Using pteropods as a case study in water quality assessment for ocean acidification

C-CAN webinar

Nina Bednaršek
University of Washington

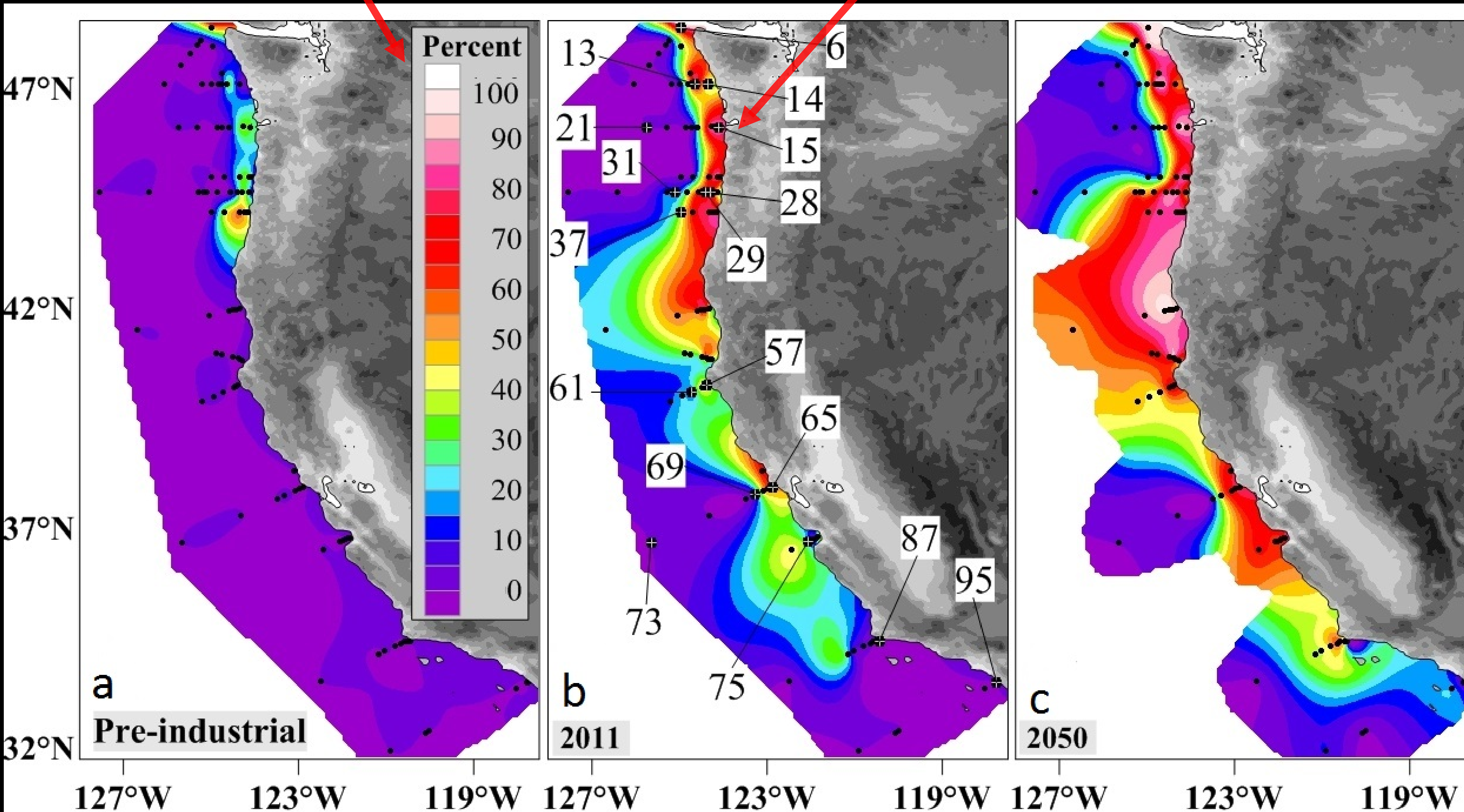
May 2015

Ocean Acidification along the US West Coast

Percentage of upper 100 m corrosive for pteropod shells.

Expansion of corrosive waters

70% corrosive - habitat loss



Bednarsek et al., *Proceedings to the Royal Society B, 2014*

Water quality standard for OA

Seriousness of acidification's impacts on ocean life recognized.

Need for development of water quality standard to evaluate the status of the water body with respect to acidification → linking the exposure measurement to an effect.

Recommended use of biological indicators (Interagency OA Group, 2011; Blue Ribbon White Science paper, 2012; OSPAR 2014).

Three criteria for aquatic life assessment:

(1) Attribution of the observed effects to ocean acidification

→ Correlative studies of field data and OA chemistry
→ Linkage to the lab studies with likely OA effects to natural environment
→ Combination of lab and field studies

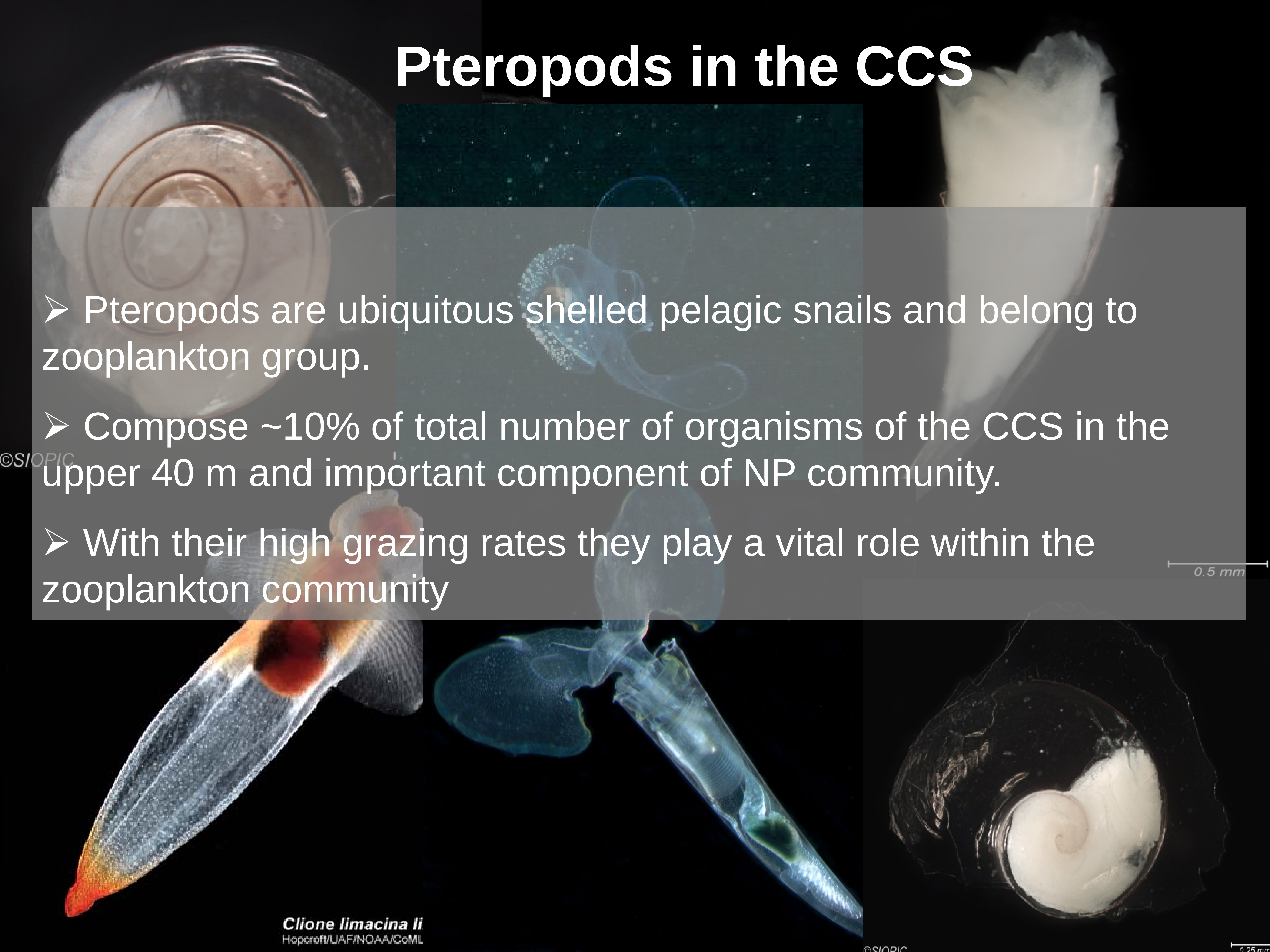
(2) Population level effect on species

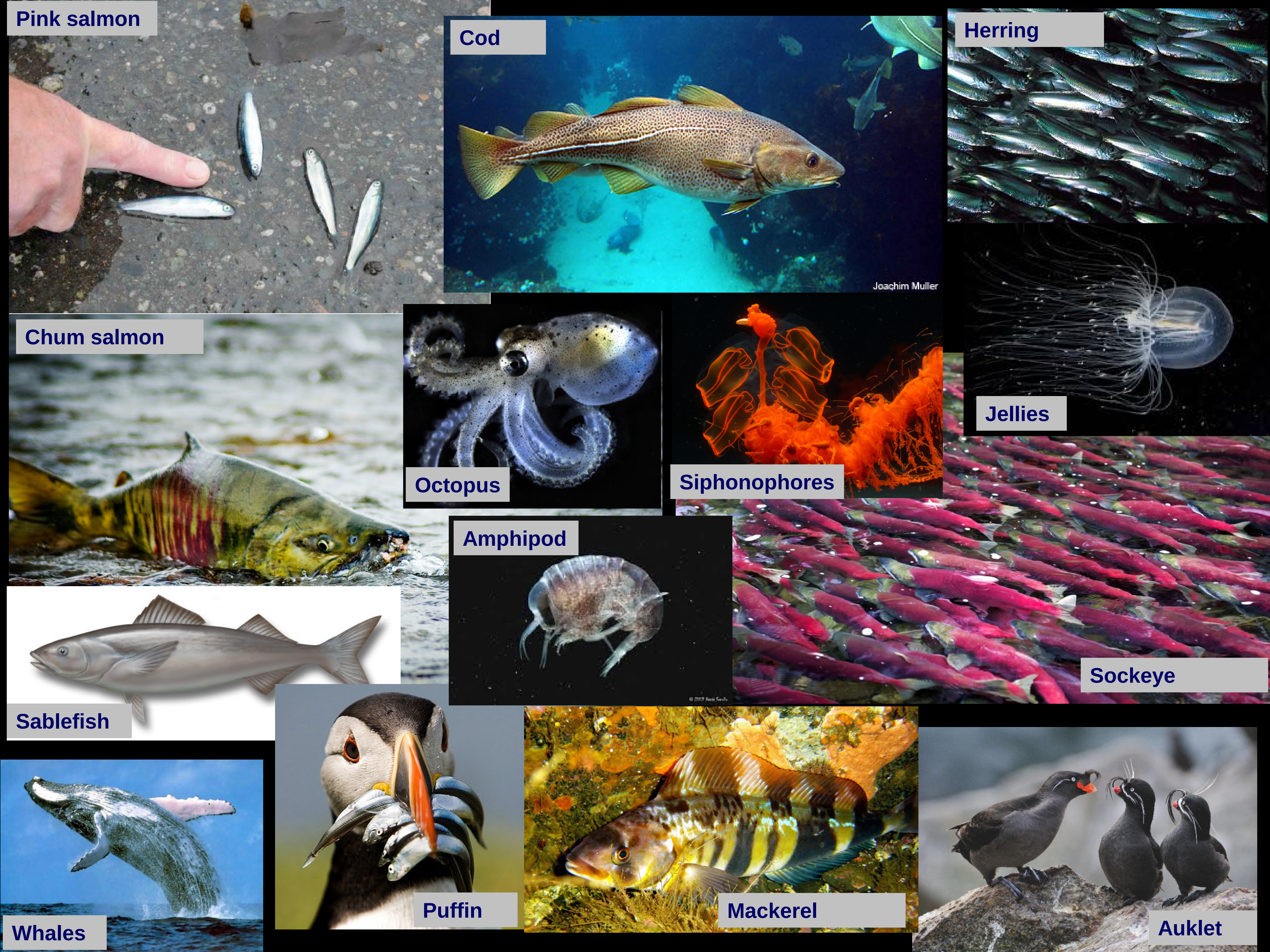
→ Demonstrated for natural population
→ Decreasing survival or fecundity as likely population level effects

(3) Ecological importance

Pteropods in the CCS

- Pteropods are ubiquitous shelled pelagic snails and belong to zooplankton group.
- Compose ~10% of total number of organisms of the CCS in the upper 40 m and important component of NP community.
- With their high grazing rates they play a vital role within the zooplankton community




Pink salmon
Cod
Joachim Muller
Herring
Chum salmon
Octopus
Siphonophores
Jellies
Amphipod
Sockeye
Sablefish
Whales
Puffin
Mackerel
Auklet

Pteropo

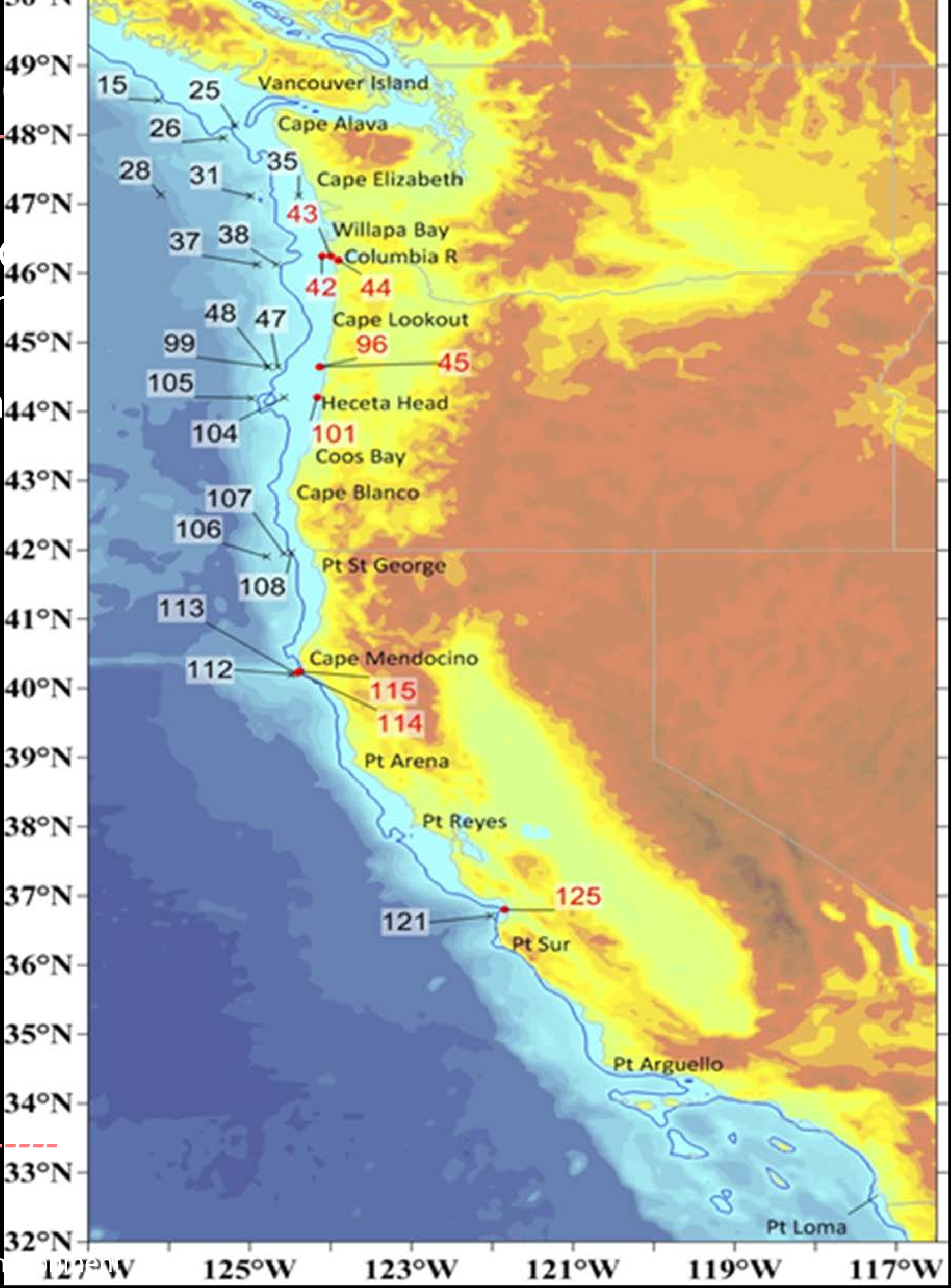
Attribution of the obser

Magnitude and duration of exposure to
conditions in the future prolonged and m

Several lines of evidence suggest th
negatively affected by OA exposure.

Changes in:
→ shell dissolution
→ shell calcification
→ survival

Combination of observations
and experiments and modelling



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(1) Attribution of the observed effects to ocean acidification

- → Correlative studies of field data and OA chemistry
- → Linkage to the lab studies with likely OA effects to natural en
- → Combination of lab and field studies

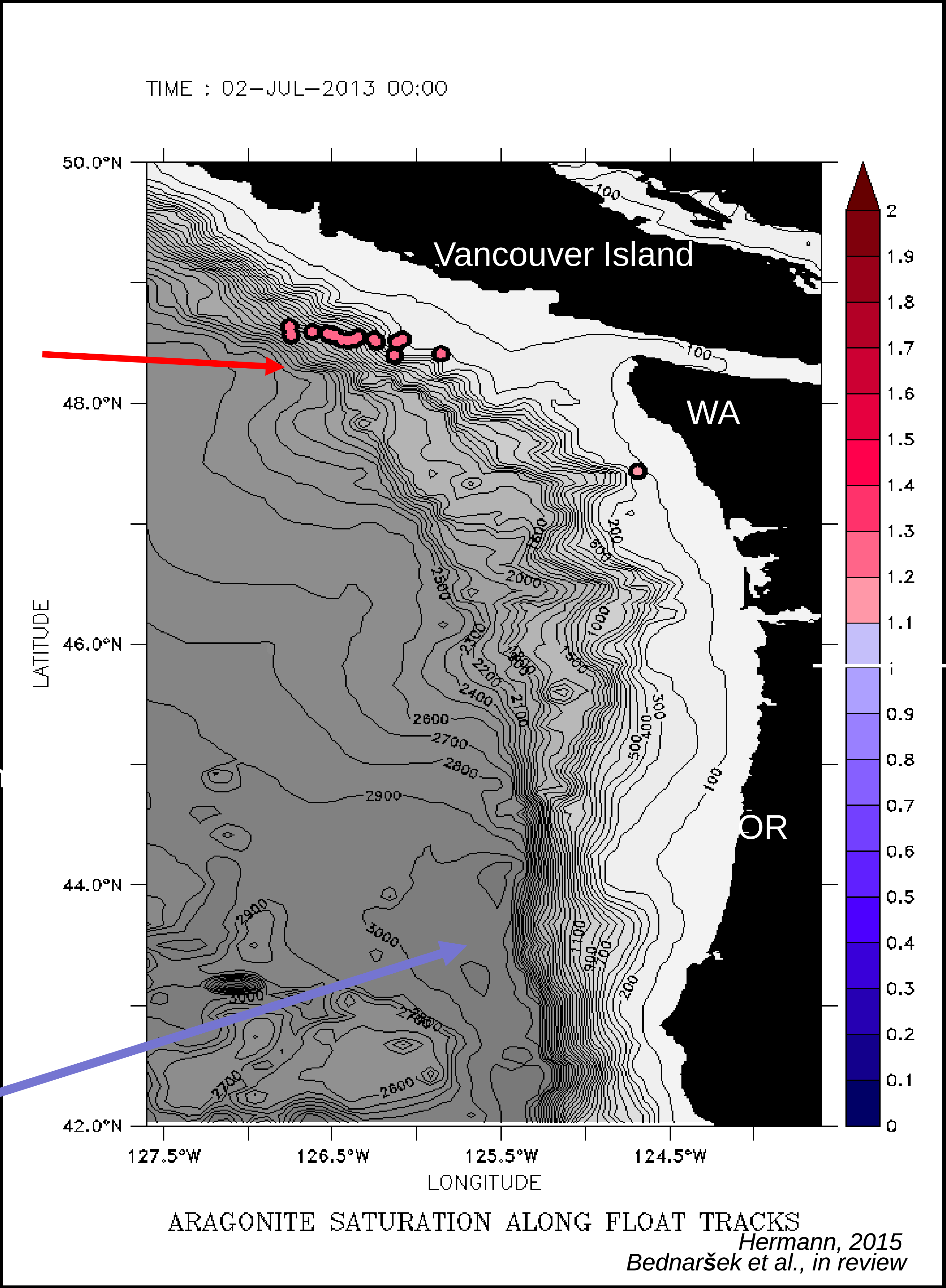
Duration and magnitude of exposure to OA

Exposure of 2-3 weeks to undersaturated waters

Tracking drifting particles.

Visualizing the level of duration and magnitude of exposure to OA as pteropods travel from the North to South of th CCS.

Exposure 30+ days to undersaturated waters

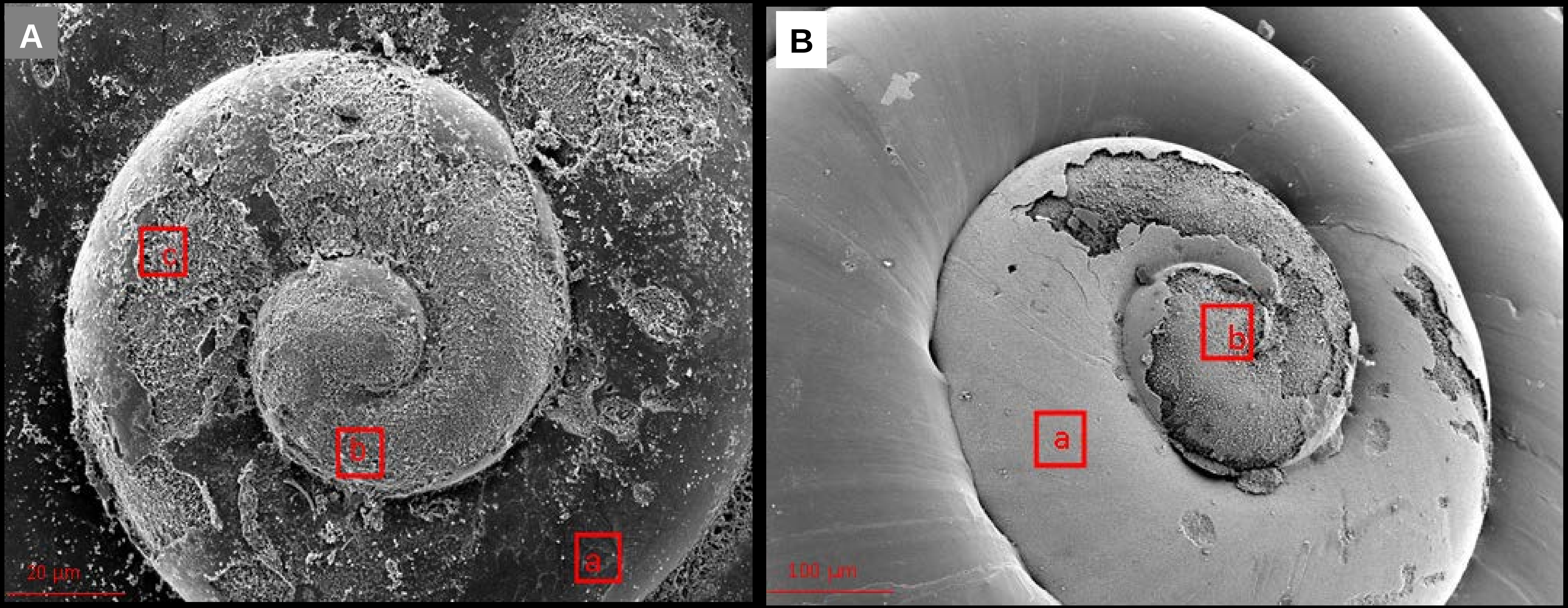


Hermann, 2015
Bednaršek et al., in review

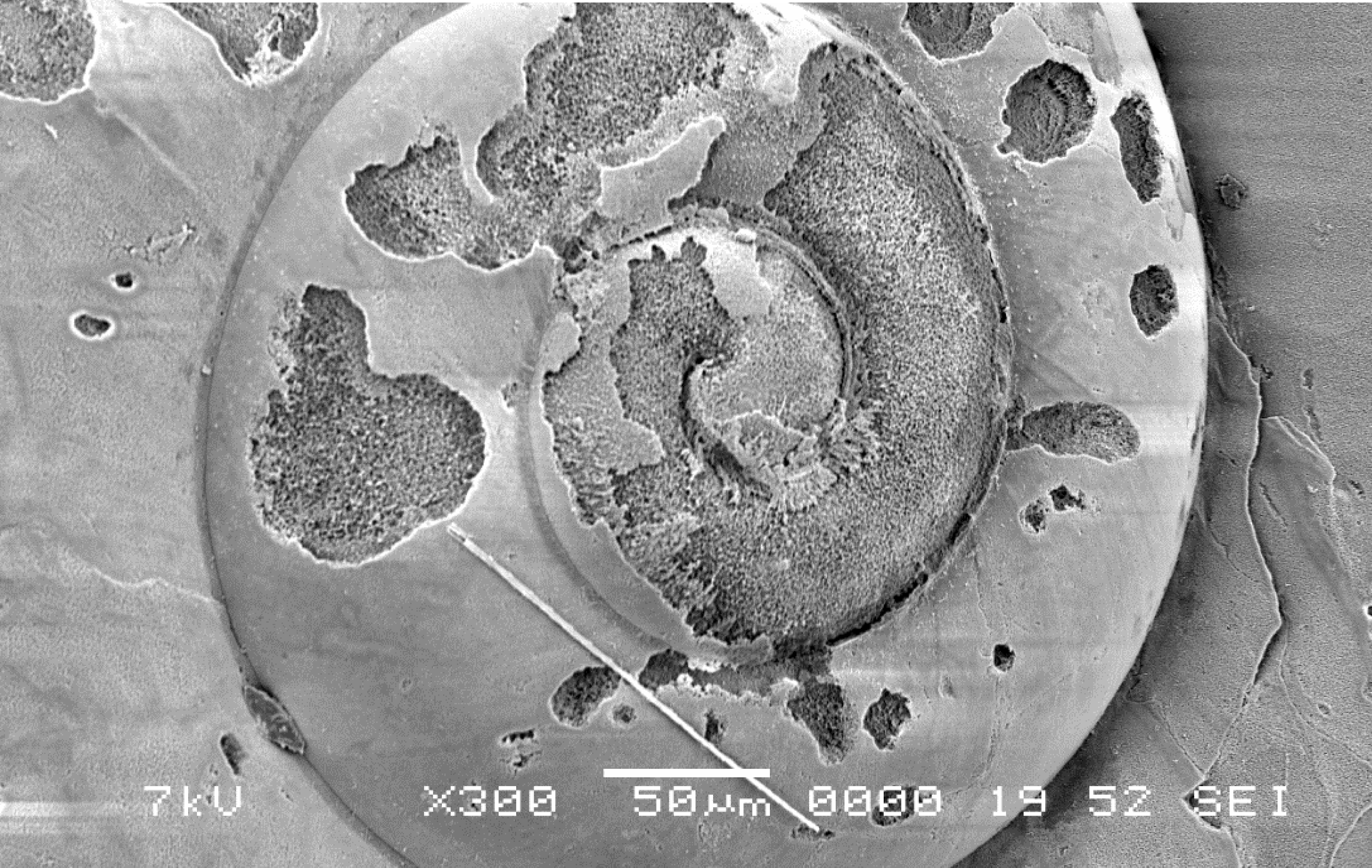
Pteropods as indicators-increased shell dissolution

Attribution of the observed effects to ocean acidification

Shell dissolution closely corresponds to carbonate chemistry conditions
Changes in dissolution extent occur on a very short time scale of response, from days to weeks.



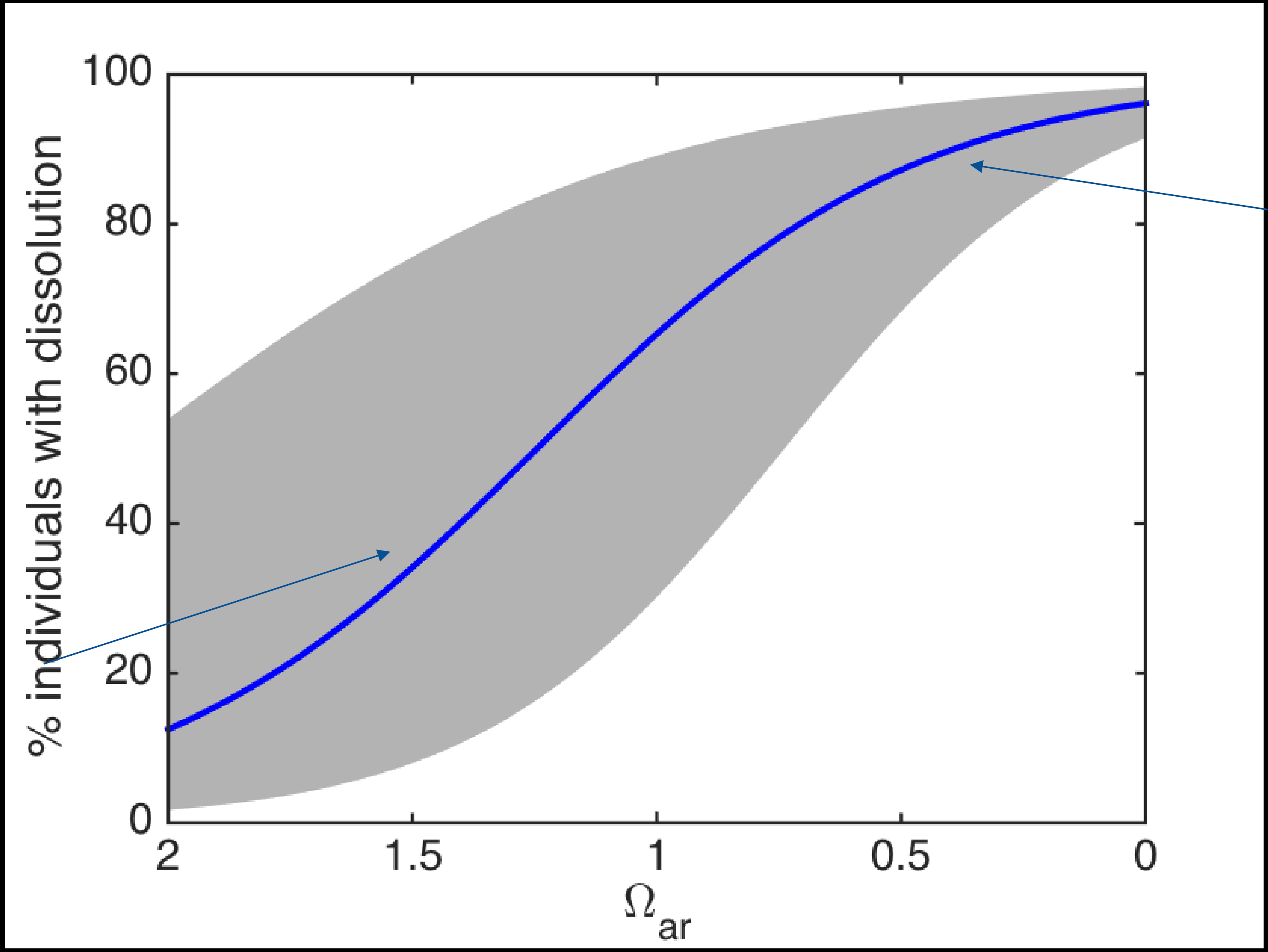
Along the West coast, more than 50% of pteropods already show severe shell dissolution; by 2070, 70% individuals will show severe dissolution.
Shell dissolution mostly in the Northern and Central CCS region.



Johnson and Bednarsek, UW/WOA

Pteropod shell dissolution

Attribution of the observed effects to ocean acidification



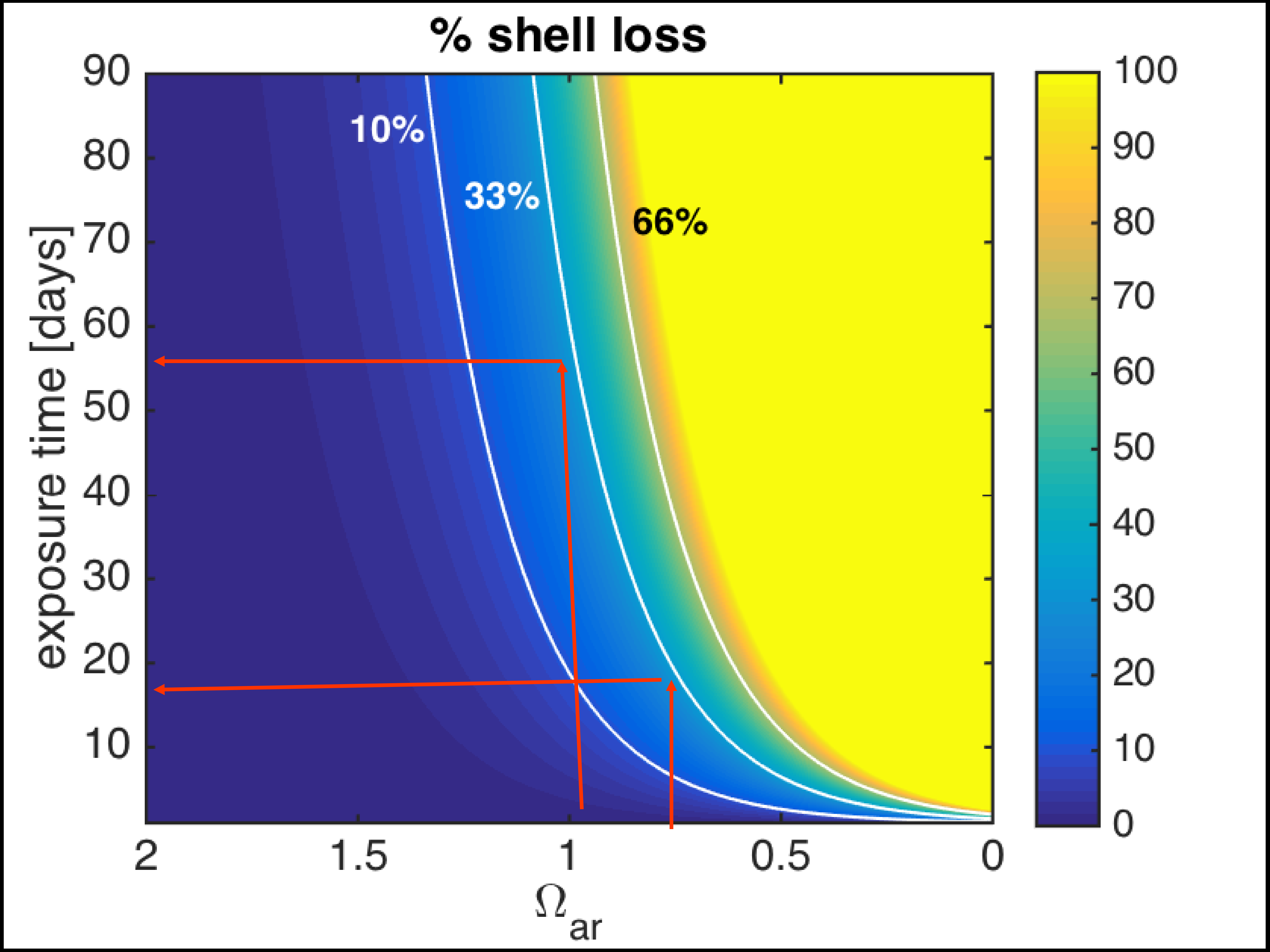
Pteropods from near-shore region

Pteropods from off-shore region

- ➢ Strong positive relationship between proportion of dissolved individuals and aragonite saturation state.
- ➢ ↓ saturation state → reduction in suitable habitat availability

Pteropods as indicators- dissolution in time and space

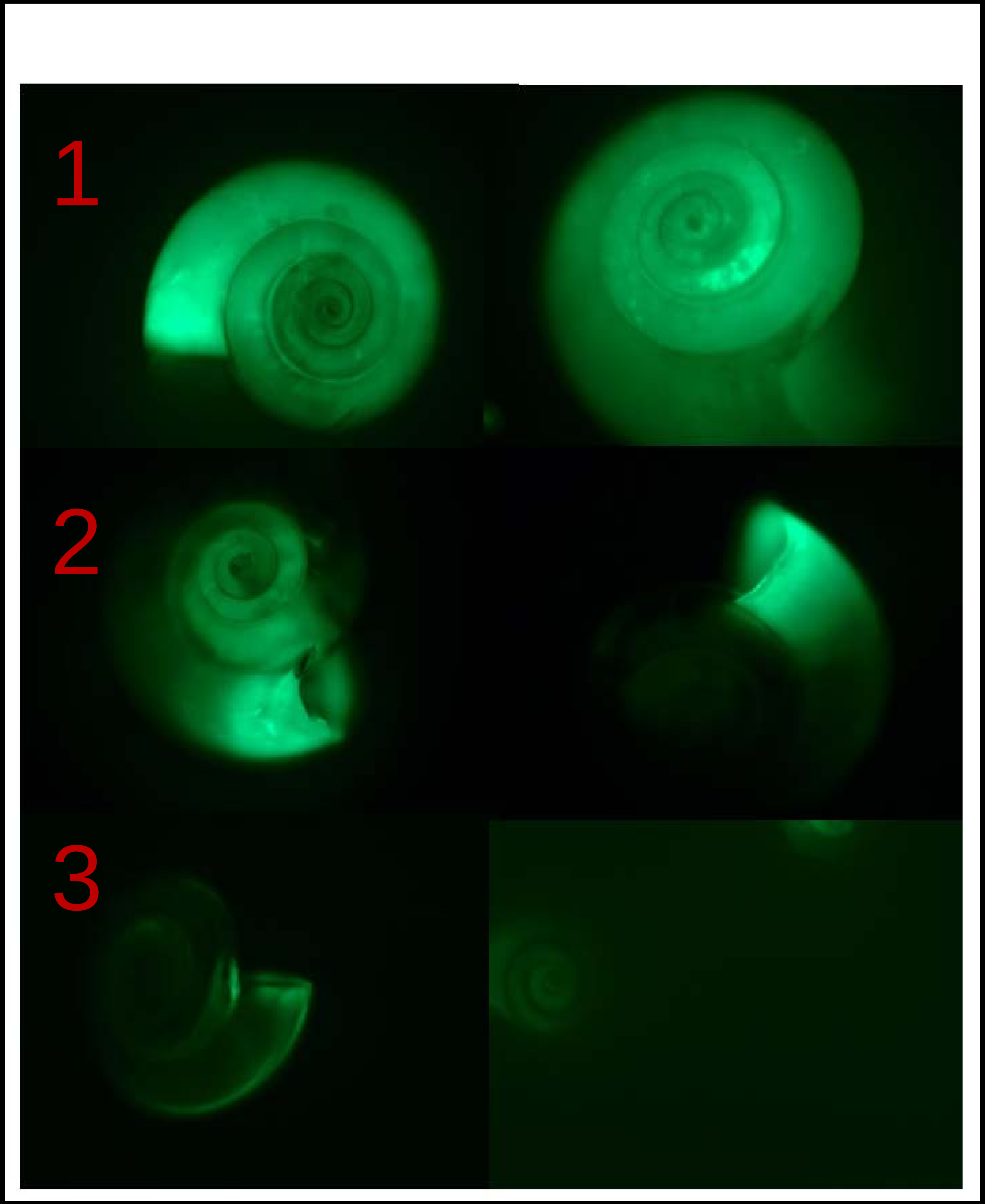
Attribution of the observed effects to ocean acidification

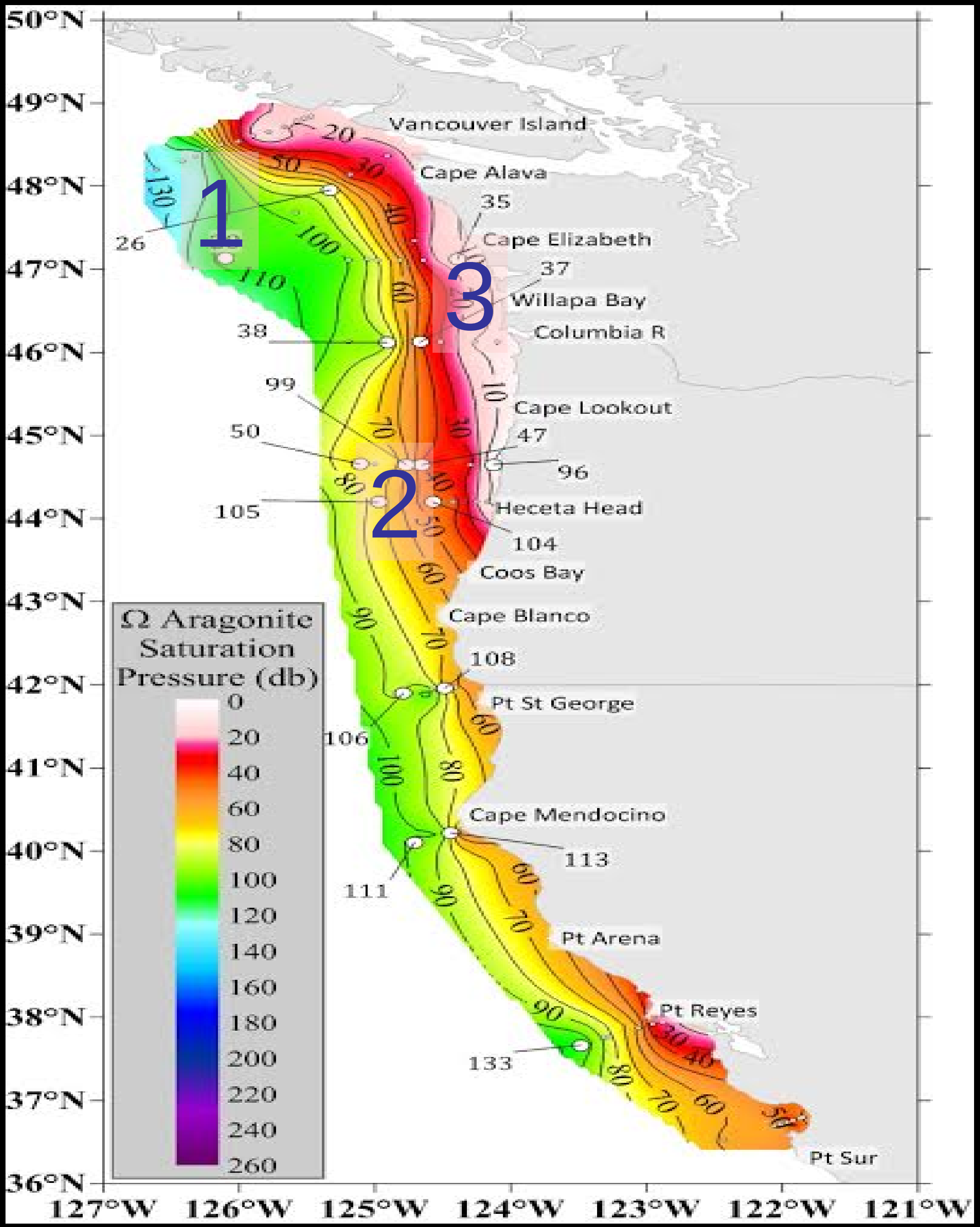


Pteropods as indicators- reduction in calcification

Attribution of the observed effects to ocean acidification

Shell calcification closely corresponds to carbonate chemistry conditions.
Response on a very short time scale, from days to weeks.





Pteropods as indicators- swimming (dis)abilities

Attribution of the observed effects to ocean acidification

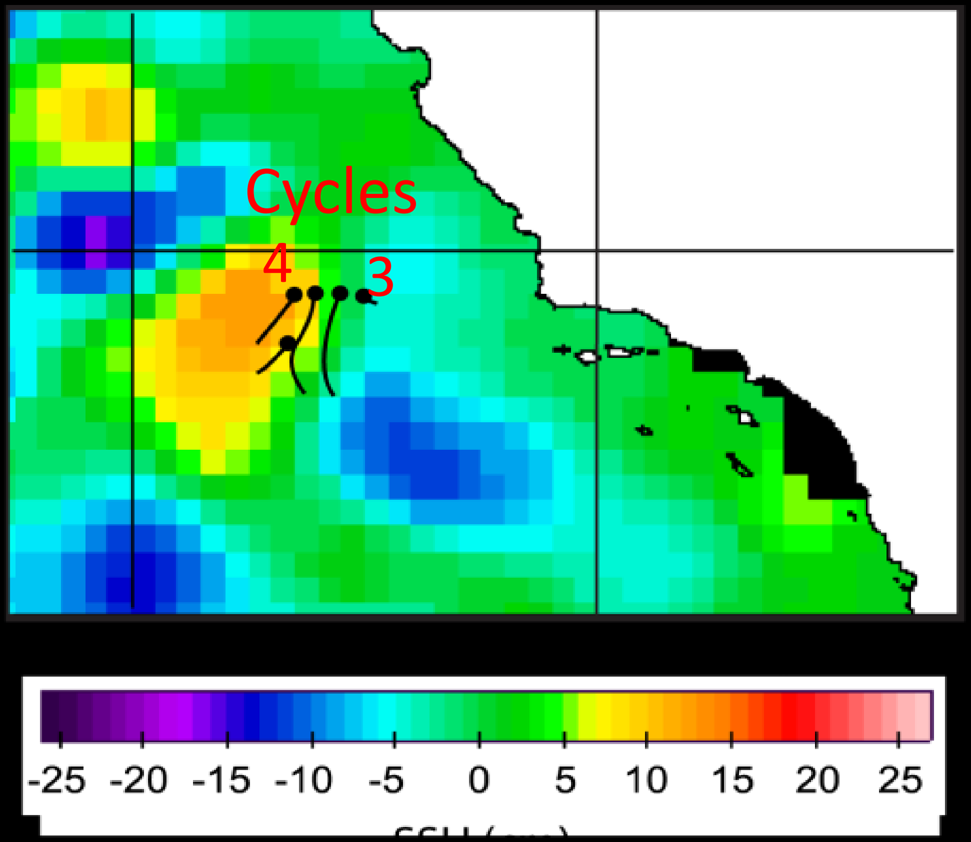
Pteropods as indicators- swimming disabilities

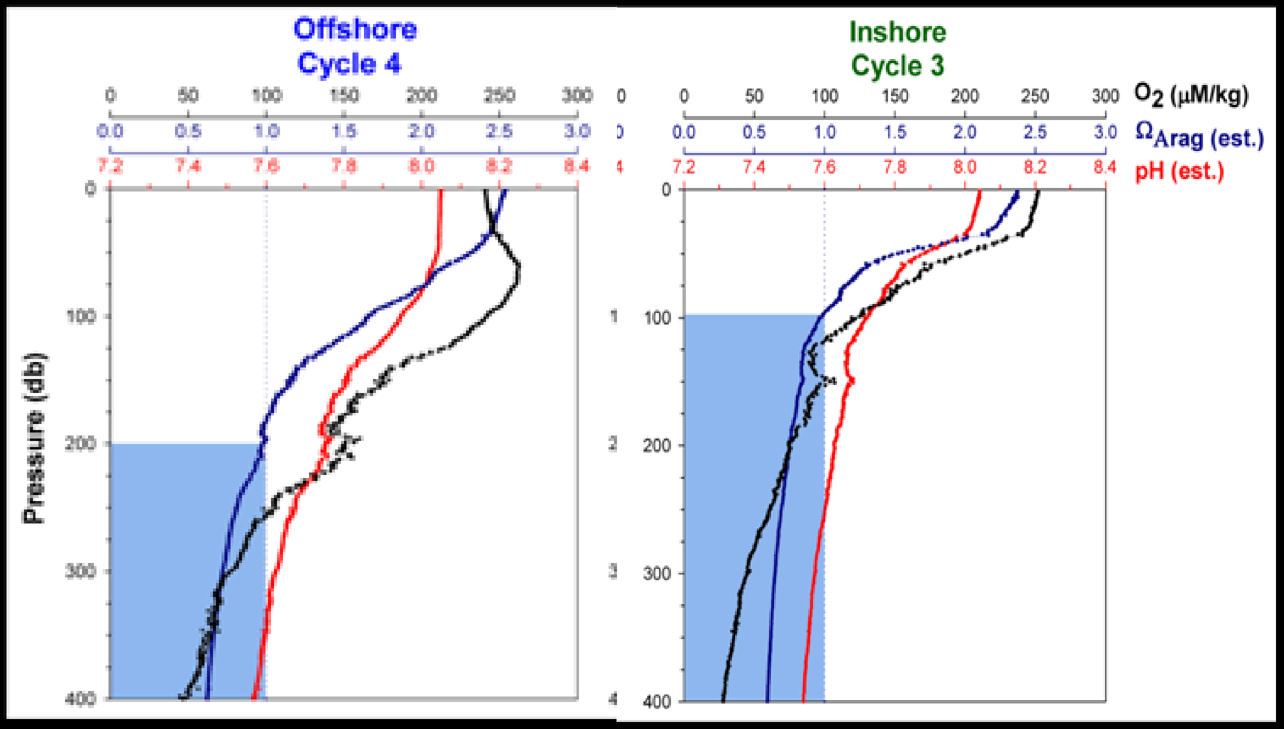
Attribution of the observed effects to ocean acidification

Pteropods as indicators- changes in behavior response

Attribution of the observed effects to ocean acidification

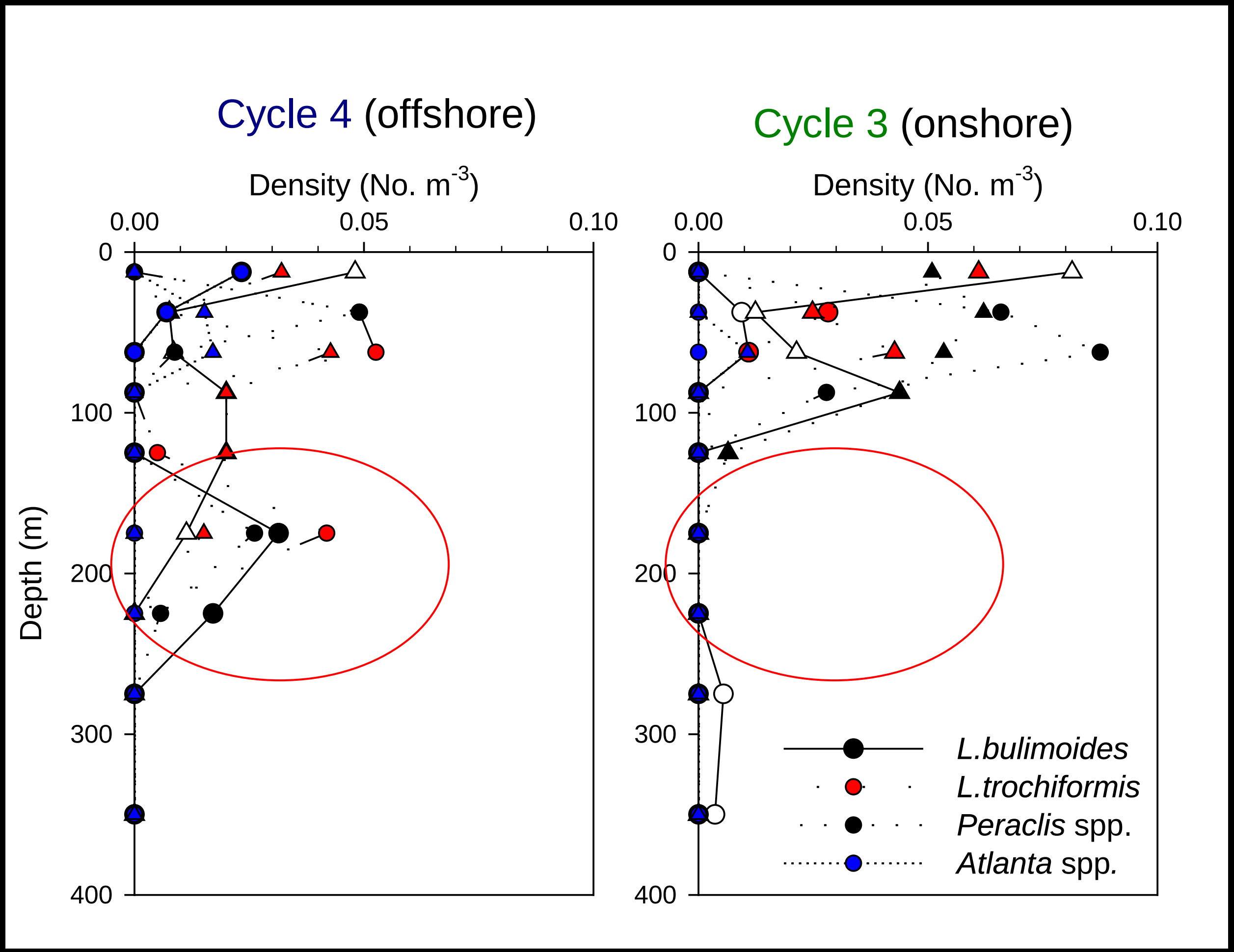
- ➢ Eddy-associated front (off- and on-shore of the front)
- ➢ Difference in the aragonite saturation depth: offshore (Cycle 4) vs onshore (Cycle 3)

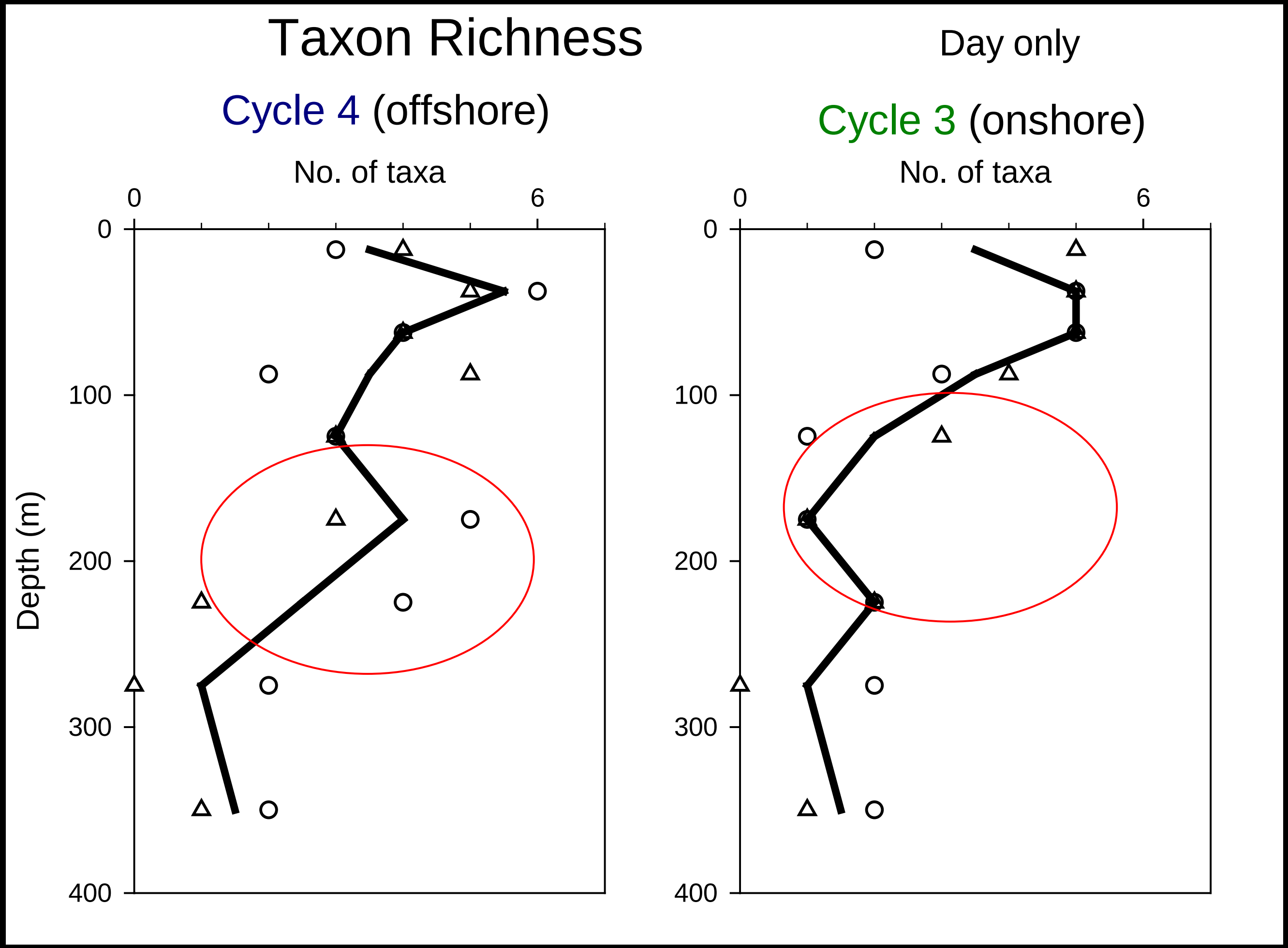




- ➢ Space-for-time exchange approach to examine pteropod vertical distribution and species richness

Changes in **vertical migration** and **species richness**





Bednarsek and Ohman, MEPS, 2015

→ Changes in pteropod vertical distribution species showing reduced occurrence in the undersaturated conditions.

→ Based on the predator-prey interaction, this could have a direct effect on the distribution of their direct predators, including different fish species → ecosystem implications!

→ Modelling (IBM): shallow vertical migration-> advection of pteropods to near-shore

Pteropods as indicators- decline in individual survival

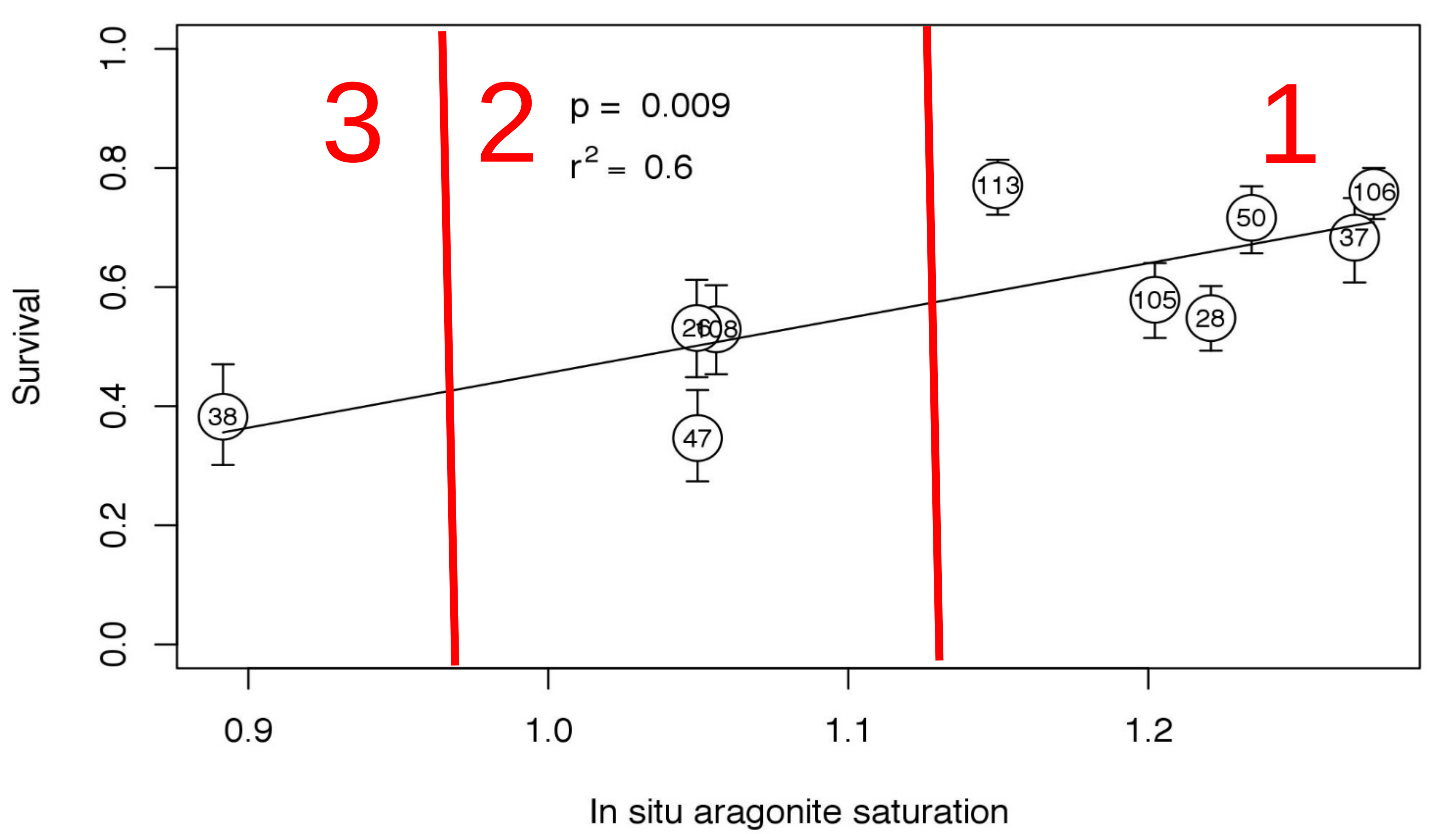
Studying multiple levels of biological organization

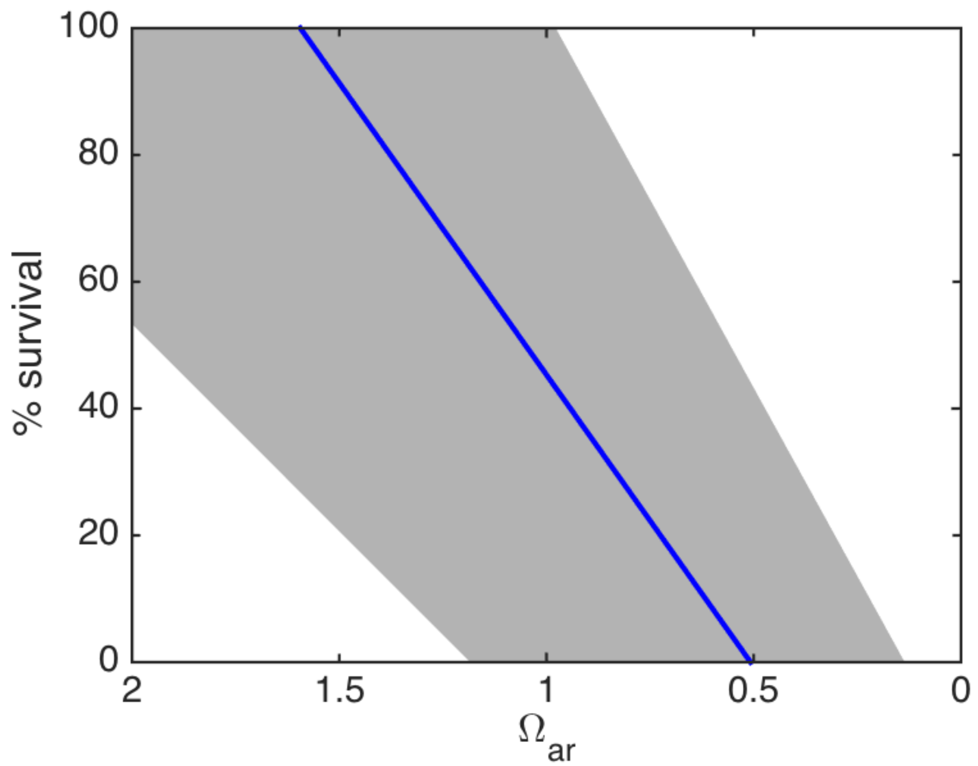
→Pteropods were exposed to experimental conditions after experiencing corrosive conditions for a few months in the natural environment.

→ Pteropods from unfavorable conditions in the natural environment had approximately 90% lower survival in the undersaturated conditions in comparison with near-saturated condition.

→Probability of survival in the high CO_2 directly correlated to the corrosive conditions in the natural environment.

Survival thresholds!

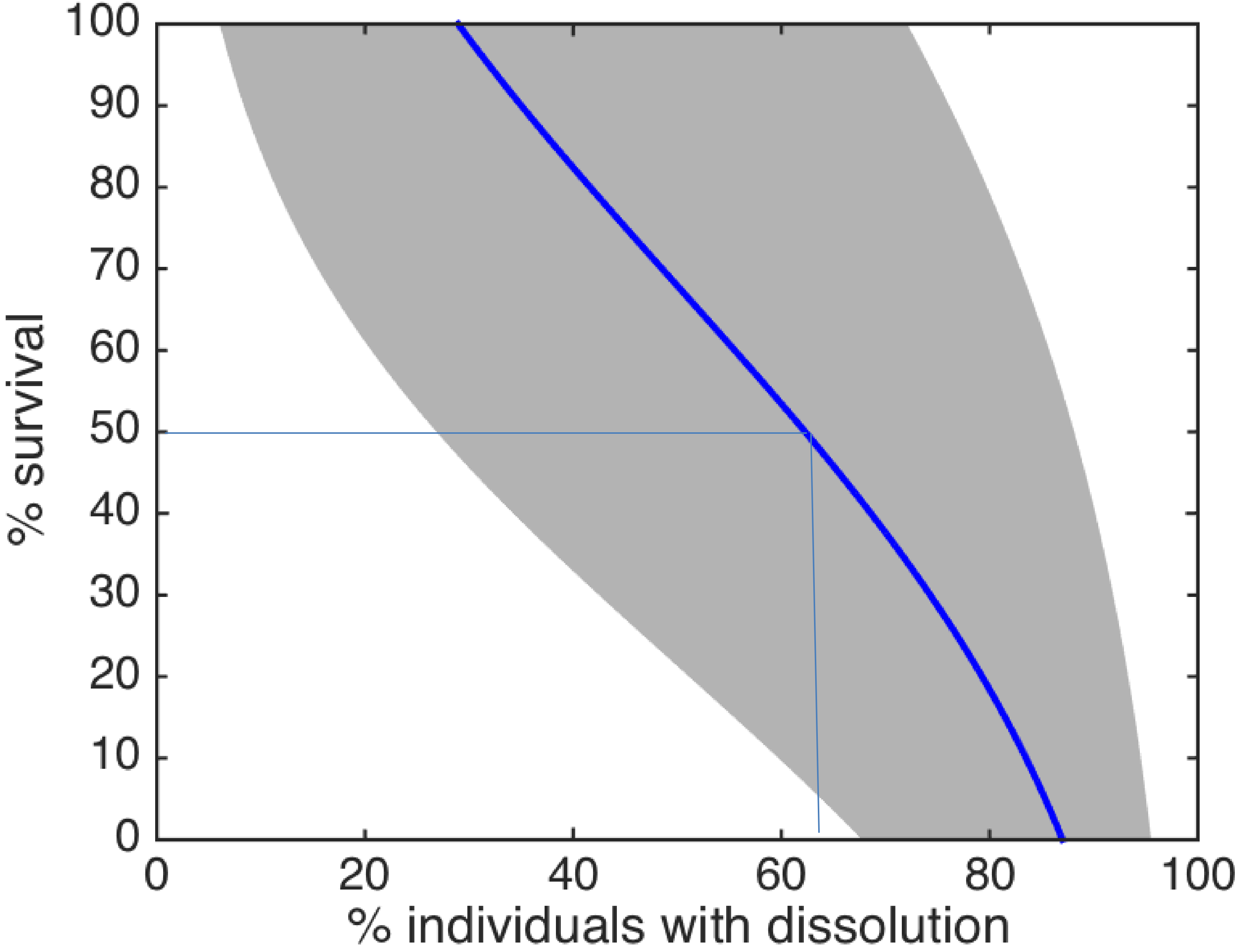




Uncertainty large, indicating potential resilience or acclimatization/adaptation strategies

Pteropods as indicators

Combining multiple levels of biological organization



Simple practical application: 2/3 pteropods

Dissolution is affecting individual survival!

Pteropods as indicators
Population level effect on species

OA exposure is encompassing multiple levels of biological organization from cellular, individual, which might be affecting population level already in the natural environment.

→ Demonstrated short-term survival impact
→ Demonstrating dissolution effect on the survival

→ The studies from the Northern CCS[1] and Central CCS[2] (more severe OA conditions) are showing long-term population decline, while Southern CCS (much less severe conditions) no effects[3] .

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(2) Population level effect on species
→ Demonstrated for natural population
→ Decreasing survival or fecundity as likely population level effects

[1]: Mackas and Galbraigh, 2012
[2]: Peterson, Fisher et al., in prep.
[3]: Ohman and Lavaniegos, 2009

Modelling work

(straw man model, Atlantis model)

PTEROPODS AS A CASE STUDY:

How do we parameterize a pH sensitive species within the model?
What information do we need from empirical studies?
How are different biological processes linked together?
How do we bring that into the ecosystem model?

INDICATOR TESTING:

Parameterizing pteropods as indicators for the rest of the ecosystem.
Warning sign of changes that are likely to happen in the other species, ecosystem health, or fisheries?

Pteropods as OA indicator

- Pteropod are ideal sentinel species because we have methodological approaches, we understand the mechanisms and they are ubiquitous.
- They respond to the small changes in Ω_{ar} very quickly → Ω_{ar} primary response variable, not confounded by other environmental variables → sensitive and specific indicator.
- Measuring biological responses in situ → developed methodology → rapid, cost-effective, easy-to-use, straightforward biomarker for monitoring of OA.
- Early warning signal.
- Food web implications: pteropods have been identified as an important food source but changes might be reverberating across higher tropic levels.
- Population effects complemented with modelling advancements.

Acknowledgement

→ EFA for funding

UW
Terry Klinger
Ryan Kelly
Ryan McCabe

NOAA
Richard Feely
Al Herman
Nick Tolimieri
Simone Alin
Jon Reum
Isaac Kaplan
Chris Harvey

Jan Newton (APL/UW)
Mark Ohman (Scripps)
Steve Weisberg (SCCWRP)

Gaps and future research

More studies needed to reduce this uncertainty:
→ Extrapolation of the results across time and scales
→ Using this approach for other species?

Scaling up from cellular to individual level seems a robust application; stronger link needs to be established between lower biological processes (dissolution vs growth rate; vertical distribution rate and survival)

Scaling up to the population level more uncertain due to lack of long-term studies → studying lower level translation effects could lessen the uncertainty.