Ecosystem Modeling & Ocean Acidification

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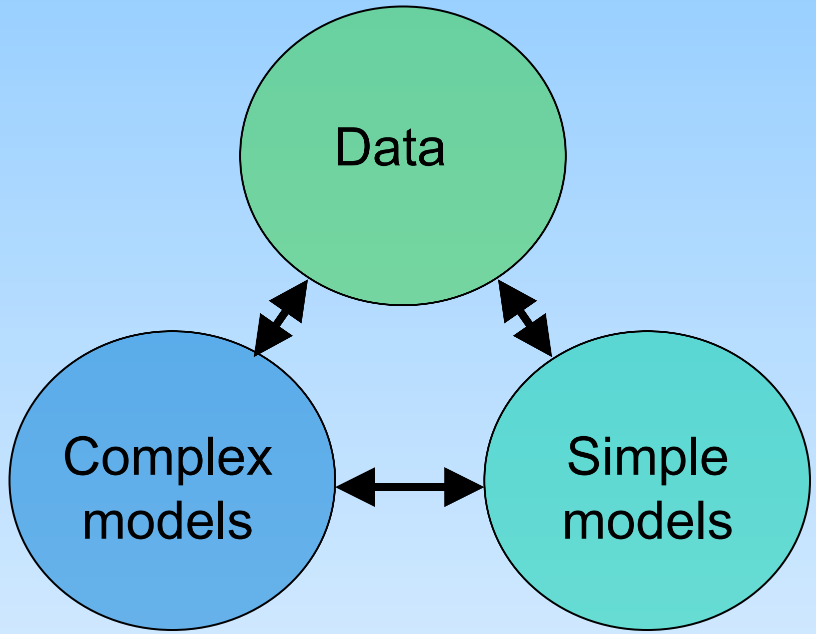
Biological Hierarchy

- cell & organism
- population & community
- ecosystem/biogeochemistry
- coupled human-natural systems

Multiple Stressors & Climate

Ecosystem Modeling of Ocean Acidification

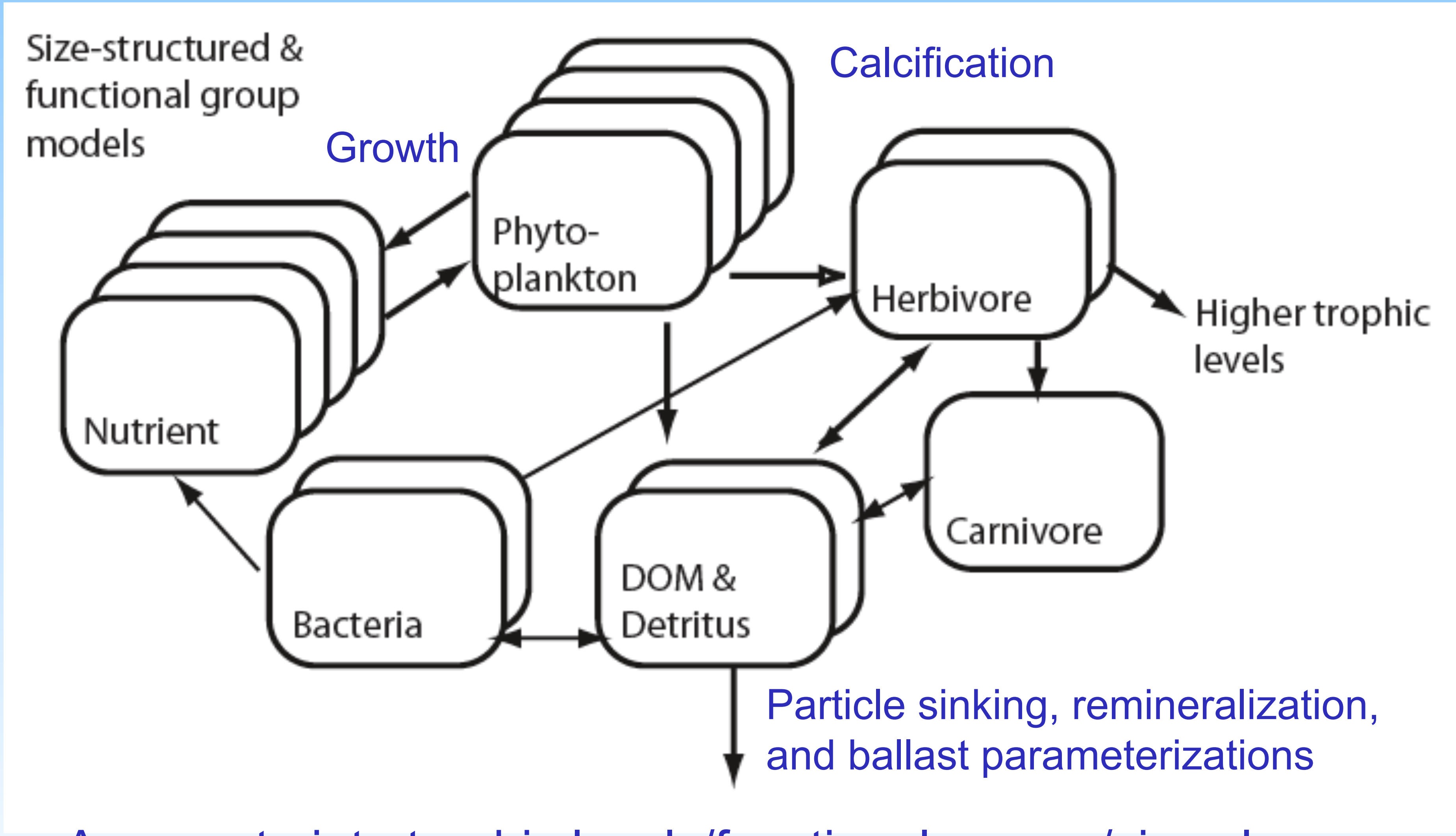


Complexity & Trade-offs

- empirical vs. dynamical
- functional form & parameters
- parameterizing across scales & unresolved processes
- data for model evaluation
- physical-chemical framework
- quantifying uncertainty

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

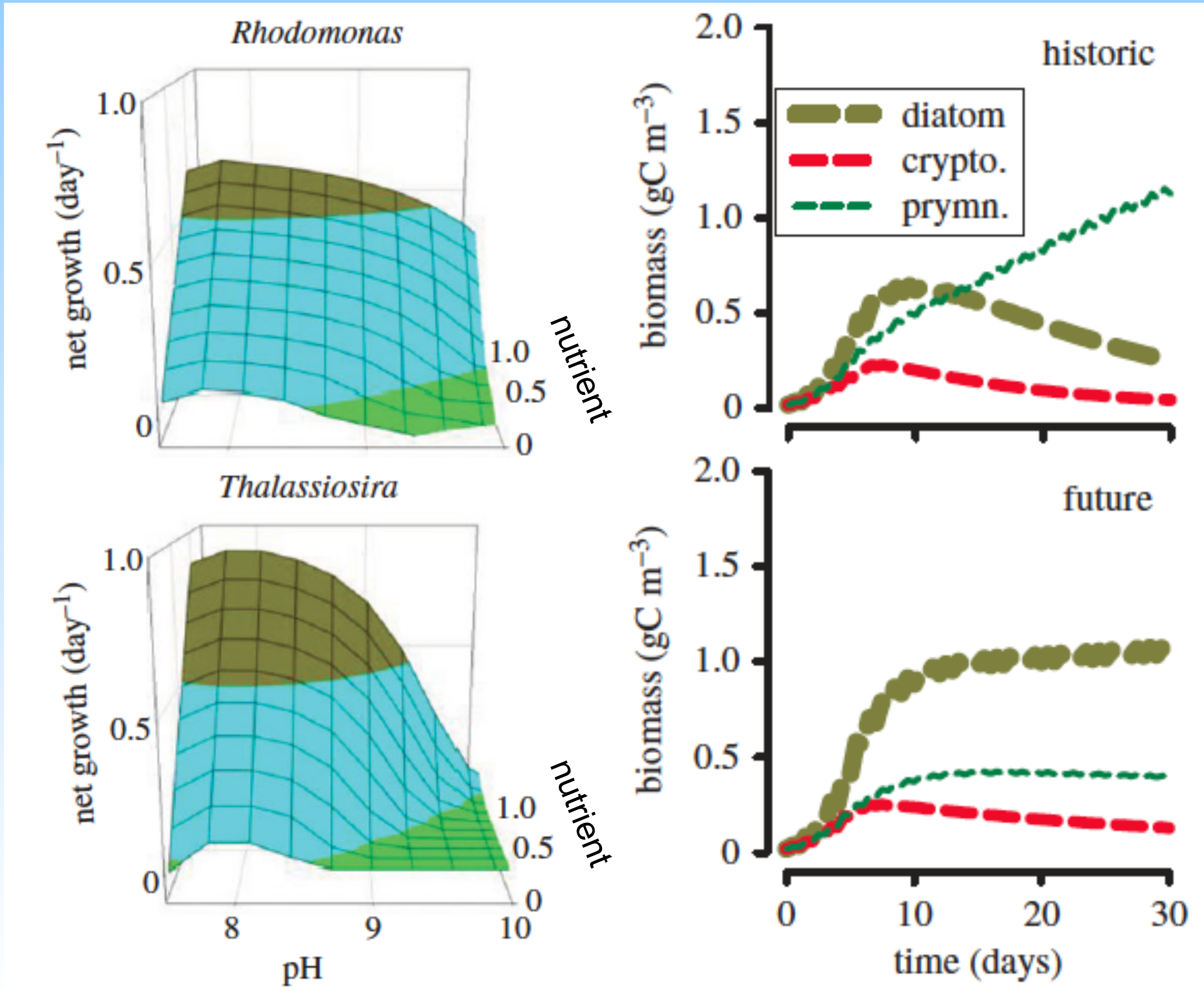
Plankton Functional Type (PFT) Models



-Aggregate into trophic levels/functional groups/size classes

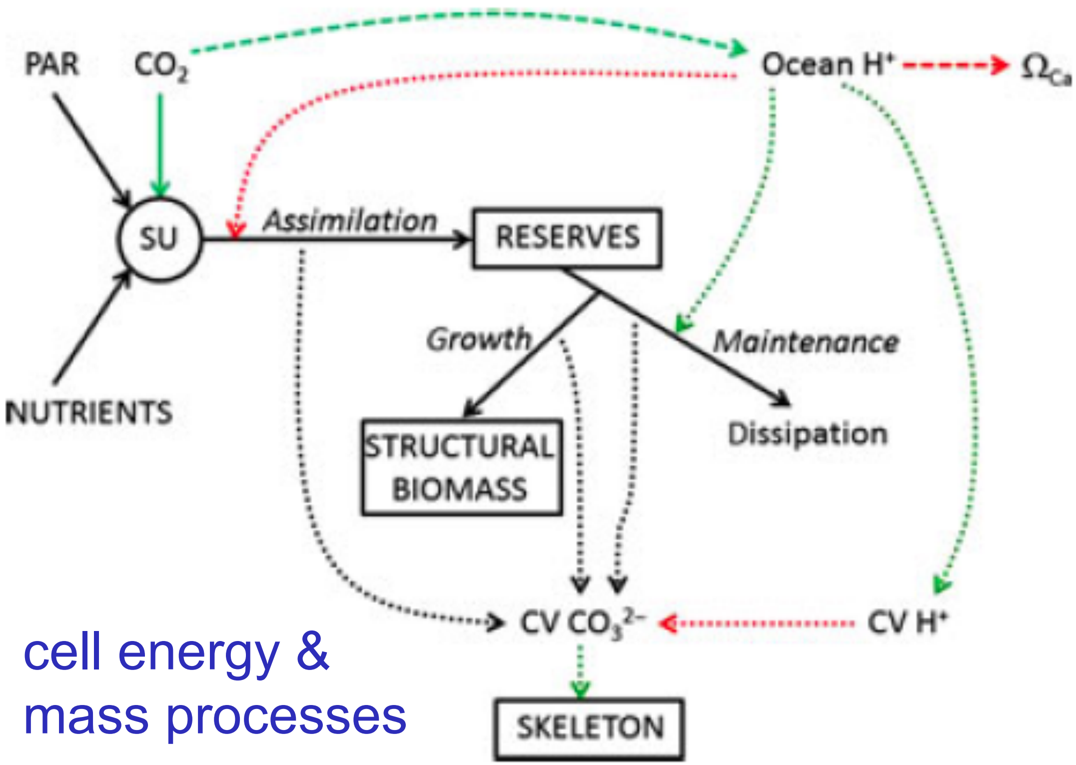
Moore et al. Global Biogeochem. Cycles 2004; LeQuere et al. Global Change Biology 2005; Hood et al. Deep-Sea Res. II 2006

Rules Governing Plankton Group Responses

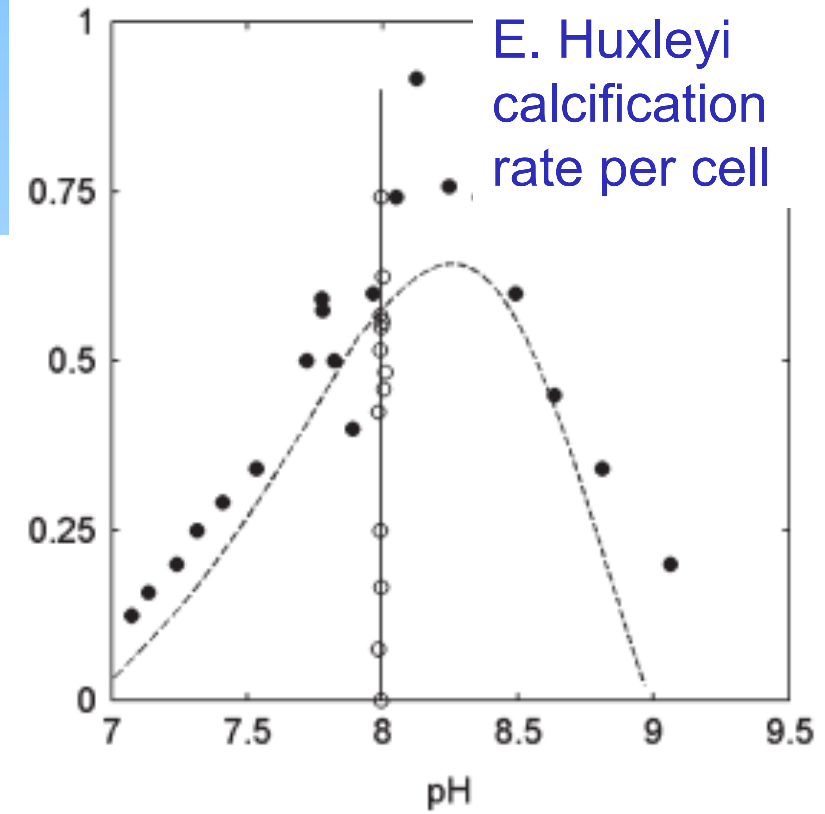


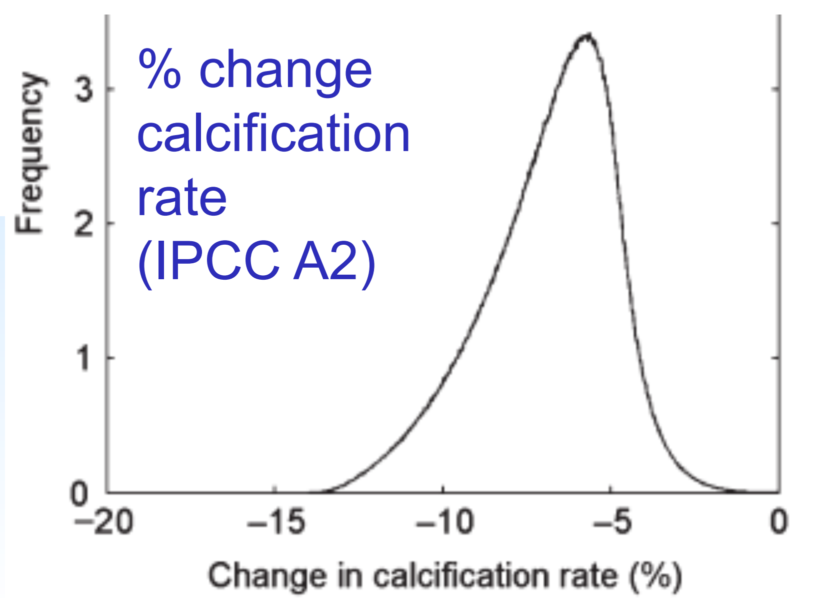
Flynn et al.
Royal Soc.
B 2015

Dynamic Energy Budget Models



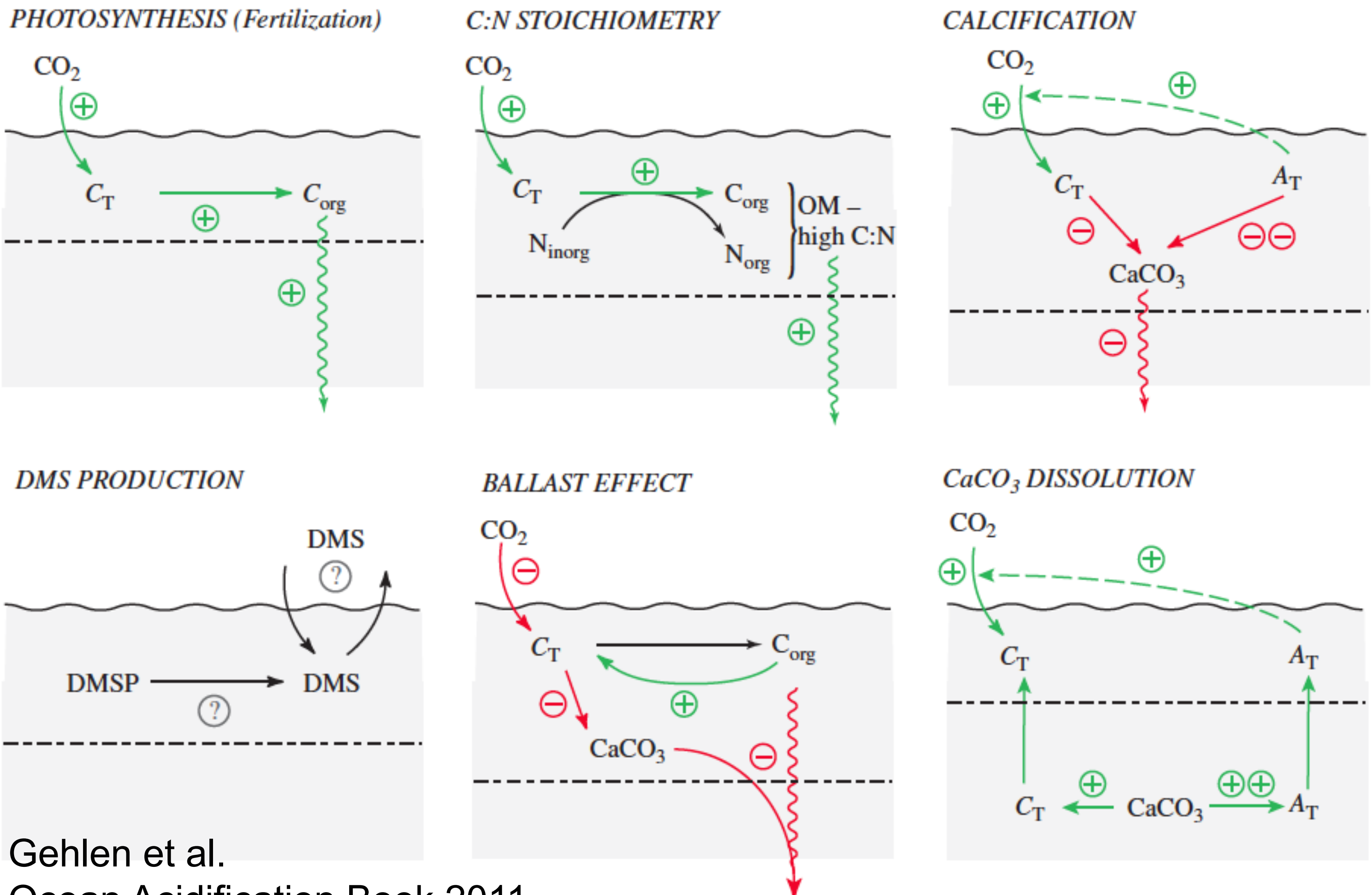
cell energy &
mass processes





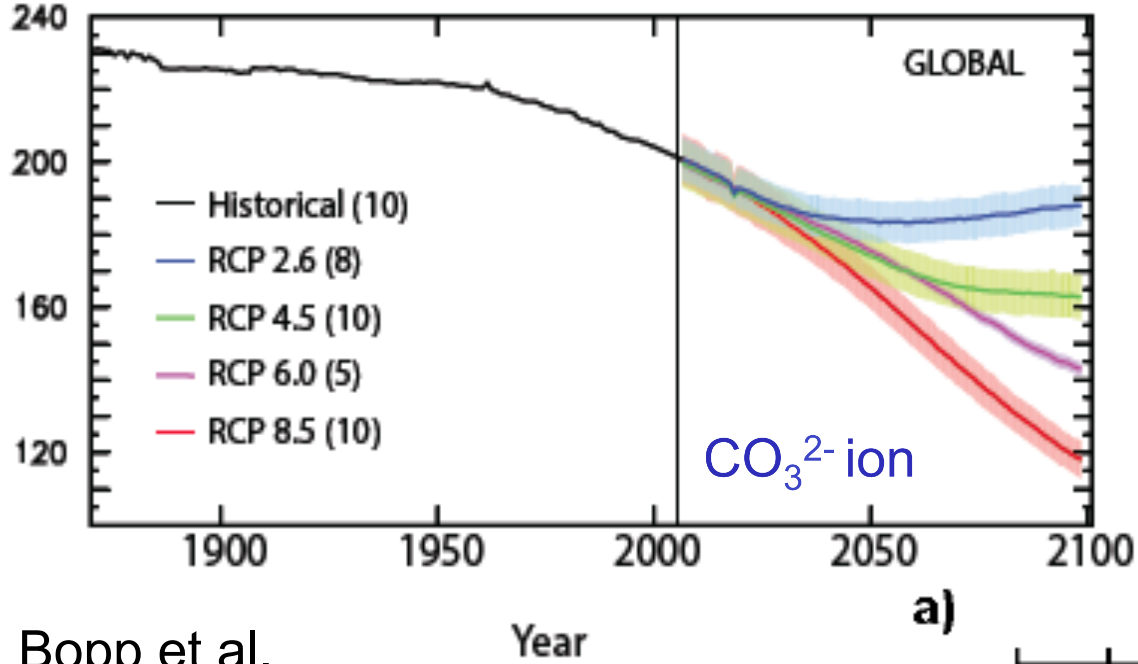
Muller & Nisbet
Global Change Biology 2014

Potential Biogeochemical Impacts & Feedbacks

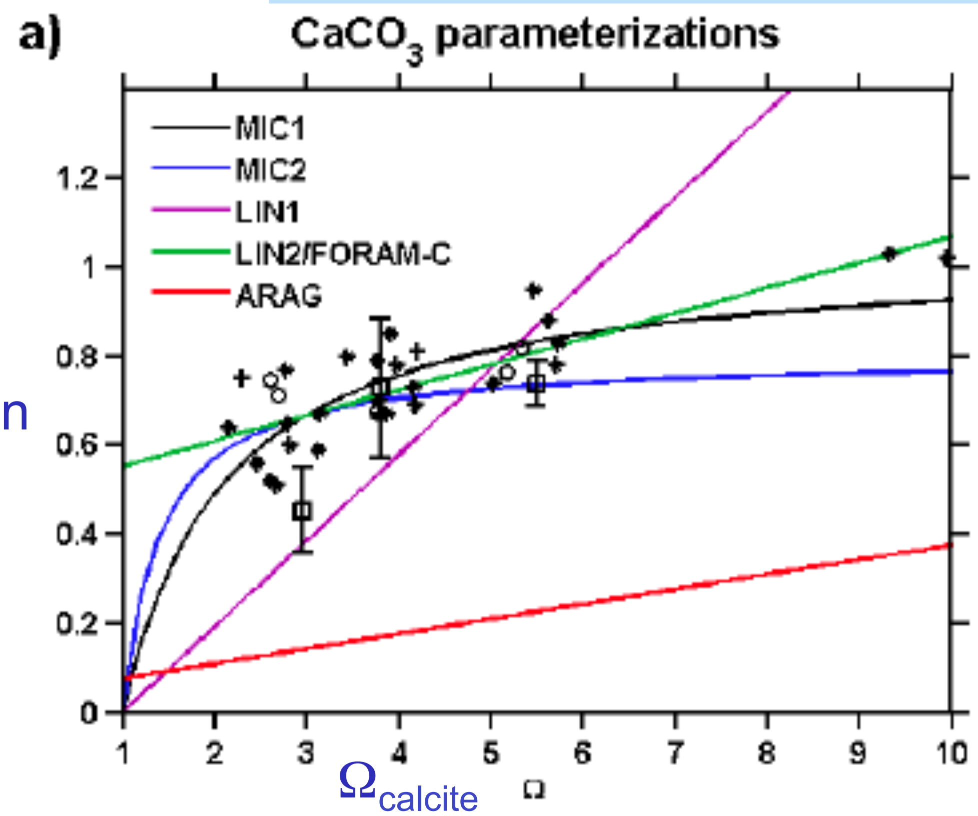


Gehlen et al.
Ocean Acidification Book 2011

$CaCO_3$ Cycle Parameterizations

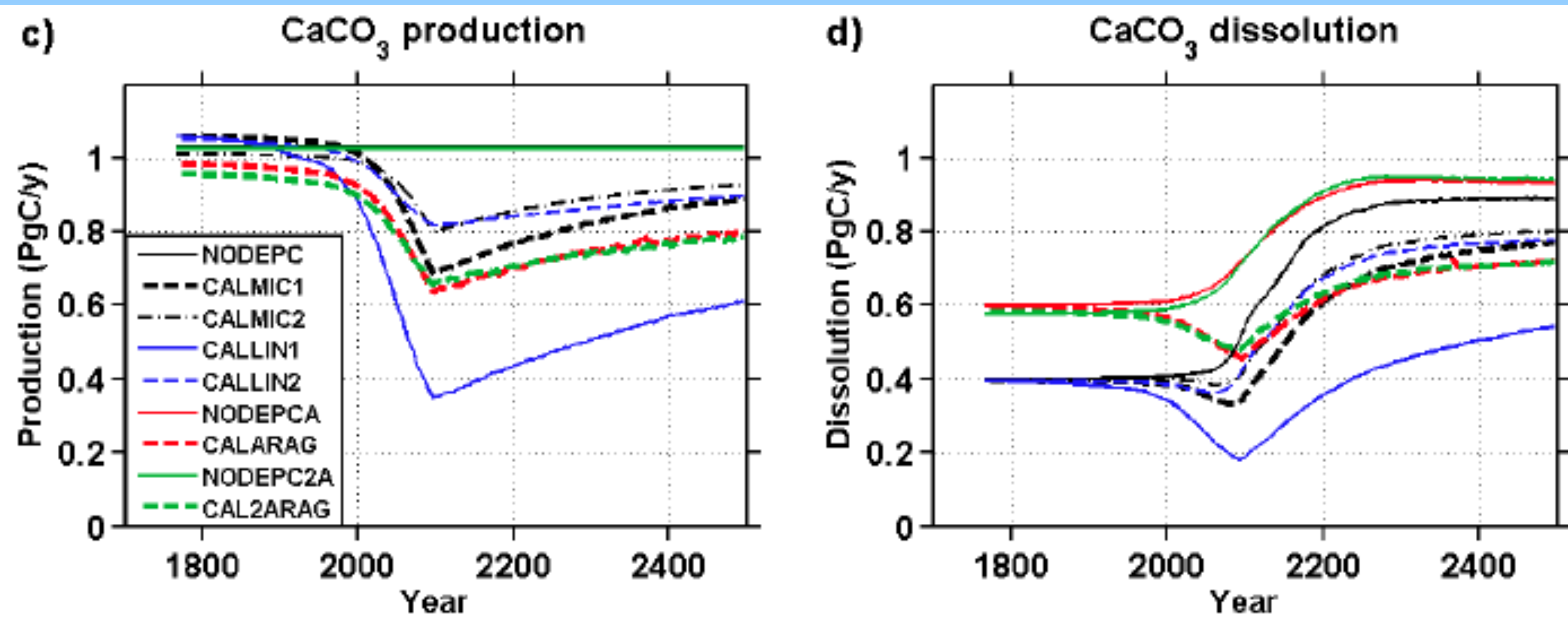


Bopp et al.
Biogeosciences 2013

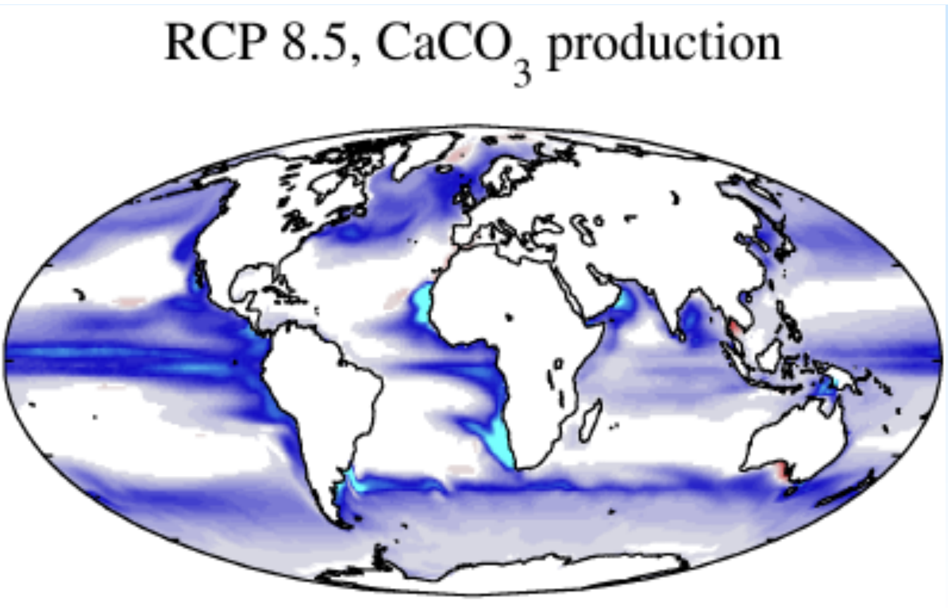


Gangstø et al.
Biogeosciences 2011
Gehlen et al.
Biogeosciences 2007

Acidification Impacts on Biogeochemistry



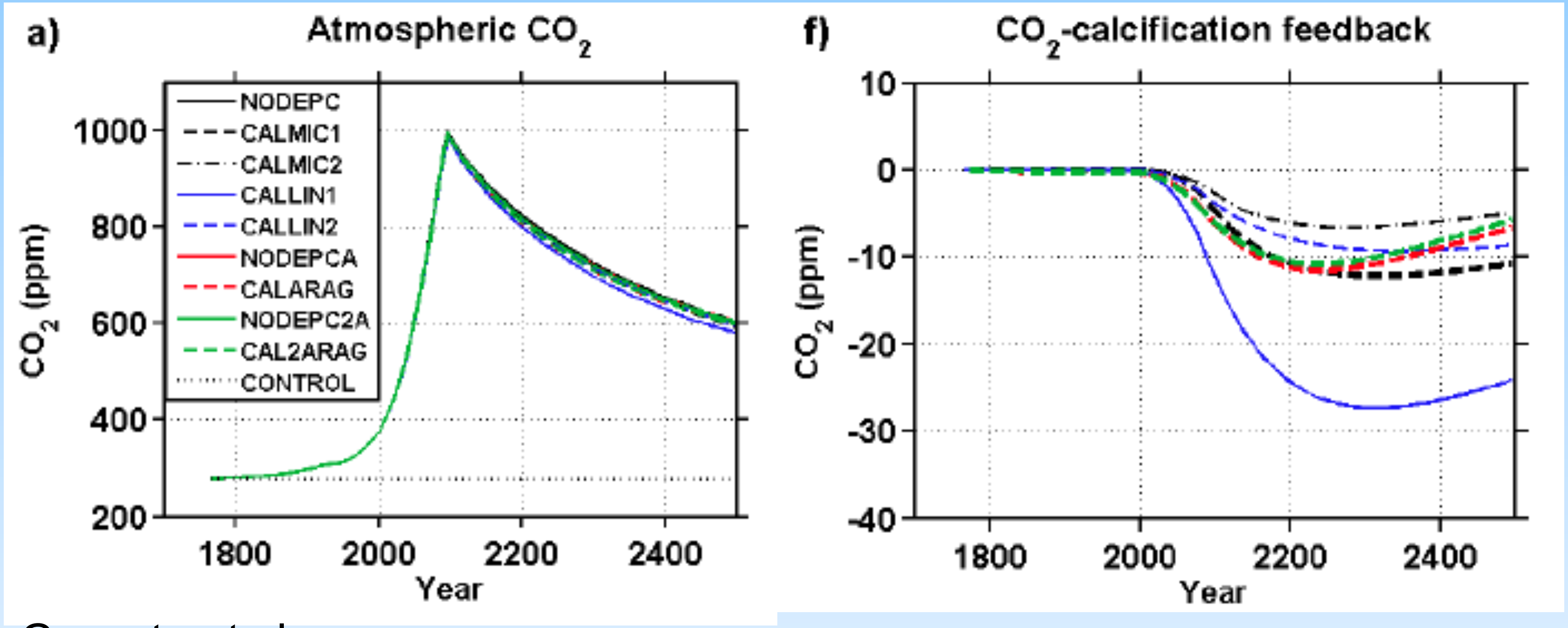
Gangstø et al. Biogeosciences 2011



	T & CO_2	T only
$CaCO_3$ prod.	-56%	-18%
Export 1000m	-41%	-18%

Yool et al. Biogeosciences 2013

$CaCO_3$ – Acidification – Carbon Cycle Feedbacks



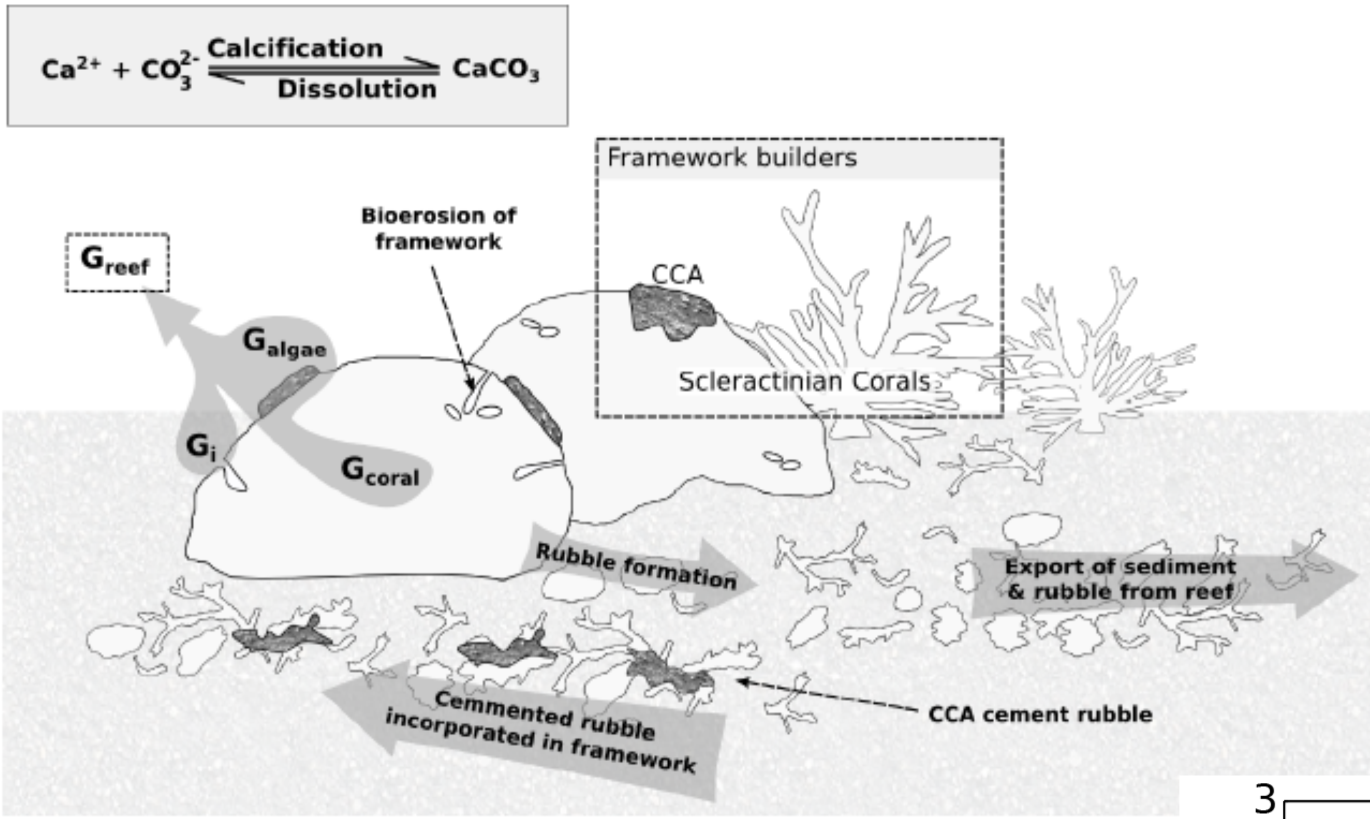
Gangstø et al.
Biogeosciences 2011

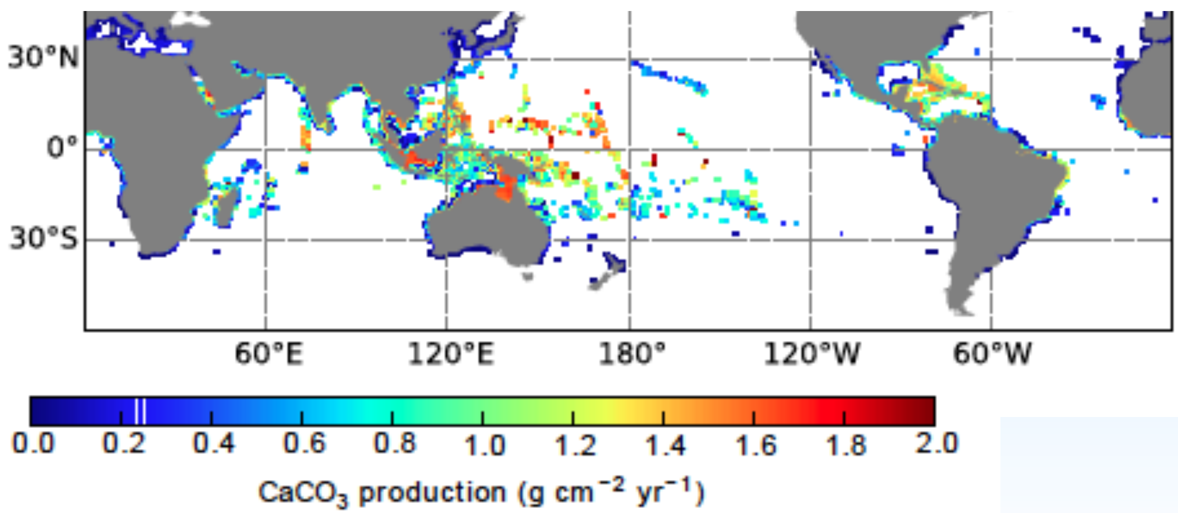
See also:
Heinze Geophys. Res. Lett. 2004
Ridgwell et al. Biogeosciences 2009
Pinsonneault et al. Biogeosciences 2012

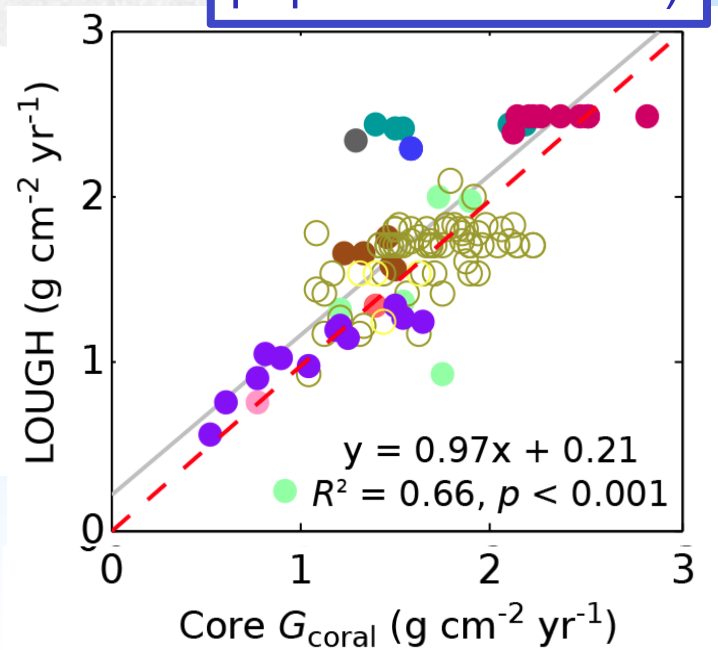
Coral Reef Carbonate Production

$CaCO_3$ production function of light, temp & $\Omega_{aragonite}$

Need improved estimates of coral cover (coral population models)

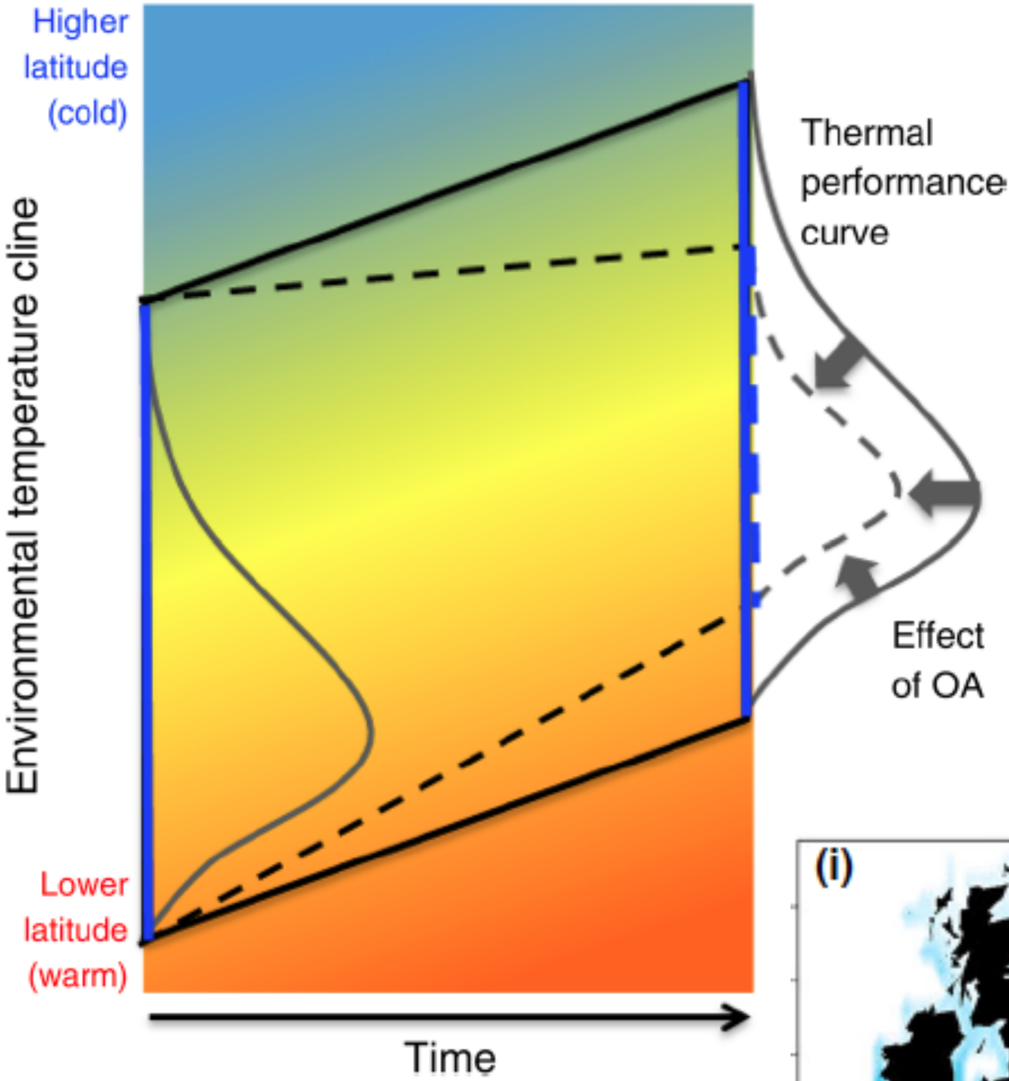






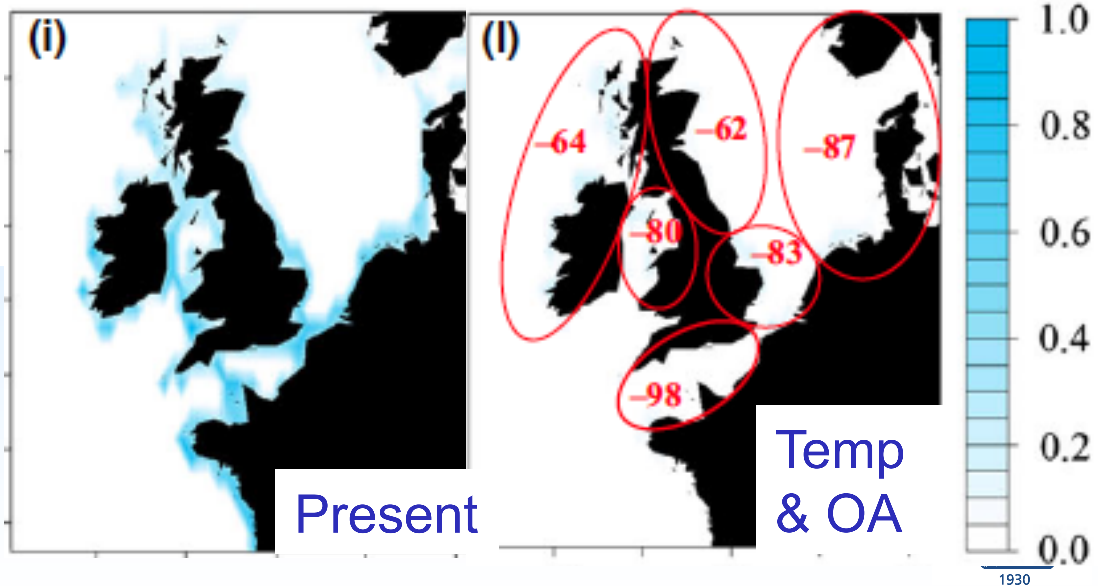
Jones et al. Biogeosciences 2015

Bioclimatic Envelope Models



Gaylord et al. Ecology 2015

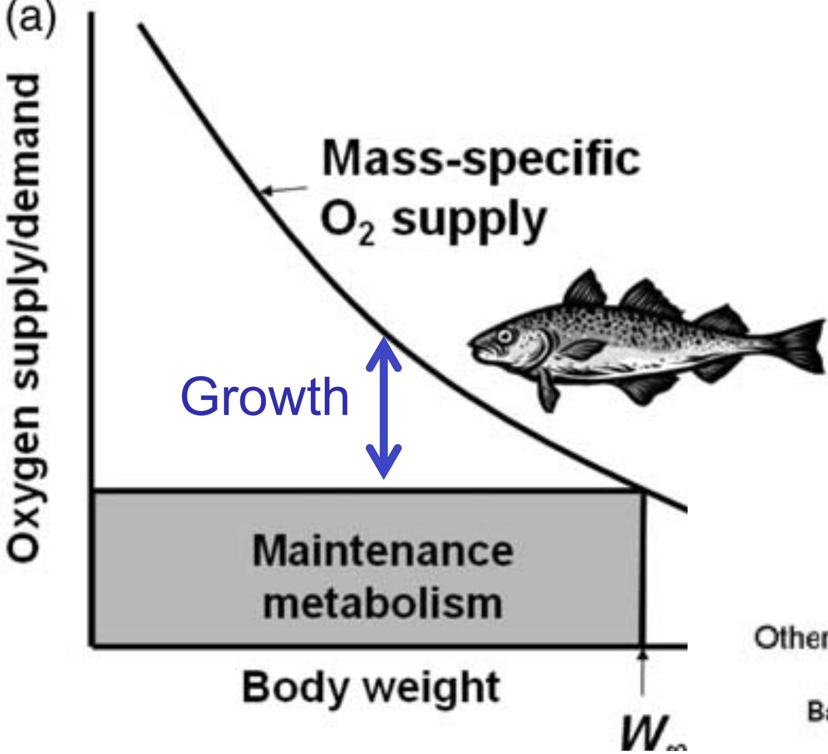
marine gastropod
Nucella lapillus



Queiros et al.
Global Change Biology 2015

Dynamic Bioclimate: Warming, Hypoxia & Acidification

Cheung et al.
ICES J. Mar. Sci. 2011



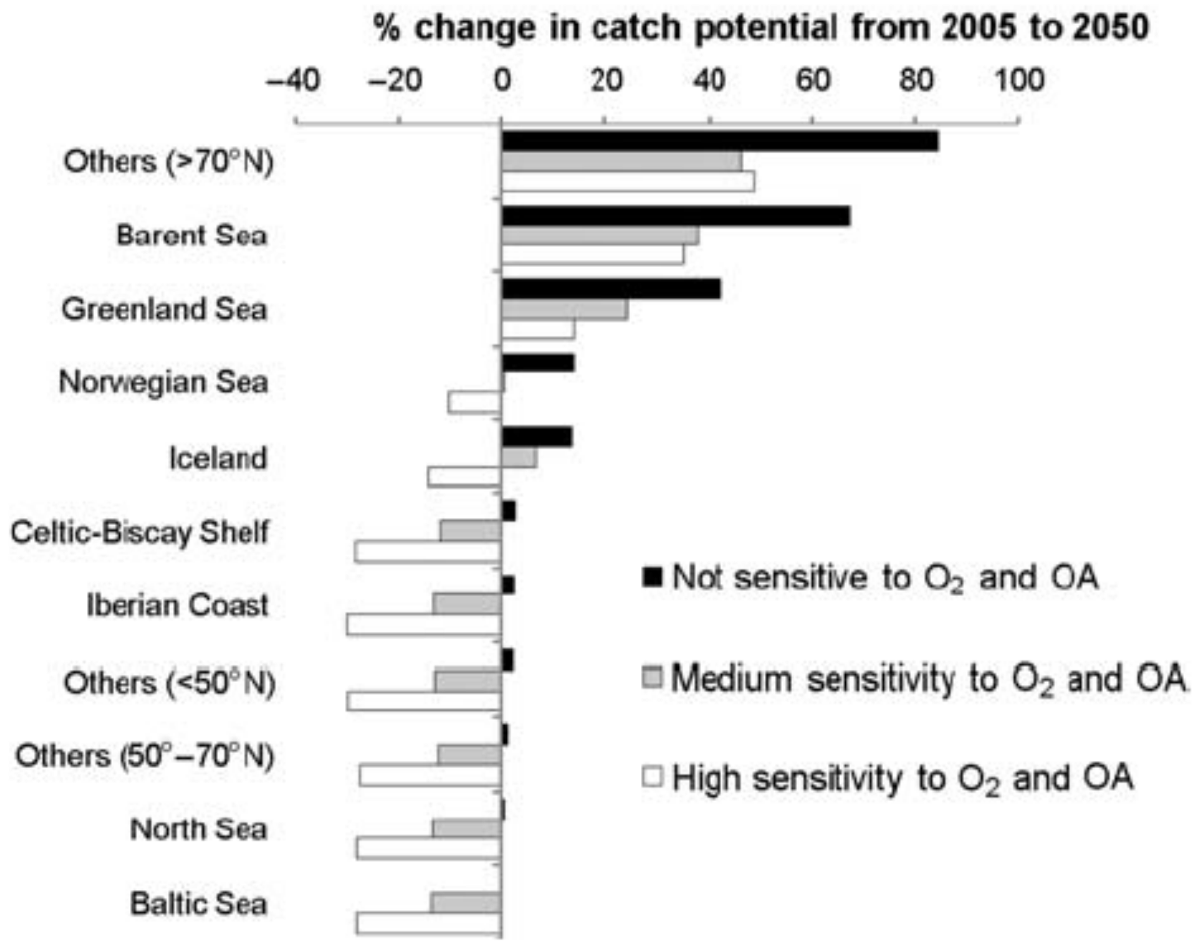
$$\frac{dB}{dt} = HW^a - kW,$$

Growth = anabolism
– catabolism

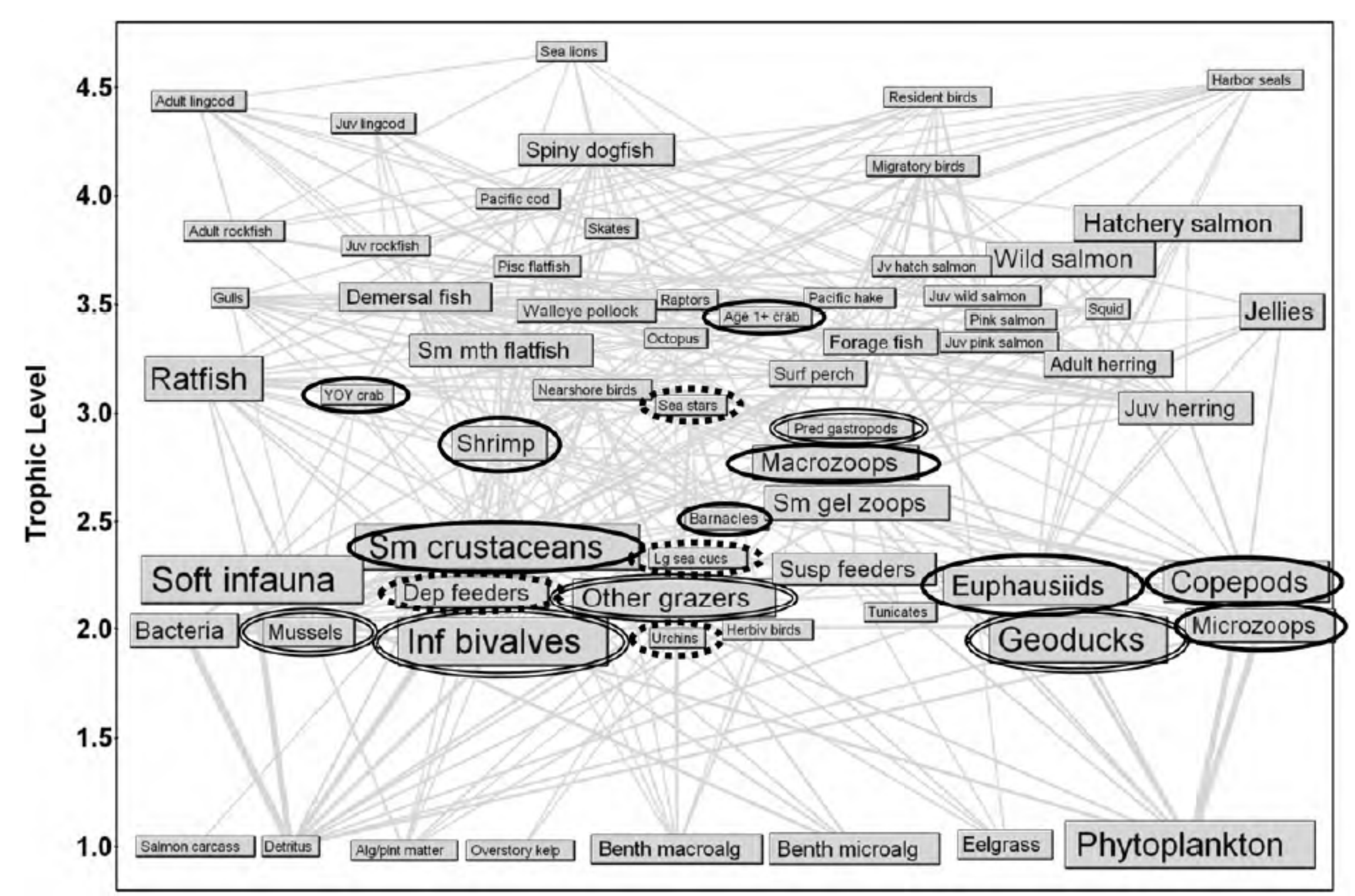
W = body weight

$$H \propto f(O_2)f_1(T),$$

$$k \propto f_2(T)f([H^+]).$$

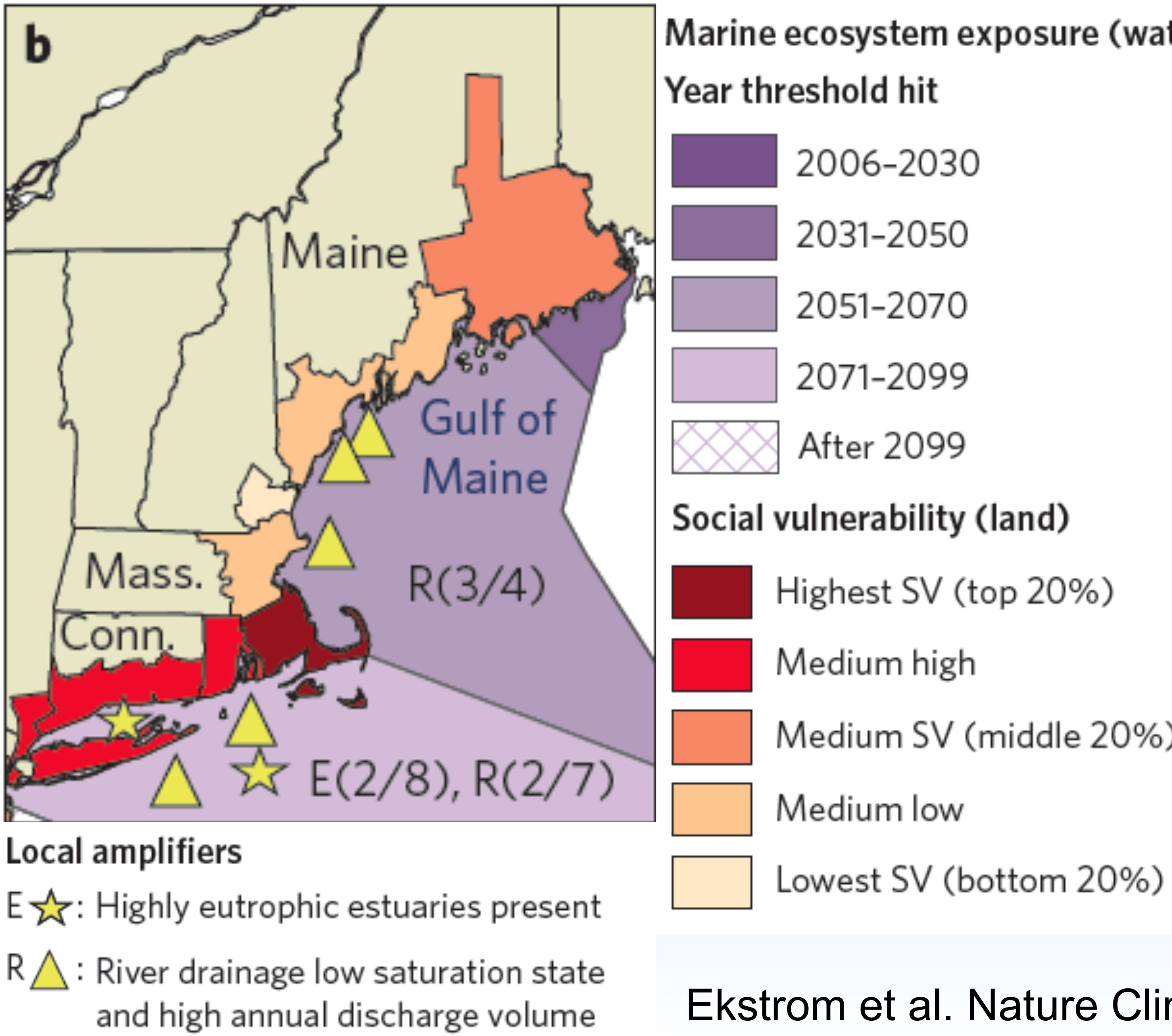


Direct and Indirect Food-web Effects



Busch et al. ICES J. Mar. Sci. 2013 Ecopath & Ecosim Foodweb

Vulnerability & Adaptation of Shellfisheries to OA



Exposure

- threshold year $\Omega_{aragonite} = 1.5$
- eutrophication
- river discharge
- upwelling

Sensitivity

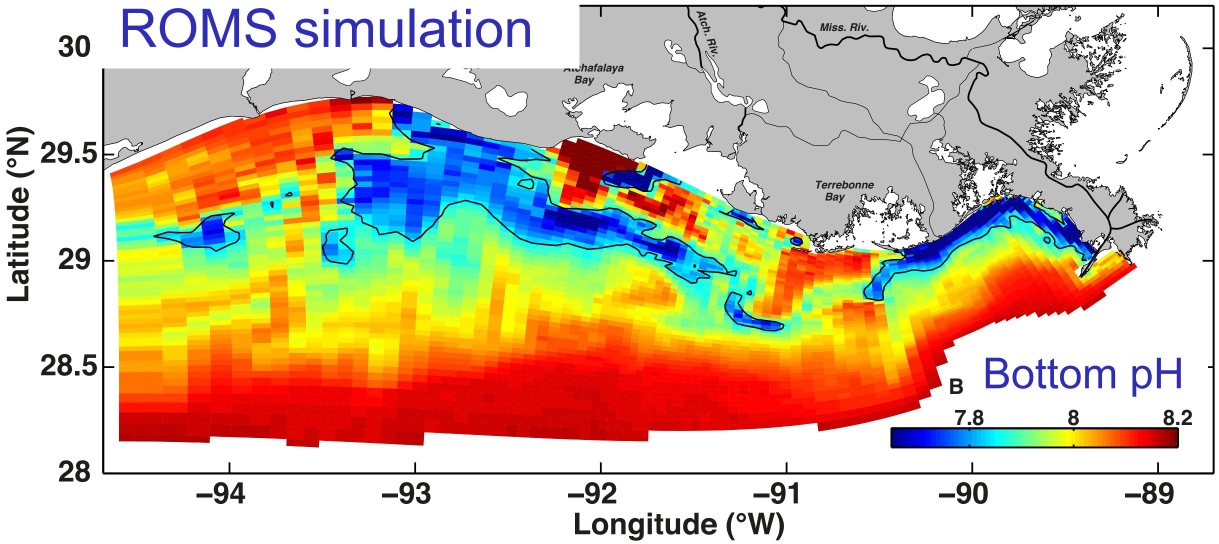
- local societal importance of shellfish

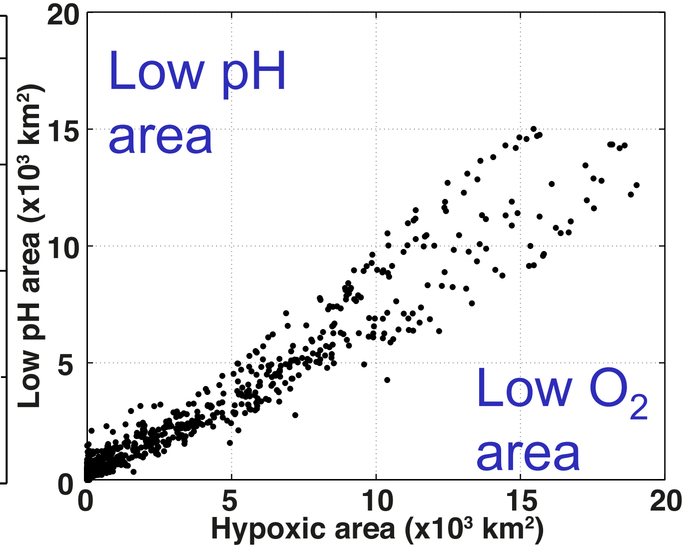
Adaptive capacity

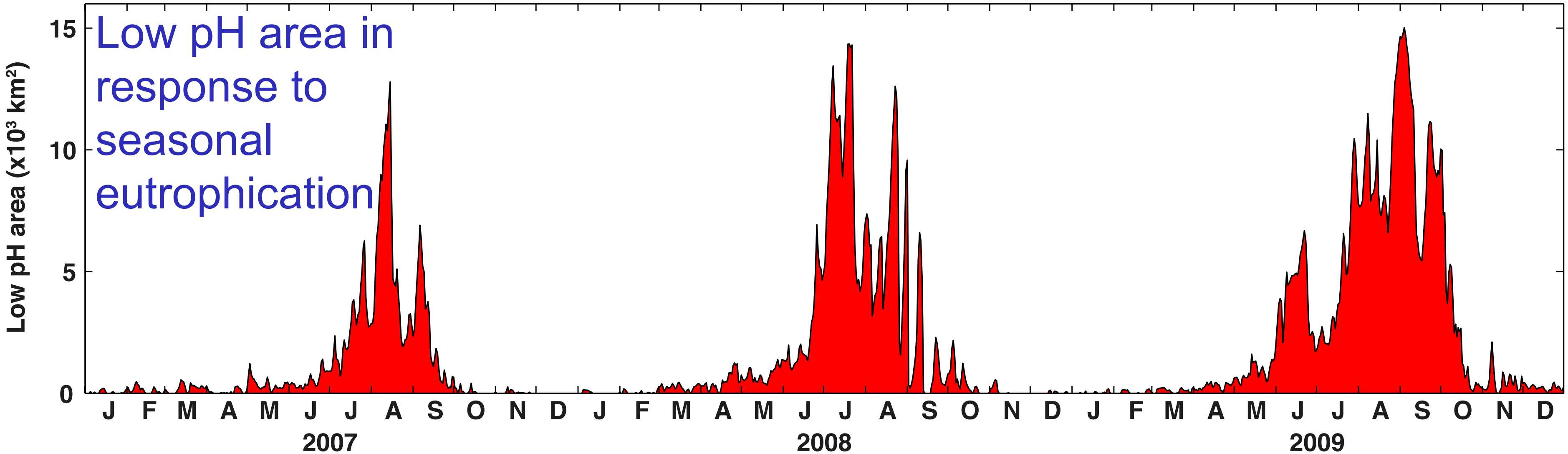
- assets available to help prepare for or avoid impacts of OA

Ekstrom et al. Nature Climate Change 2015

Regional/Coastal Biogeochemical Models



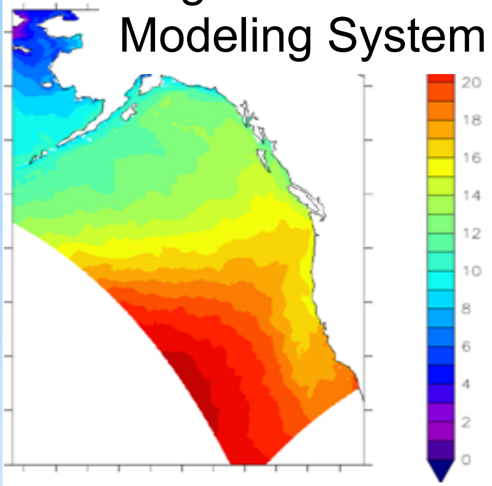




Laurent, Fennel, Cai, Huang, Barbero & Wanninkhof (in prep.)

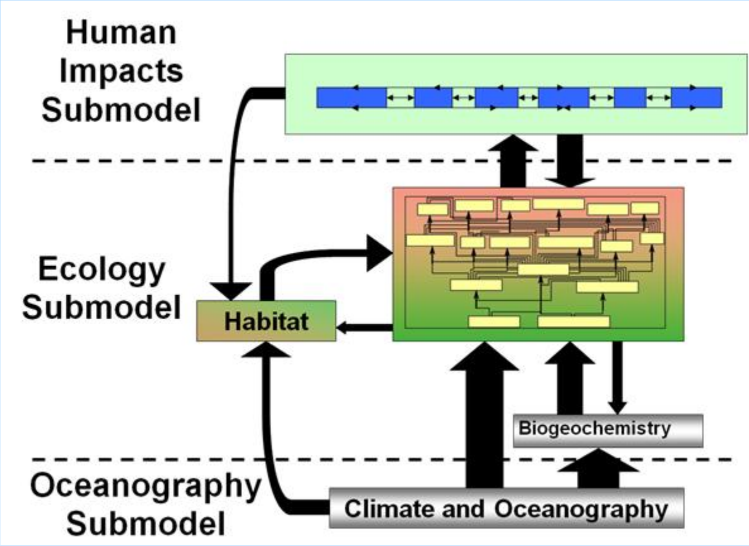
Vulnerability Assessment of California Current Food Webs and Economics to Ocean Acidification

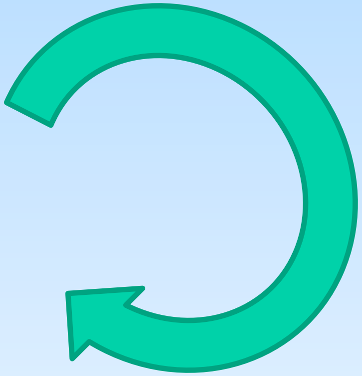
Regional Ocean Modeling System



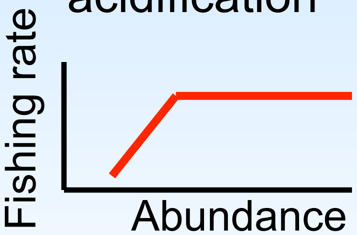
Biology meta-analysis

Atlantis ecosystem model





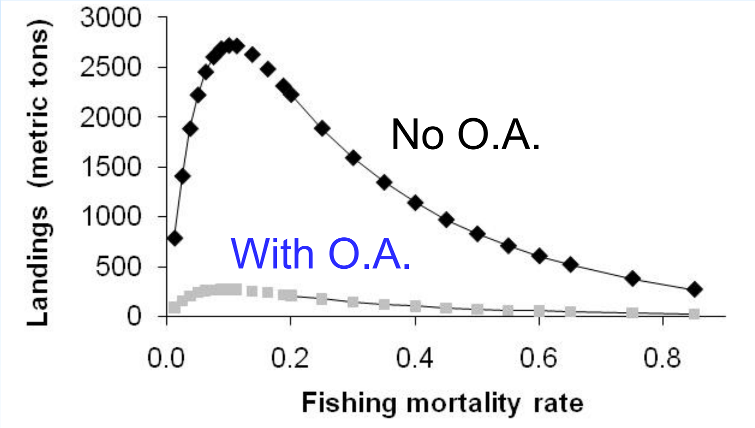
Test management strategy performance in the face of ocean acidification



Spatial economic impacts: input-output model.

JOBS $ INCOME

Stock productivity



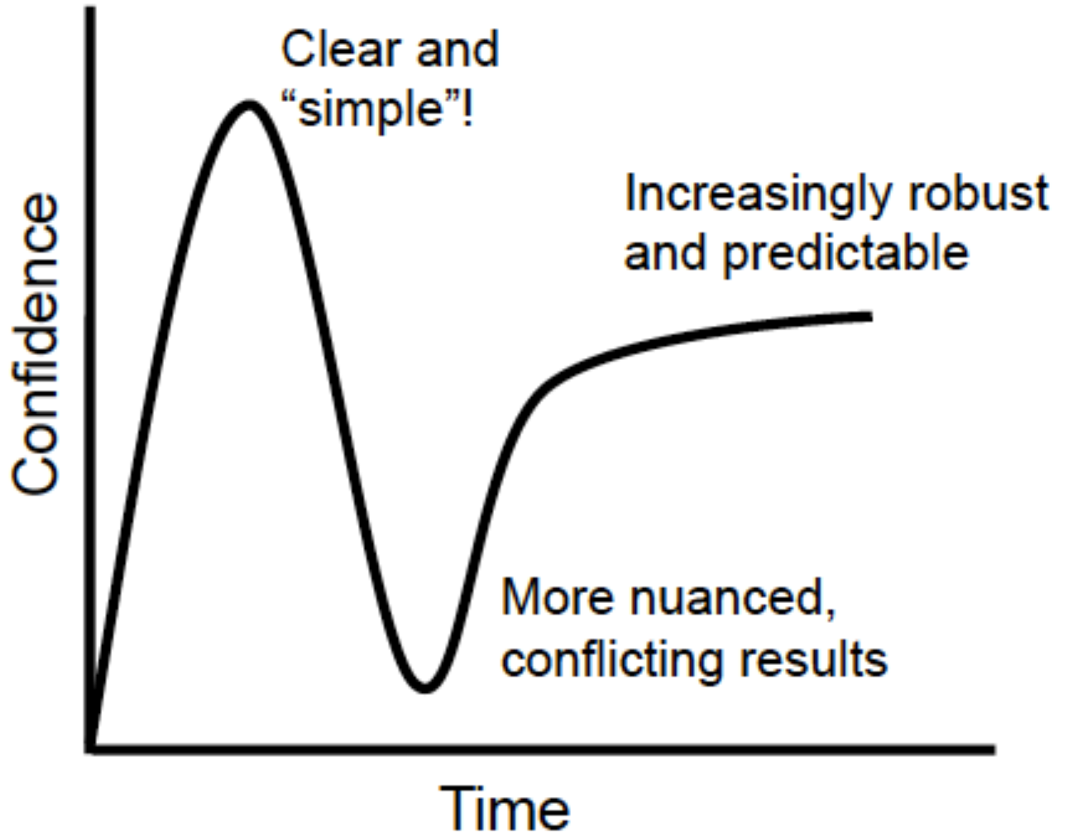
Kaplan, Busch, Fulton, Leonard, Hermann, Harvey, Essington & McElhany (in prep.)

What Have We Learned in the Past Decade?

June 2005

THE ROYAL SOCIETY

Ocean acidification due to increasing atmospheric carbon dioxide



Busch et al. Oceanography 2015 (in press)

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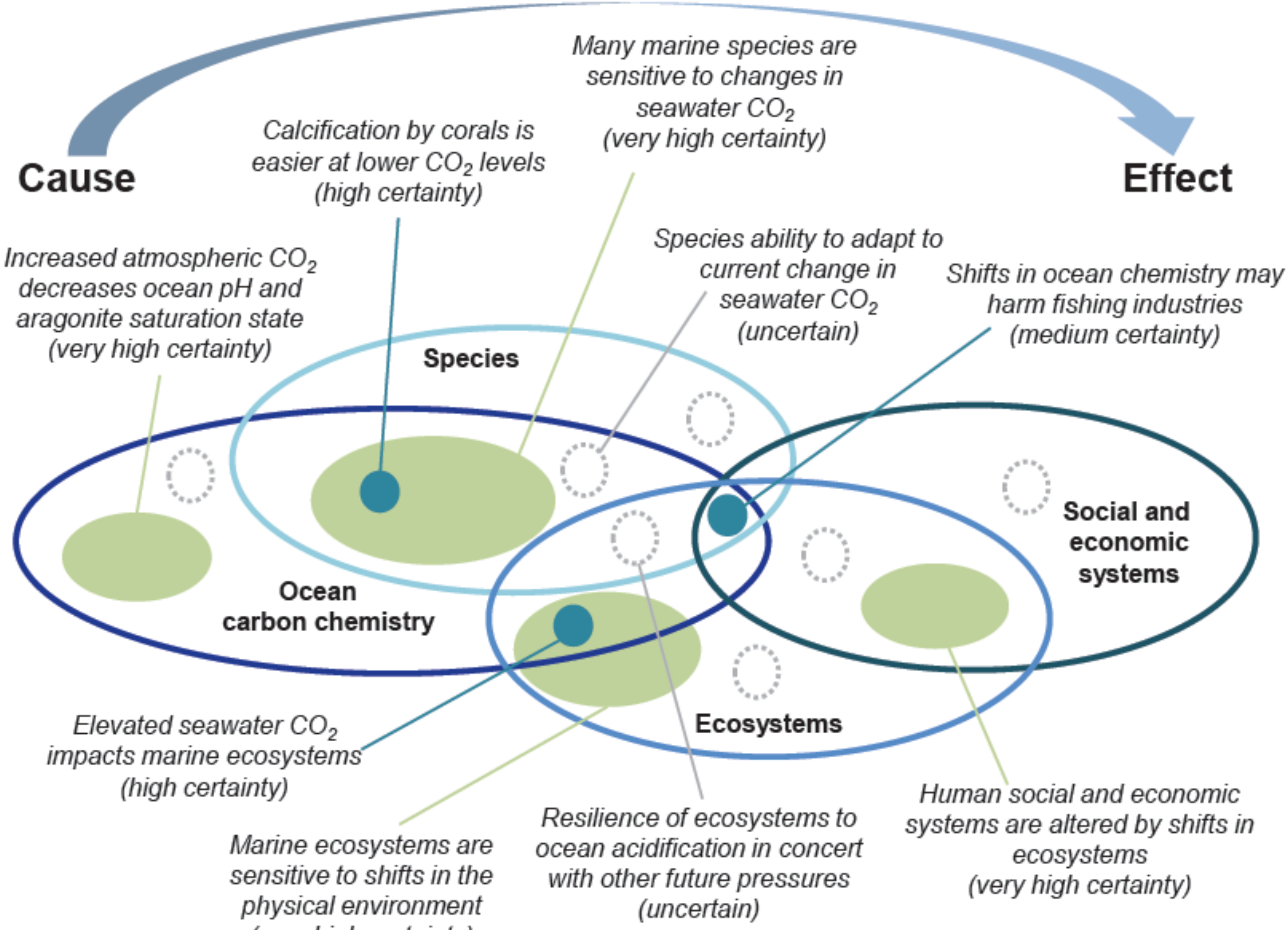
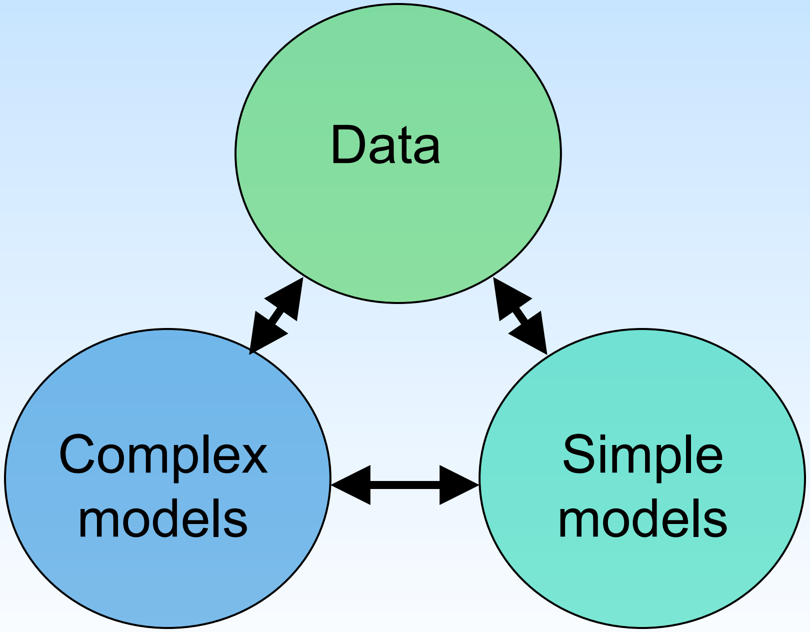


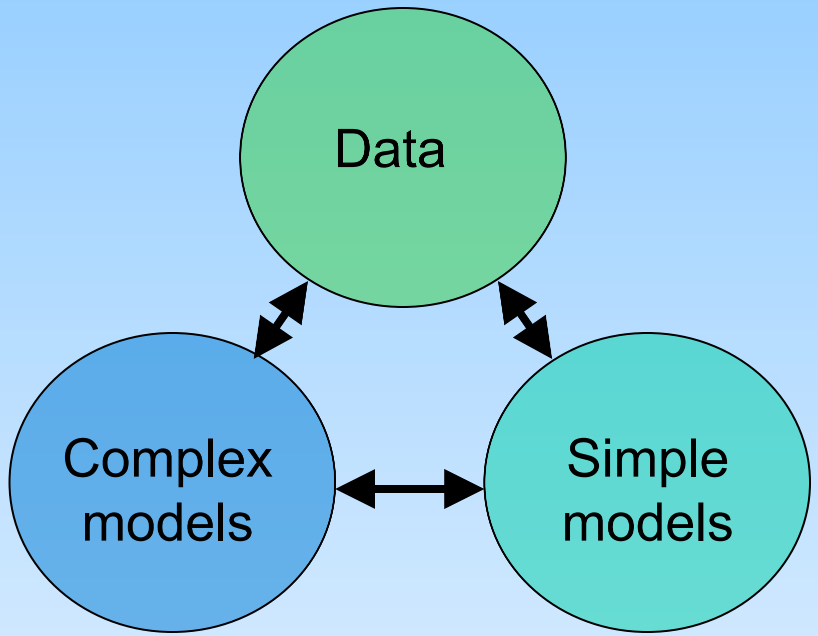
Busch et al. Oceanography 2015

"I am never content until I have constructed a mechanical model of the subject I am studying. If I succeed in making one, I understand; otherwise I do not.“
- Lord Kelvin

"People don't understand the earth, but they want to, so they build a model, and then they have two things they don't understand,”
-Gerard Roe in “The Whale and the Supercomputer” by C. Wohlforth



Ecosystem Modeling of Ocean Acidification



Complexity & Trade-offs

- empirical vs. dynamical
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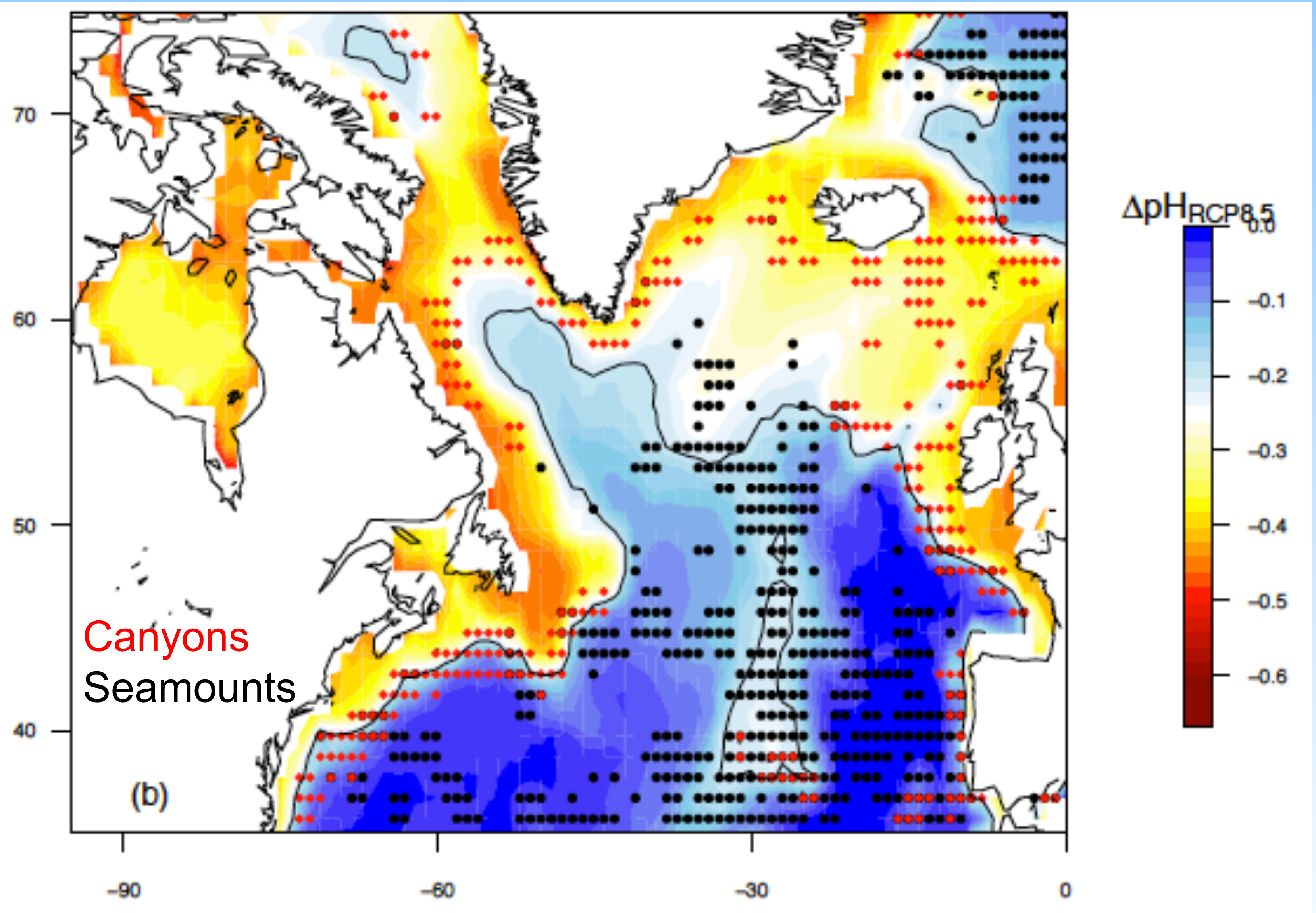
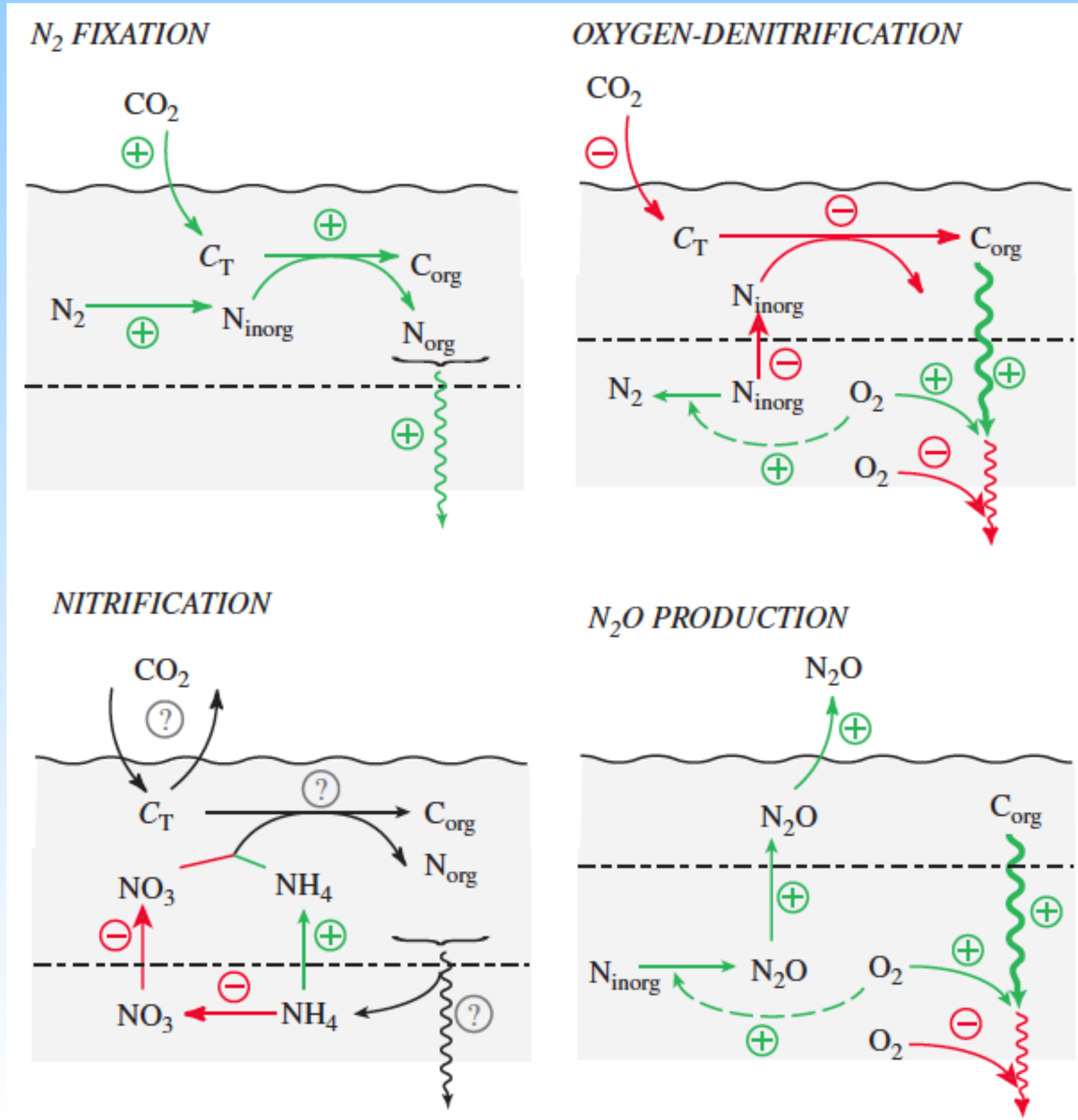
- data for model evaluation
- physical-chemical framework
- quantifying uncertainty

Extra Slides

Projected Deep pH Trends & Biodiversity Threats

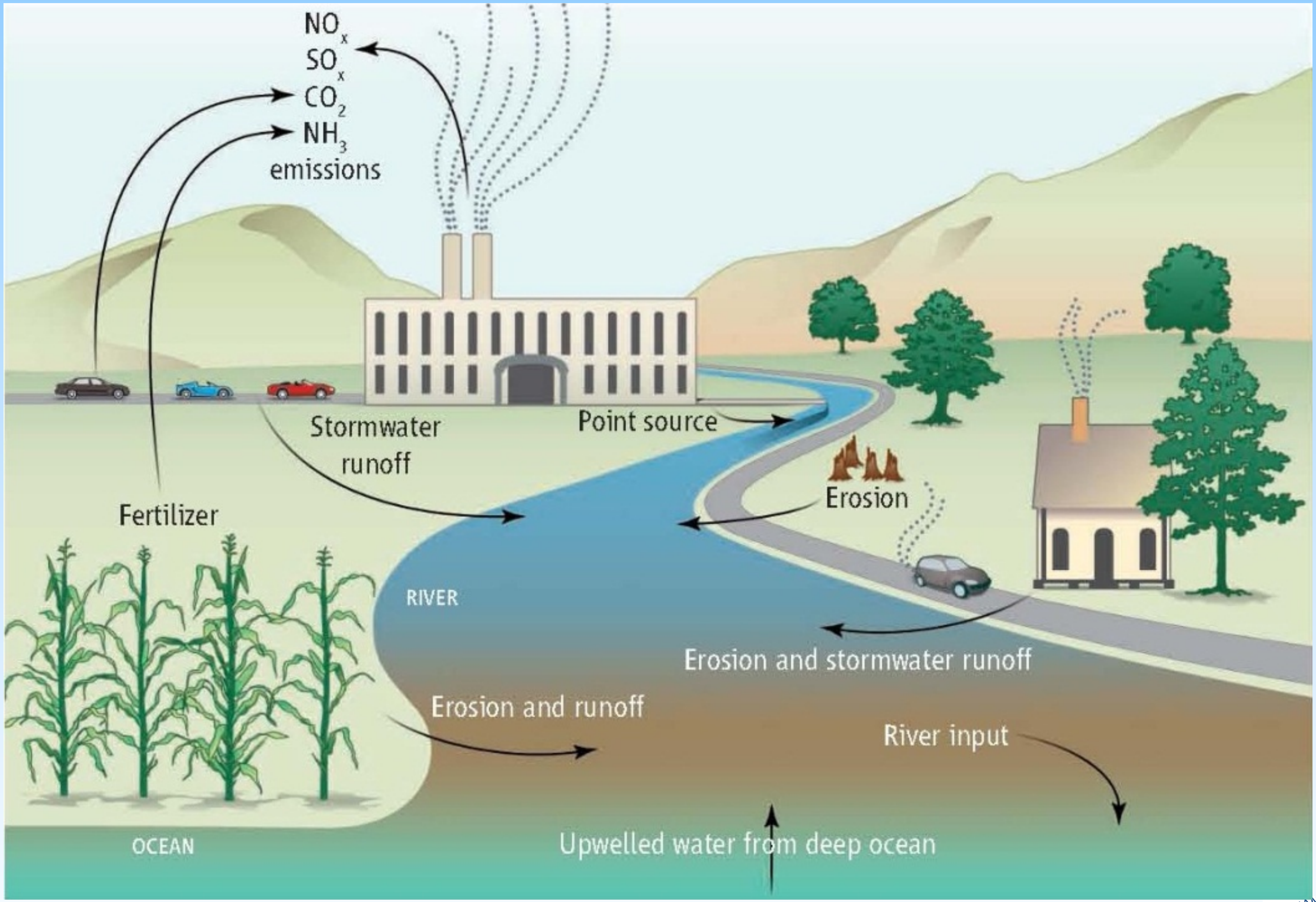


Gehlen et al. Biogeosciences 2014



N_2 FIXATION
CO_2
C_T
C_{org}
N_2
N_{inorg}
N_{org}
OXYGEN-DENITRIFICATION
CO_2
C_T
C_{org}
N_{inorg}
N_2
N_{inorg}
O_2
O_2
NITRIFICATION
CO_2
C_T
C_{org}
N_{org}
NO_3
NH_4
NO_3
NH_4
N_2O PRODUCTION
N_2O
N_2O
C_{org}
N_{inorg}
N_2O
O_2
O_2

Other Local Sources of Acidification



Doney et al. PNAS 2007; Doney Science 2010; Kelly et al. Science 2011