Ocean Acidification:
From Global Climate Change to Local Impact

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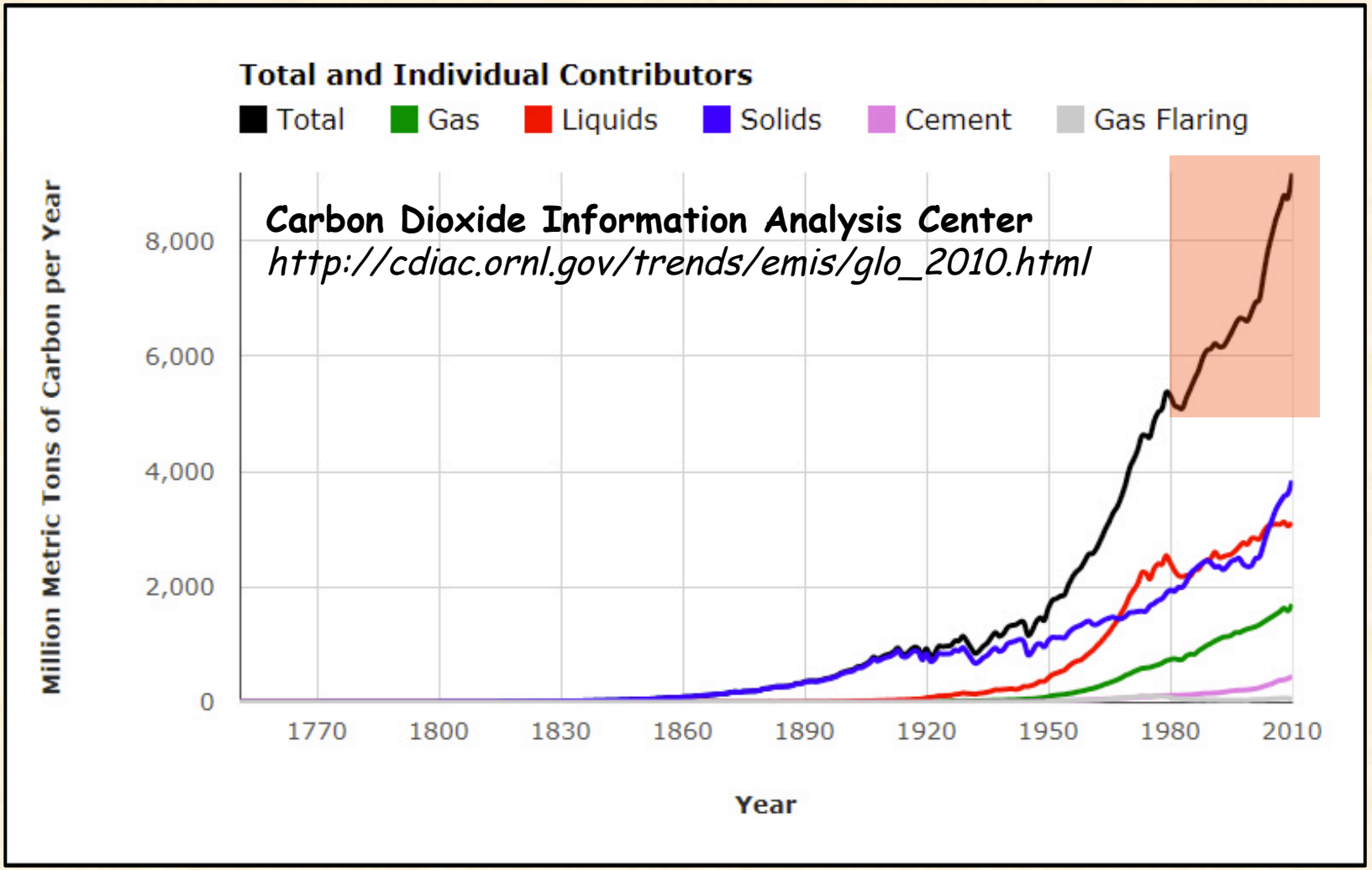
CCCma

CO_2 Emissions from Burning of Fossil Fuels & Cement# Production

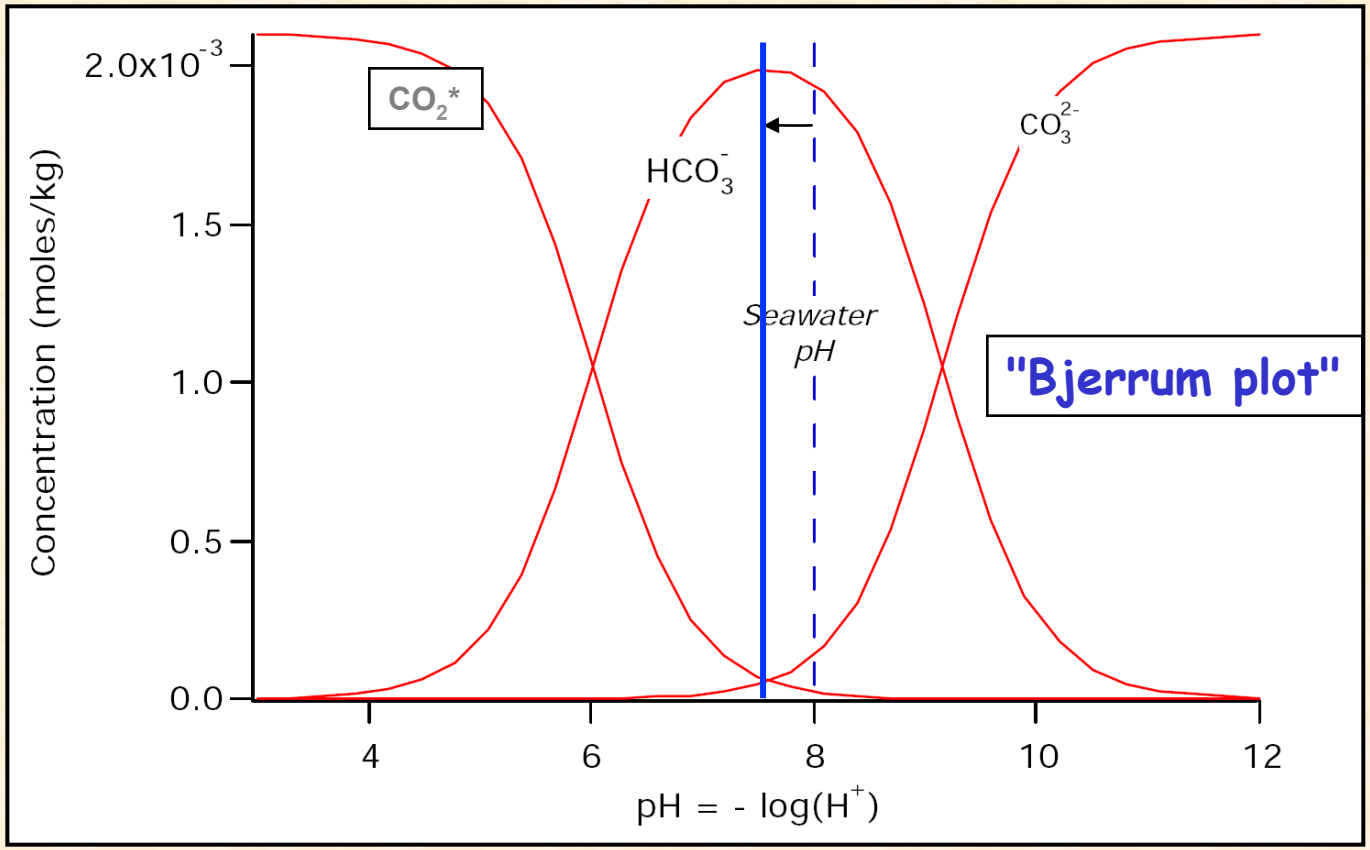


#$CaCO_3$ (limestone) ➔ CaO (quicklime) + CO_2

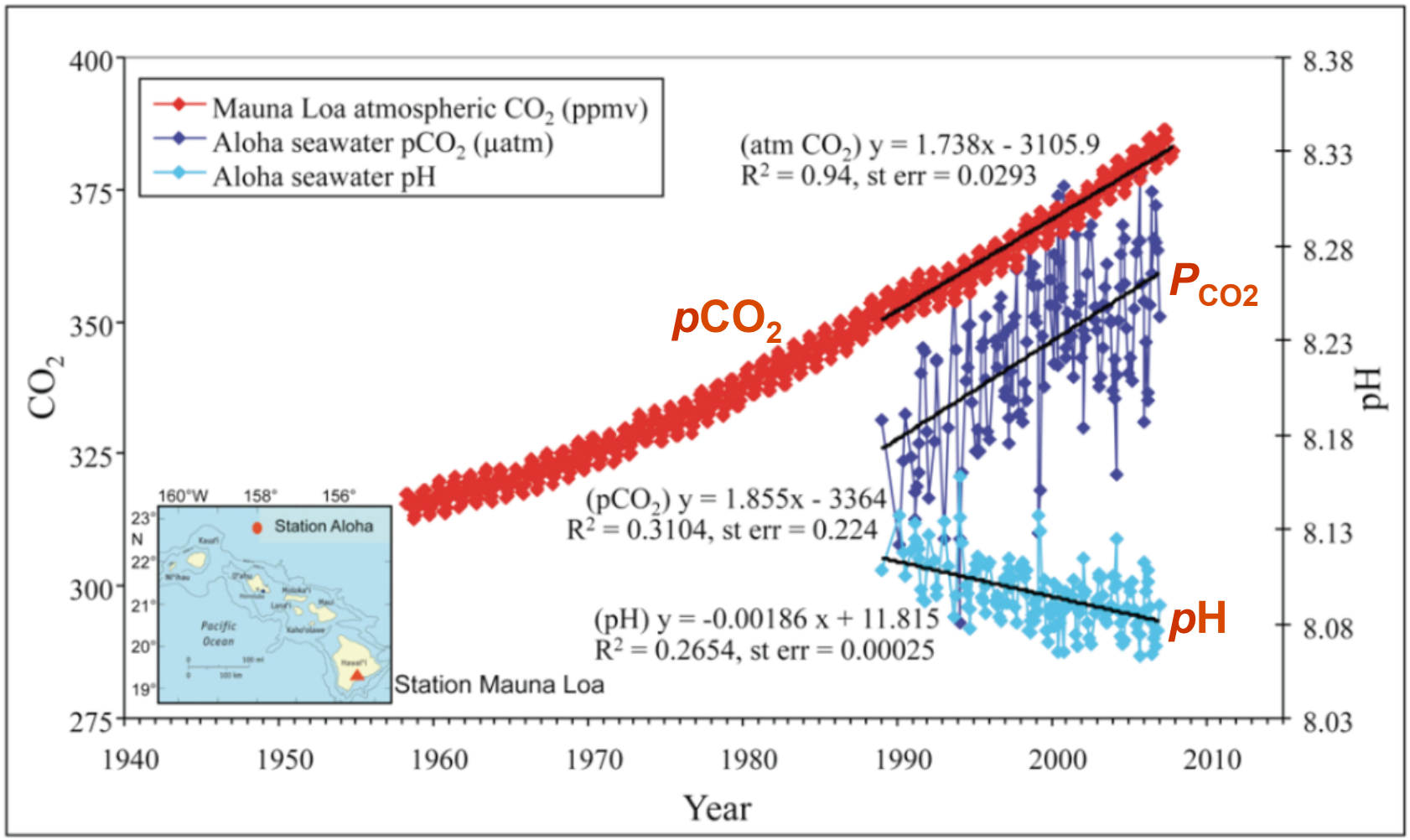
Adding CO_2 Increases Ocean Acidity

$$CO_2 + H_2O \underset{\Rightarrow}{\overset{K_1}{\leftrightarrow}} HCO_3^- + H^+ \underset{\Leftarrow}{\overset{K_2}{\leftrightarrow}} CO_3^{2-} + 2H^+$$

$$CO_2 + H_2O + CO_3^{2-} \Rightarrow 2HCO_3^-$$

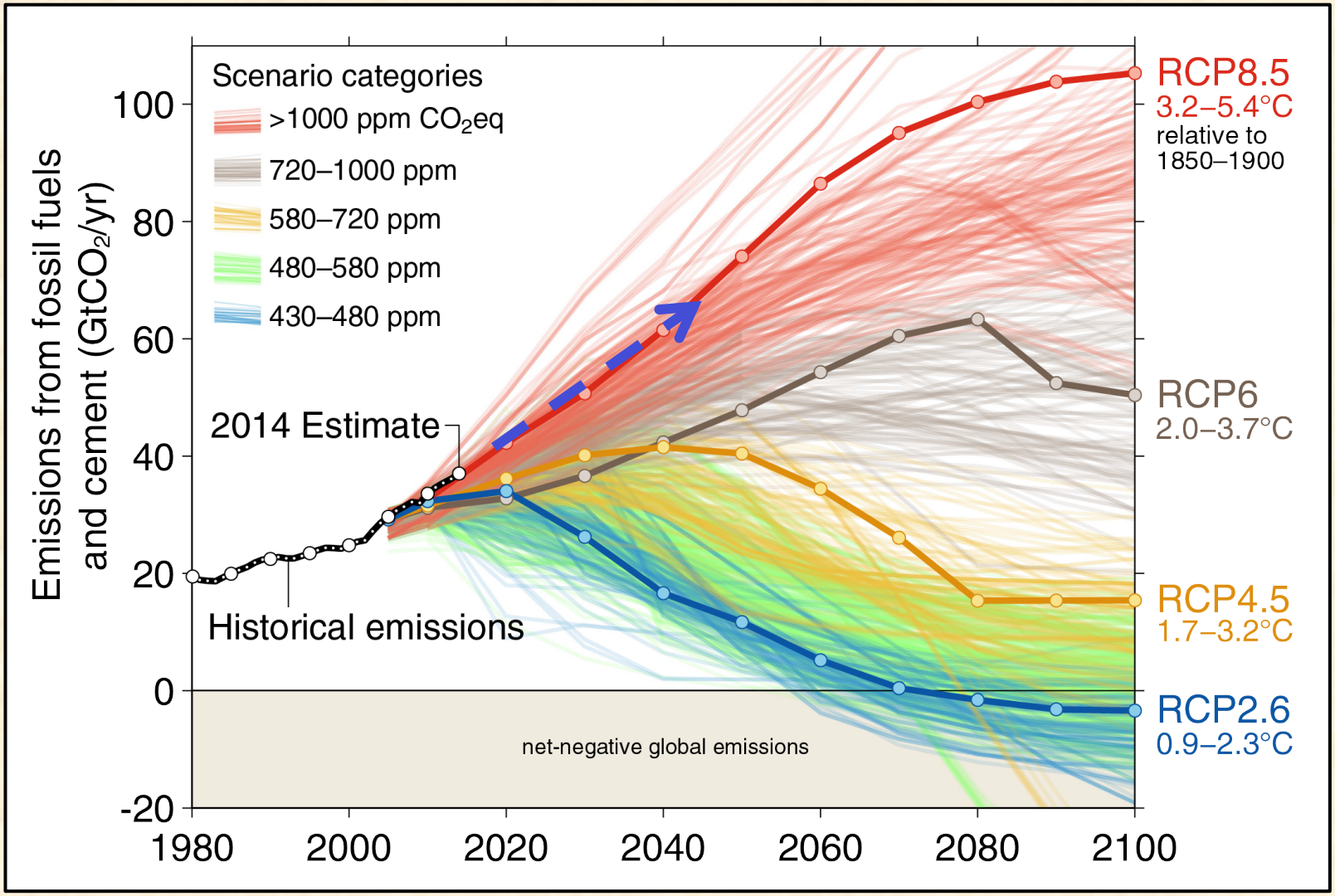


Ocean Surface P_{CO2} Tracks Atmospheric pCO_2



Iglesias-Rodriguez et al., 2010. Plenary Paper, OceanObs09, ESA Publ. WPP-306
[adapted from Dore et al., 2009, US-PNAS, 106(30)]

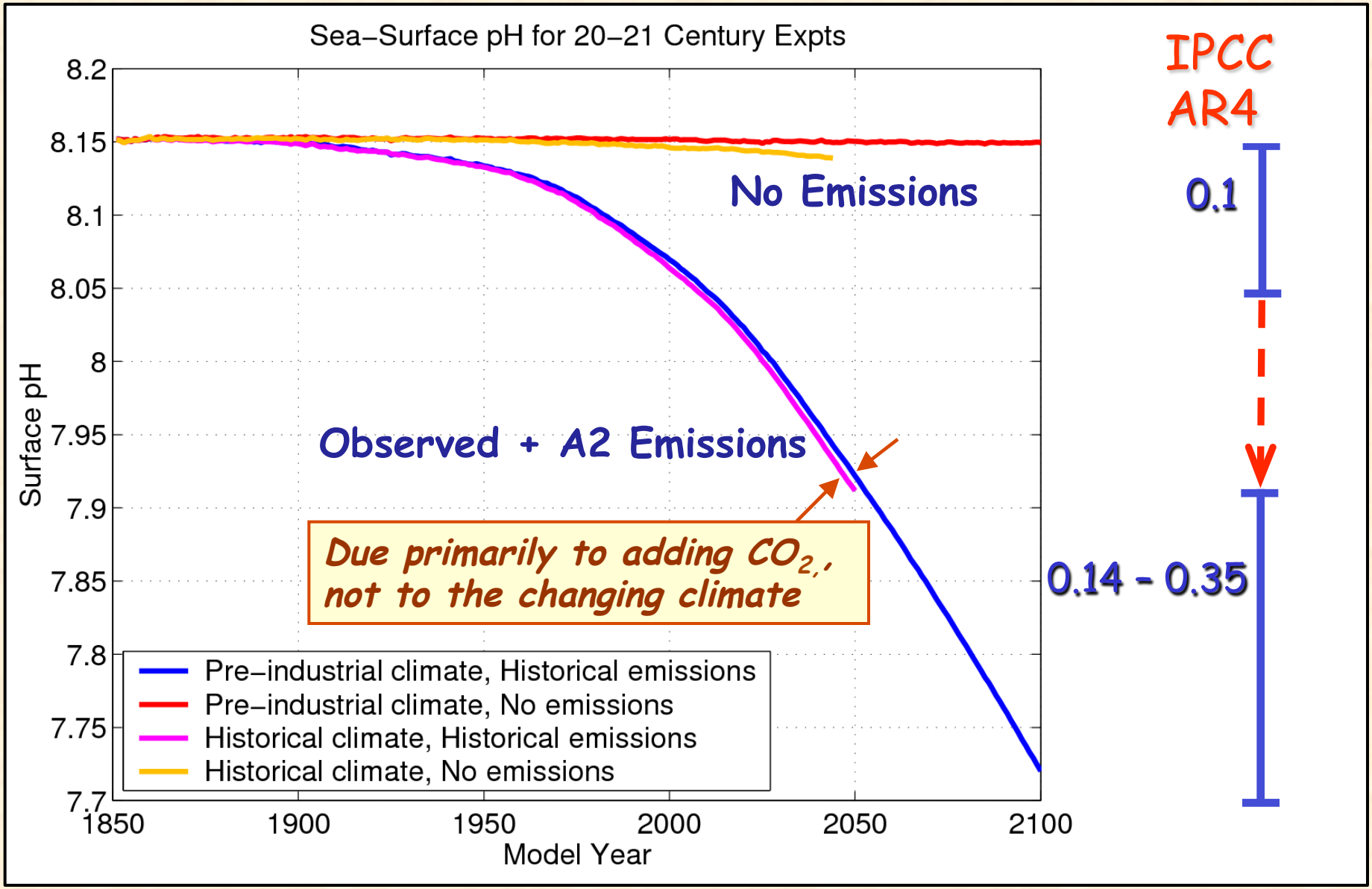
What Track Are We On?



http://www.globalcarbonproject.org/carbonbudget/index.htm

21 September 2014

CCCma Ocean Model Surface pH Decrease



Denman et al., 2011, ICES Journal of Marine Science, 68: 1019-1029.

Climate Change Economics, Vol. 3, No. 1 (2012) 1250002 (29 pages)

DOI: 10.1142/S2010007812500029

World Scientific
www.worldscientific.com

THE ECONOMIC IMPACT OF OCEAN ACIDIFICATION ON CORAL REEFS

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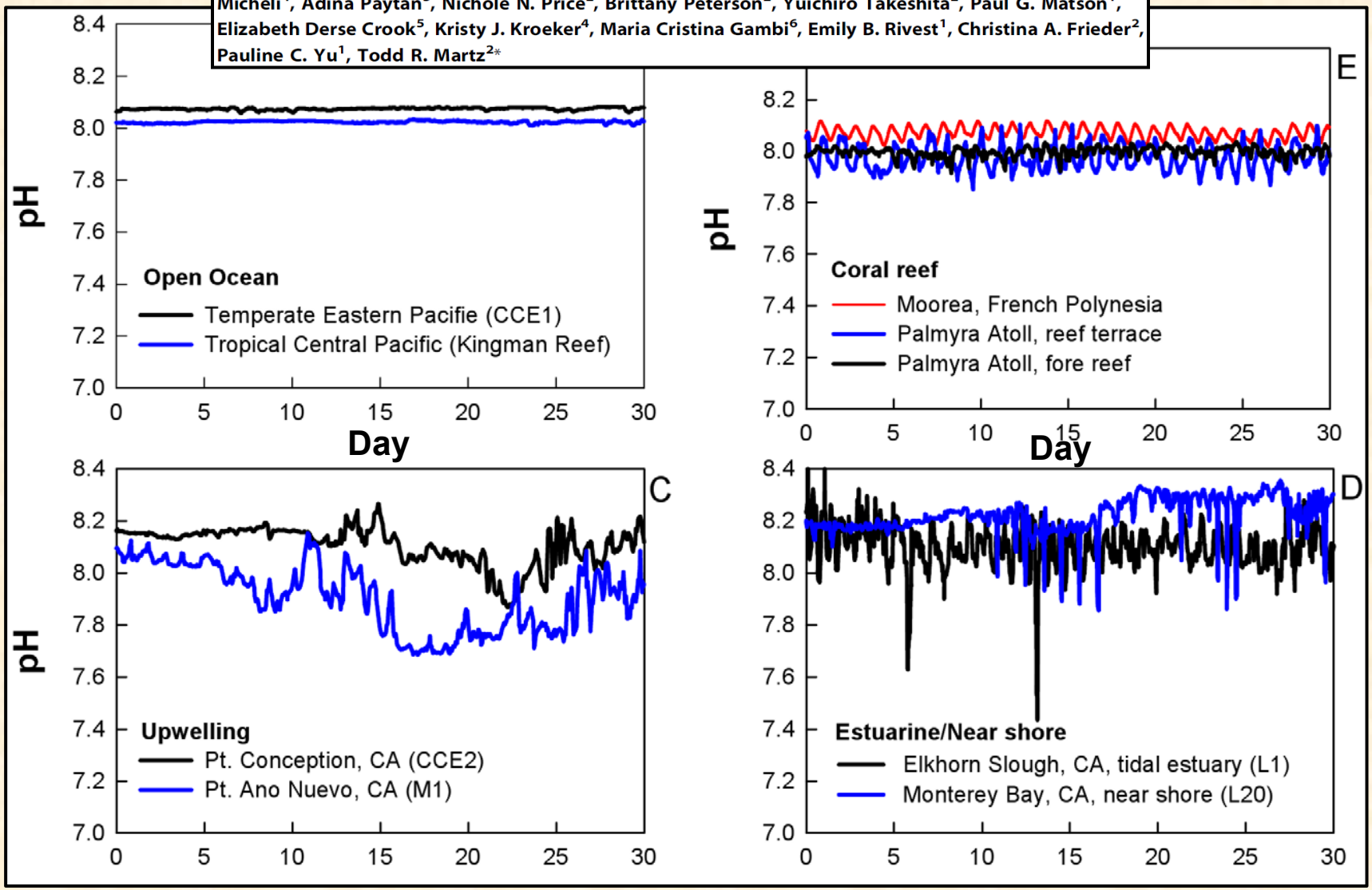
The costs of dealing with ocean acidification damages (to coral reefs alone) over the next century are estimated to add about 10% to the total costs of dealing with climate change

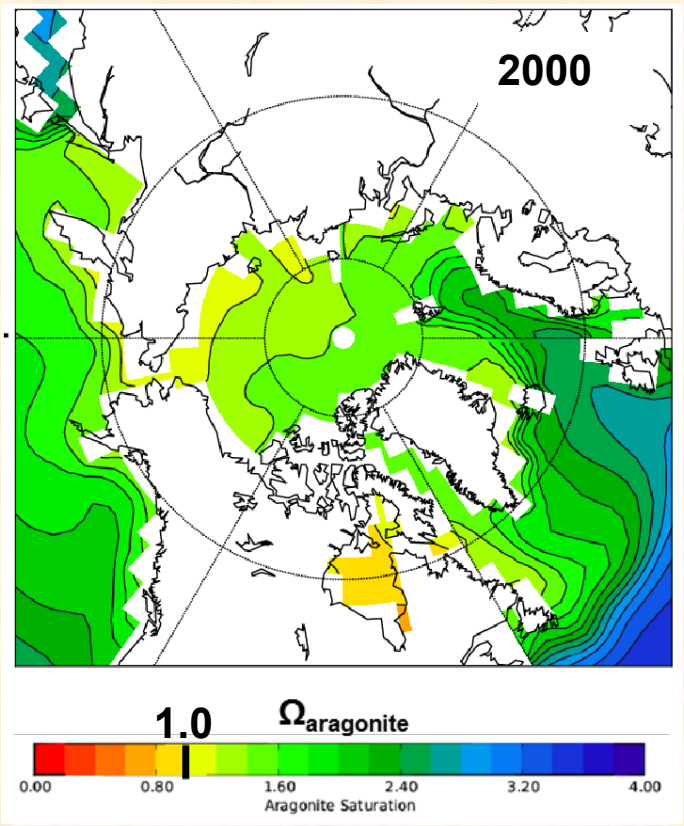
OPEN ACCESS Freely available online

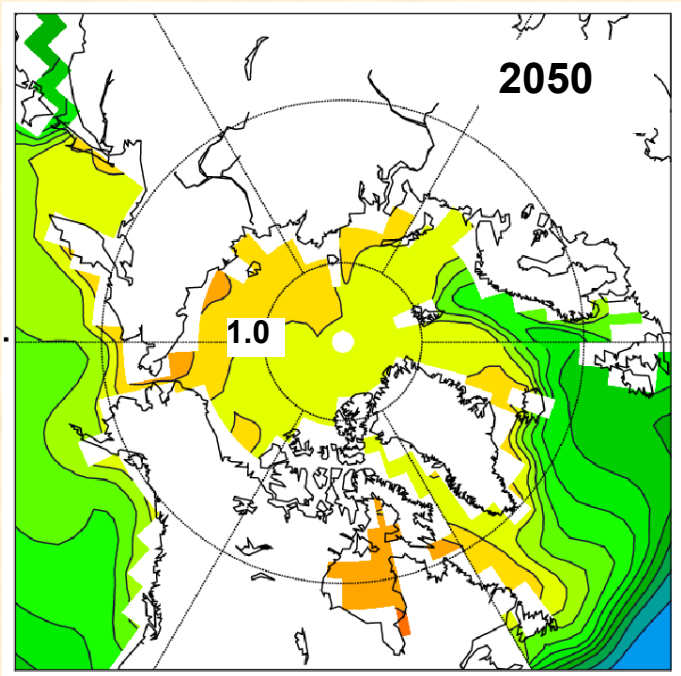
PLoS one

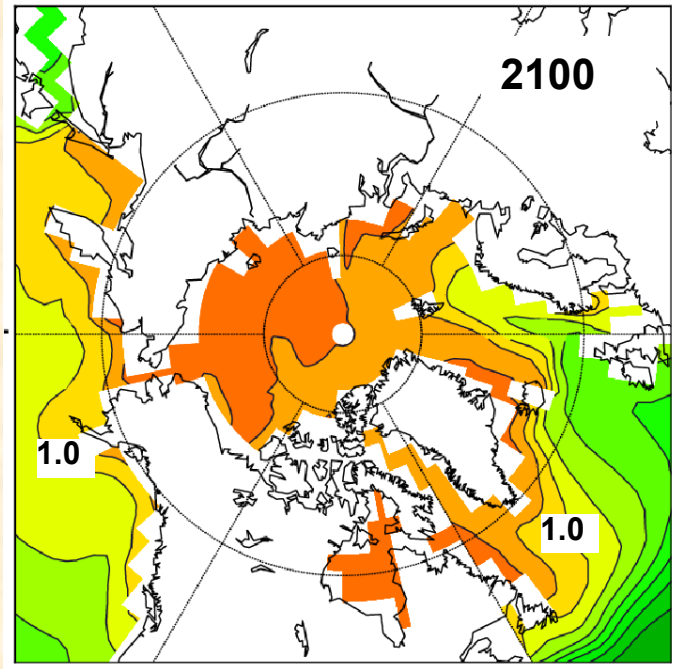
High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison

Gretchen E. Hofmann[1], Jennifer E. Smith[2], Kenneth S. Johnson[3], Uwe Send[2], Lisa A. Levin[2], Fiorenza Micheli[4], Adina Paytan[5], Nichole N. Price[2], Brittany Peterson[2], Yuichiro Takeshita[2], Paul G. Matson[1], Elizabeth Derse Crook[5], Kristy J. Kroeker[4], Maria Cristina Gambi[6], Emily B. Rivest[1], Christina A. Frieder[2], Pauline C. Yu[1], Todd R. Martz[2]*







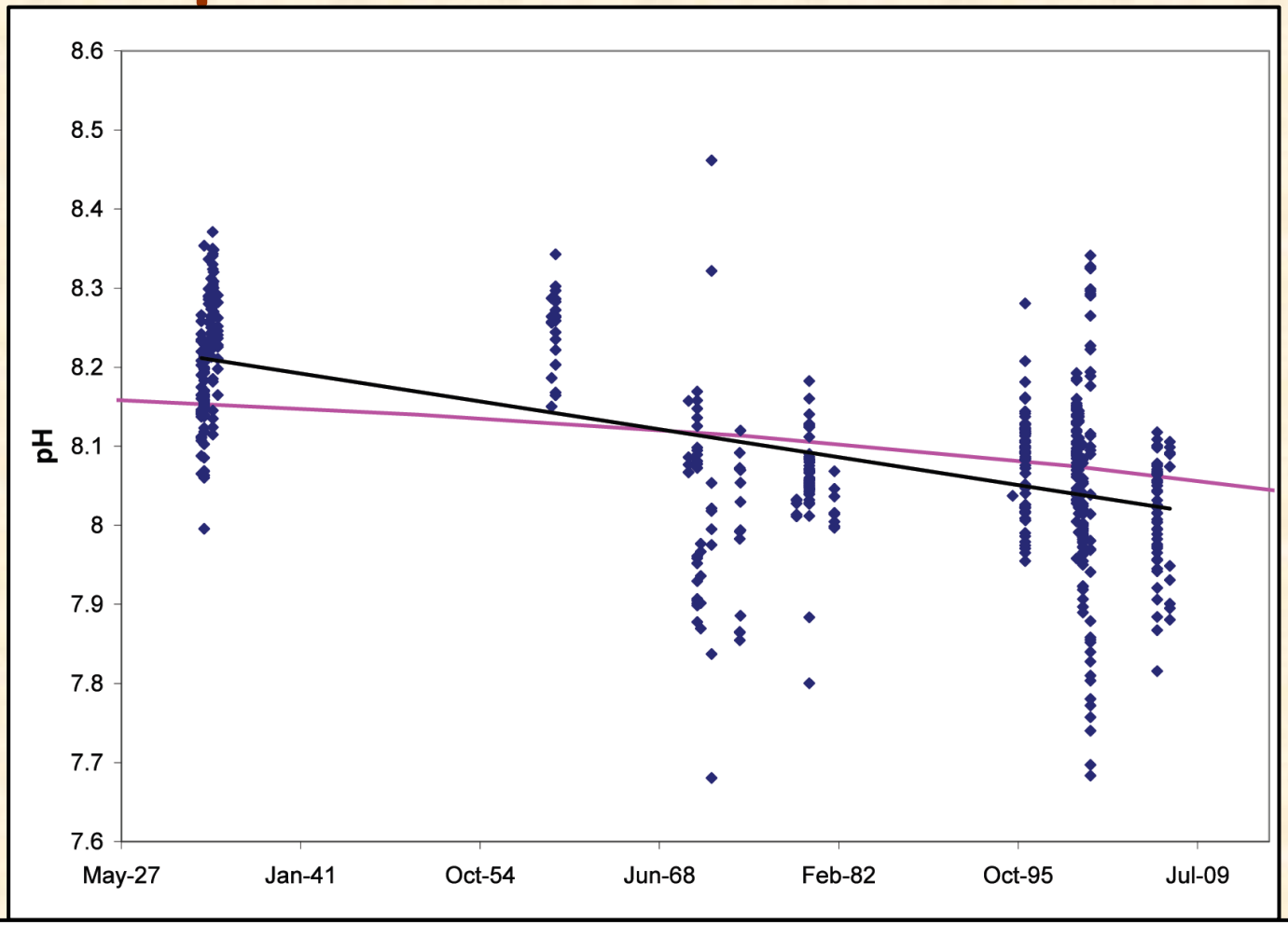


Saturation State → $\Omega_A < 1$ at High Latitudes

'A2' CanESM1.1 Simulations

[N. Steiner, CCCMA/DFO; Denman et al. 2011, ICES-JMS]

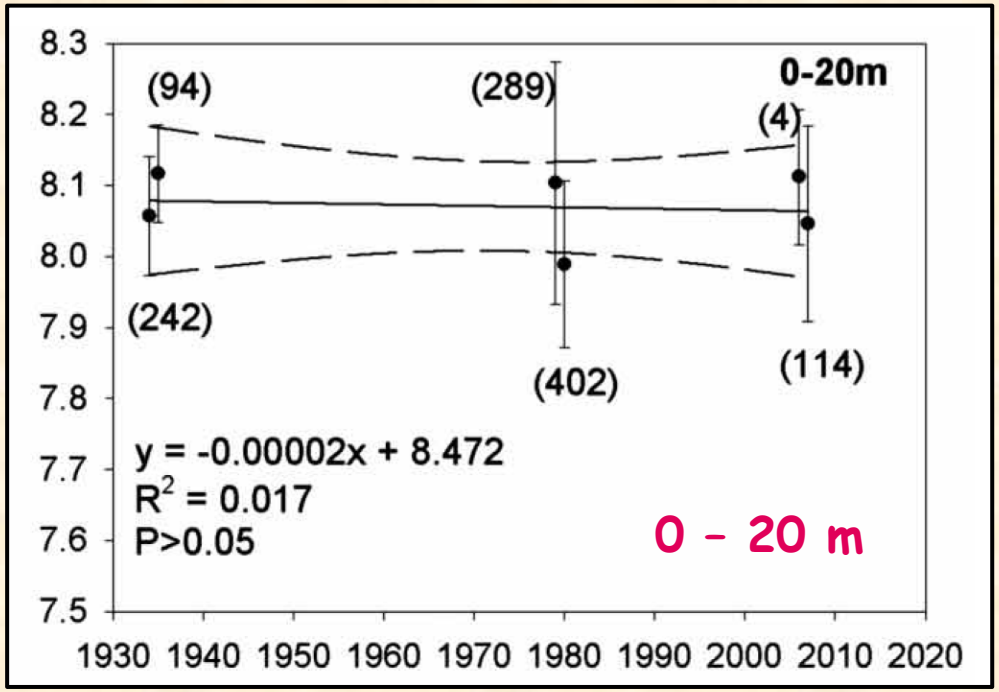
Long Term pH Decrease on the Scotian Shelf



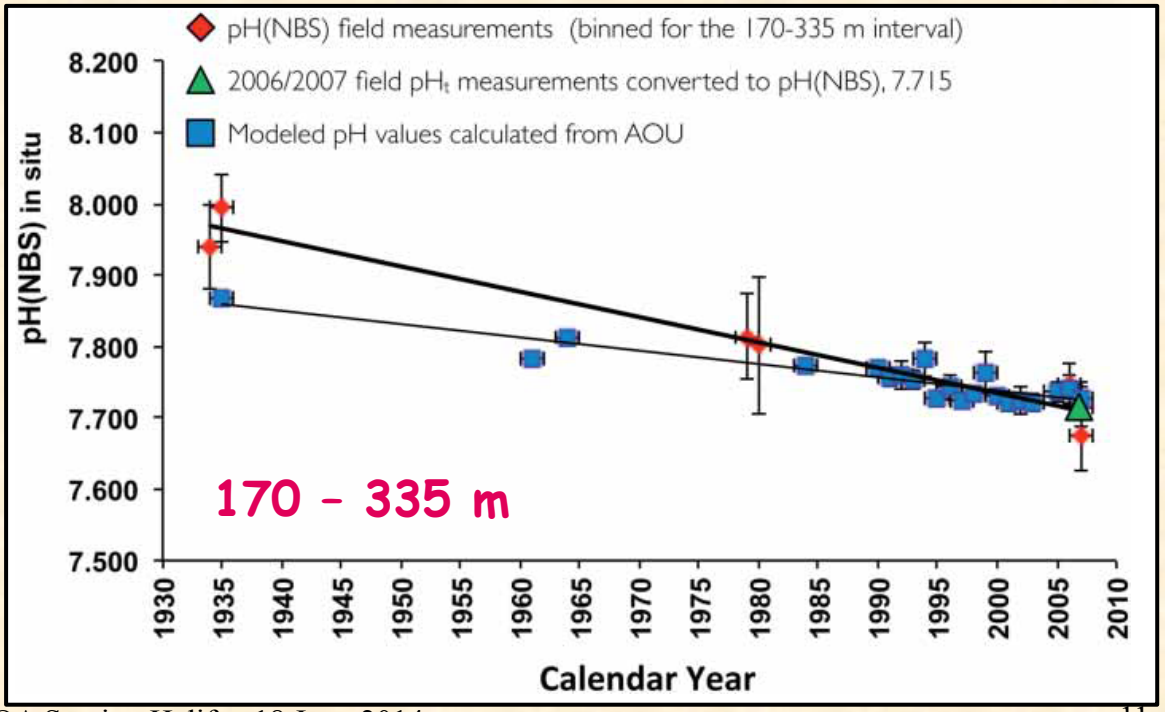
Decrease in pH on the Scotian Shelf over the past century. Time is reported in month and year (DFO 2009). Blue data points represent pH measurements from various locations on the Scotian Shelf, the black trend line indicates a decrease in pH with time, and the pink trend line represents the mean global ocean decrease in pH over the same time period. *[K. Curran & K. Azetsu-Scott, DFO-BIO, Oct 2012.]*

Long Term pH in the Lower Saint Lawrence Estuary

[Mucci, Starr, Gilbert & Sundby, 2011, Atmosphere-Ocean 49]



- Modelled pH estimated from Apparent Oxygen Utilization (AOU) using the remineralization reaction



Multiple Stressors: Decreasing Ω_{arag} & O_2

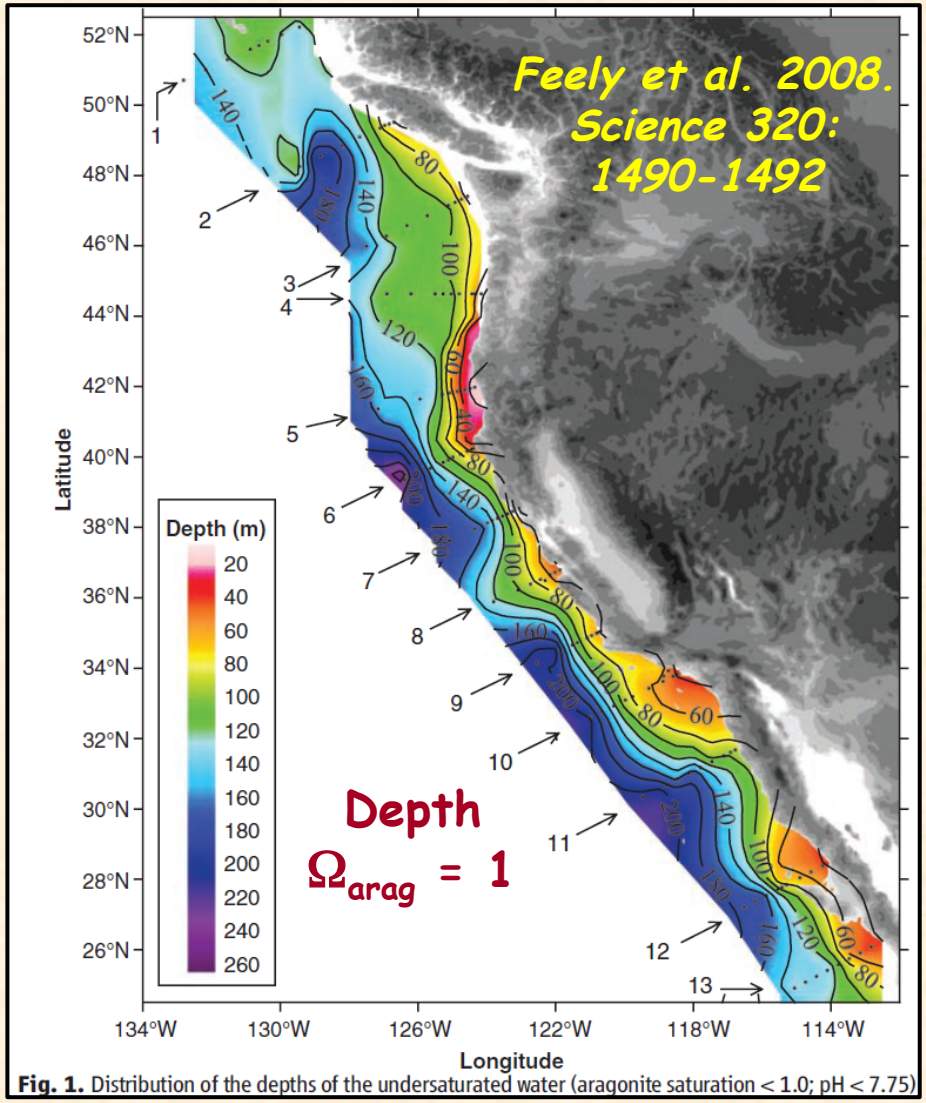
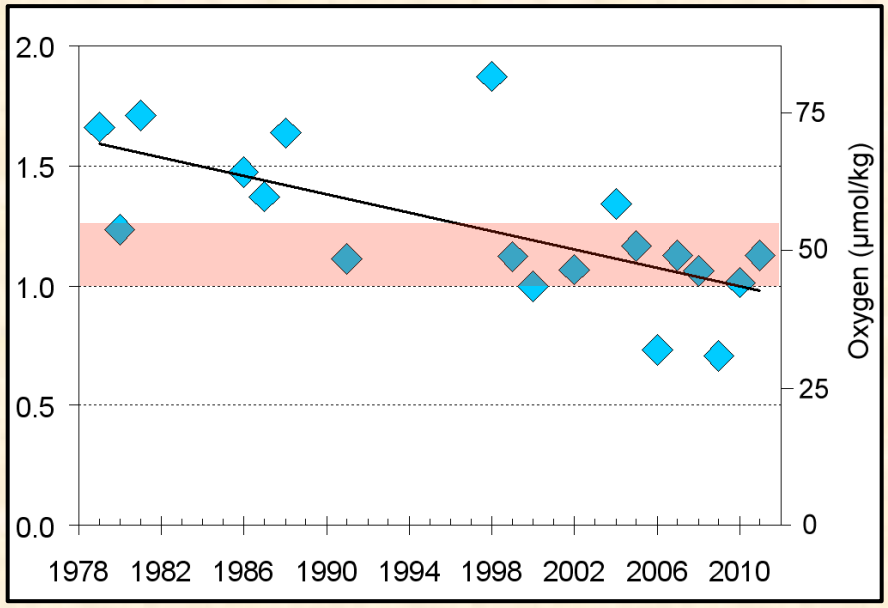


Fig. 1. Distribution of the depths of the undersaturated water (aragonite saturation < 1.0; pH < 7.75)

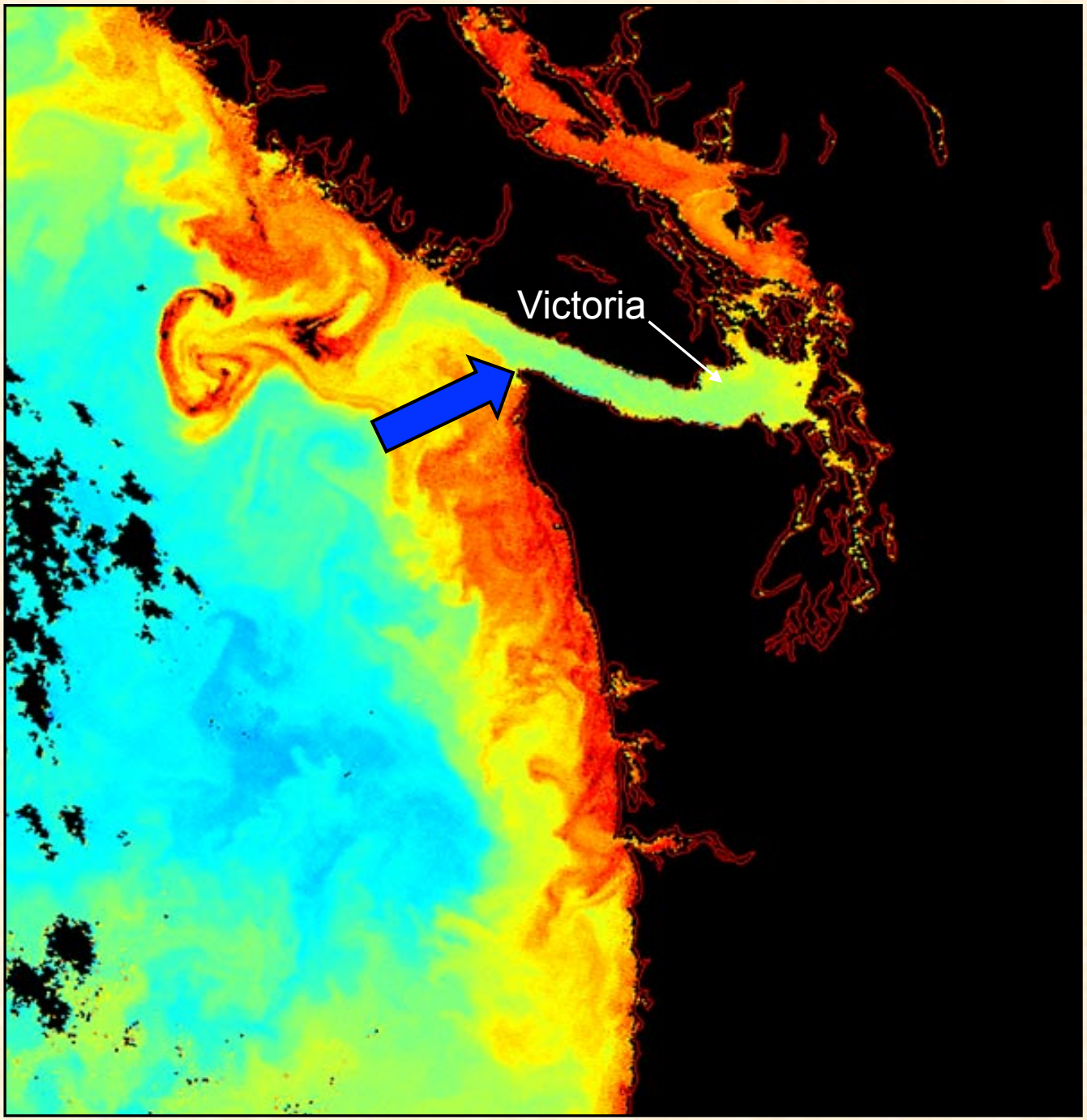


Dissolved Oxygen at 125 m, south of La Pérouse Bank in water 143 m deep.

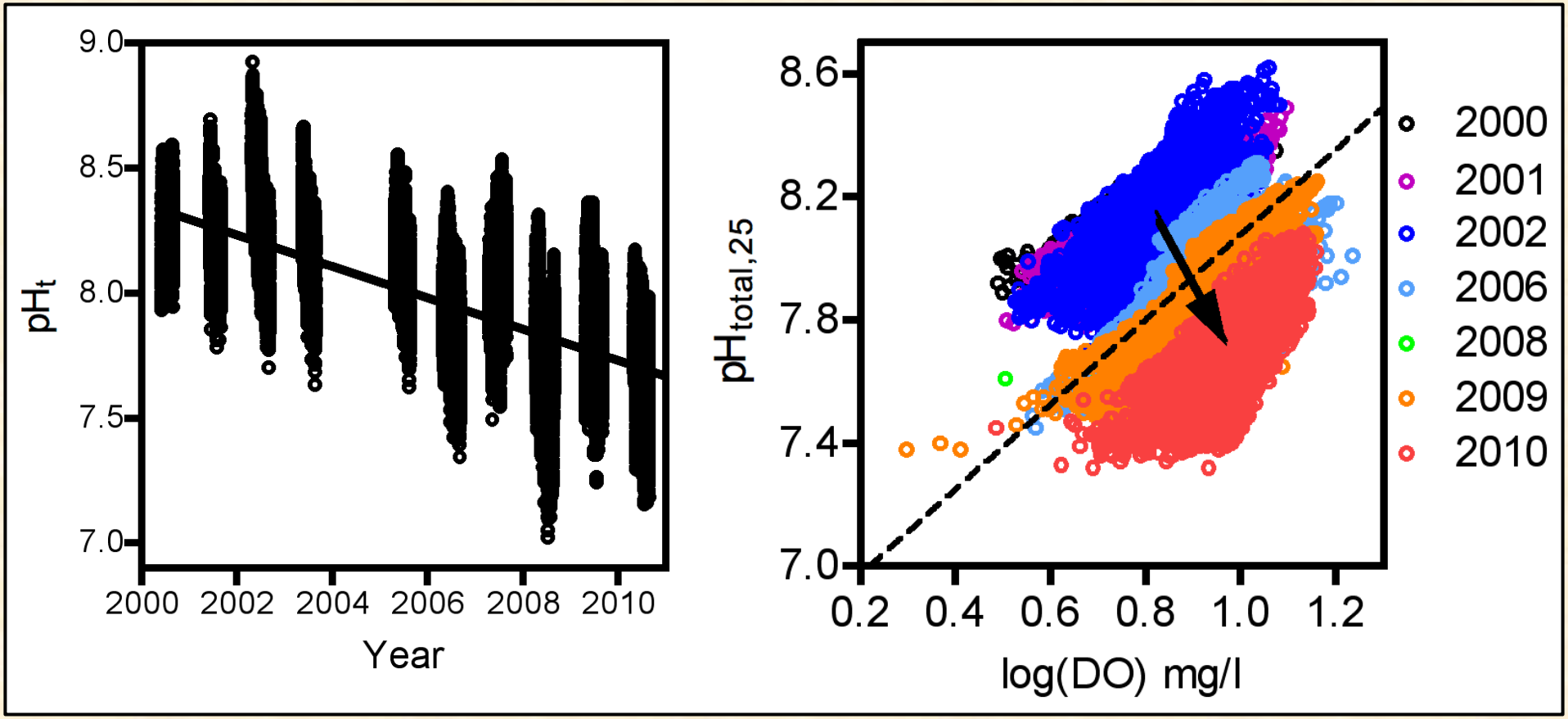
From: *Crawford and Peña, 2013 Atmosphere-Ocean, DOI:10.1080/07055900.2012.753028.*

Upper Water Phytoplankton Chlorophyll Concentrations from Satellite

Red areas offshore indicate upwelled high nutrient, low pH, low O_2 waters yielding high chlorophyll concentrations on this colour scale



Tatoosh Isl. SW Tip of Juan de Fuca Strait



In a given year pH varies with O_2 , but pH at same O_2 is decreasing from 2002 to 2010.

[Wootton & Pfister, PLoS1, 2012]

Time Series of pH collected by the Vancouver Aquarium

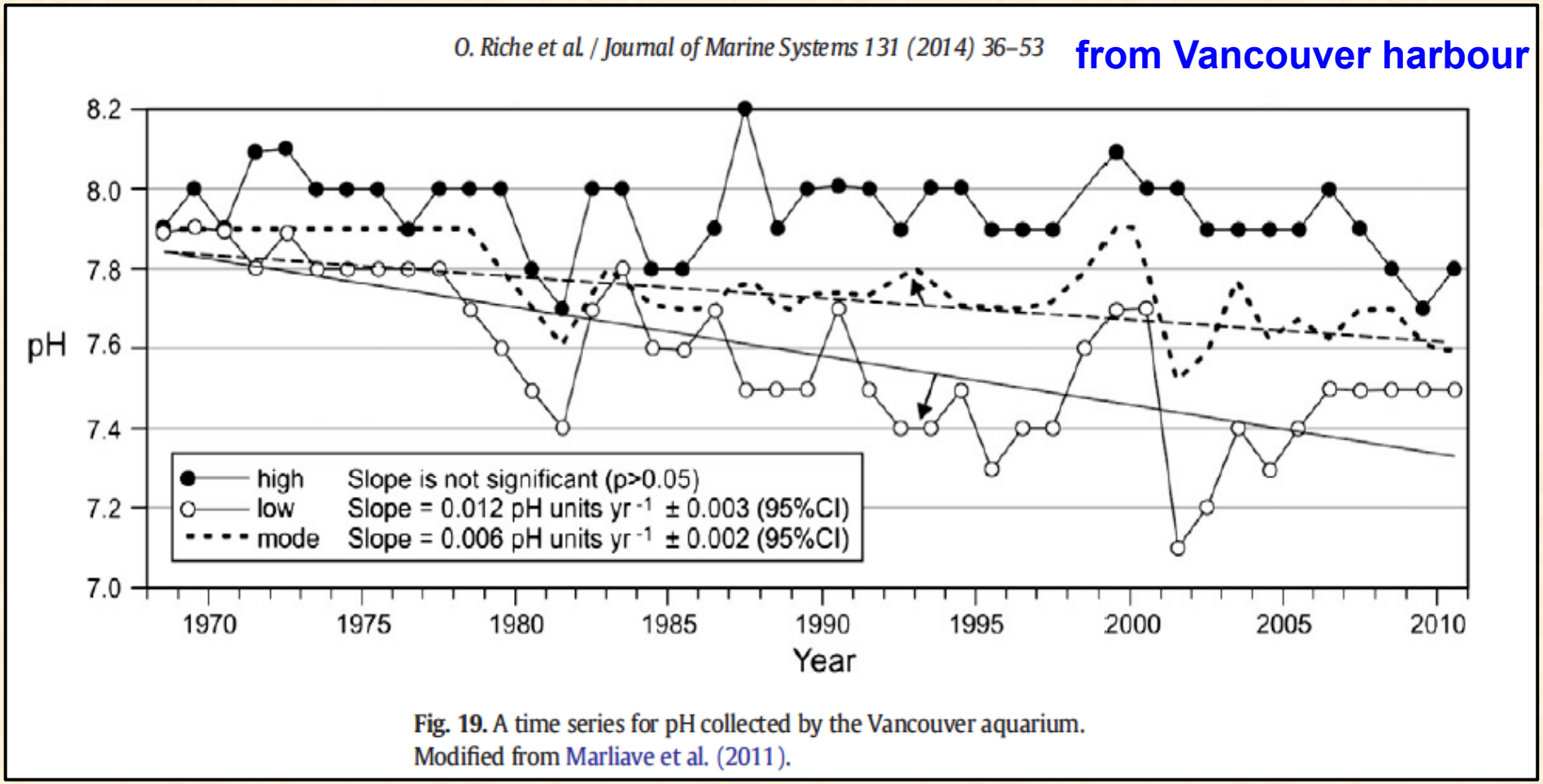


Fig. 19. A time series for pH collected by the Vancouver aquarium. Modified from Marliave et al. (2011).

Scallop Farming in the Strait of Georgia

Oysters + scallops farmed in BC ~$30M (2013)

NEWS

10 million scallops are dead; Qualicum company lays off staff

Island Scallops in Qualicum Bay said it has suffered $10 million in losses because of high acidity levels in the Georgia Strait. — *Image Credit: JOHN HARDING PHOTO*

by John Harding - Parksville
posted Feb 25, 2014 *at* 9:00 AM — *updated* Feb 25, 2014 *at* 3:44 PM

High acid levels in the waters around Parksville Qualicum Beach have killed 10 million scallops and forced a local shellfish producer to scale operations back considerably.

Island Scallops CEO Rob Saunders said the company has lost three years worth of scallops and $10 million.

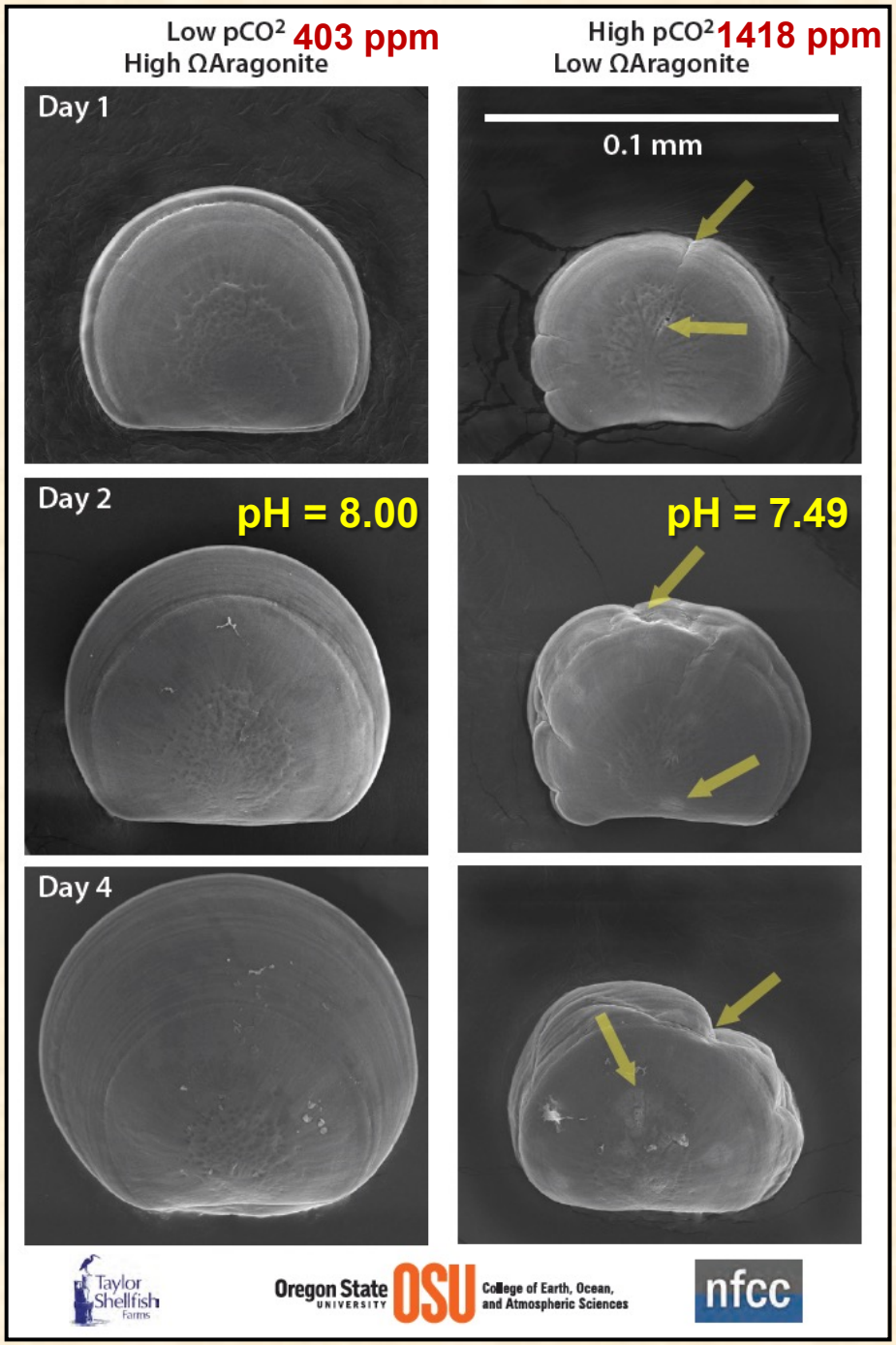
Pacific Oyster Larvae Subjected to Different pH Values

Raised by the Taylor Shellfish Hatchery in natural waters of Dabob Bay, WA.

Images are Scanning Electron Microscopy (SEM) of representative larval shells

The scale bar in the upper right panel is 0.1 mm, or approximately the diameter of a human hair.

Photo credit- Brunner/Waldbusser.



Review Paper Hot off the Press

PLOS | ONE

February 11, 2015

RESEARCH ARTICLE

Effects of Ocean Acidification on Temperate Coastal Marine Ecosystems and Fisheries in the Northeast Pacific

Rowan Haigh[1‡], Debby Ianson[2‡*], Carrie A. Holt[1‡], Holly E. Neate[1,3], Andrew M. Edwards[1,3‡]

1 Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7, Canada, 2 Institute of Ocean Sciences, Fisheries and Oceans Canada, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2, Canada, 3 Department of Biology, University of Victoria, P.O. Box 1700, Station CSC, Victoria, British Columbia, V8W 2Y2, Canada

‡ These authors contributed significantly to this work.
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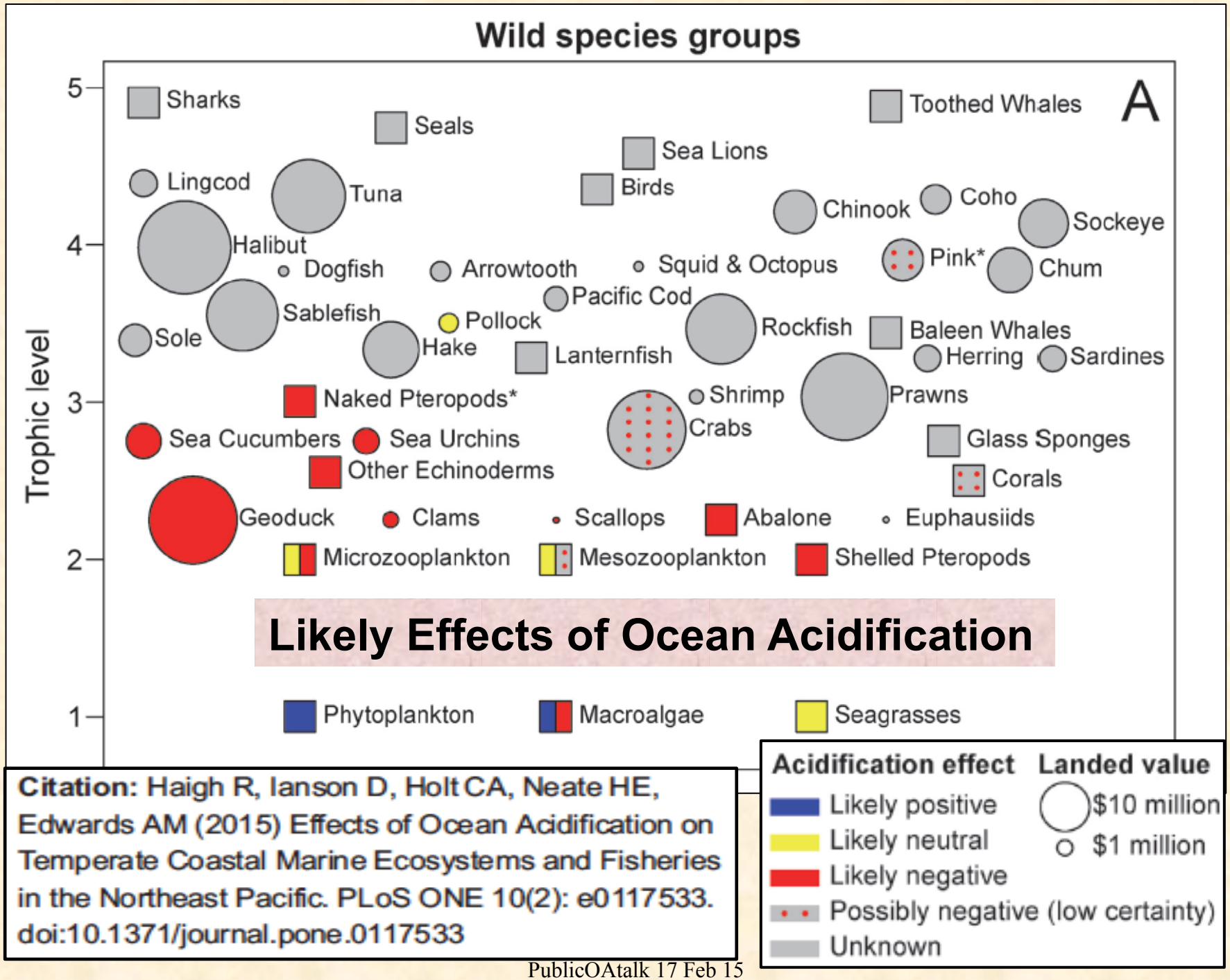
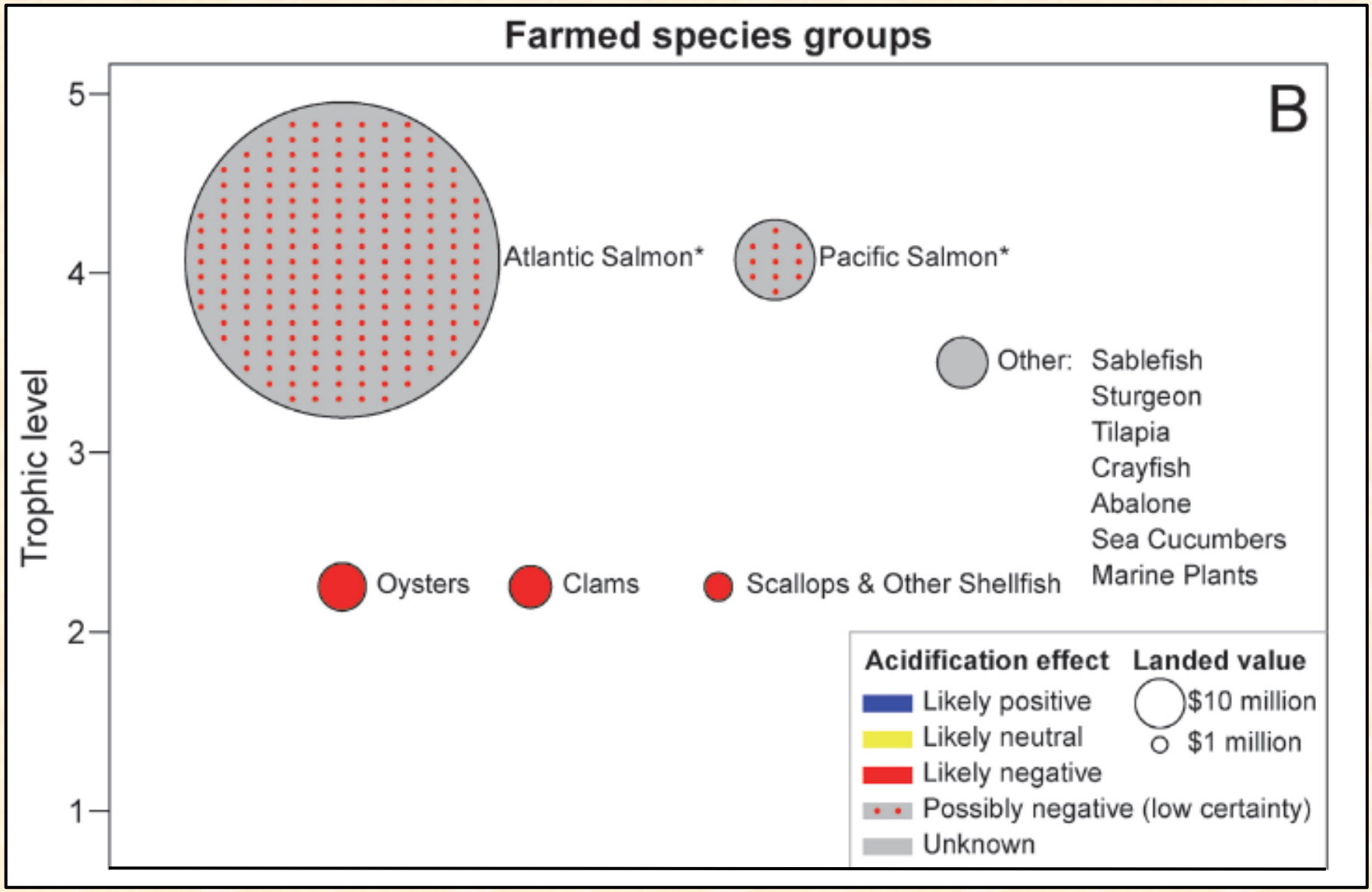


Citation: Haigh R, Ianson D, Holt CA, Neate HE, Edwards AM (2015) Effects of Ocean Acidification on Temperate Coastal Marine Ecosystems and Fisheries in the Northeast Pacific. PLoS ONE 10(2): e0117533. doi:10.1371/journal.pone.0117533

Likely Effects of Ocean Acidification



COMMENTARY:

Lessons learned from ocean acidification research

Ulf Riebesell and Jean-Pierre Gattuso

NATURE CLIMATE CHANGE | VOL 5 | JANUARY 2015 |

Need to expand:

1. **From single to multiple drivers** - including warming, de-oxygenation and increased stratification
2. **From organisms to ecosystems**
3. **From *acclimation*** (physiological, usually within 1 lifetime) **to *adaptation*** (through selection within existing genetic variation or via genetic mutation)
4. **Observations to develop a 'climatology'** of pH and pCO_2 in critical coastal habitats

Thanks

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