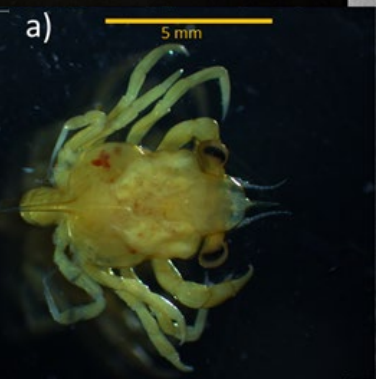


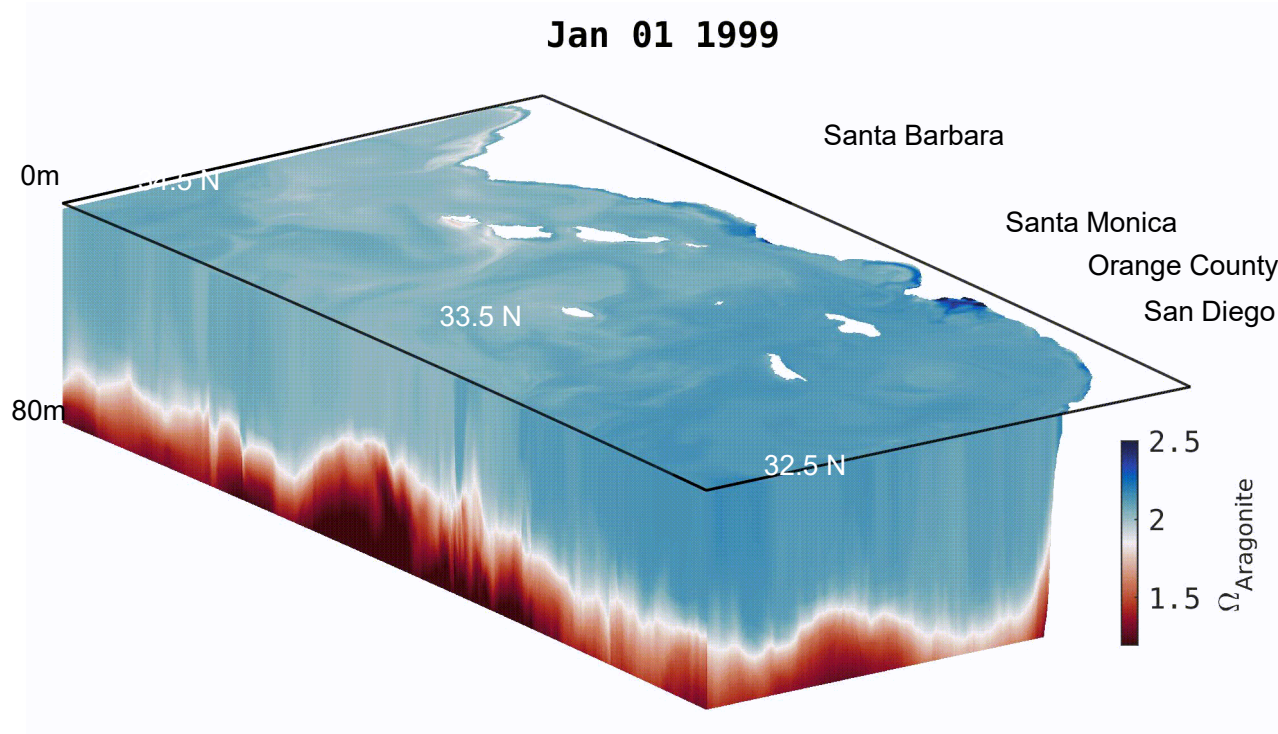
STATE OF SCIENCE: CRITICAL OA THRESHOLDS FOR SENSITIVE CALCIFIERS ALONG THE CALIFORNIA COAST



Commission meeting
March 5th 2021



ROMS-BEC Model is Capable of Mechanistic, 3D, High Resolution Representation of OA in combination with other stressors



How does this translate to biological effects?



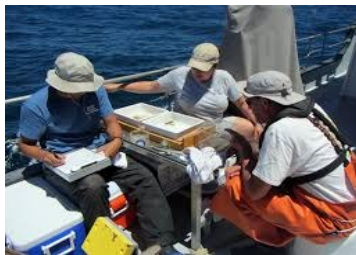
We've Been Developing Science to Assess Biological Effects to Ocean Acidification

Threshold and Index Development

Laboratory Experiments



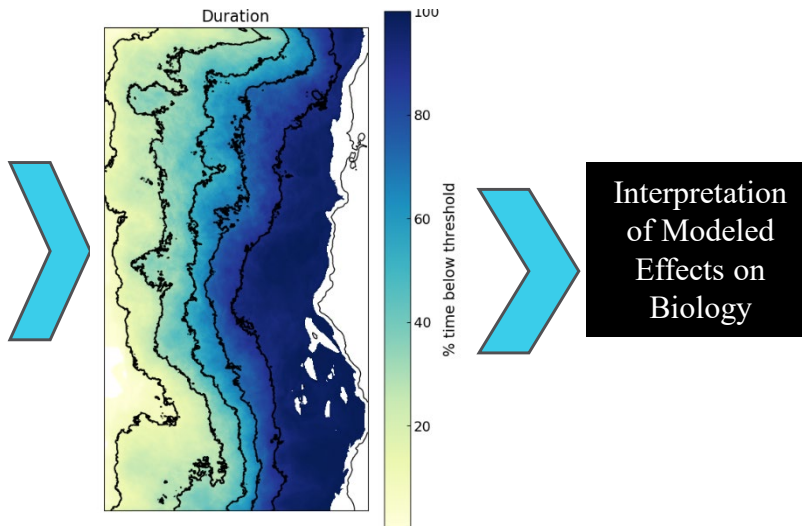
Field Observations



Data Synthesis & Expert Consensus



Application to Model Output

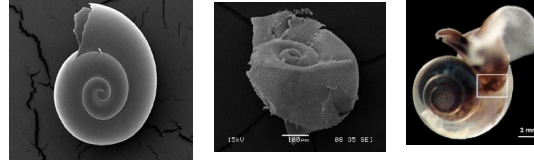


Duration of excursions of Adult Survival at 200 m depth, June to February ($\Omega = 0.95$, 14 days)

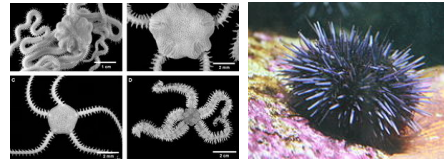
Outcome of OA Threshold Development

- **Data collection and literature review**
 - 135 studies with 40k datapoints
- **Expert review, consensus on thresholds**
 - 21 international experts
 - 35 thresholds, multiple pathways of impact, different life stages and habitats
- **Uncertainty assessment**
 - Using IPCC approach* to assign the confidence score to each thresholds

Pteropods: Pelagic (0-500m) zooplankton



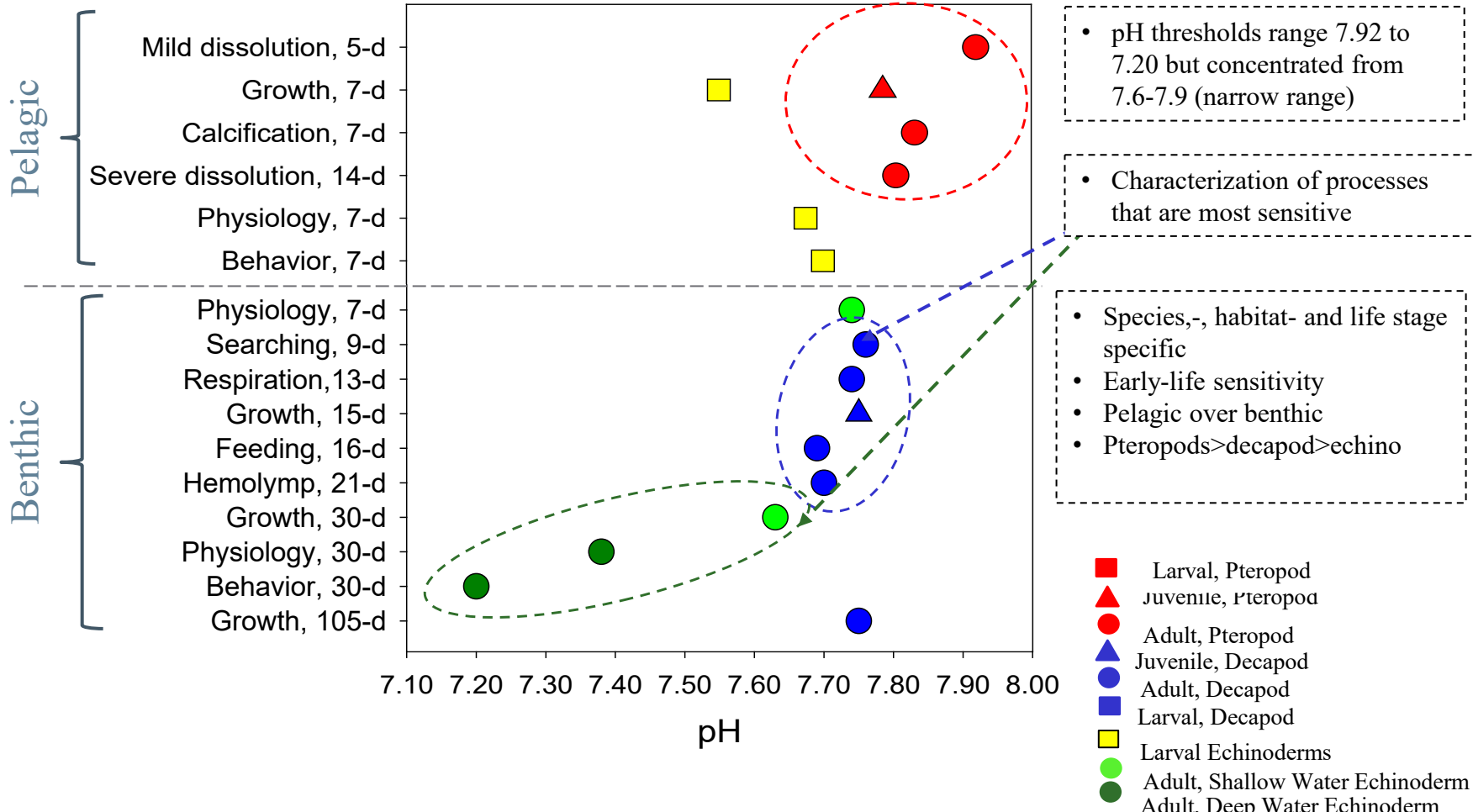
Echinoderms: Shallow to deep pelagic and epibenthic



Decapods: Shallow to deep pelagic and epibenthic



Synthesis of the Synthesis: OA Thresholds

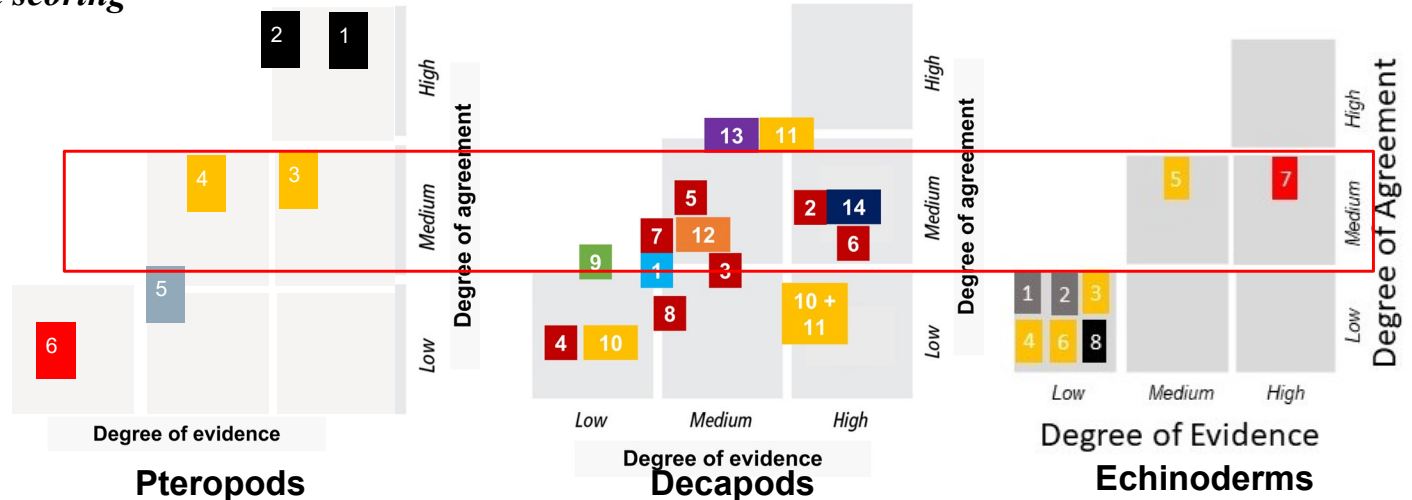


Expert Confidence Rating Should Be A Factor In Choosing Threshold

Agreement ↑	High Agreement Limited Evidence	High Agreement Medium Evidence	High Agreement Robust Evidence	Confidence Scale
	Medium Agreement Limited Evidence	Medium Agreement Medium Evidence	Medium Agreement Robust Evidence	
	Low Agreement Limited Evidence	Low Agreement Medium Evidence	Low Agreement Robust Evidence	
	Evidence (amount and consistency) →			

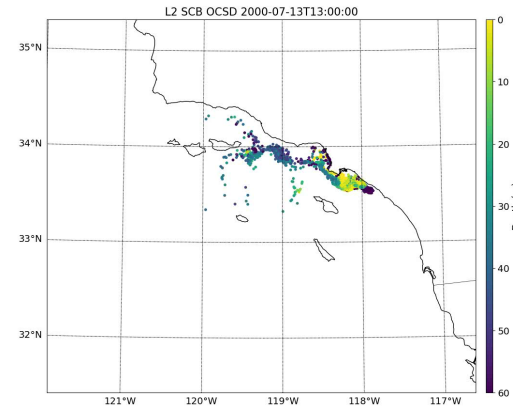
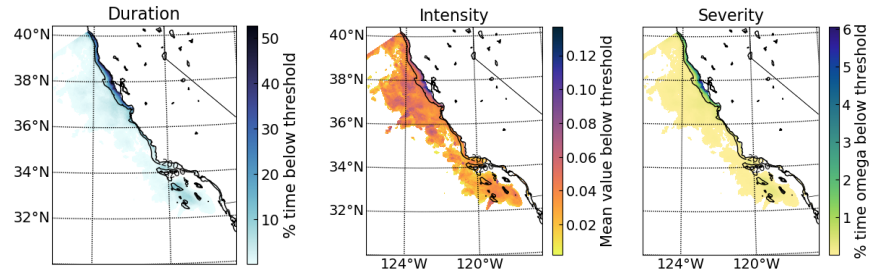
IPCC confidence scoring

- Range of different confidence scores
- Mostly in the medium range (medium agreement with medium- to robust- evidence)
- Lower certainty thresholds



Factors that increase uncertainty related to threshold interpretation

- What temporal/spatial extent of effect would trigger a management response?
- Larvae and pteropods don't stay stationary in water column
 - How does this mobility affect exposure history?
- OA in combination with temperature, oxygen can further limit suitable habitat
 - How do we account for effects of variable exposure and multiple stressors in the coastal habitats?



Variability and Multiple Stressors Matter

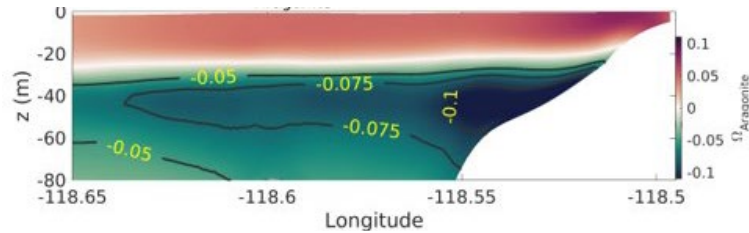
- When it comes to interpreting biological effects due to *variable* OA conditions and *multiple stressors*, we are still at the beginning.
- This is especially pertinent in the coastal regions with the uncertainty related to time-averaging, non-linear response, etc.
- Using IPCC scoring, we assess that predicting biological responses under multiple and variable exposure is scored with ‘*low confidence*’

Approaches for improved understanding of variable and multiples stressors

- State-of-the-art experimental set-up

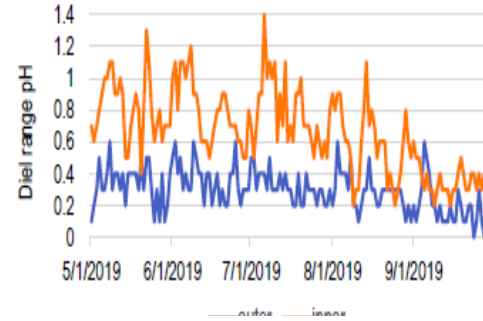
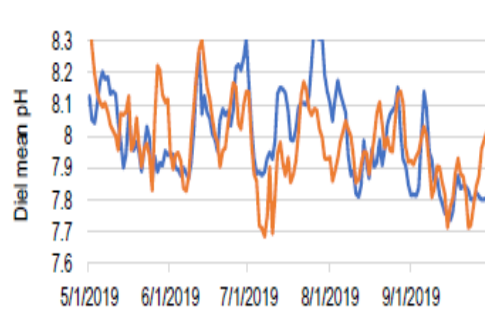


- Field observations and Modelling

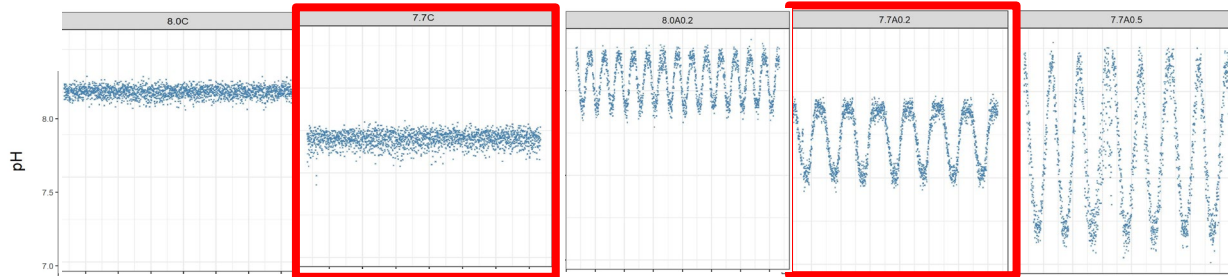


Variable exposure additionally impacts biological responses

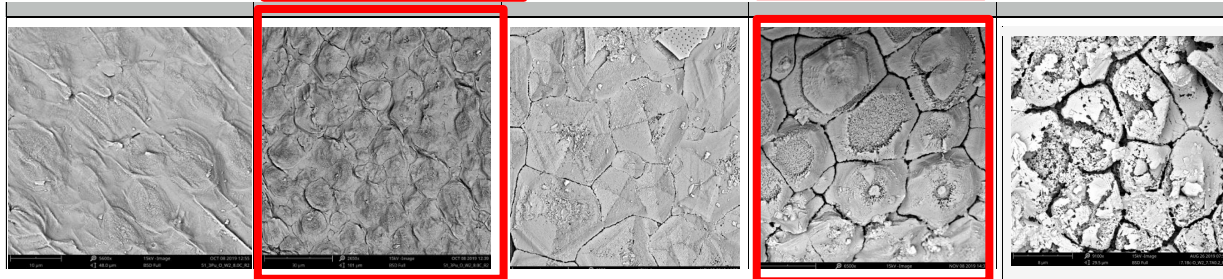
Natural conditions
on the coast and in
the estuaries



Experimental
set-up



Biological
responses



Management and
restoration

inform

determine

strategize

Multiple stressors

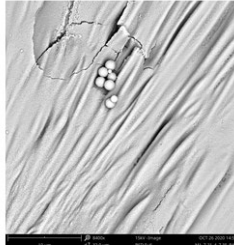
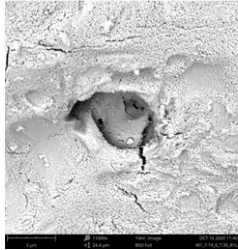
Biological effects under low DO and low pH

Severity of dissolution

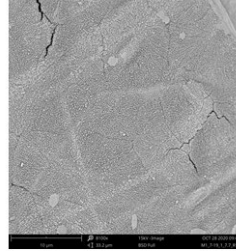
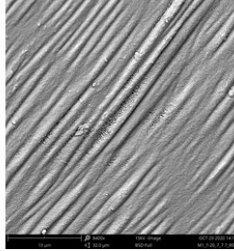
Depth of ridges

Exposure of crystal heads

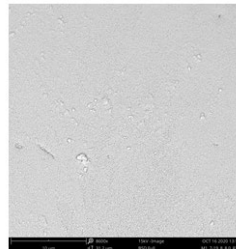
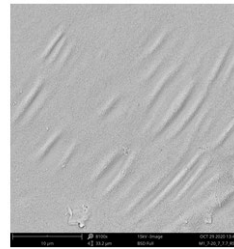
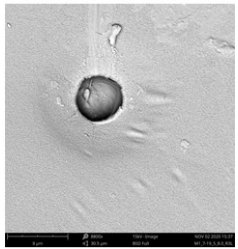
Low pH/low DO



Mid pH/Mid DO



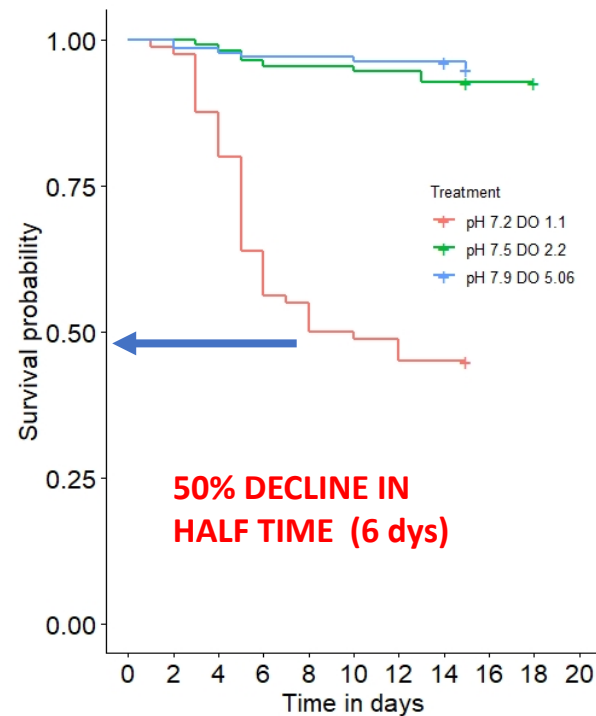
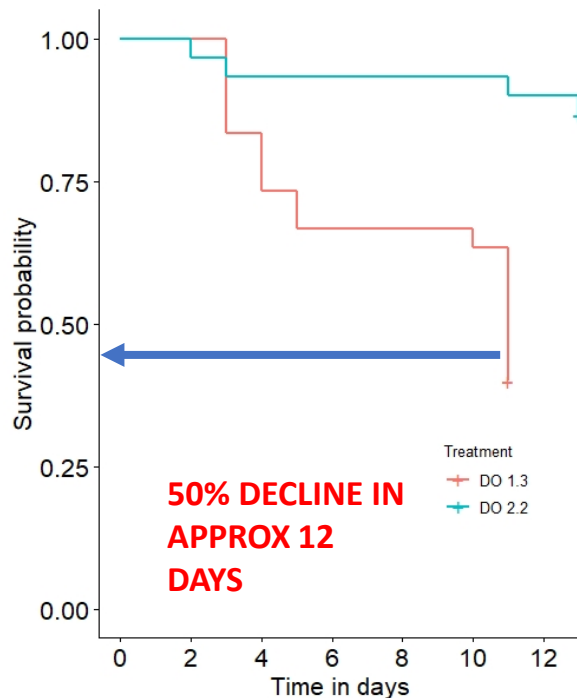
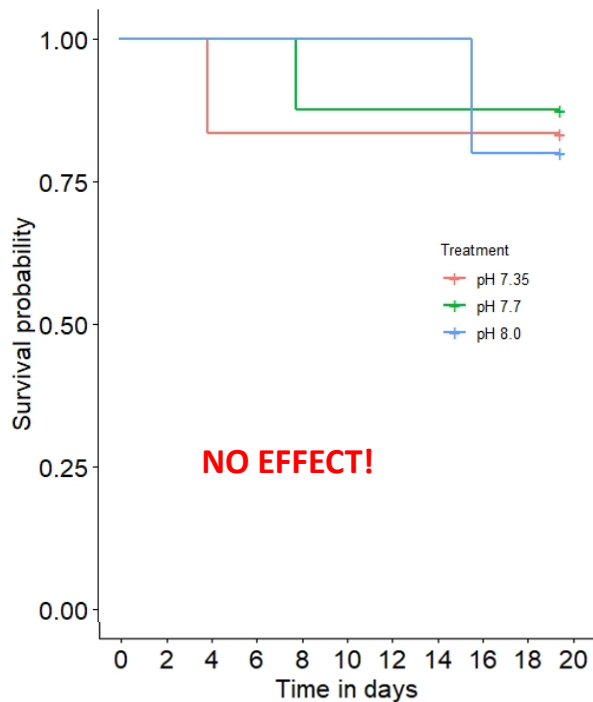
High pH/High DO



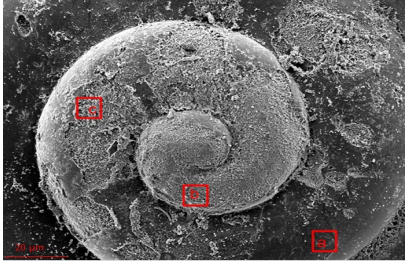
- Exoskeleton dissolution in juvenile Dungeness crabs
- Multiple stressor: pH and DO (interact in their habitats)

More severe dissolution with low DO/low pH compared to OA exposure only

Survival of Dungeness juveniles under single vs. multiple stressors



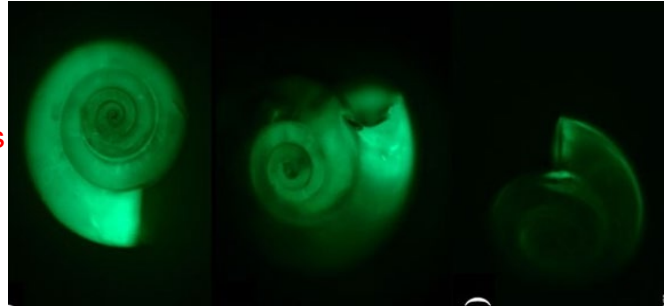
Field results support thresholds



Shell dissolution

Field data: $\Omega_{ar}=1.3$ for 7 days

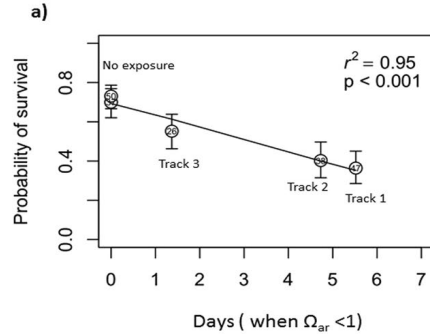
Threshold=1.2 for 2 weeks



Reduced calcification

Field data: Ω_{ar} of 0.9-1 for 14 days

Threshold: 1.2 for 7 days



Increased mortality:

Field data: Ω_{ar} of 0.9 for 30 days

Threshold: 0.95 for 2 weeks

Take Home Messages

- We've made great strides in developing thresholds for static conditions
 - Univariate thresholds for acidification for 3 marine calcifying taxa, representing multiple habitats.

More work for a more accurate understanding of biological impacts under variable OA conditions and under the multiple stressor exposure

- Integrated science approach need to understand and comprehensively interpret these effects.
- Combination of field results, extensive monitoring, meta-analyses and synthesis work, further experiments and modelling...