Adaptation as a Response to Ocean Acidification – Is it Possible and How do We Look for it?

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The National Adaptation Forum

2-4 April 2013, Denver, Colorado

Hofmann Lab: Our Research

Global Change Biology in Marine Ecosystems

What are current ocean conditions? → *How are species currently adapted to this environment?* → *How might species respond to future changes?*

Collaborations:

OMEGAS
Ocean Margin Ecosystems Group for Acidification Studies

CSOC
CONSORTIUM FOR THE STUDY OF OCEAN CHANGE

Santa Barbara Coastal
Long Term Ecological Research

OCEAN ACIDIFICATION
Training & Research Consortium

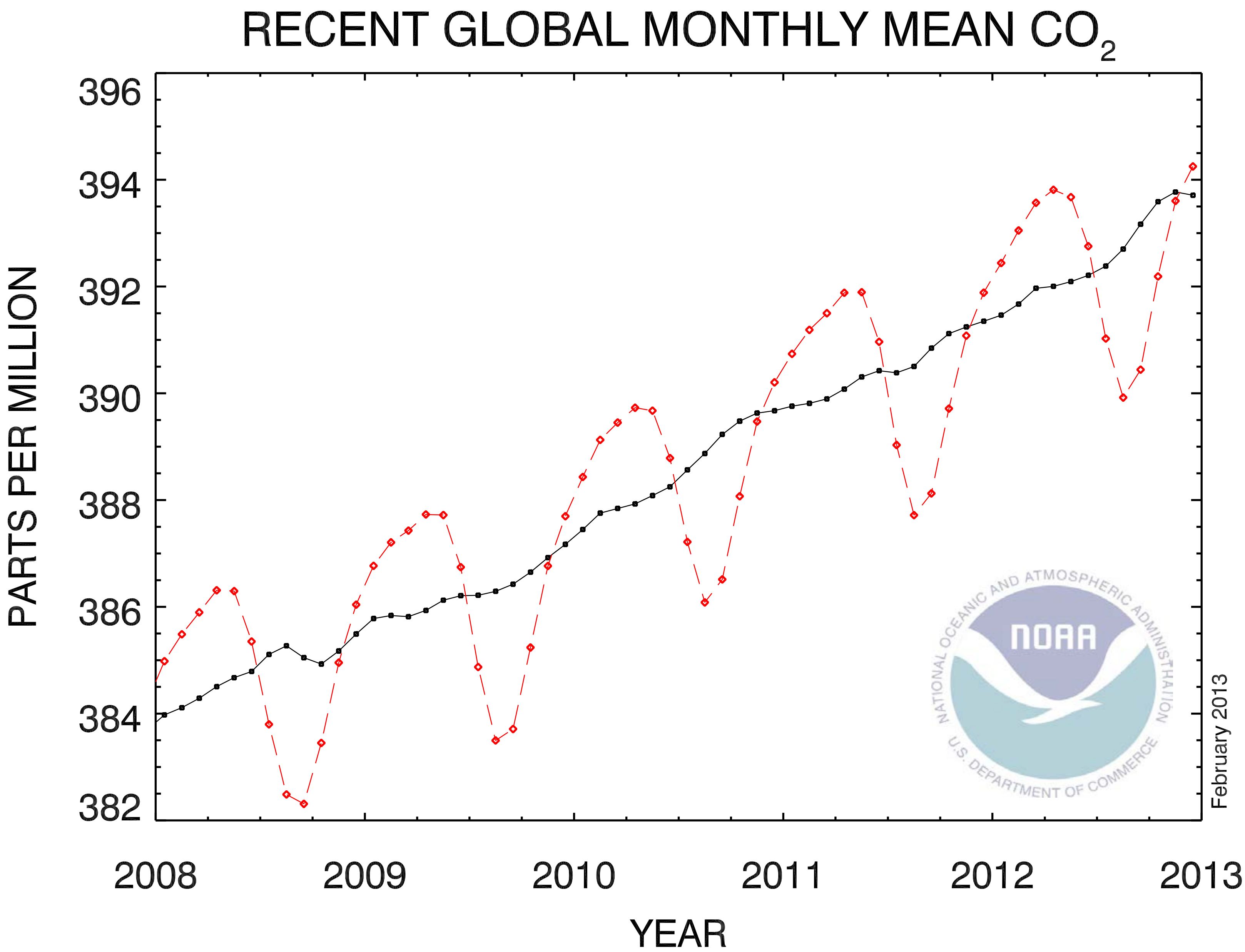
Adaptation (the DNA kind) as a response to ocean acidification

- Is it possible?
- How do we look for it?

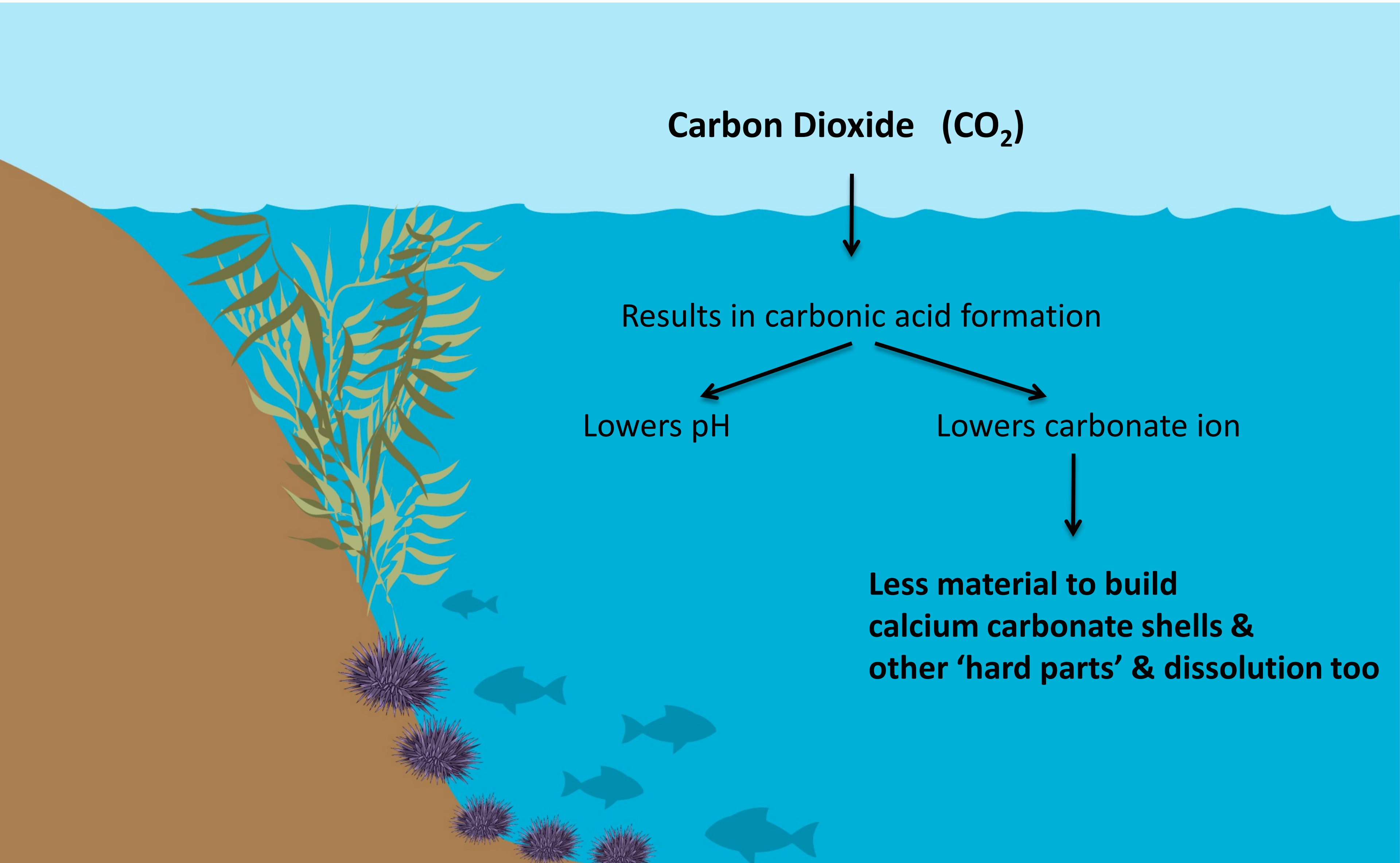
- What's the problem?

Ecosystem   Organism   Food

Recent Global CO_2, December 2012: 394.25 ppm



The Biological Consequences of Ocean Acidification



Huge challenge to calcifying organisms

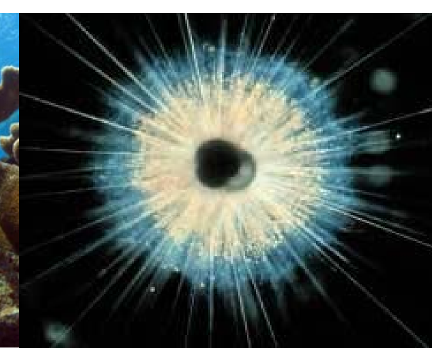
- **Reduced capacity to perform calcification**
- **Effects on growth and development**











How do we learn if key seafood species will adapt to future OA?

Is it possible?

How do we look for it?

Thinking about OA & Evolution: what do we know?

- First, evolution can occur on relatively short ecological times scales (rapid)

That is, evolutionary and ecological time scales are not always completely different

Carroll et al. (2007) Functional Ecology 21: 387-393

Trinidadian guppy (*Poecilia reticulata*)

David Reznick: The Guppy Project at UCR

Thinking about OA & Evolution: what do we know?

- Second, evolutionary rescue <u>can</u> occur

Bell and Gonzalez (2009) Ecology Letters 12: 942-948

Evolutionary rescue (ER) of yeast in an experimental evolution selection experiment – using high saline conditions

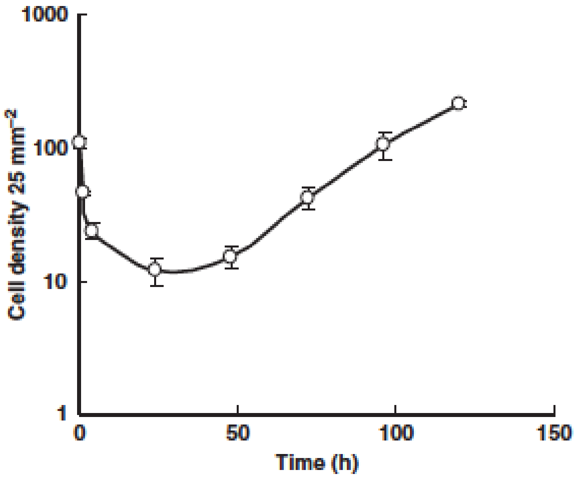


Figure 1 Collapse and recovery of yeast populations (mean ± 1 SE) exposed to high-salt concentration. The concentration used was 125 g L^{-1} of NaCl in yeast–peptone–dextrose medium. The initial inoculum was 10 μL of a 24-hour YPD culture into 140 μL medium, comprising ~5 × 10^5 cells, with 4 replicate populations sampled on each occasion. Cell counts made on a 5 × 5 mm^2 randomly selected on the surface of the YPD plate.

Adaptation and seafood: what do we need to know?

- **Rapid evolution can occur from two sources:**
  ① Standing genetic variation
  ② New mutations

- ***For OA studies, standing variation for pH tolerance in populations will determine the capacity for adaptation to OA in the future***

- **How to look for standing variation in populations?**

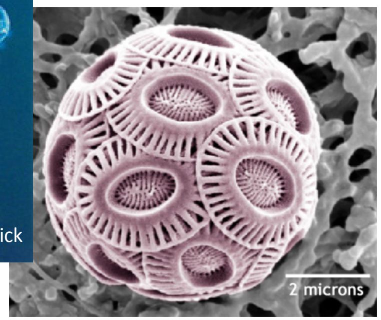
Hoffmann and Sgrò (2011) *Nature* 470: 479-485

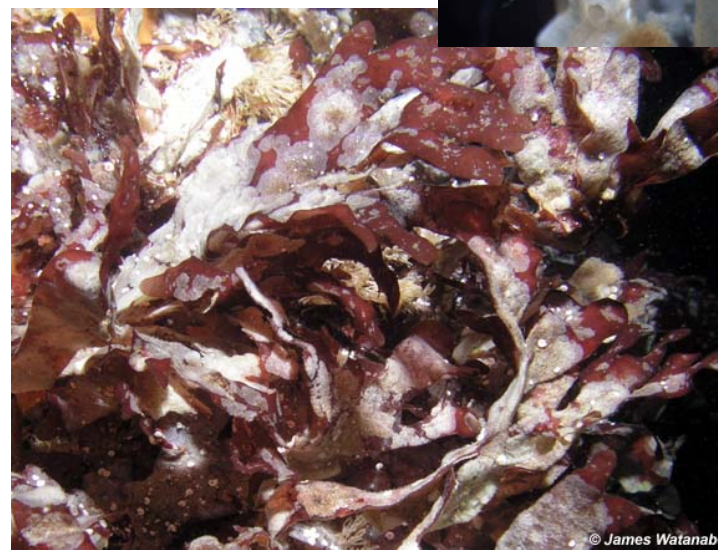
Three strategies in the search:

1. **Genetic differences**
2. **Local adaptation** = “hot spots” for adaptation
3. **Breeding experiments**

We are learning about variation between genotypes, stocks & strains

1. Langer et al. (2009) *Biogeosciences*
Differences in response variables for 4 strains of coccolithophore *E. huxleyi*





3. Pistevos et al. (2011) *Oikos*
Clonal differences in *Celleporella hyalina*,
an encrusting bryozoan

2. Parker et al. (2011) *Marine Biology*
Sydney rock oyster *Saccostrea glomerata*
Differences between wild populations & wild oysters

Second Option

Local adaptation –

Let Mother Nature help you….

Local Adaptation & OA

the fine-tuning of populations to their local environment via natural selection

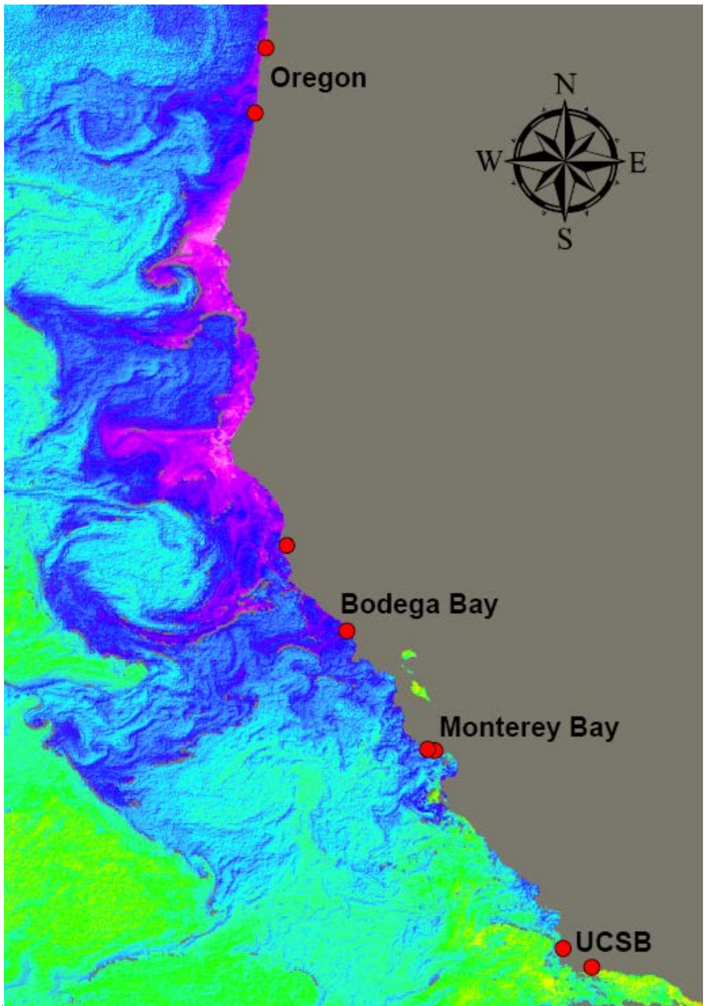
- Existing (and persistent) variation in environmental conditions may select for populations that evolve different performances, or phenotypes, and these have a fitness advantage

Local Adaptation & OA

Is there local adaptation to gradients in the "OA seascape" as we know it today?

Hot spots for adaptation?

OMEGAS: OA and local adaptation in the California Large Marine Ecosystem (CCLME)



http://hofmannlab.msi.ucsb.edu/omegas

Co-locate sensors with biology

- **Capture the <u>OA mosaic</u> along the CCLME**
- **Measure variability of populations in OA tolerance**

<u>Design</u>: Pairs of sites in contrasting oceanographic settings, in four regions of the CCLME from Oregon to southern California

Local adaptation in wild invertebrates of the CCLME

1. Mosaic of pH on the coast

2. There are major differences in performance of calcifying organisms

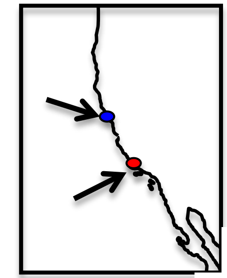
Third Option

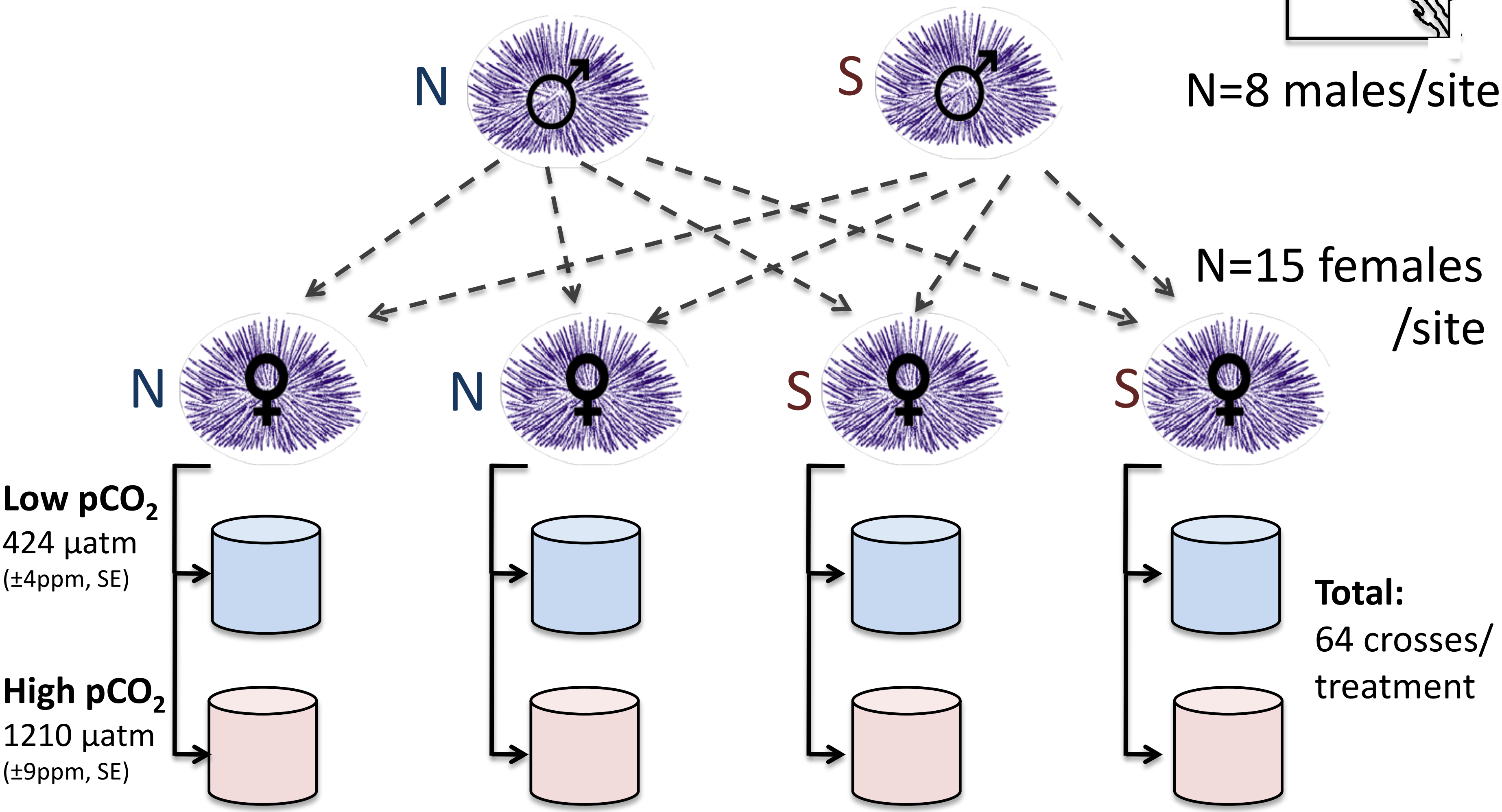
Breeding experiments –

Is that tolerance heritable?

CRITICAL ISSUE

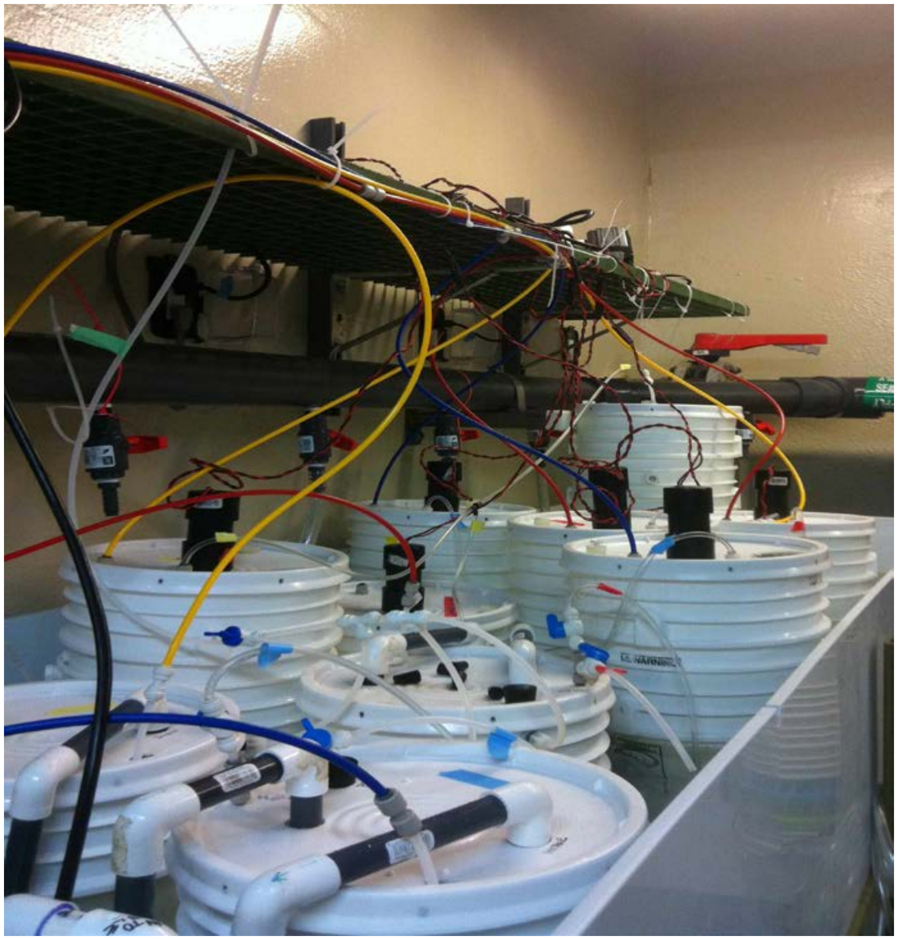
Breeding experiment: Cross Design



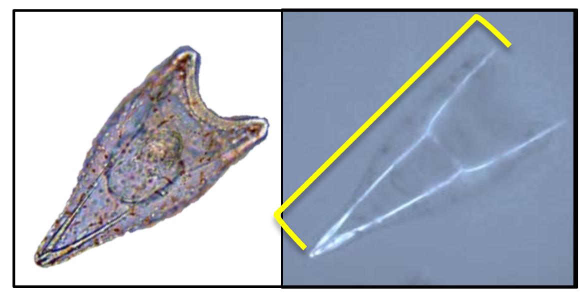


Courtesy of Drs. Morgan Kelly & Jacqueline Padilla-Gamiño (UCSB)

Larval culture

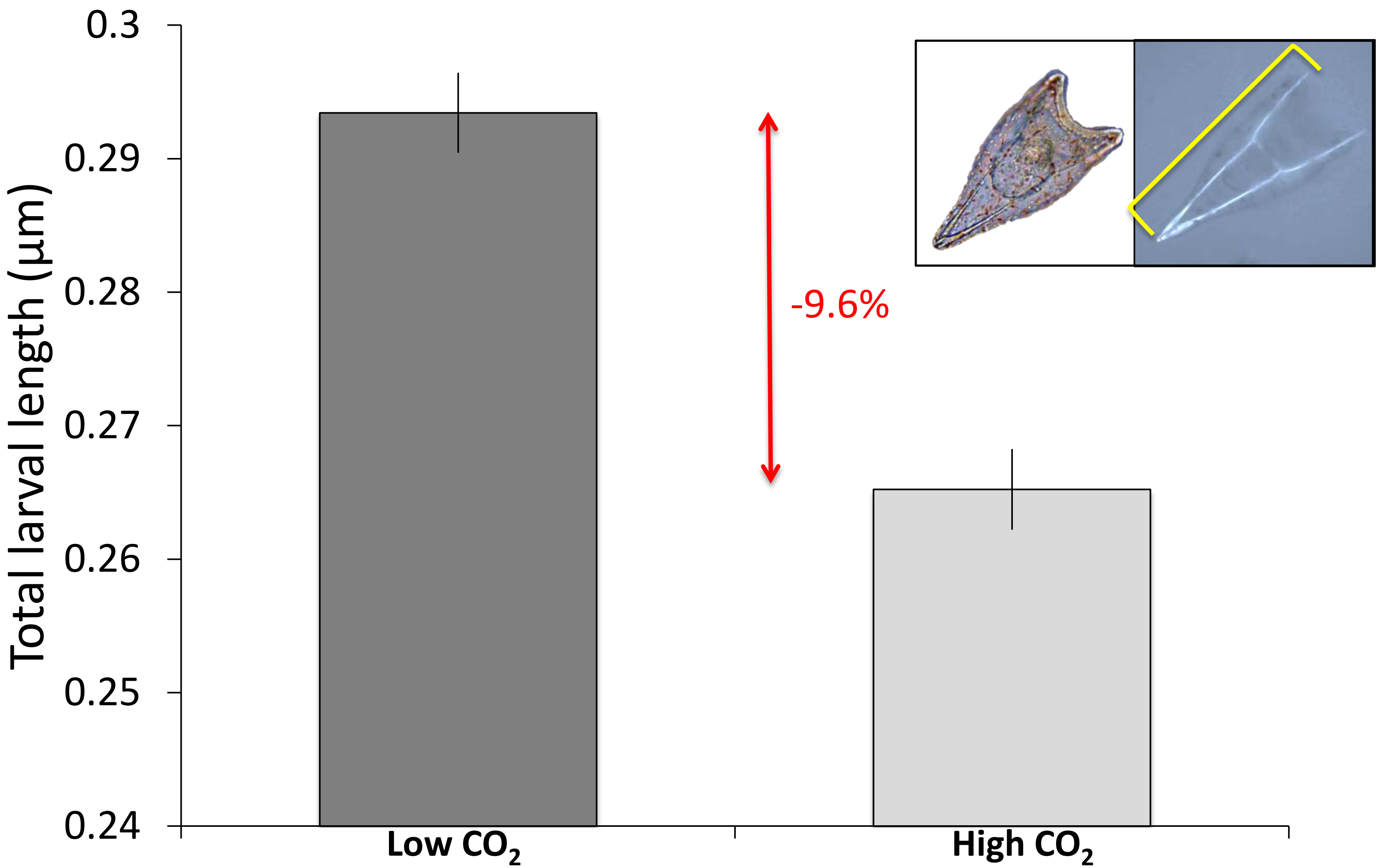


- Larvae reared for 5 days @ 13˚C
- Response variable= total larval length



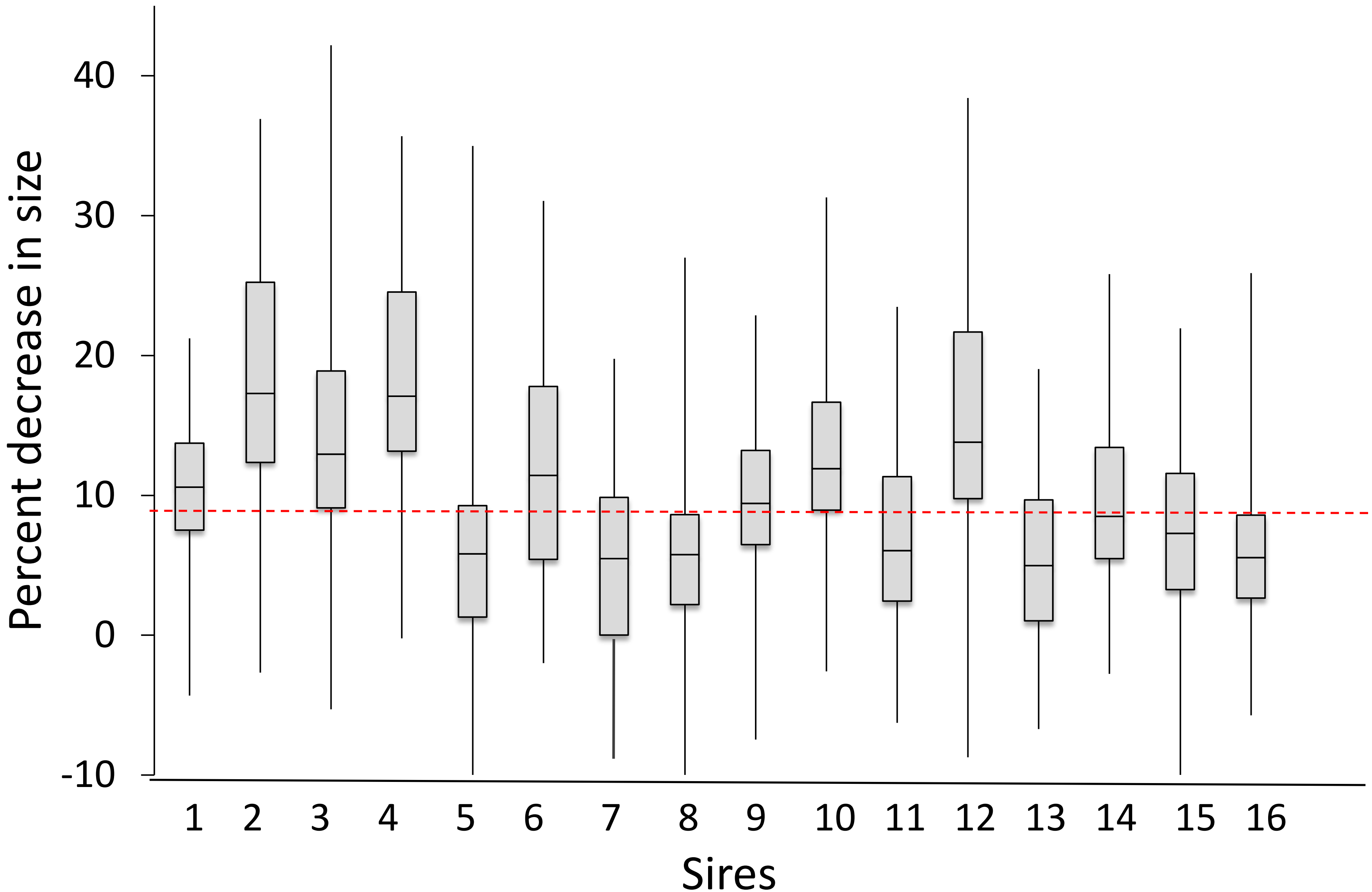
N=25 larvae/cross x pCO_2 treatment. (Total of 3,200 larvae)

Larvae raised under elevated CO_2 are smaller

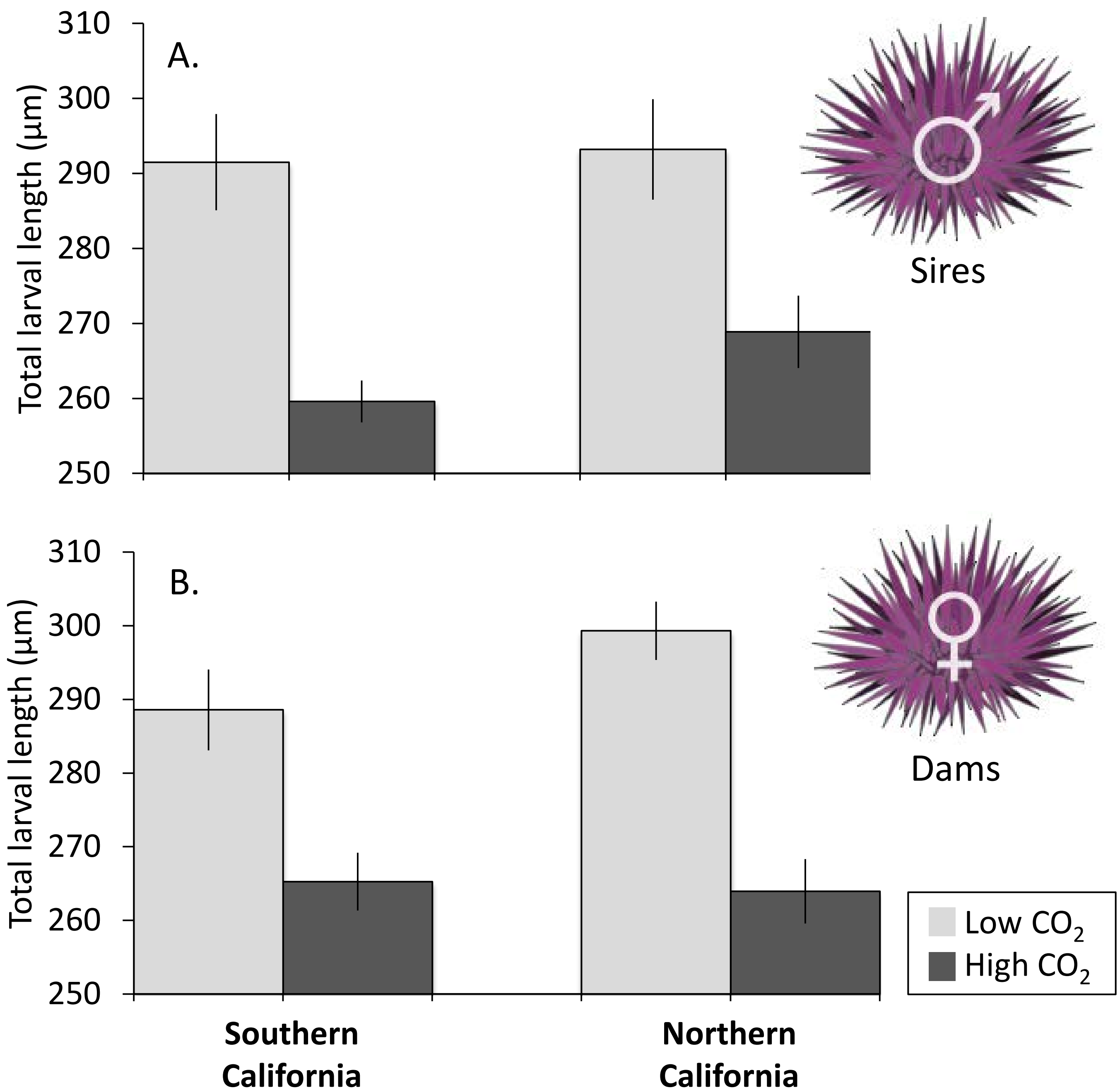


$F_{1,3180}=1088$ $p<0.0001$

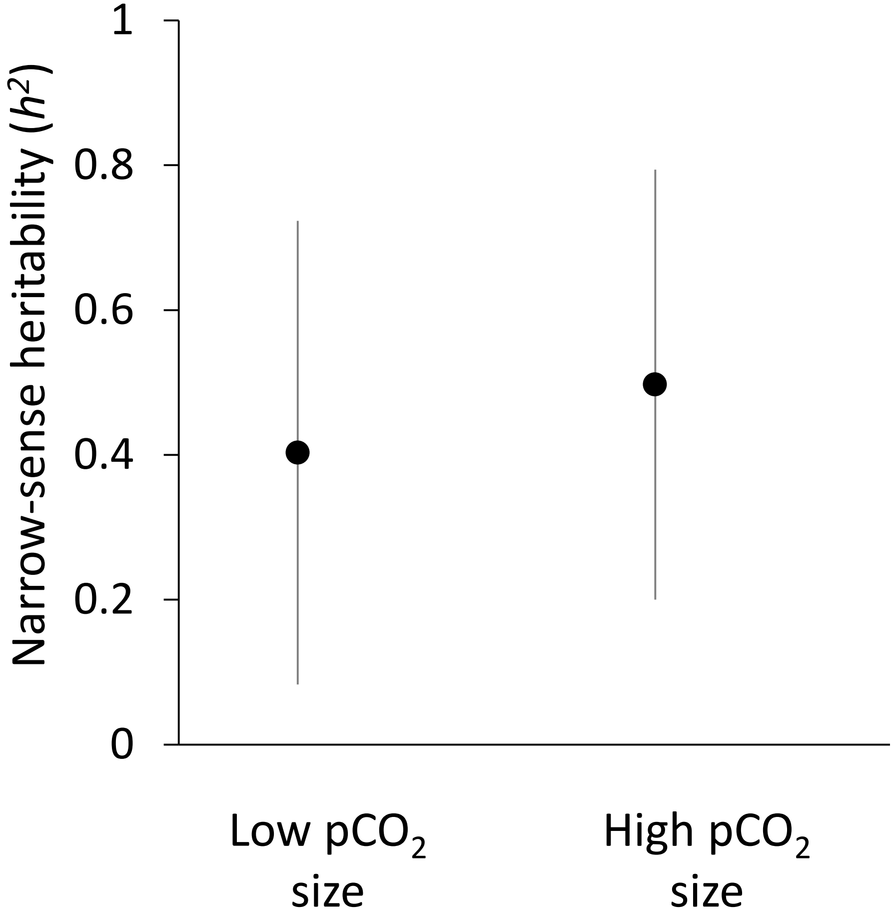
Sensitivity to elevated pCO_2 varies among and within families

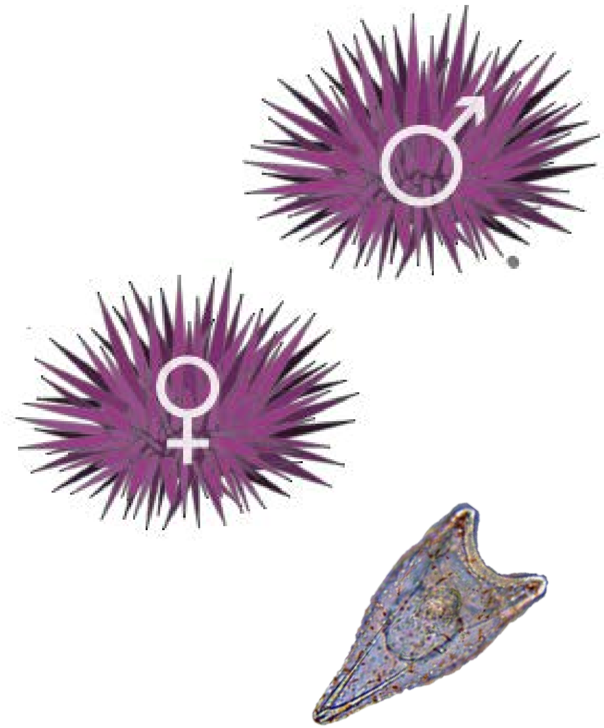


Preliminary analysis: Offspring of northern CA sires are **larger** than the offspring of southern CA sires under high pCO_2



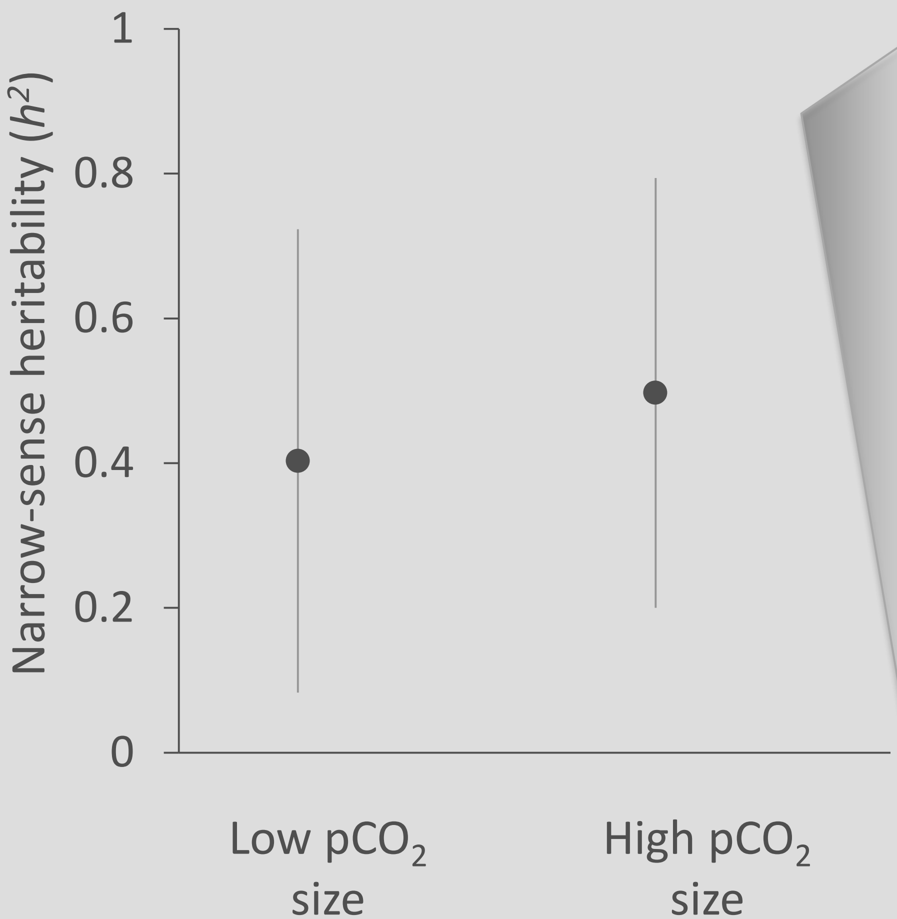
Significant genetic variation for size under high pCO_2



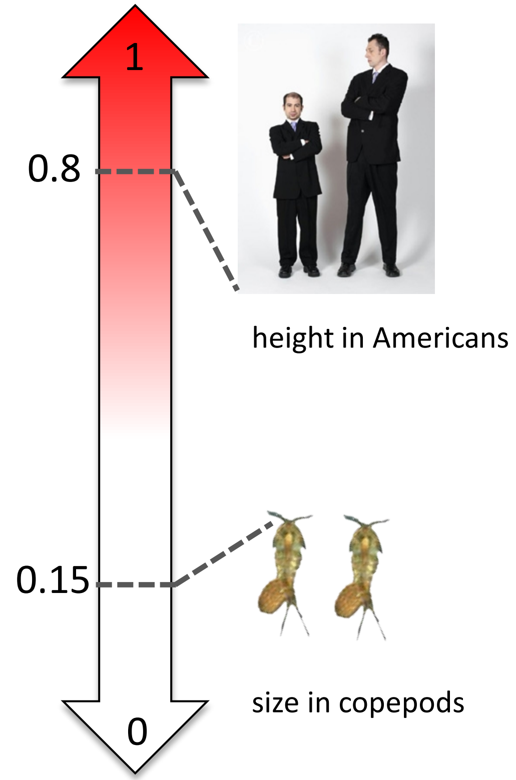


Kelly et al. (2012) in preparation

Significant genetic variation for size under high pCO_2



heritability: proportion of variation controlled by additive genetic effects



Will there be sushi?

Approaches that can look for genetic variation, resilience and tolerance in key food species.

Red sea urchin - uni

Mussel seed