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Seasonal patterns of estuarine acidification in seagrass beds of the Snohomish Estuary, WA

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Speaker
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Outline of talk

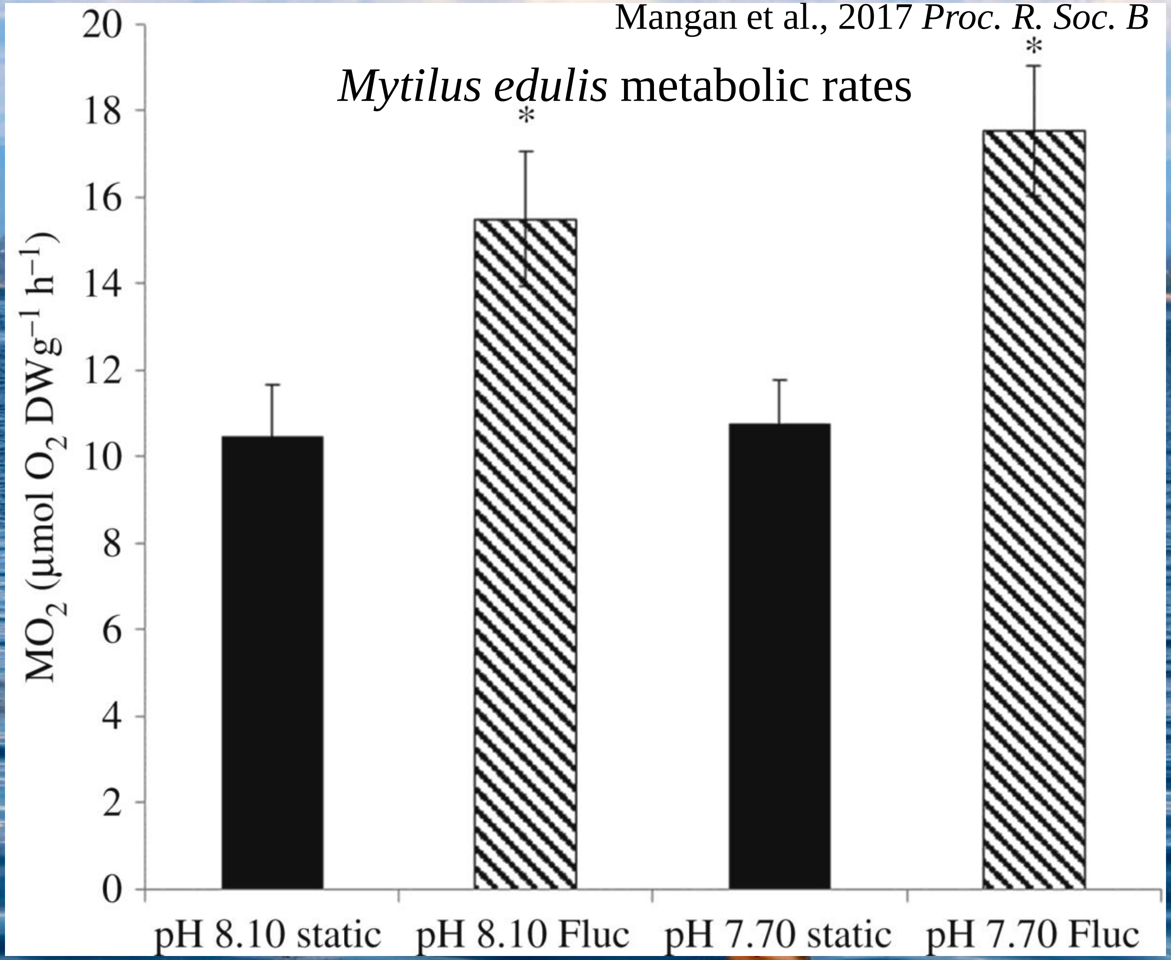
1. Why do we need to understand more about carbonate chemistry in estuarine habitats?

2. How does OA manifest in these habitats on daily and seasonal time scales?

3. What does this mean for exceedance of physiological and water quality thresholds?

Project background and motivation

1. Short-term fluctuations in carbonate chemistry, or "carbonate weather", impact organismal fitness

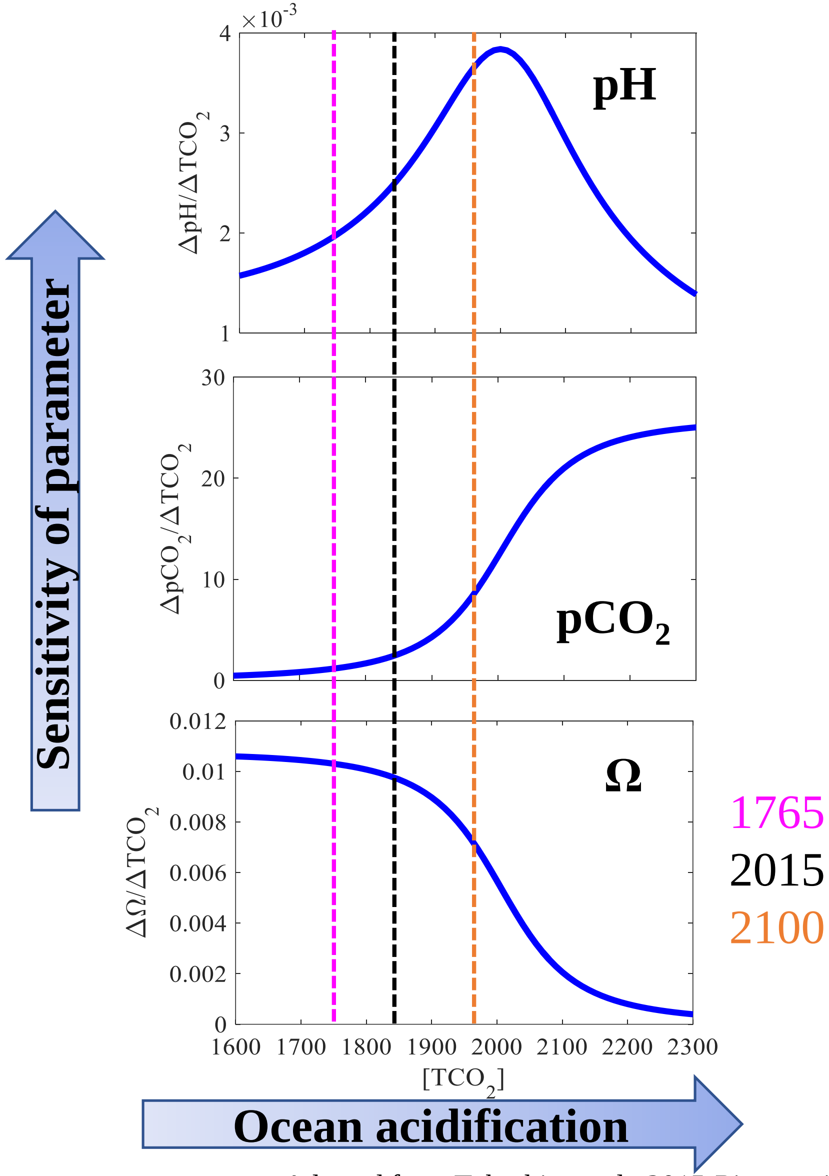


Project background and motivation

1. Short-term fluctuations in carbonate chemistry, or “carbonate weather”, impact organismal fitness

2. Carbonate weather is predicted to become more extreme with ocean acidification
   - -OA increases baseline [TCO_2]
   - -Local metabolism drives [TCO_2] variability
   - -OA + metabolism = ↑baseline TCO_2 + ↑ pH & pCO_2 variability

Intrinsic thermodynamic properties of the carbonate system, therefore widely applicable in metabolically intensive systems



Adapted from Takeshita et al., 2015 *Biogeosciences*

Outline of talk

1. **Why do we need to understand more about carbonate chemistry in estuarine habitats?**
   - **Improved understanding of natural vs. OA-forced signals of variability**
   - **Frequency, duration, and magnitude of organismal exposure to stressful conditions**

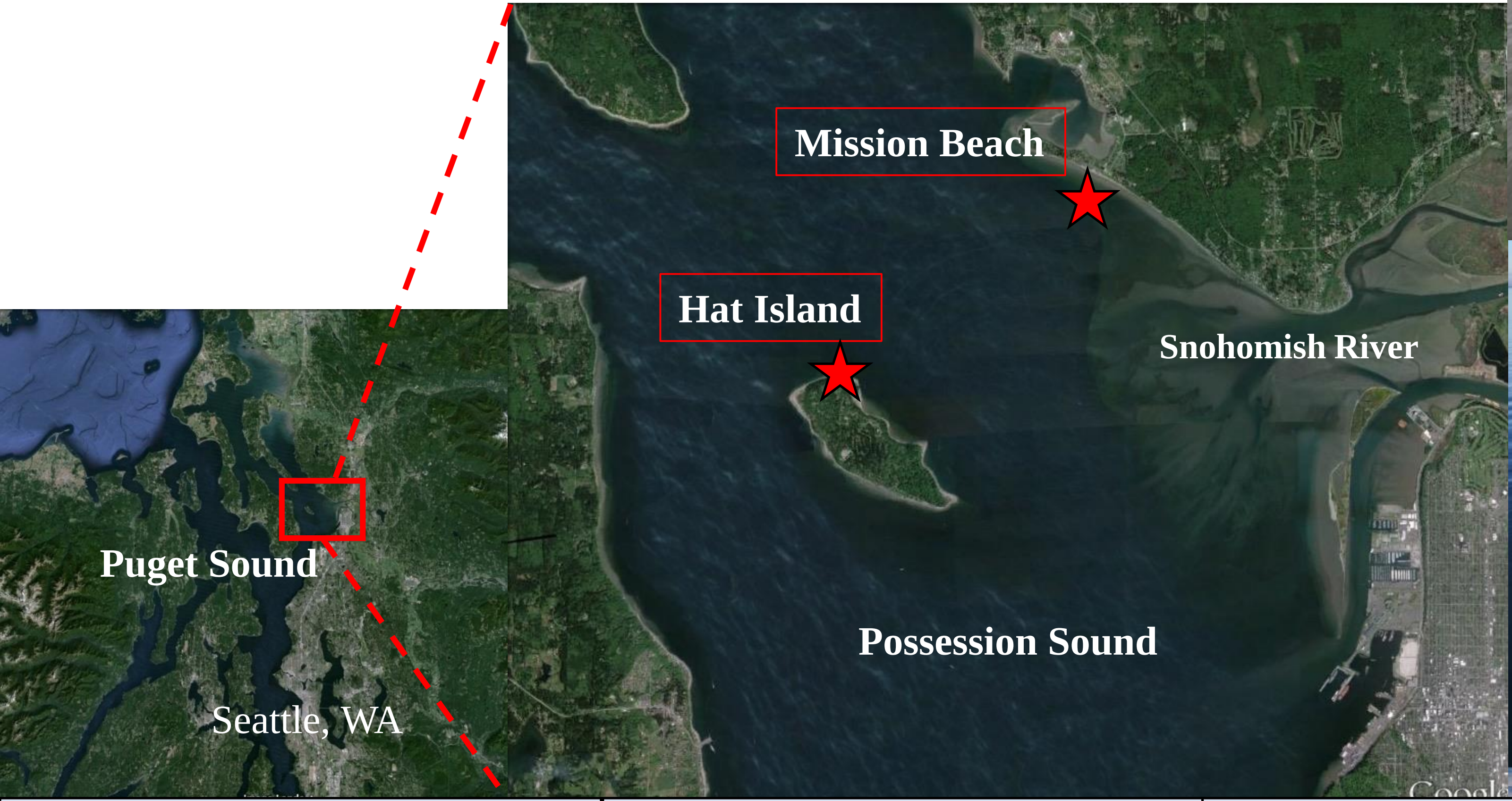
2. How does OA manifest in these habitats on daily and seasonal time scales?

3. What does this mean for exceedance of physiological and water quality thresholds?

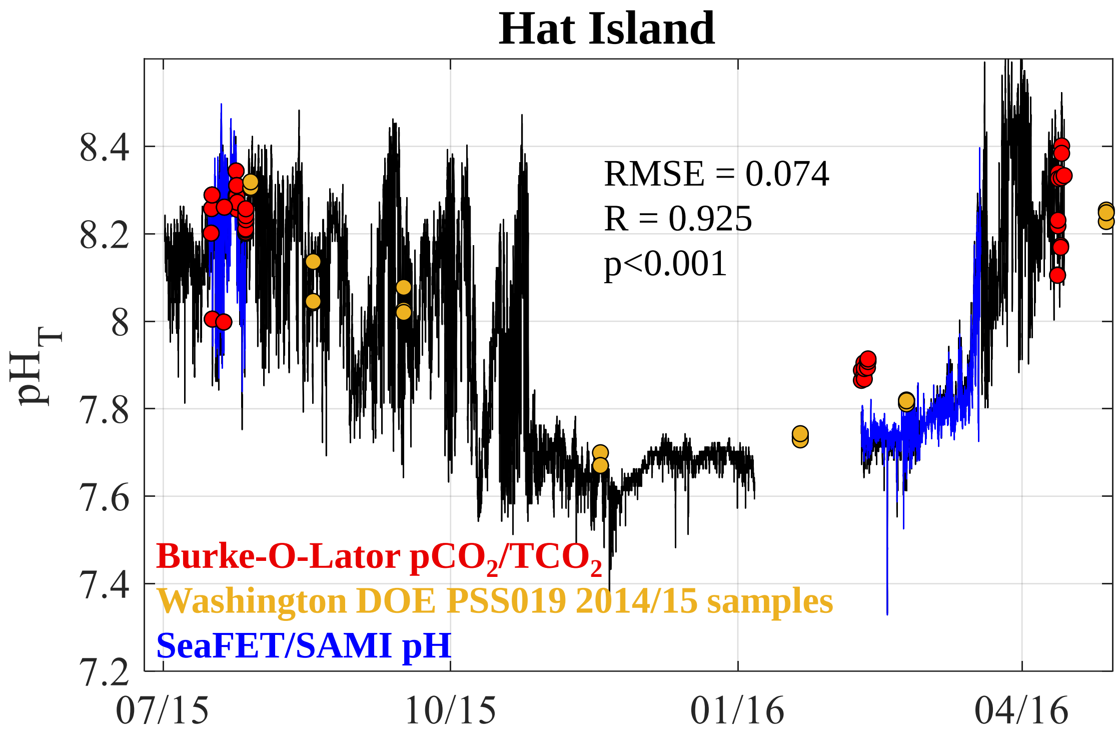
Field sampling

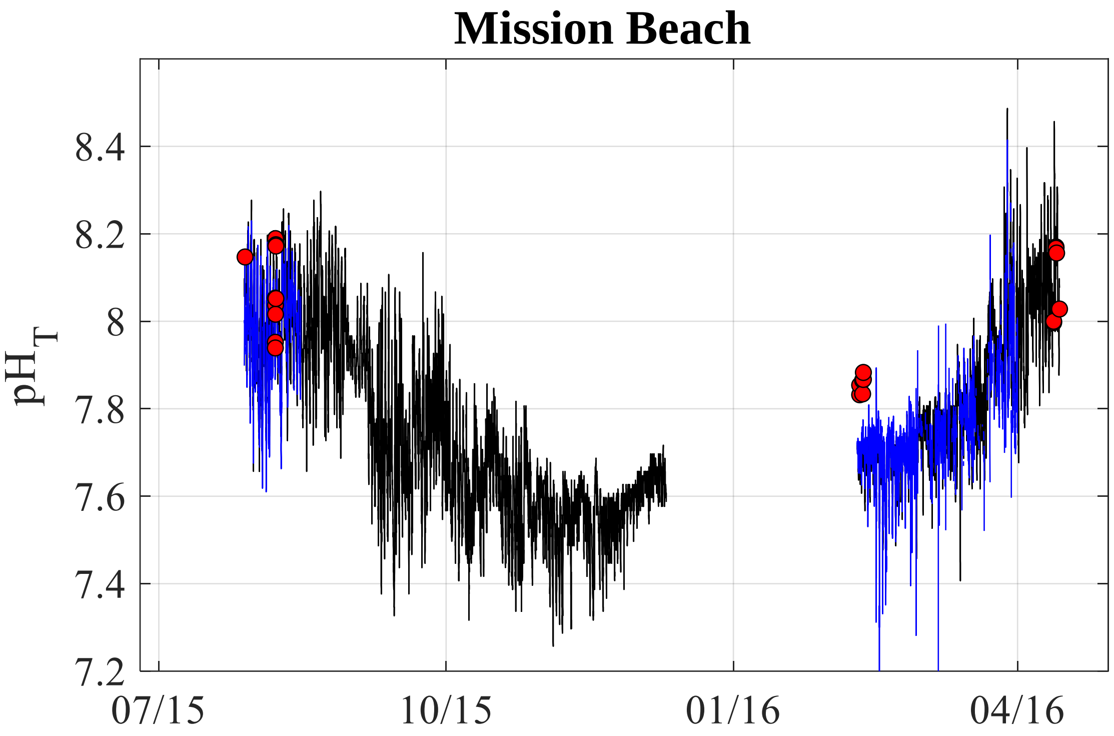
July 2015 – April 2016

- 2 study sites in subtidal seagrass beds (0.5m - 4.5m)
- YSI, SeaFET, and SAMI pH deployments
- Grab samples for TCO_2 & pCO_2



Field observations





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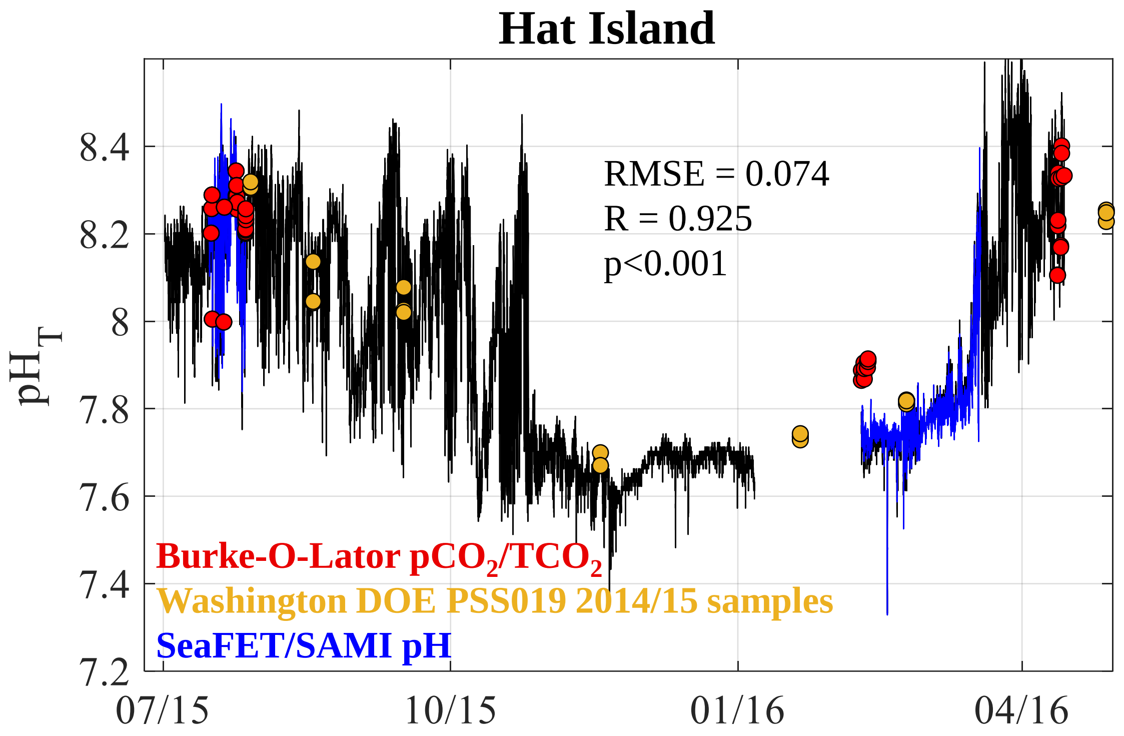
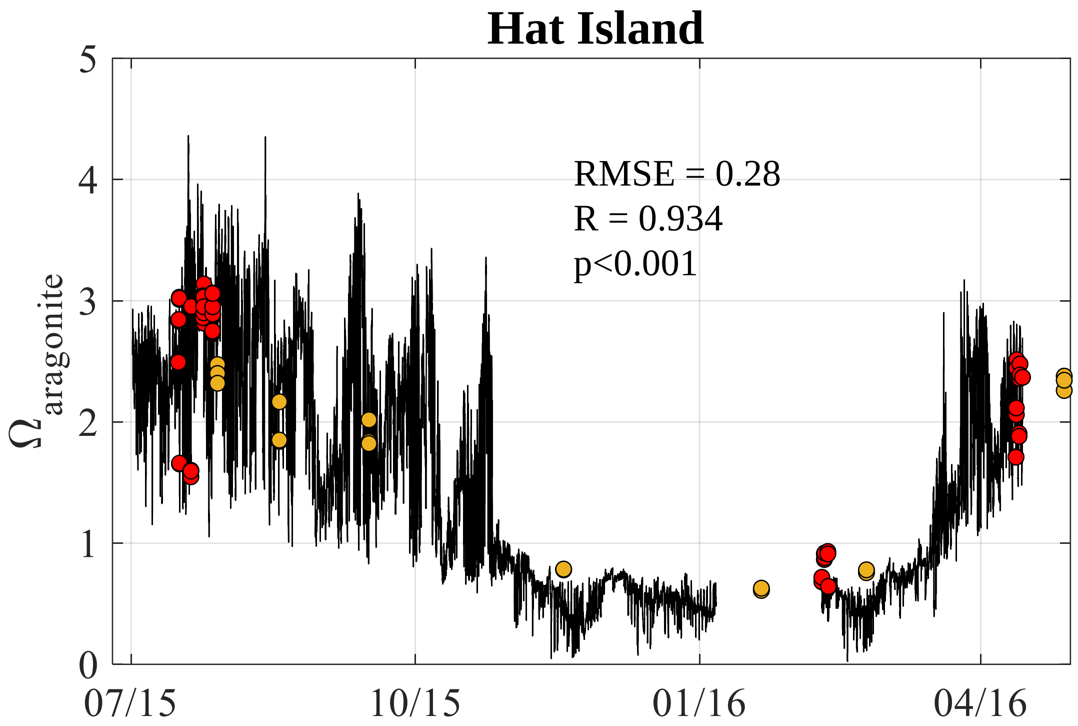
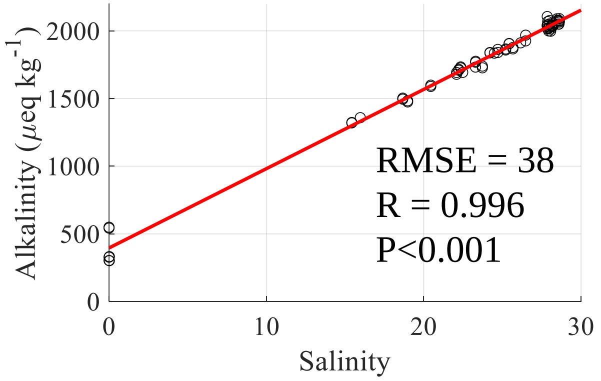
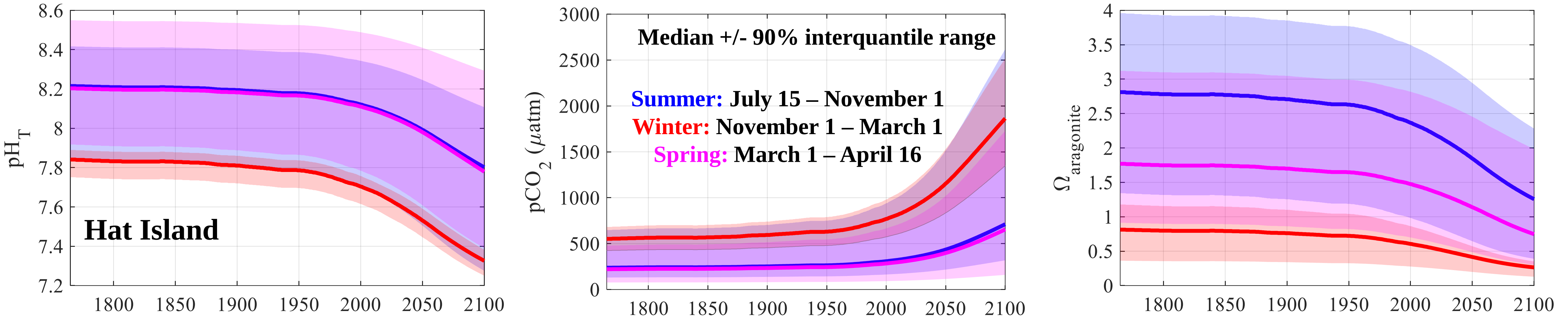






Calculated full carbonate system using *in-situ* pH and salinity-derived alkalinity (Alk_{sal})

OA simulations from 1765-2100



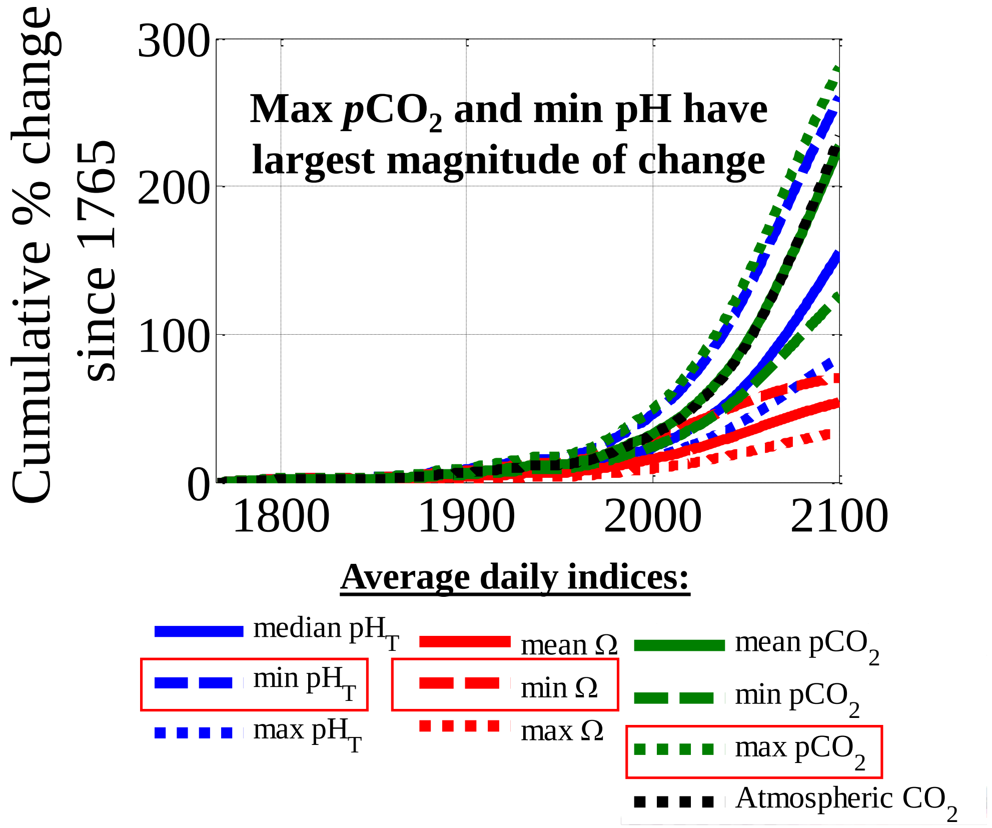
C_{anth} modeled using adaption of the ΔC* method (detailed in Pacella et al., 2018)

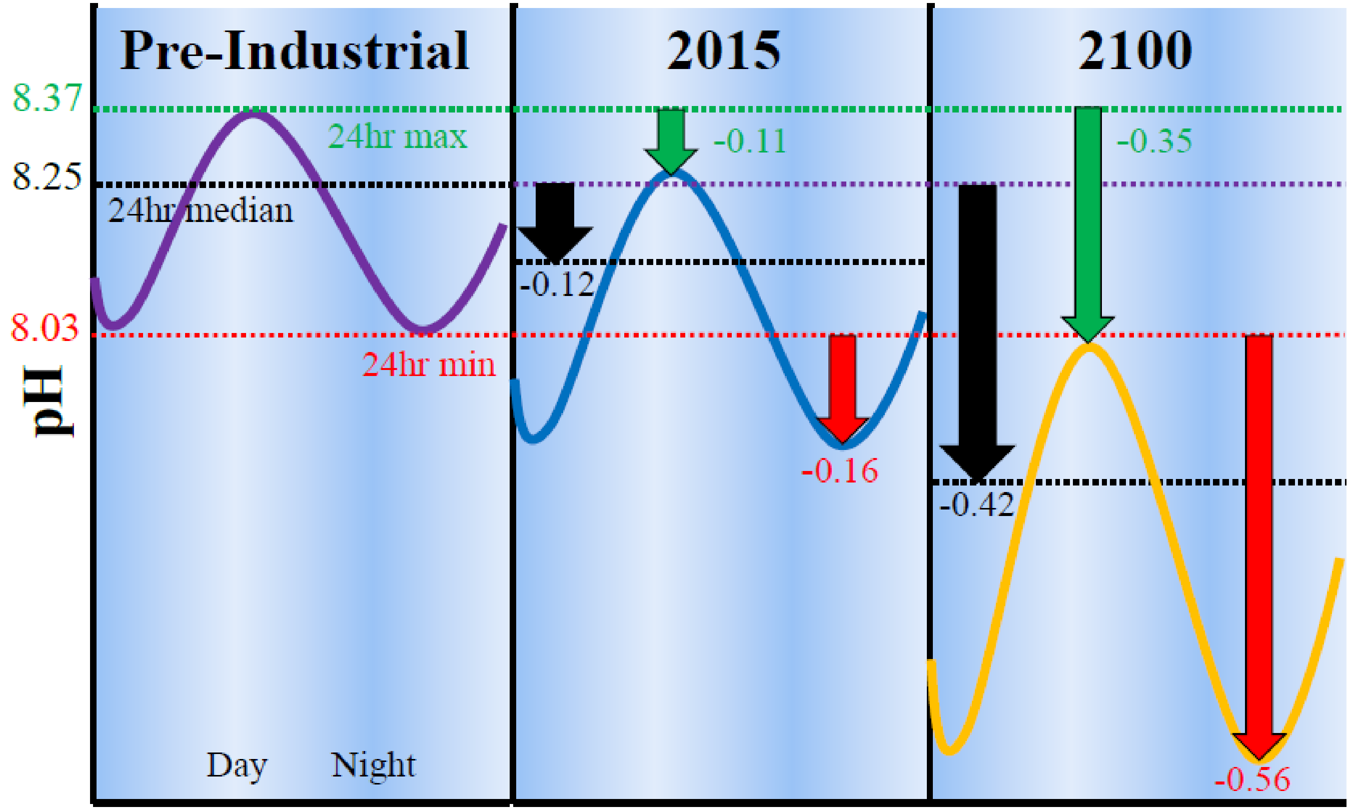
Atmospheric CO_2 from the RCP 8.5 scenario

Estimated C_{anth} agrees well with published values for contemporary surface waters in the California Current

How does OA affect daily and seasonal carbonate chemistry dynamics?

OA alters carbonate weather and seasonal climatology of carbonate chemistry

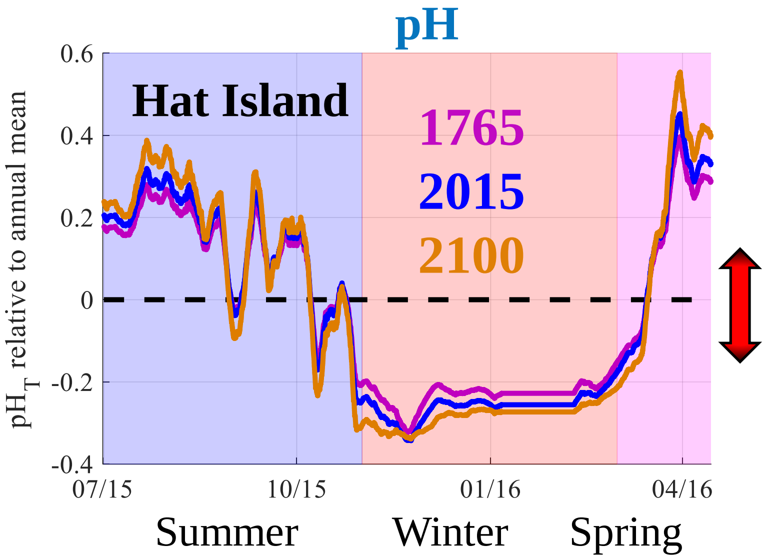


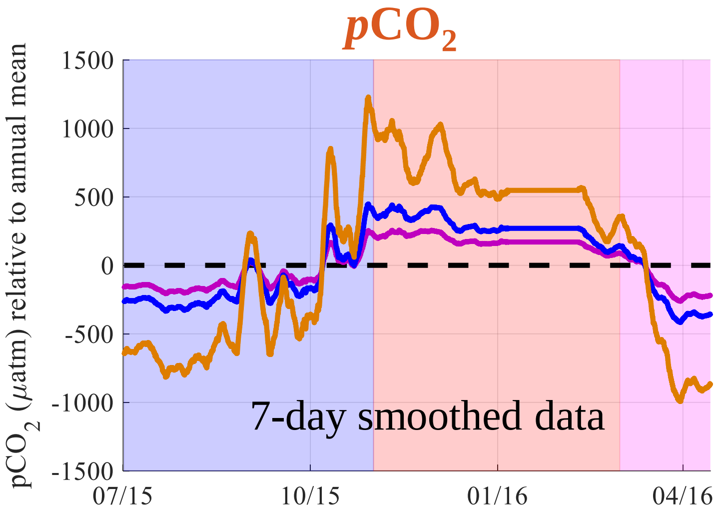


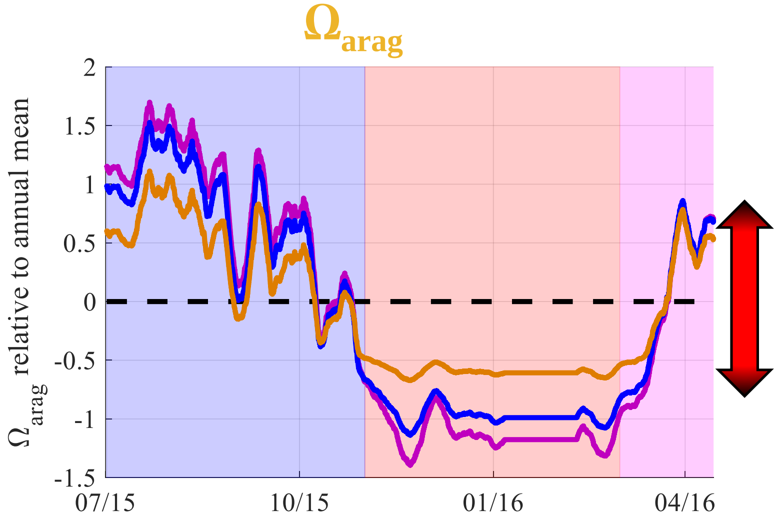
Pacella et al., 2018 *PNAS*

- OA reduces the ability of the system to buffer natural extremes, causing preferential amplification of low pH (and high pCO_2) during times of additive C_{anth} and metabolic CO_2
- Most harmful carbonate parameters for coastal organisms are changing up to 2x more rapidly than medians

OA alters carbonate weather and **seasonal climatology of carbonate chemistry**







↑[H^+] seasonality

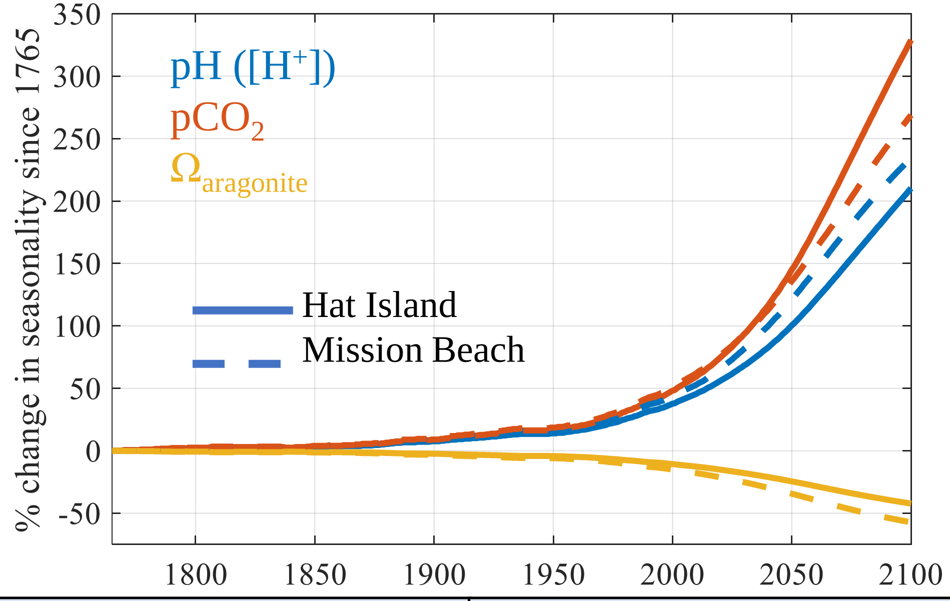
+60% +225%

↑pCO_2 seasonality

+70% +300%

↓Ω_{arag} seasonality

-15% -50%



Outline of talk

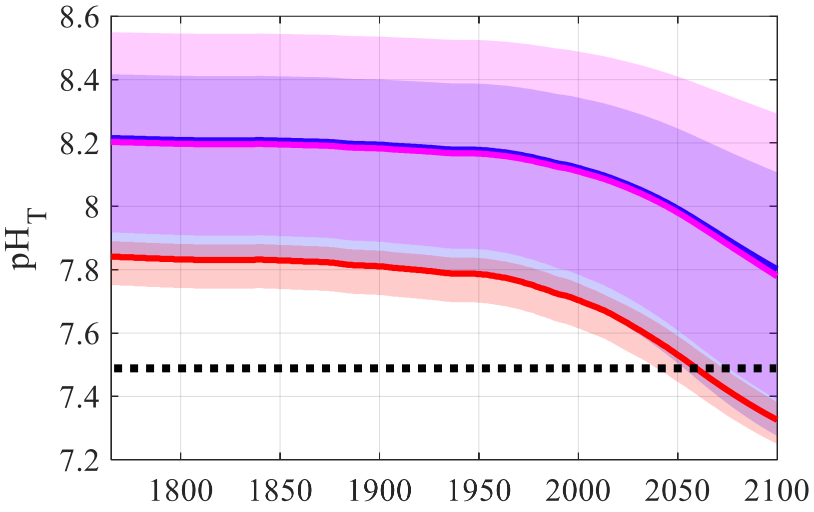
1. Why do we need to understand more about carbonate chemistry in estuarine habitats?
   - Improved understanding of natural vs. OA-forced signals of variability
   - Frequency, duration, and magnitude of organismal exposure to stressful conditions

2. How does OA manifest in these habitats on daily and seasonal time scales?
   - C_{anth} reduces ability of system to buffer natural carbon cycling
   - High pCO_2 and low pH conditions changing most rapidly
   - Carbonate weather and seasonal climatology more extreme for pH and pCO_2, dampened for Ω_{arag}

3. **What does this mean for exceedance of physiological and water quality thresholds?**

Interaction between “natural” and OA-driven changes to buffering capacity controls the timing of crossing of **physiological** and water quality thresholds

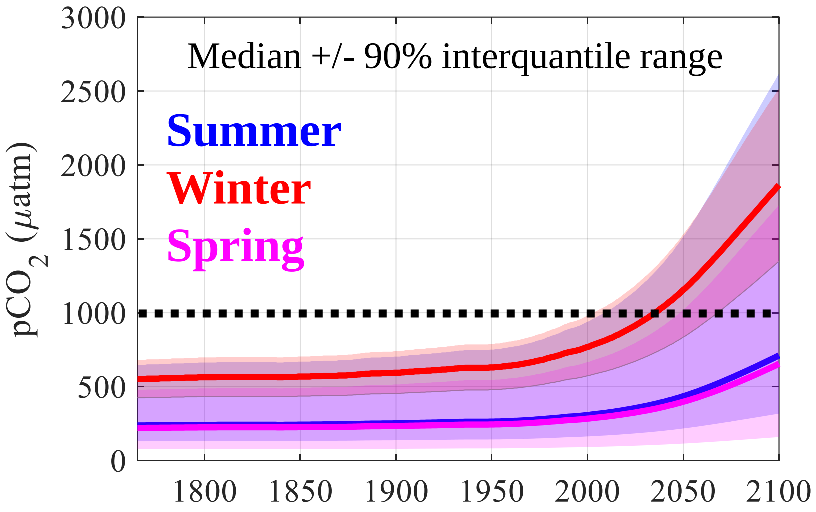
pH



C. magister larvae survival

(Miller et al., 2016 *Mar. Biol.*)

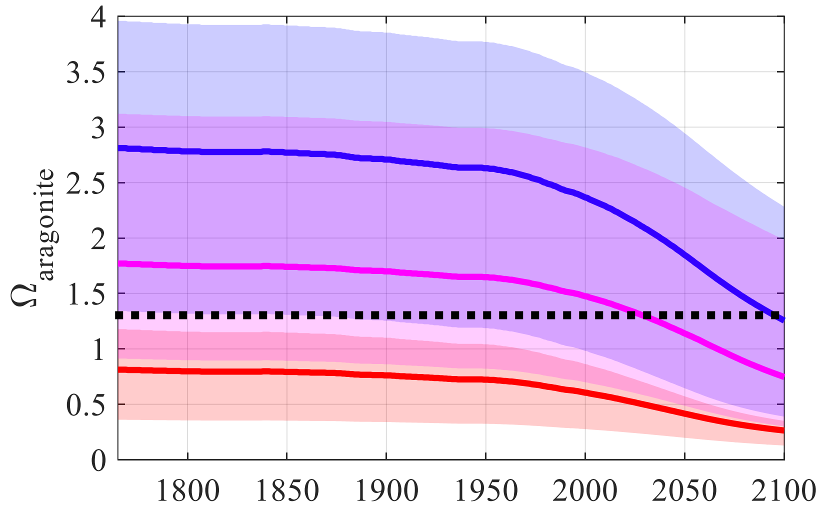
pCO_2



Hypercapnia

(McNeil and Sasse 2016, *Nat. Clim. Chang.*)

Ω_{arag}

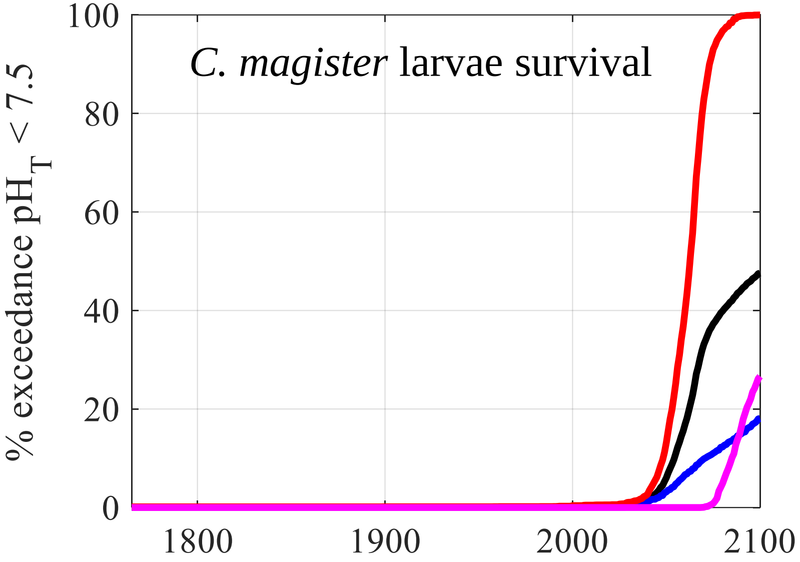


Early *M. californianus* development

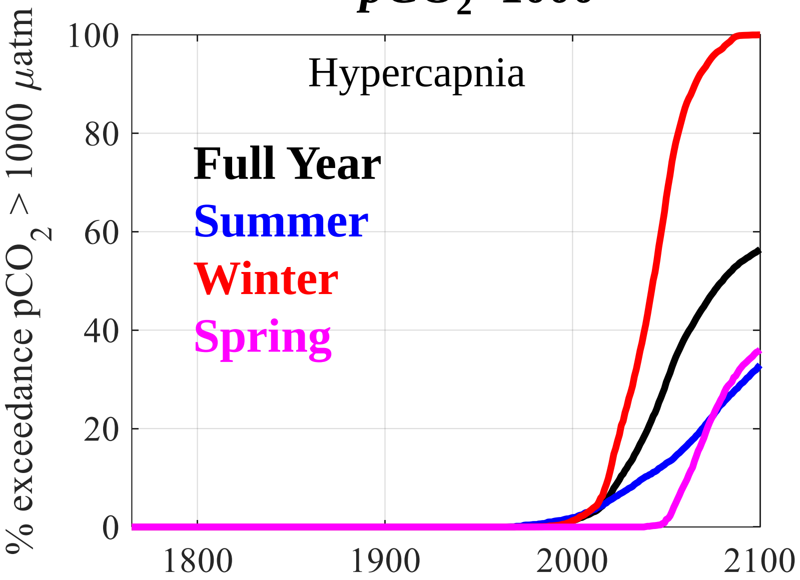
(Waldbusser et al., 2015 *PLoS ONE*)

Interaction between “natural” and OA-driven changes to buffering capacity controls the timing of crossing of **physiological** and water quality thresholds

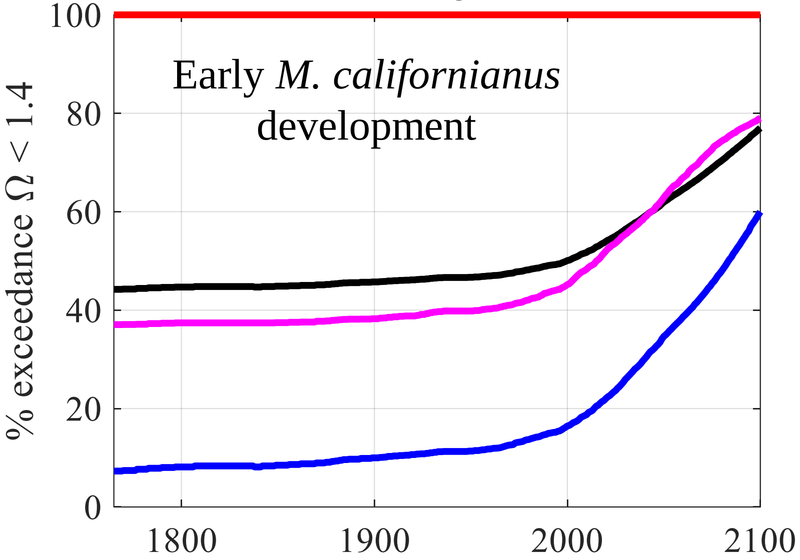
pH<7.5



pCO$_2$>1000



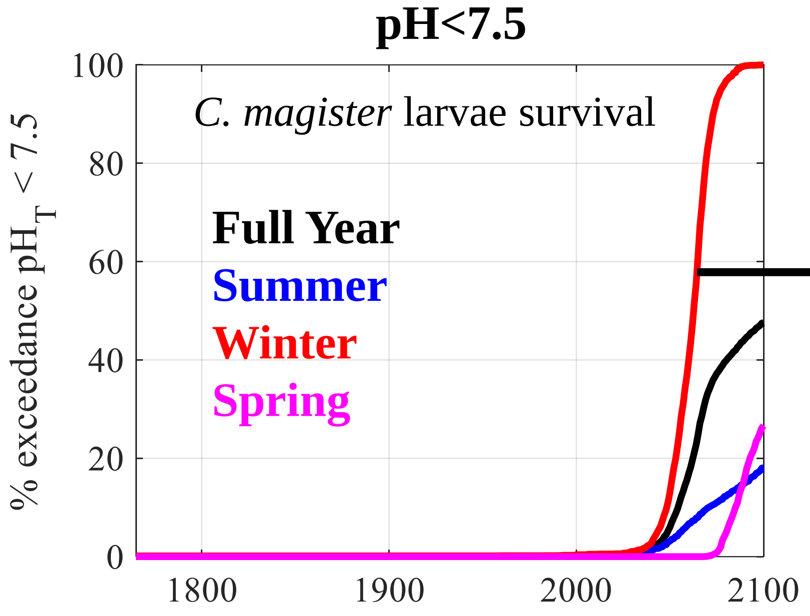
Ω_{arag}<1.4



Regular exceedance of pH and pCO$_2$ thresholds by mid-century…

…currently in acceleration of Ω_{arag} exceedance?

Interaction between "natural" and OA-driven changes to buffering capacity controls the timing of crossing of **physiological** and water quality thresholds



Phenology of Dungeness crab

Table 3.1 Peak reproductive timing throughout the range of *C. magister*

Location	Moulting/ mating	Egg deposition	Hatching	Larval duration (range of time)	Settlement
Oregon–Washington	March–June	October–December	January–March	130 (89–143)	April–August
Puget Sound	April–September	October–December	February–May	150	June–August
British Columbia	No data	September–February	December–June	No data	July–Later

Rasmuson 2013, *Adv. Mar. Bio.*

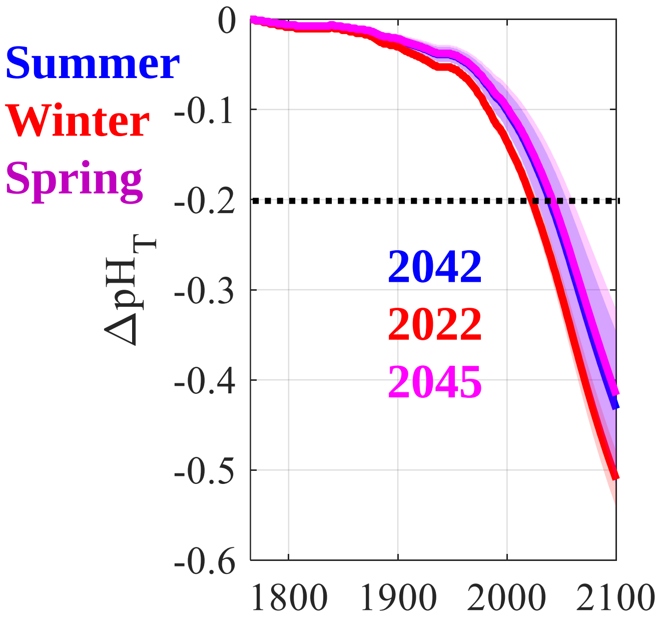
Overlap of poor environmental conditions driven by OA and phenology of OA-sensitive life stages creates potential for organismal impacts

>10% annual exceedance by 2050, 14 years and 100ppm atmospheric CO_2 earlier due to reduced buffering

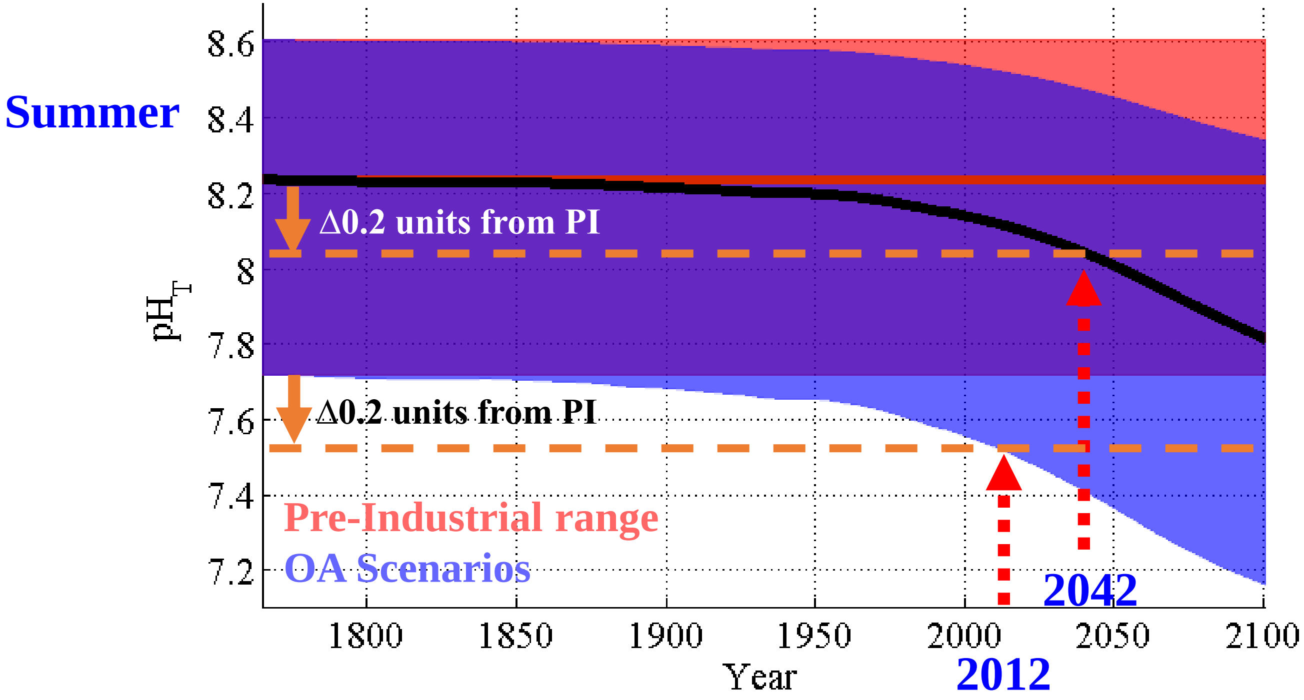
Interaction between "natural" and OA-driven changes to buffering capacity controls the timing of crossing of physiological and **water quality** thresholds

EPA's recommended criterion states that the pH of marine waters "should not be changed more than 0.2 units outside the naturally occurring variation"

Changes to seasonal climatology



Changes to carbonate weather



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3. **What does this mean for exceedance of physiological and water quality thresholds?**
    - **Earlier exposure to more severe stressful conditions for organisms**
    - **OA drives variable time to exceedance of existing recommendations for water quality criteria**

Key Take-aways

1. Estuaries are naturally dynamic chemical environments, which primes these systems for more rapid and severe changes to the CO_2 system with OA

    - Analogous to naturally high-CO_2 upwelling zones

2. The interaction of natural CO_2 cycling and C_{anth} in these habitats causes high *p*CO2, low pH, and low Ω_{arag} conditions to change most rapidly

    - Indices most relevant for organismal impacts

3. Understanding OA effects on time scales relevant for organisms will help identify times of synchronous threshold exceedance and OA-sensitive life stages

How does magnitude and duration of threshold exceedance translate into organismal/ecosystem impacts??

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