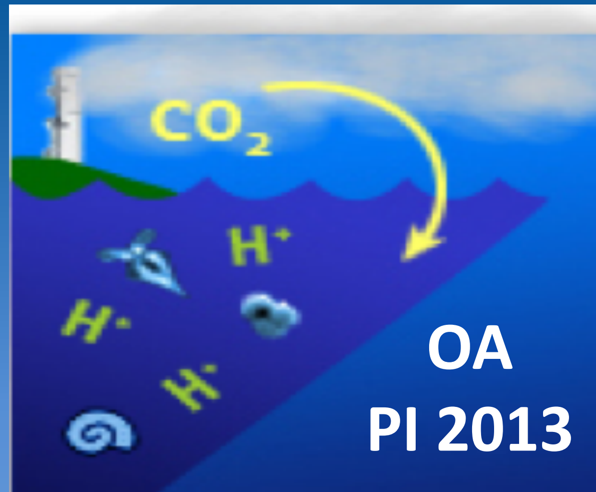


Advances in OA Research Where are we now…?

Professor Gretchen Hofmann

Department of Ecology, Evolution and Marine Biology

University of California, Santa Barbara

Second U.S. Ocean Acidification PI Meeting
September 17-20, 2013
Gallaudet University's Kellogg Conference Center
Washington, D.C.

Last time we met: *“Skin in, Skin out”*
Integrative Biology in OA Research

Molecular | **Cellular** | ⟵ **Organism** ⟶ | **Population** | **Community**

Molecular
- Proteomics
- Gene Expression
- Nano too

Cellular
- pH_e/ph_i
- Calcification
- Biochemical
- Enzymes
- Photosynthesis
- Oxidative stress

Organism
- Metabolic rate
- Energetics
- Acid/base phys.
- Growth
- Reproduction
- Calcification
- Development
- Photosynthesis
- Respiration
- Biomaterials
- ‘Hard parts’

Population / Community
- Disease
- Reef-wide calcification
- Recruitment
- Local Adaptation
- Species Interactions (trophic)
- Demographics

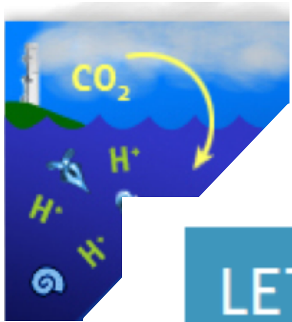
Symbiosis

Methodological Advances*

Highlight five developments:

1. Species interactions & ecosystem function
2. Experimental systems to support multistressors
3. Co-locating sensors with “Biology”
4. Use of next-generation sequencing (NGS)
5. Science Communications

*My humblest apologies for things I might have missed or not covered. Many thanks to those who shared data and images with me.

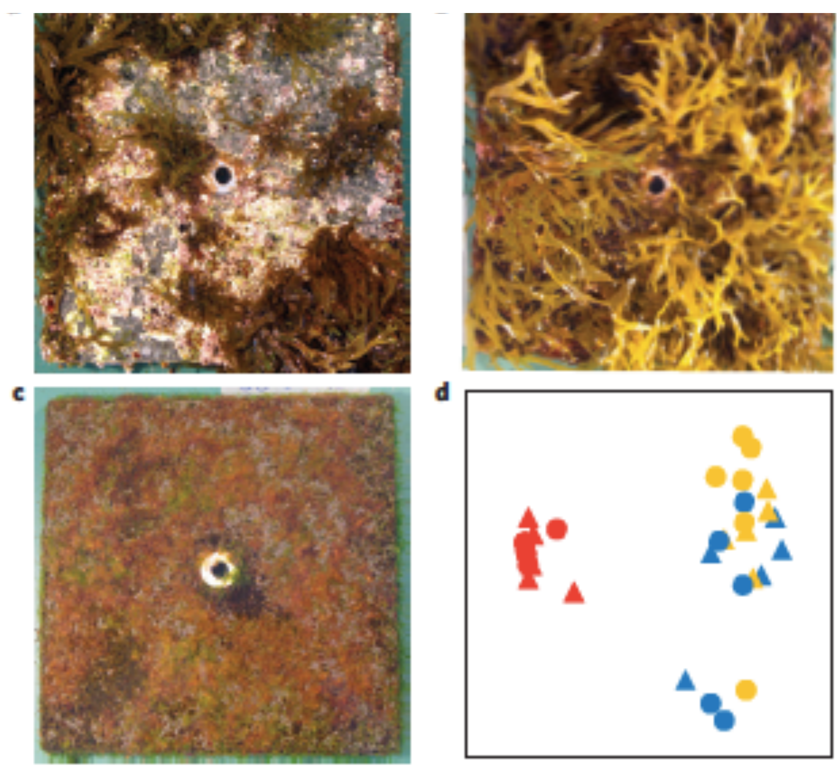


1. Species interactions

LETTERS
PUBLISHED ONLINE: 9 SEPTEMBER 2012 | DOI: 10.1038/NCLIMATE1680
nature climate change

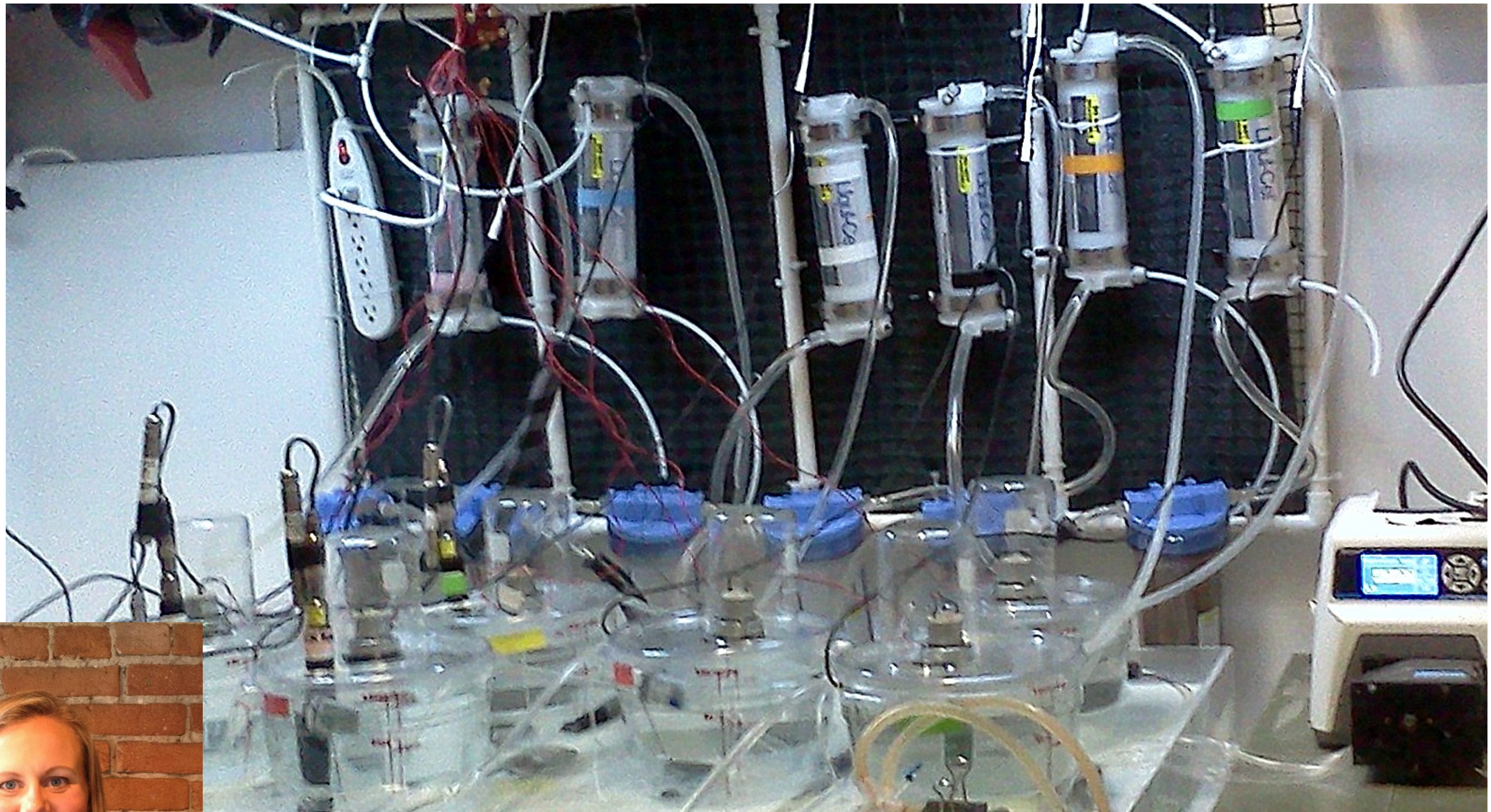
Ocean acidification causes ecosystem shifts via altered competitive interactions

Kristy J. Kroeker[1]*, Fiorenza Micheli[1] and Maria Cristina Gambi[2]



2. New lab systems – support "multistressor" studies:

Apparatus to support independent regulation of CO_2 concentration, O_2 levels, and temperature in a controlled environment



Bockman et al. (2013) *Biogeosciences*, 10, 5967–5975, 2013

2. Diatoms, multistressors & community composition

Tatters et al., (2013) *Phil Trans R Soc* B20120437

2. Experimental coral reefs

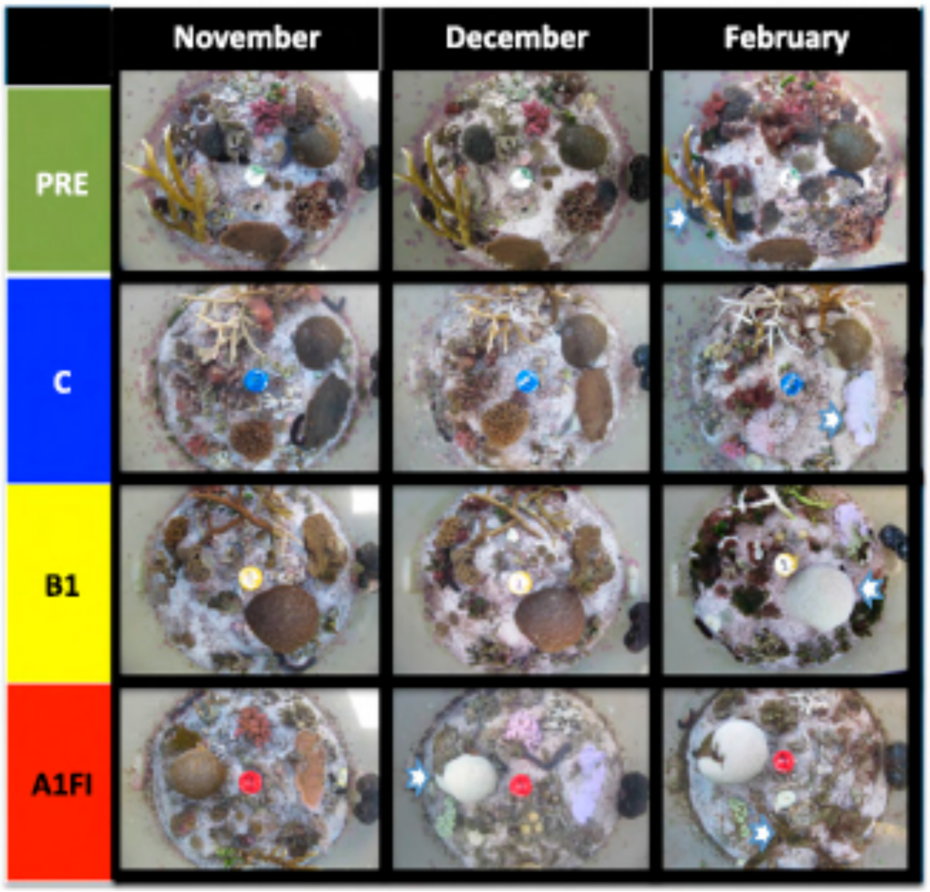
PNAS

Future reef decalcification under a business-as-usual CO_2 emission scenario

Sophie G. Dove[a,b,c,1], David I. Kline[a,b,2], Olga Pantos[a,b], Florent E. Angly[d], Gene W. Tyson[d,e], and Ove Hoegh-Guldberg[a,b,c]

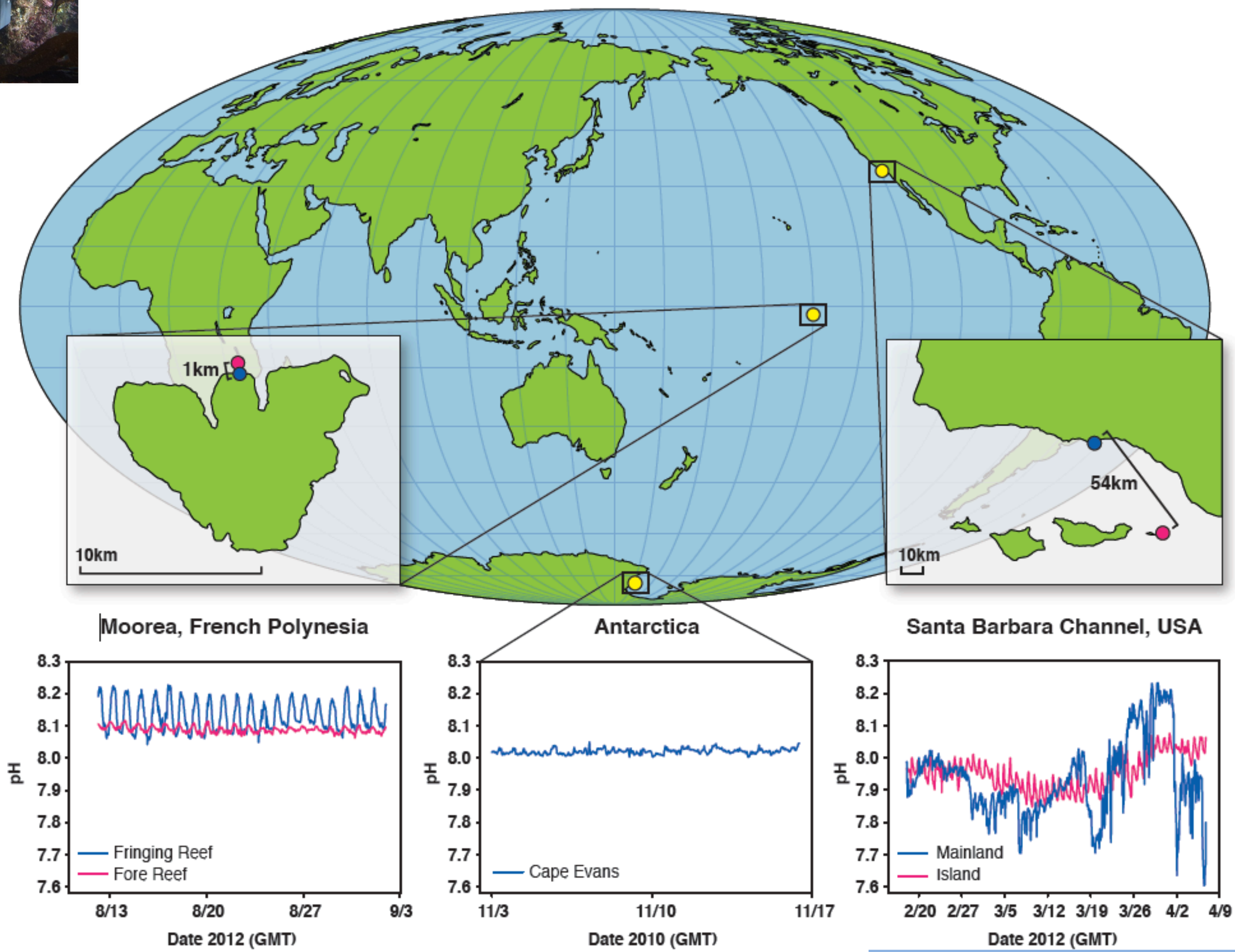
[a]Global Change Institute, [b]School of Biological Sciences, [c]Australian Research Council Centre for Excellence in Coral Reef Studies, [d]Australian Centre for Ecogenomics, and [e]Advanced Water Management Centre, University of Queensland, St. Lucia, QLD 4072, Australia

Edited by Paul G. Falkowski, Rutgers, The State University of New Jersey, New Brunswick, NJ, and approved August 6, 2013 (received for review February 16, 2013)



www.pnas.org/cgi/doi/10.1073/pnas.1302701110

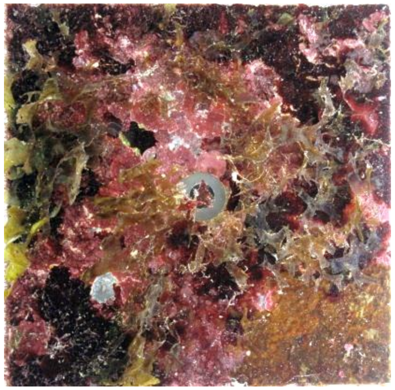
3. Co-location of Sensors with Biology



Hofmann et al (2013) *Oceanography* 26: 140

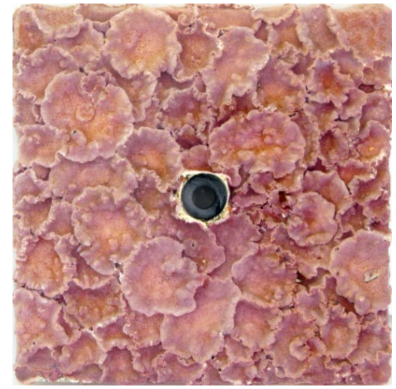
Daily seawater pH ↓
seasonal low

Daily seawater pH ↑
seasonal low



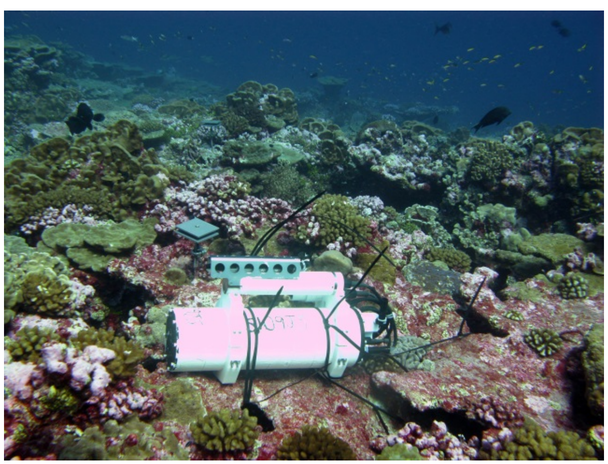
SeapHOxes and SeaFETs are paired with coral recruitment plates to relate development of early successional communities on reefs with environmental condition

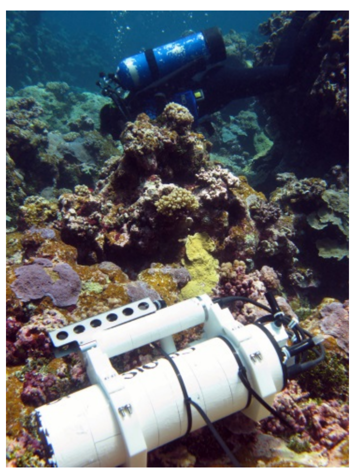
Price et al. 2012 *PLoS One*

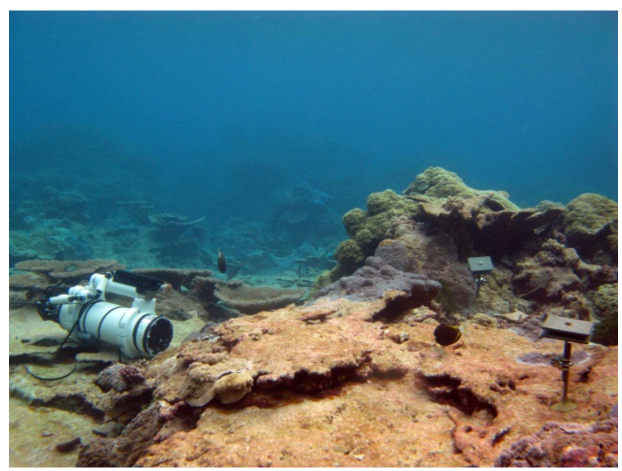


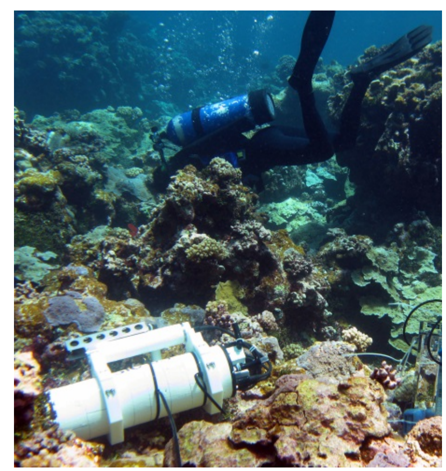
Bioeroders and soft-bodied species

Calcifiers and reef builders





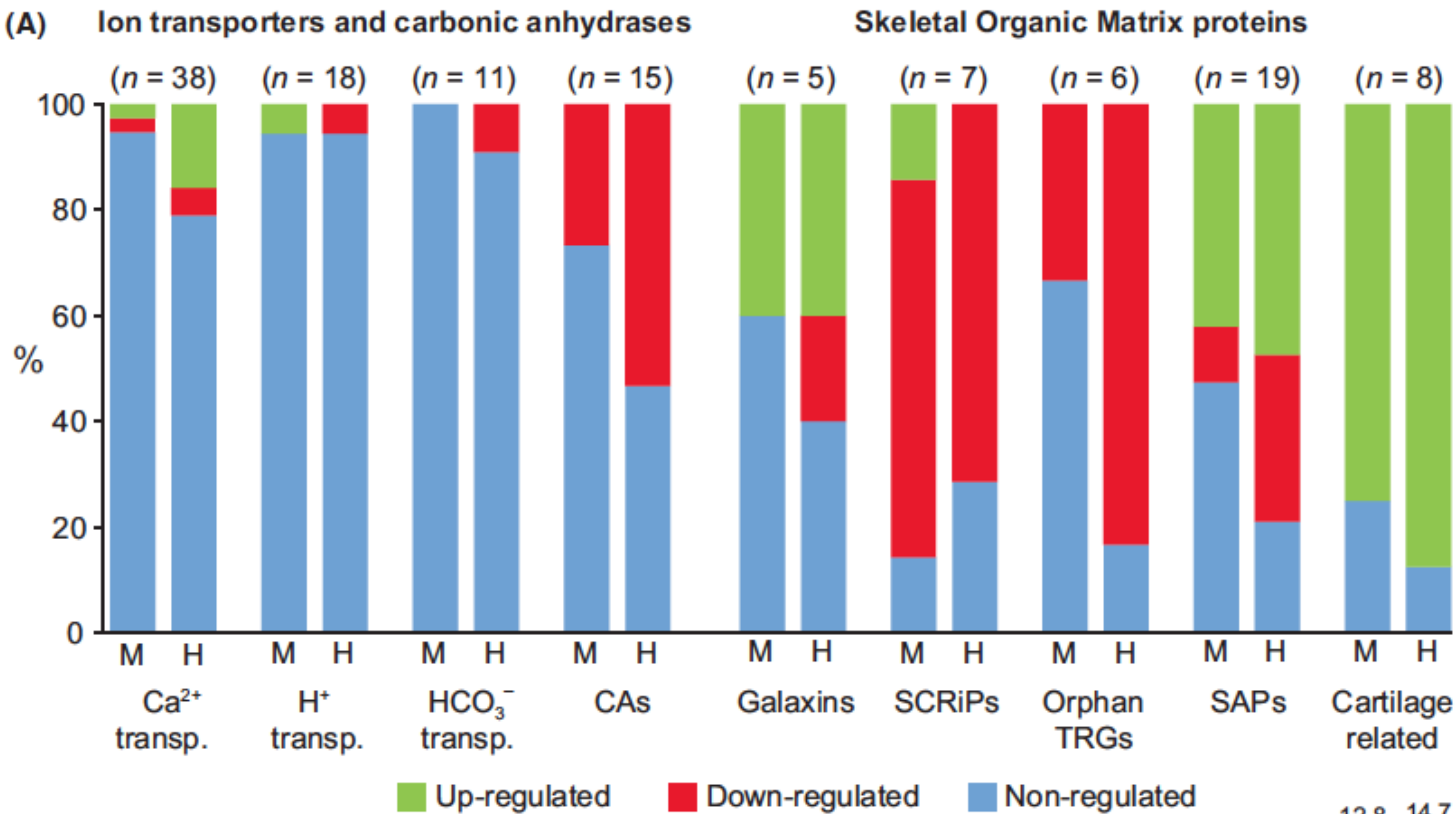




4. Next Generation Sequencing (NGS)

- Molecular genomic applications
  - NGS available to people who can do a “good experiment”, no longer the provenance of genomicists

Whole Transcriptome Analysis of *Acropora millepora* with Illumina RNAseq

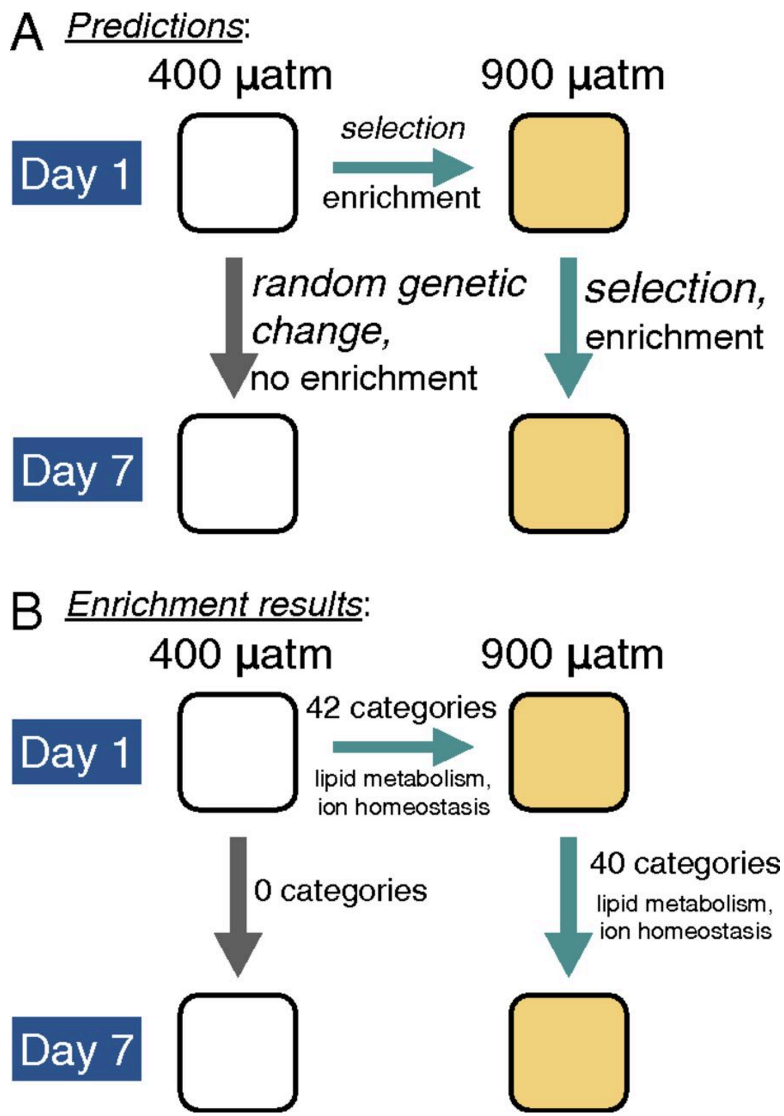


Moya et al. (2012) *Molecular Ecology* 21: 2440-2454

4. Next Generation Sequencing (NGS)

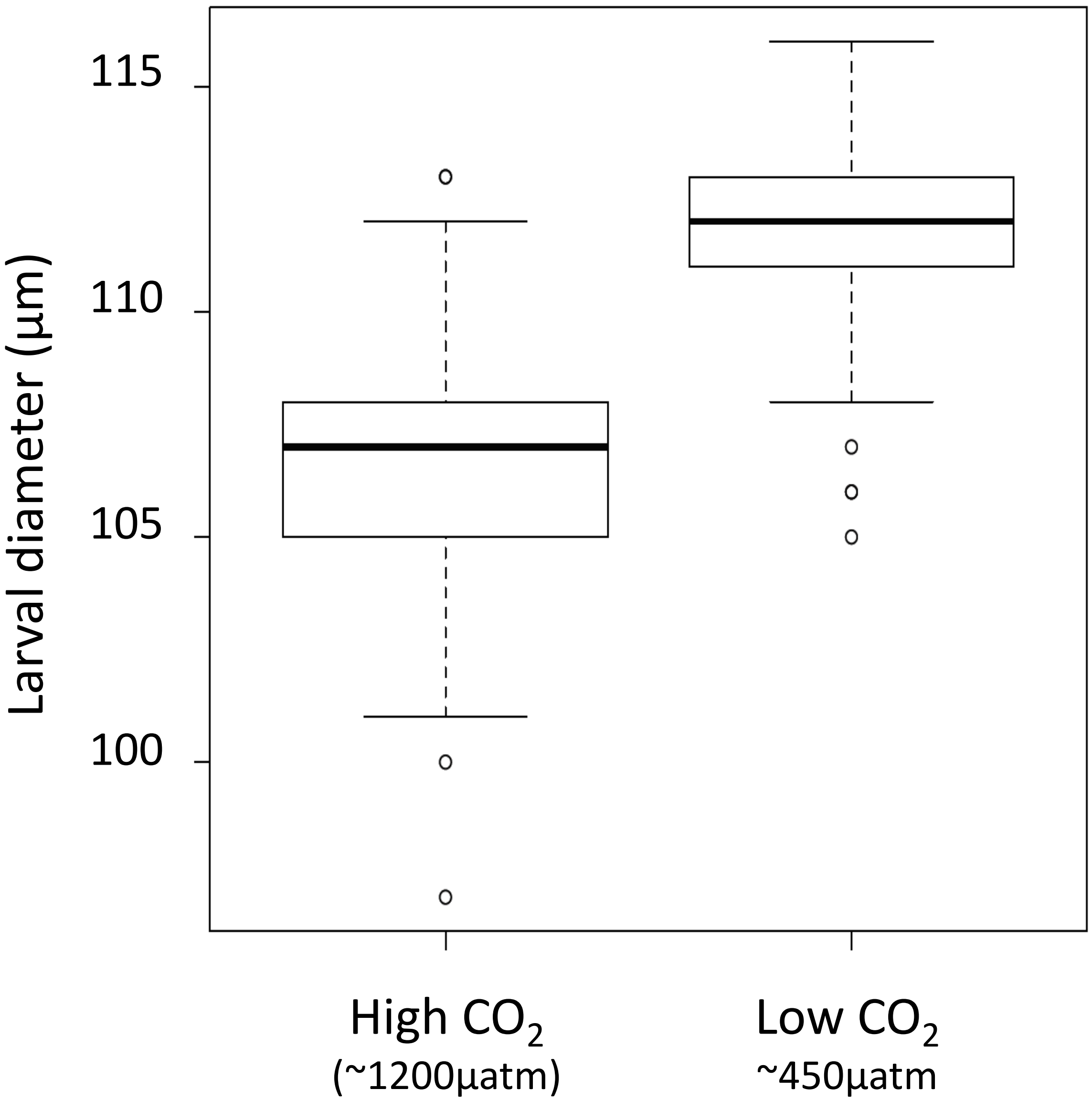
- Genomic applications
  - NGS available to people who can do a good experiment, no longer the provenance of genomicists
- Examine capacity for adaptation or looking for polymorphisms in the DNA for genes – Single Nucleotide Polymorphisms (SNPs)
  - Liu S, Yeh C-T, Tang HM, Nettleton D, Schnable PS (2012) Gene Mapping via Bulked Segregant RNA-Seq (BSR-Seq). PLoS ONE 7(5): e36406. doi:10.1371/journal.pone.0036406

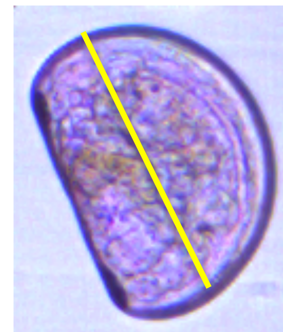
Summary schematic of predicted evolutionary forces and enrichment results (A) and observed protein function enrichment results for greater changes in allele frequency (B) between the four day and treatment combinations



Pespeni M H et al. PNAS 2013;110:6937-6942

4. An approach to look at the genotype-phenotype connection: *Larvae reared under high CO_2 are smaller…*





Mytilus californianus

… but there is lots of variation!

Morgan Kelly, unpubl. results

RNA seq to identify differences among resistant vs. sensitive larvae

low CO_2 **small larvae**	low CO_2 **large larvae**	high CO_2 **small larvae**	high CO_2 **large larvae**

↓

Bulk RNA extraction,
100 bp PE Illumina
sequencing
(24 libraries)

1) Gene expression:

-What are the expression differences between high and low pCO_2?

-What are the expression differences in resistant vs. sensitive larvae?

2) **SNPs:**

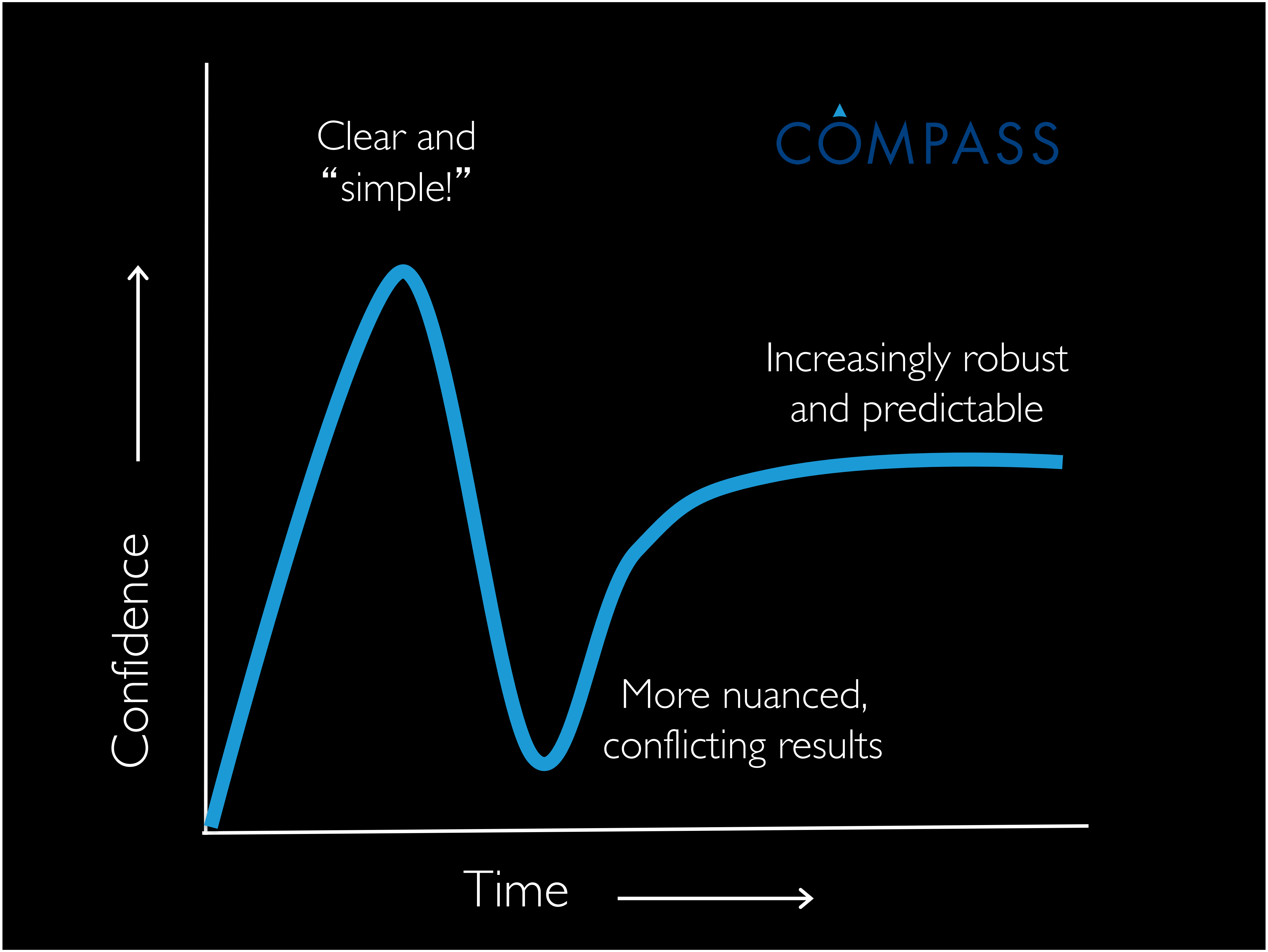
-Are there **SNPs** associated with larvae that are resistance to high pCO_2?

4. Strategic approaches to measuring evolutionary approaches

- Munday et al. *Ecology Letters* (Accepted)

Table 1. The various approaches to measuring evolutionary potential, with strengths, limitations, relevant organisms, and some examples from the marine literature.

Approach	*Strengths*	*Limitations*	*Relevant organisms*	*Examples*
Molecular / genomics	• Can survey populations for molecular variation (i.e., among individual alleles) • Can give insight into mechanisms of gene expression • Can be applied to natural populations	• Genotype-phenotype map often poorly resolved: difficult to link allelic variation to heritable phenotypic variation in quantitative traits that are likely to be most relevant in adaptive evolution • May not predict evolutionary potential unless applied to individuals of known pedigree (in which case, some of the limitations of quantitative genetic approaches also apply)	All organisms, especially large, long-lived or rare species that are not amendable to laboratory breeding experiments or experimental evolution	Barshis et al 2013 Pespeni et al 2013


COMPASS
Clear and "simple!"
Increasingly robust and predictable
More nuanced, conflicting results
Confidence
Time

5. Science Communication

COMPASS

- Three OA trainings:
  - Monterey, here in DC, and next one in Hawaii
- Profiles in OA Courage!

The Elevator Speech

Bryan Walsh,
Time Magazine

Emily Carrington,
University of Washington

The Radio Interview

Jeff Runge
Univ. of Maine (L)

&

Jon Hamilton (R)
Science Desk, NPR news

Summary OAPI 2013

- Advances in understanding species interaction – more on ecosystem function to come
- OA occurs with other abiotic factors
- Observing linked to “Biology” is powerful
- Next generation sequencing, an emerging tool to study evolutionary potential
- By February 2014, 60 people in our community will have advanced training to communicate their OA science