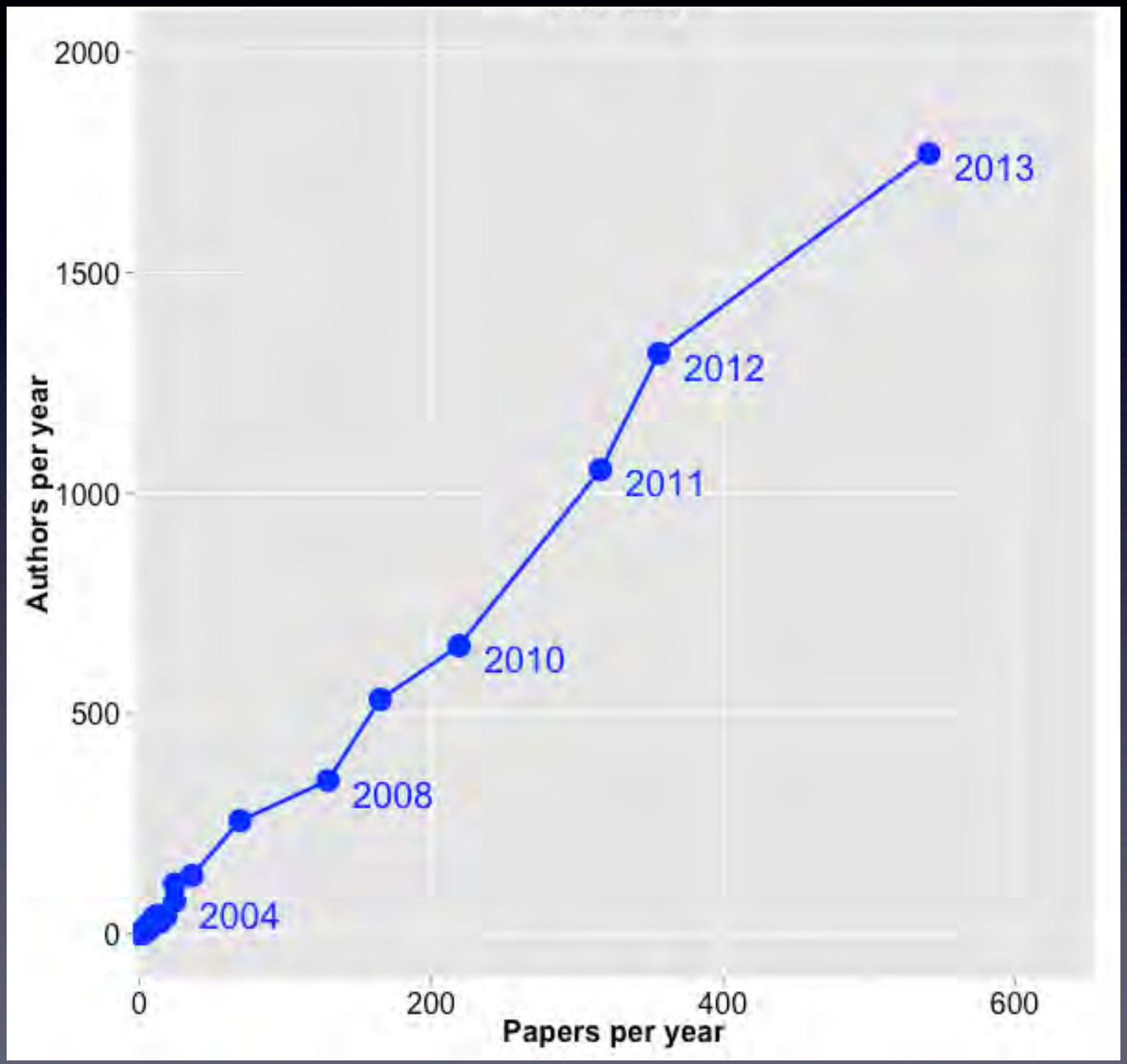
Bates et al. (2014)



Range 1995-2009:
-0.0015 to -0.0022 units yr^{-1}

IPCC AR5 WG I

Surge of information



Gattuso & Hansson, OA-ICC

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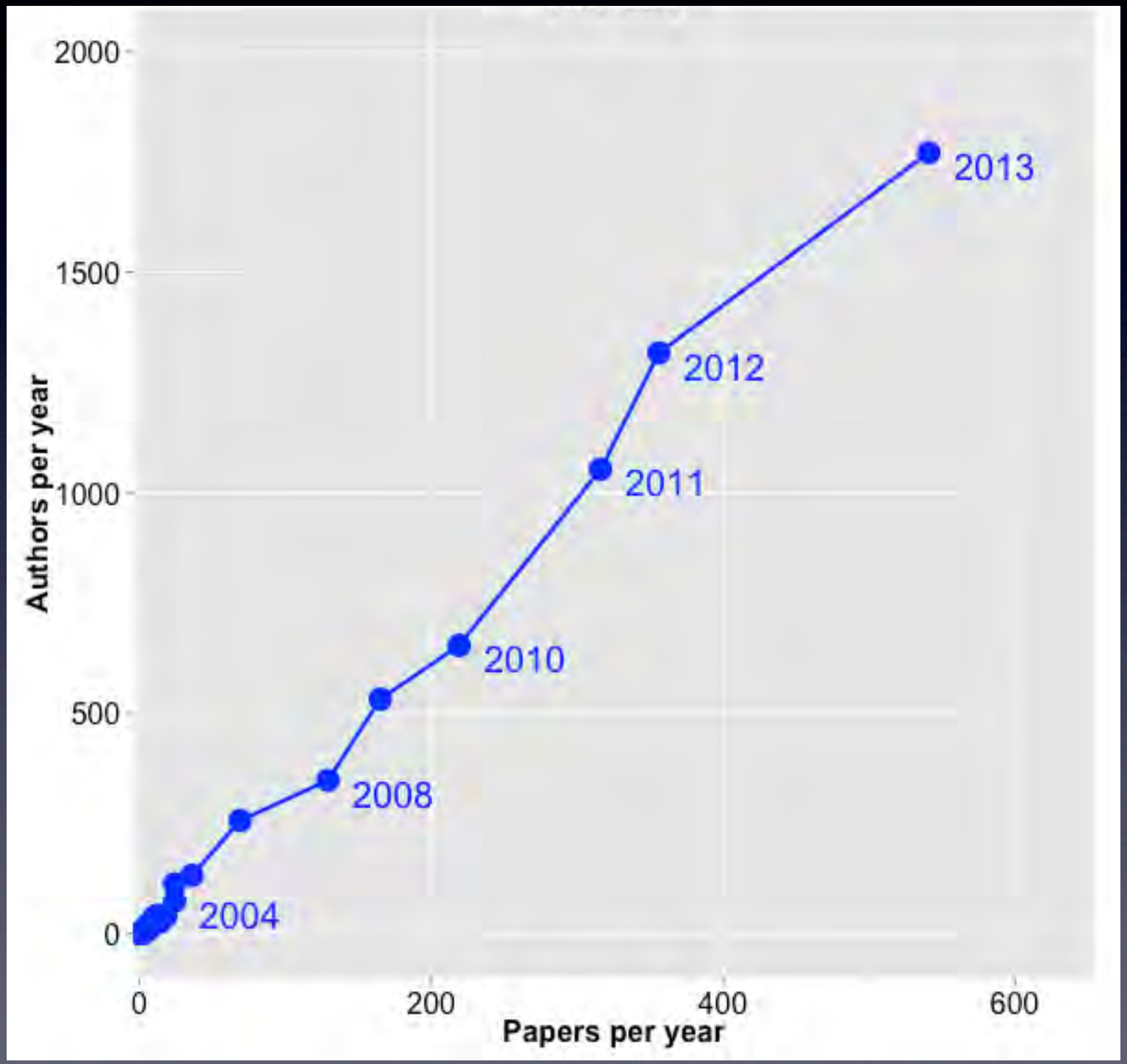

Papers:

- 561 in 2013
- 50% in past 3 years
- +39% y^{-1} since 2000 vs +5% y^{-1} in WoS

Authors:

- 1804 in 2013

Gattuso & Hansson, OA-ICC

OA Ocean Acidification

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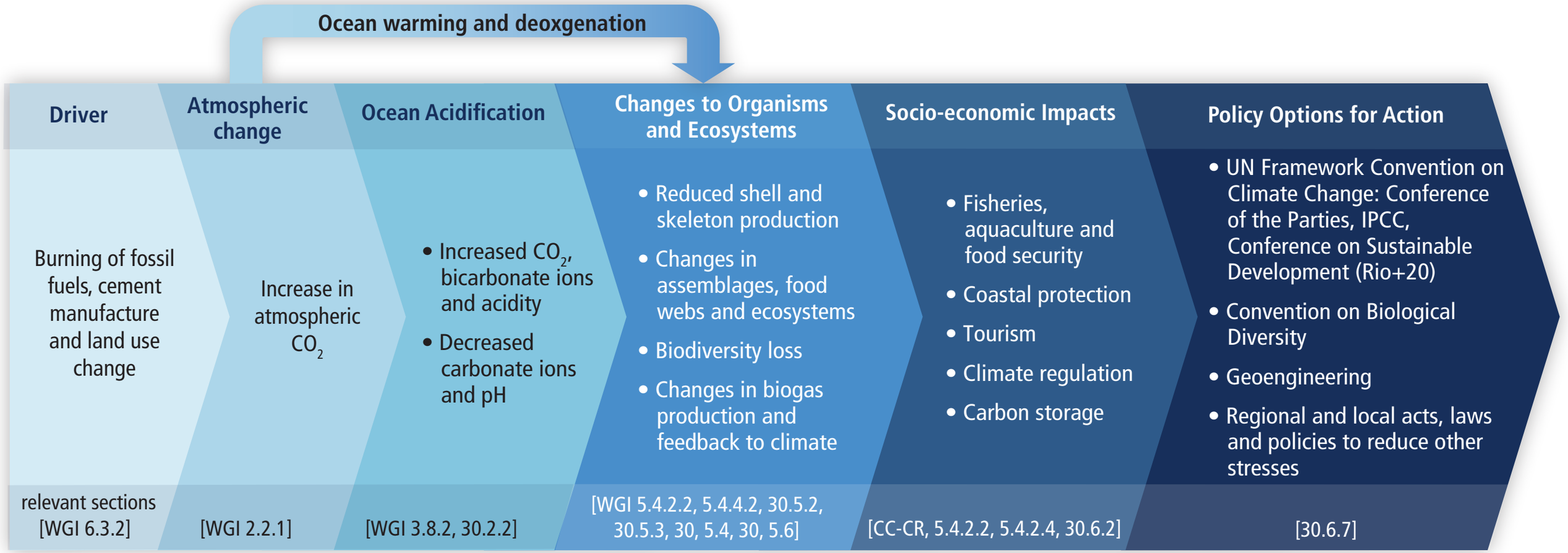

Gattuso et al. (2014; IPCC AR5 WGII)

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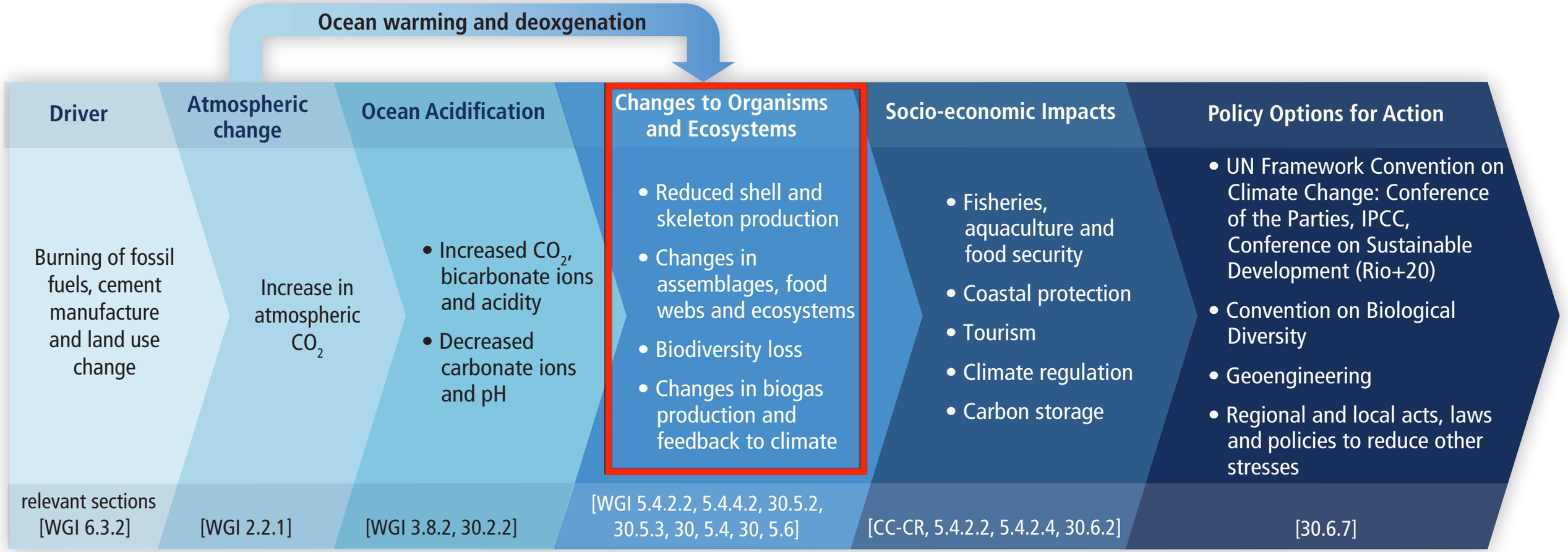
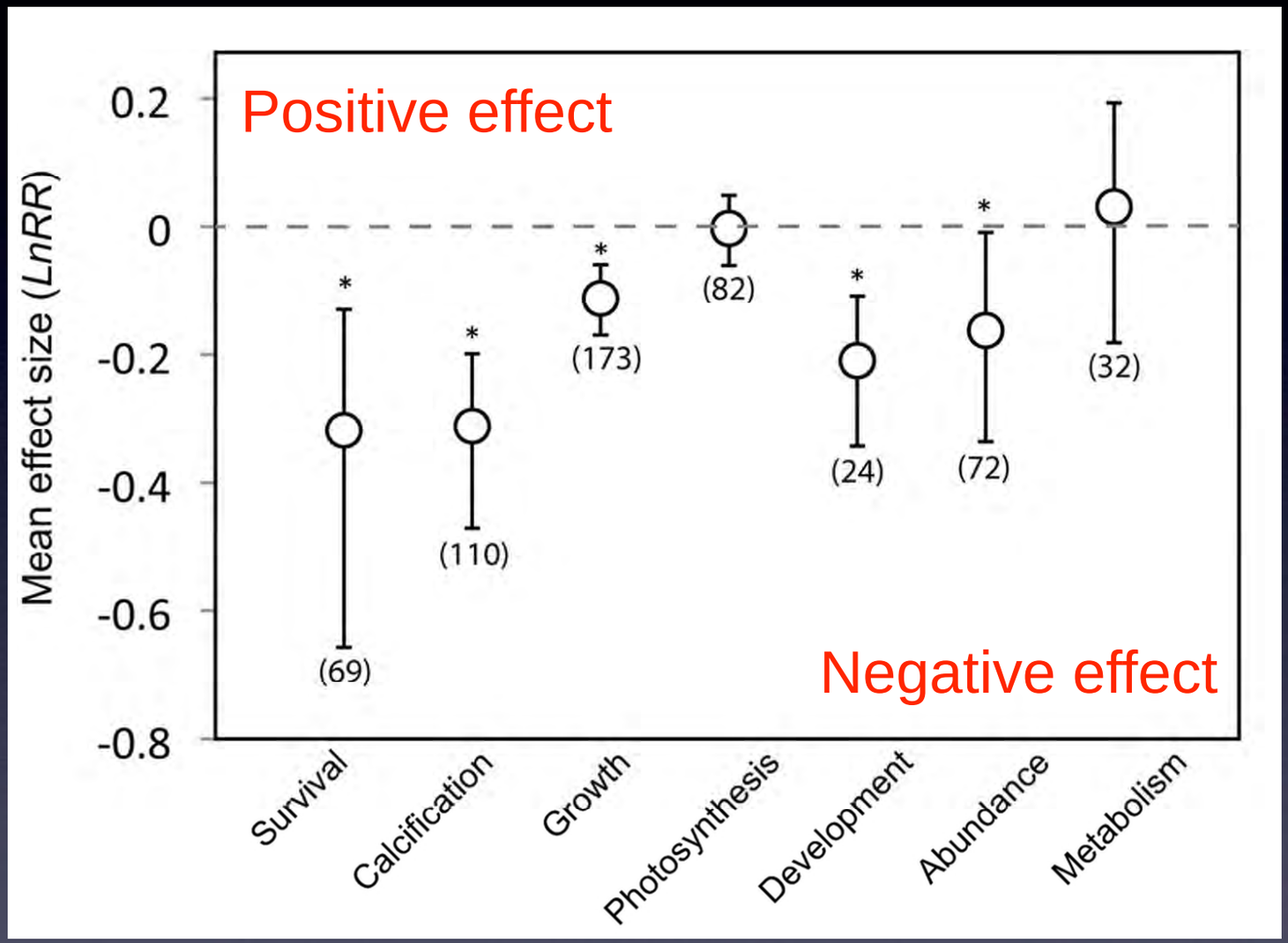


Gattuso et al. (2014; IPCC AR5 WGII)

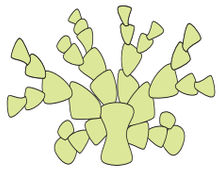
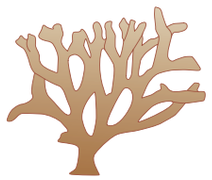
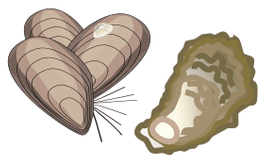
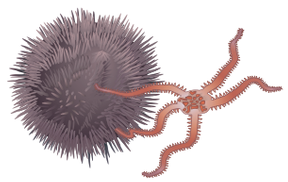
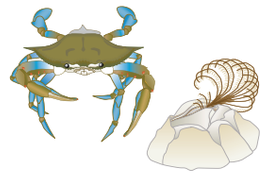
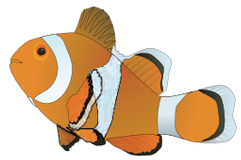
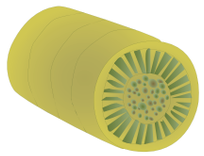
Meta-analysis: Kroeker et al. (2013)

- Significant negative effect on:
  - survival
  - calcification
  - growth
  - development
  - abundance

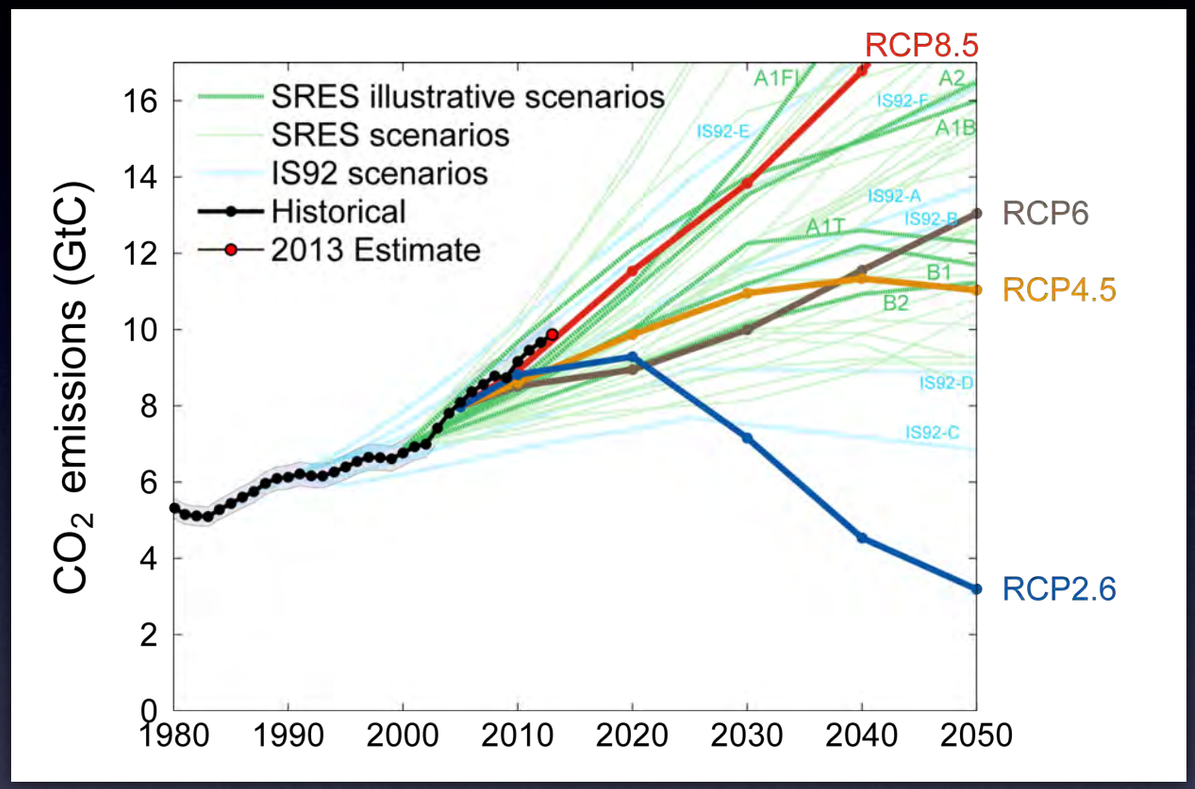


Meta-analysis: Kroeker et al. (2013)

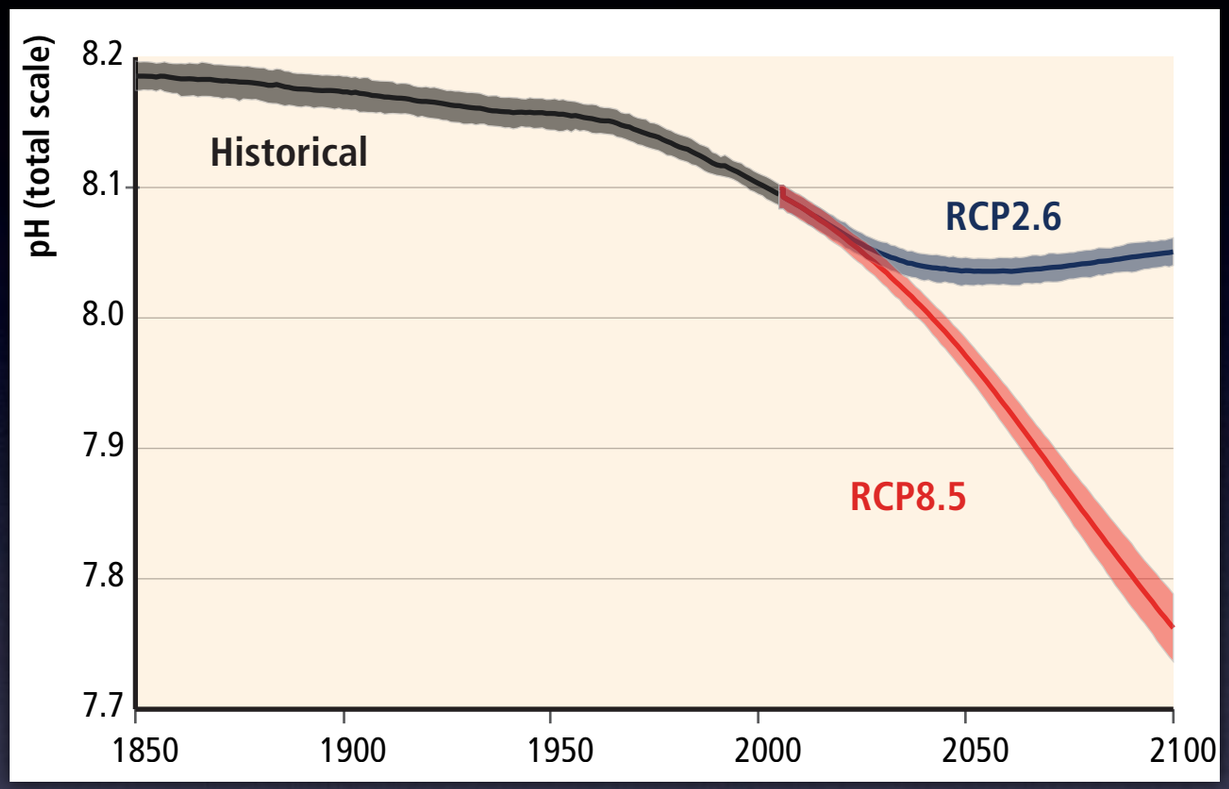
- Enhanced <25%
- No effect
- Reduced <25%
- Reduced >25%
- Not tested

Taxa	Response	Mean Effect
 Calcifying algae	Survival	
	Calcification	
	Growth	
	Photosynthesis	-28%
	Abundance	-80%
 Corals	Survival	
	Calcification	-32%
	Growth	-23%
	Photosynthesis	
	Abundance	-47%
 Coccolithophores	Survival	
	Calcification	-9%
	Growth	
	Photosynthesis	
	Abundance	
 Molluscs	Survival	-34%
	Calcification	-40%
	Growth	-17%
	Development	-25%
	Abundance	
 Echinoderms	Survival	
	Calcification	
	Growth	-10%
	Development	-11%
	Abundance	
 Crustaceans	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
 Fish	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
 Fleshy algae	Survival	
	Calcification	
	Growth	+22%
	Photosynthesis	
	Abundance	
 Seagrasses	Survival	
	Calcification	
	Growth	
	Photosynthesis	
	Abundance	
 Diatoms	Survival	
	Calcification	
	Growth	+12%
	Photosynthesis	
	Abundance	

Future projections

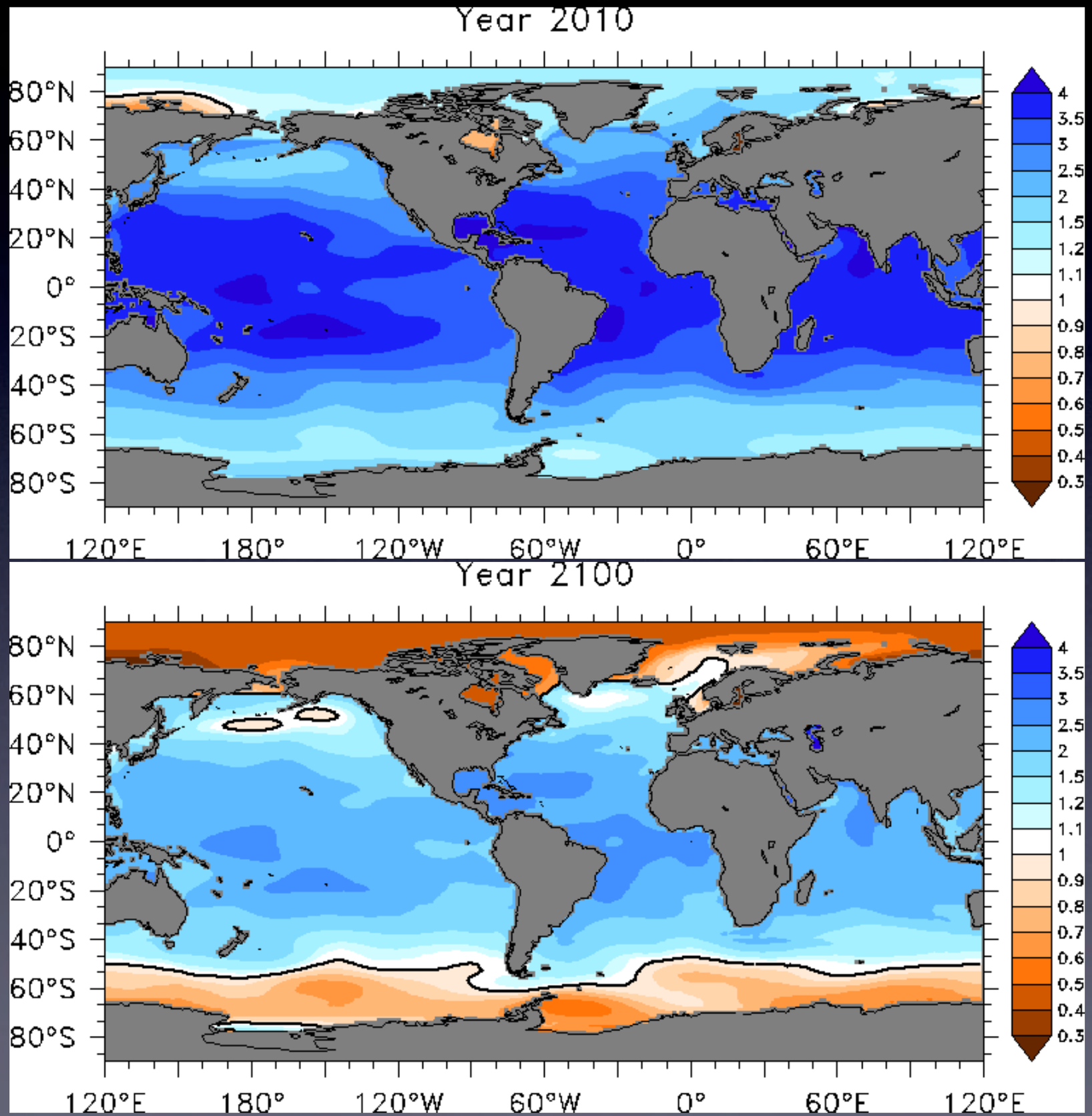


Le Quéré et al. (2013)



IPCC AR5 WG I

Future projections

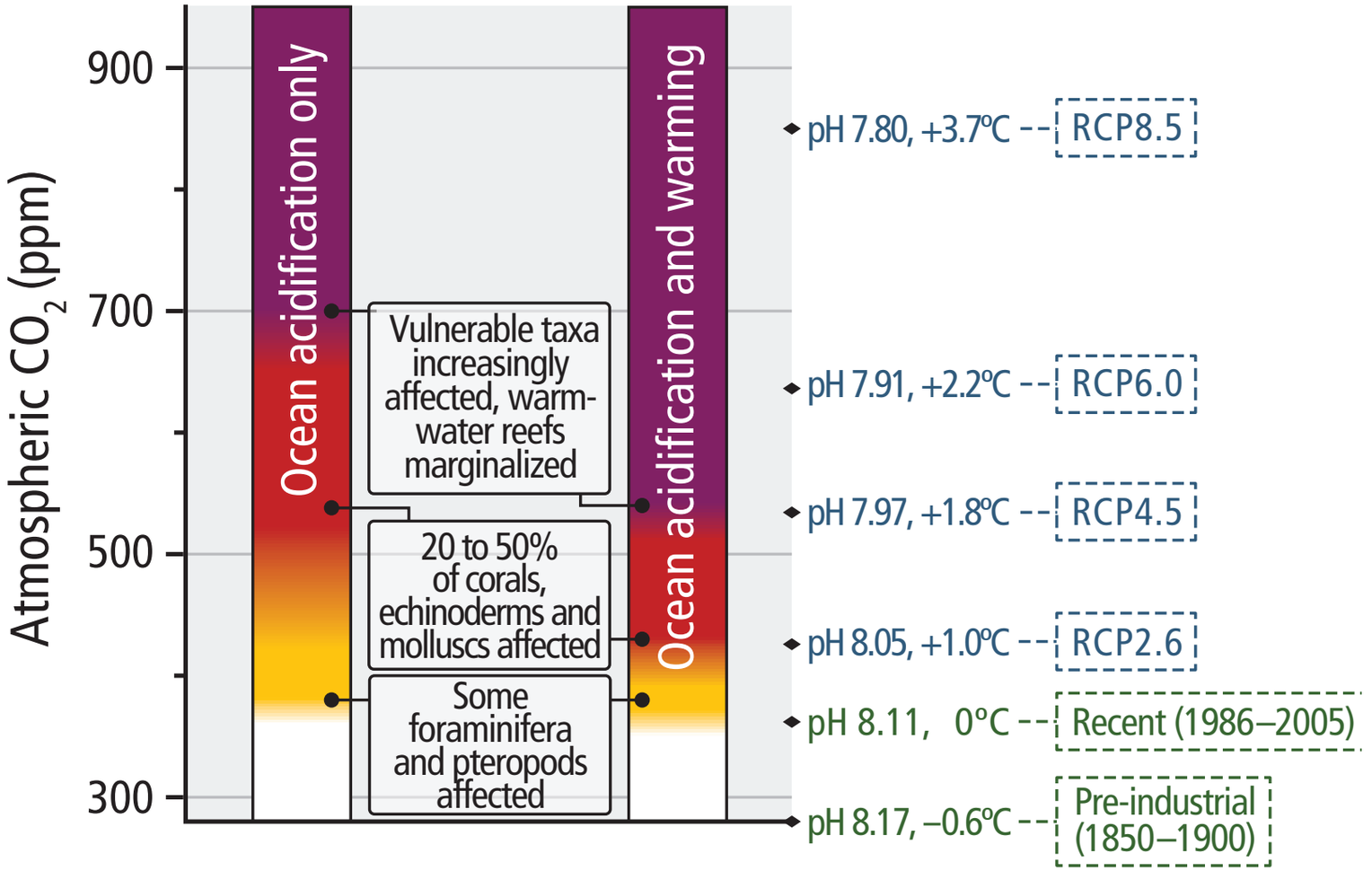


Omega aragonite, courtesy Jim Orr

Future risks

Increasing risk from RCP2.6 to RCP8.5

(b) Risk for marine species impacted by ocean acidification only, or additionally by warming extremes



Projected pH, temperature for 2081–2100
Observed pH, temperature
(temperature in ºC relative to 1986–2005)

Level of additional risk due to climate change

Undetectable | Moderate | High | Very high

IPCC AR5 SPM

Take home messages

- **Chemical effects**: very high confidence
- **Biological and ecological effects**: high to low confidence
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- **Knowledge gaps**:
  - Multiple drivers*
  - Evolutionary adaptation*
  - Response of communities (*in situ*)
  - Nutritional quality
  - Food web, up to top-predators (socio-economy)
  - Fish (Munday, Caprio and others)

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Phil Munday's keynote on Friday

What is the way forward?

Time to reflect: successes

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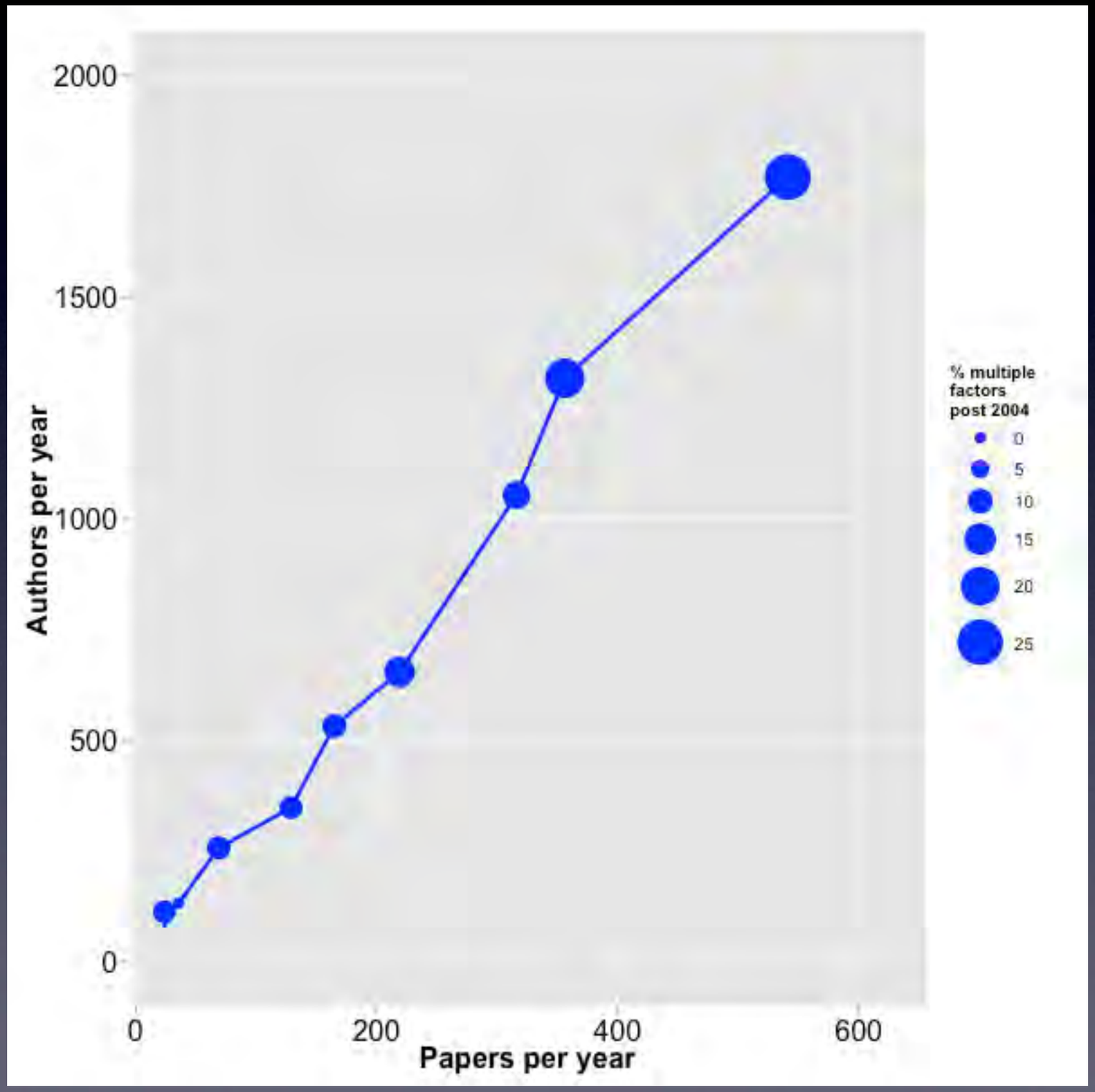
- Close collaboration within and between national and international projects
- Early community-driven agreement on best practices in ocean acidification research and data reporting
- Concerted communication spear-headed by a Reference User Group
- International coordination (EPOCA, now OA-ICC)
- Large number of high profile reports
- Growing recognition at intergovernmental level (US State Department's "Our Ocean Conference")

Time to reflect: limitations

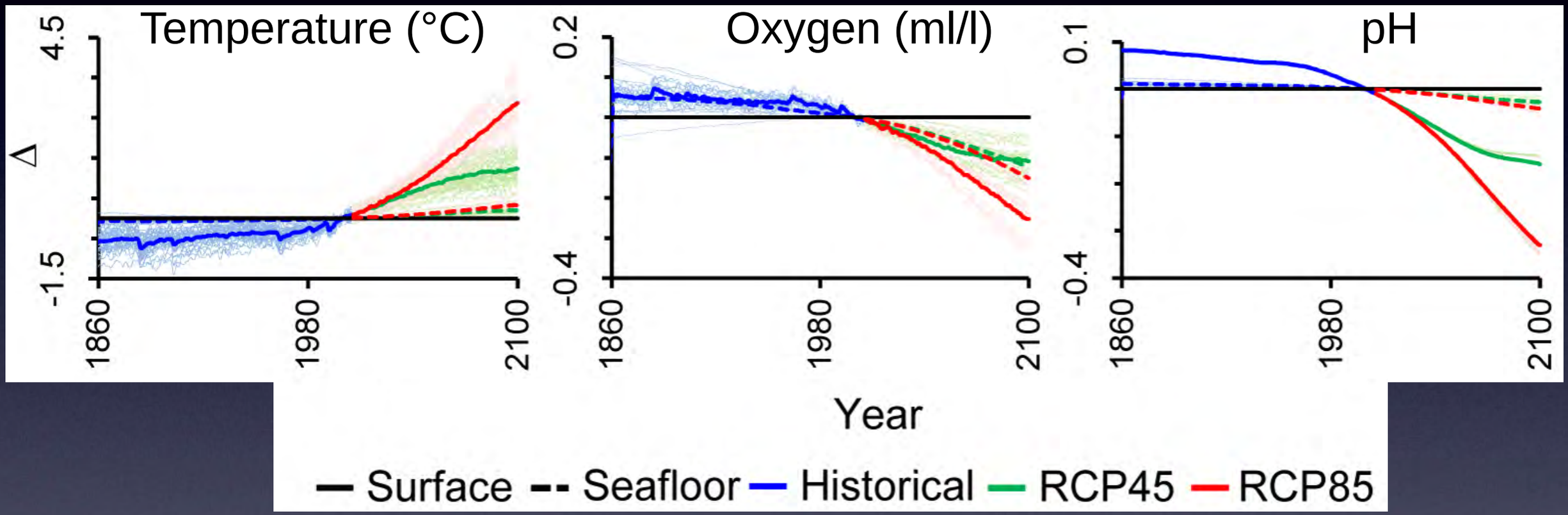
- Mostly on **individual species:** competitive and trophic interactions poorly studied
- **Lab studies**, few responses of communities (even fewer *in situ*)
- **Single driver** (80% of perturbation experiments) although interactive (additive, synergistic or antagonistic) effects not predictable from single driver
- **Short-term:** selection of standing genetic variation or via novel mutations poorly constrained

Studies of multiple drivers



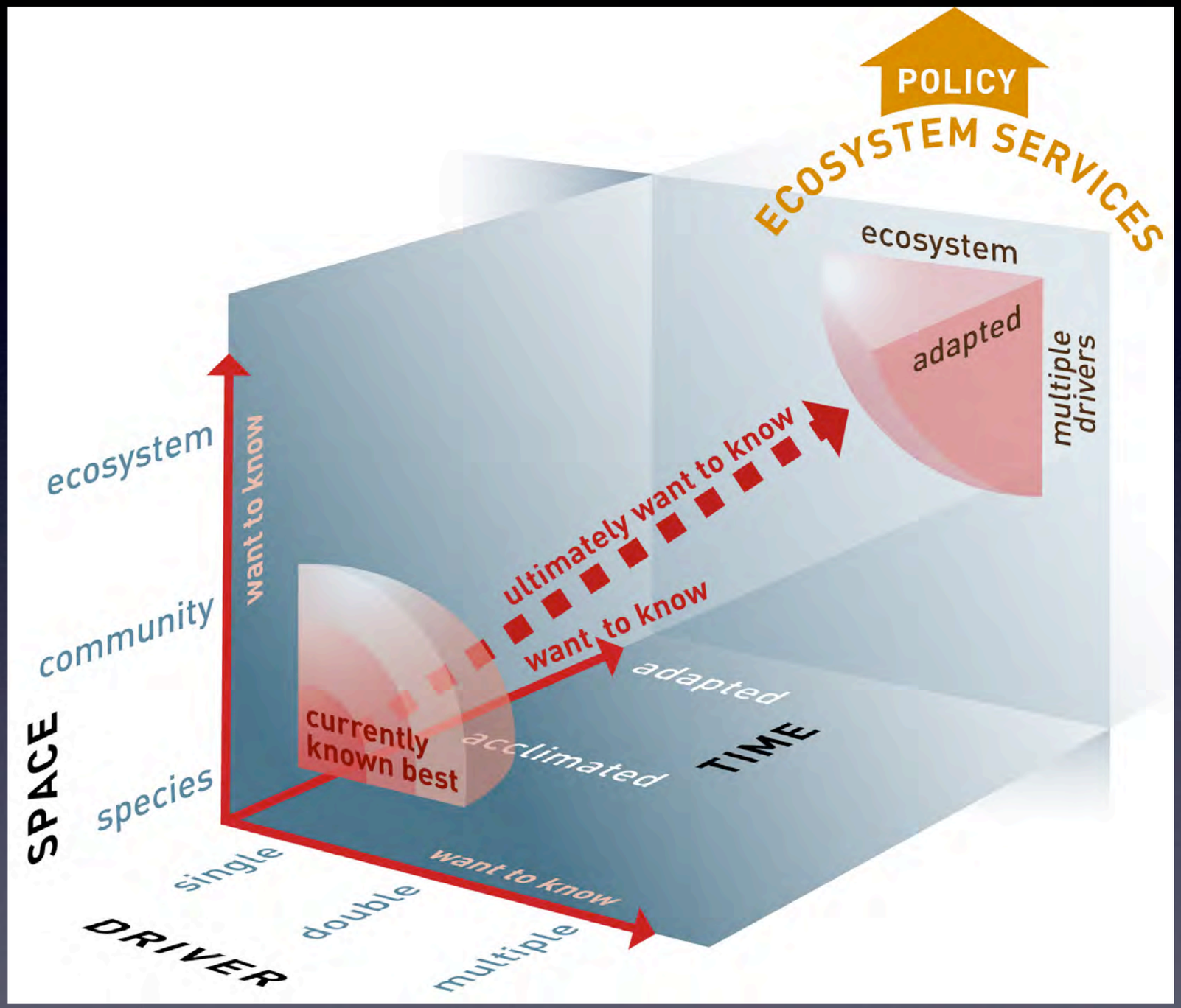
Gattuso & Hansson, OA-ICC

Multiple global drivers: pH, temperature, O_2…



Mora et al. (2013)

Experimental space



Riebesell & Gattuso (2015)

Approaches

Approach	Cost	Replicability	Ecological relevance
Laboratory experiments	Very low	Very high	Very low
Field observations (monitoring)	Medium	Very low	Very high
CO_2 vents	Low	Very low	Very high
Laboratory mesocosms	Medium	Medium	Medium
FOCE	High	Medium	High

Gattuso et al. (2014)

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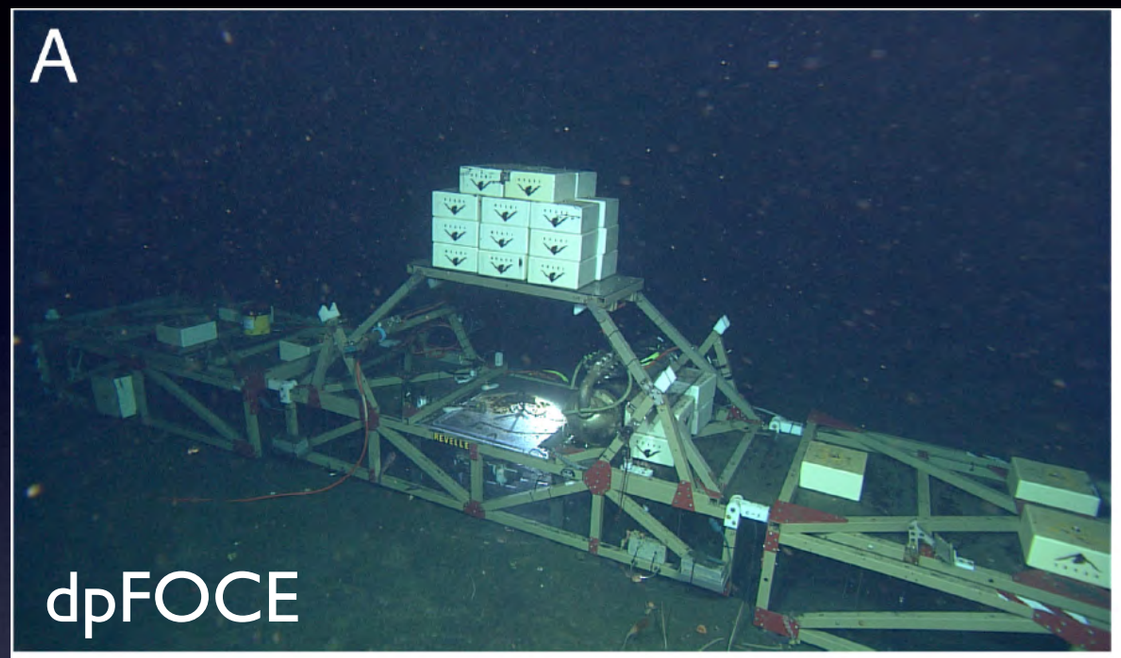
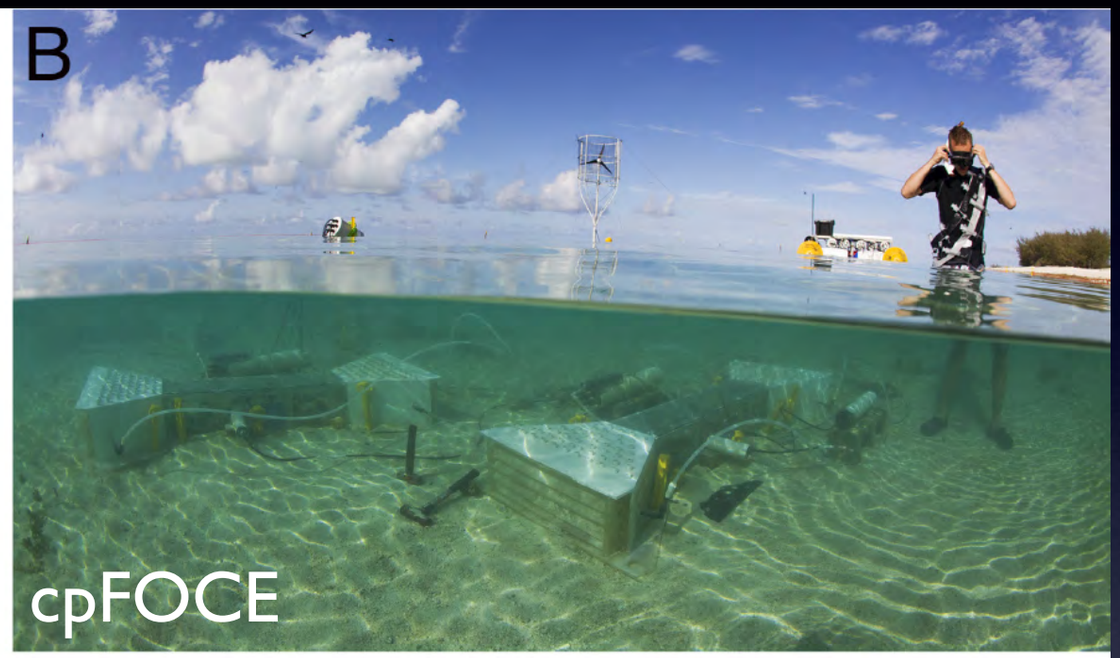
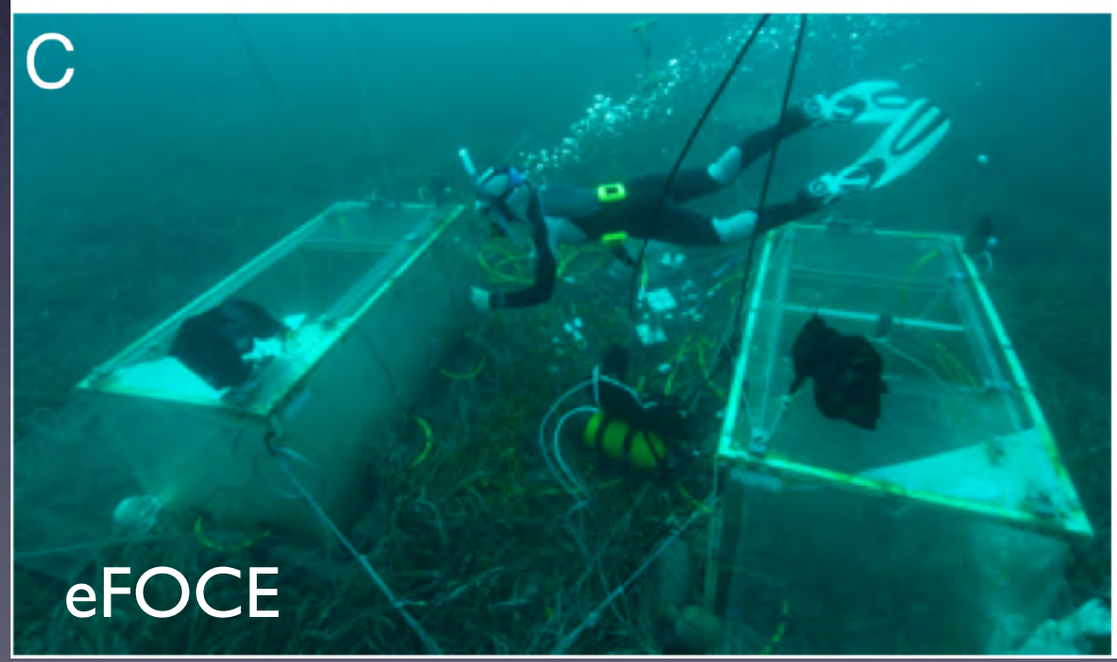
Gattuso et al. (2014)

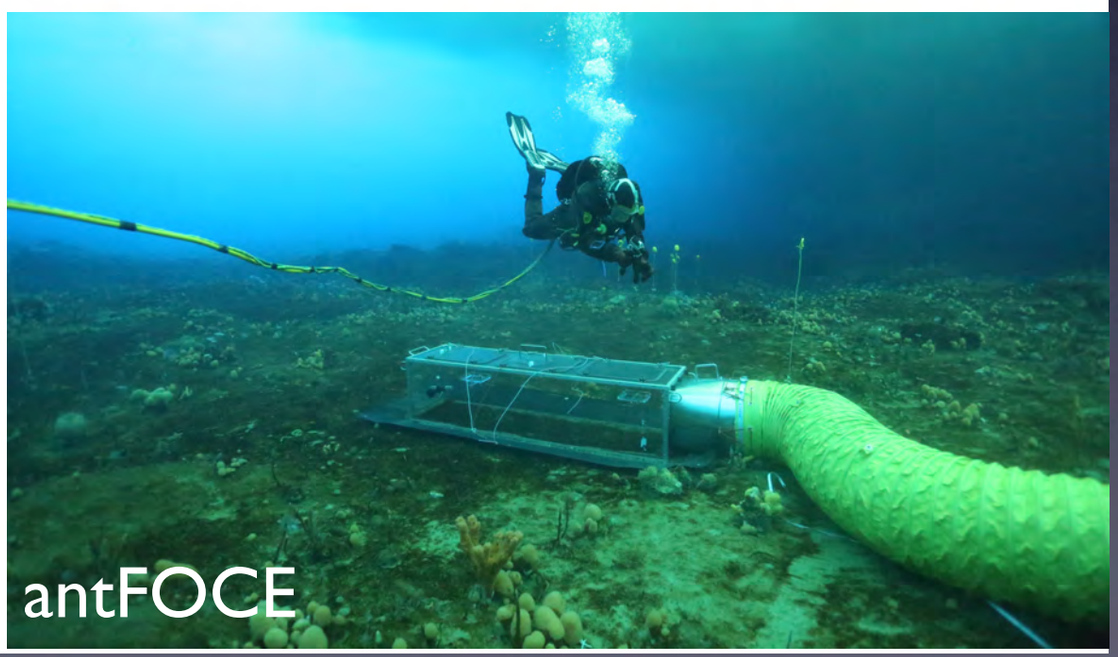
+ Paleo + Modeling

Free Ocean CO_2 Enrichment (FOCE) experiments

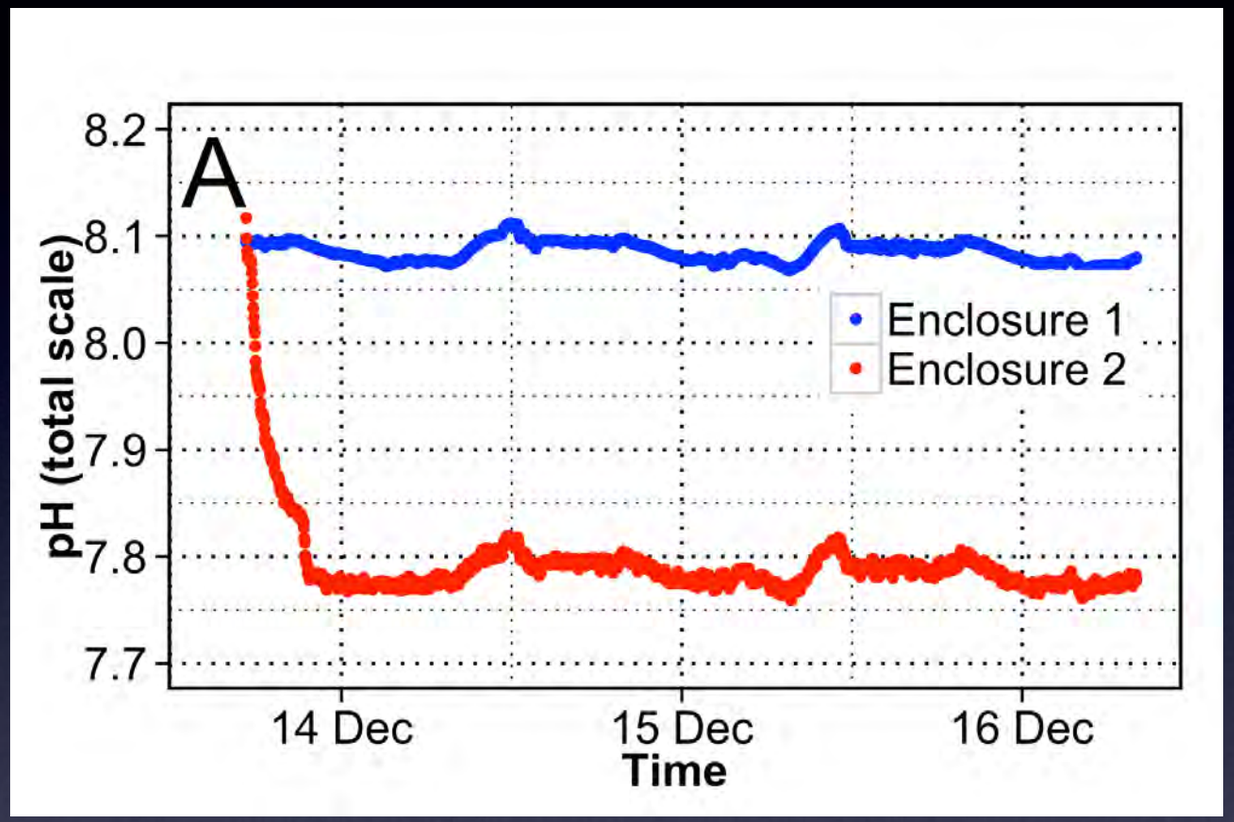


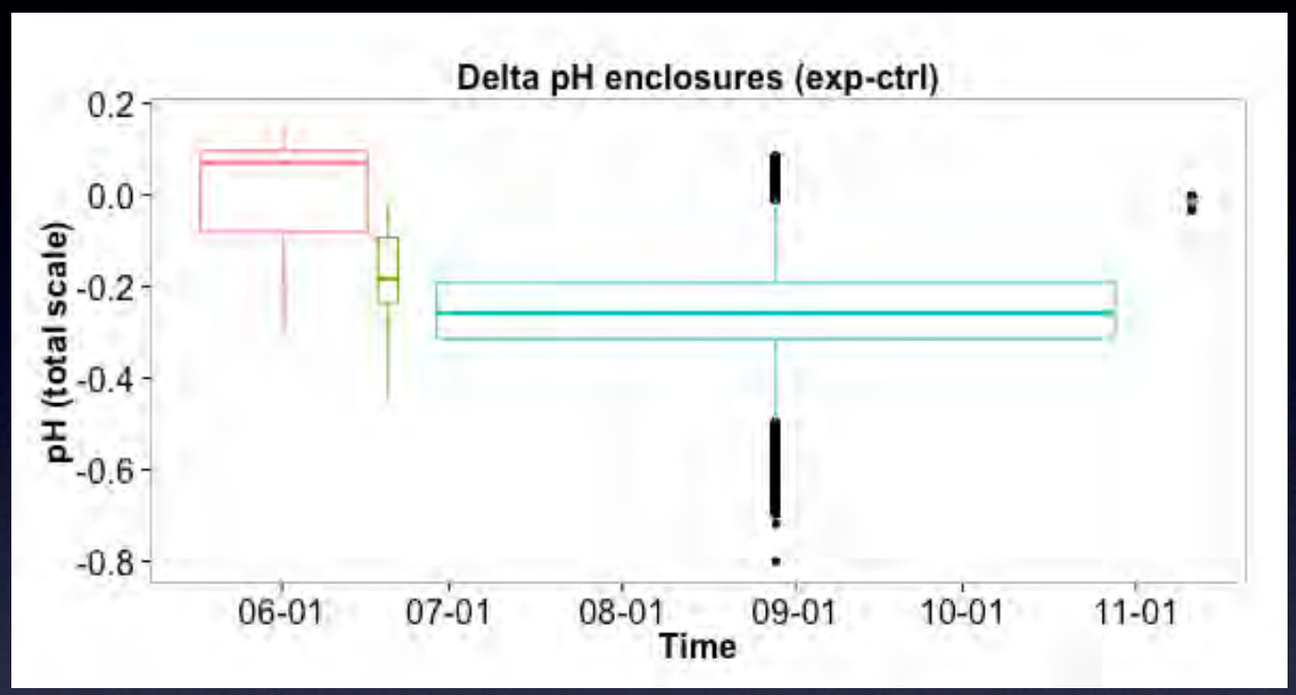






pH control (eFOCE)





FOCE systems not the magic approach

- No work on natural communities yet (beside eFOCE)
- Relatively small volume/surface
- Still relatively closed (natural flow not replicated)
- No multiple drivers design yet (ocean warming and acidification, suboxia)
- Costly, requires high level of expertise in engineering
- Considerable room for improvement and other approaches needed

Conclusion

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- **Set priorities**:
  - reference and keystone species, including ecosystem engineers
  - identify commonalities and develop unifying concepts
  - focus on species, processes and ecosystems most vulnerable or resilient to ocean change
  - processes from sub-cellular to ecosystem dynamics and biogeochemical cycling

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  - processes from sub-cellular to ecosystem dynamics and biogeochemical cycling
- **Emphasize** ecosystem services, management options and policy advice

OA-ICC: free resources

IAEA Ocean Acidification International Coordination Centre OA-ICC

- News stream (20 posts a week)
- Bibliographic database (2233 refs) updated every 3 months
- Data management (on Pangaea)
- Expert workshops
- Training courses
- Intercomparison exercices
- ...

http://www.iaea.org/ocean-acidification

Check out session
S2: Ocean acidification talks + posters
(N. Bates & S. Birchenough)
today and tomorrow

Thank you!