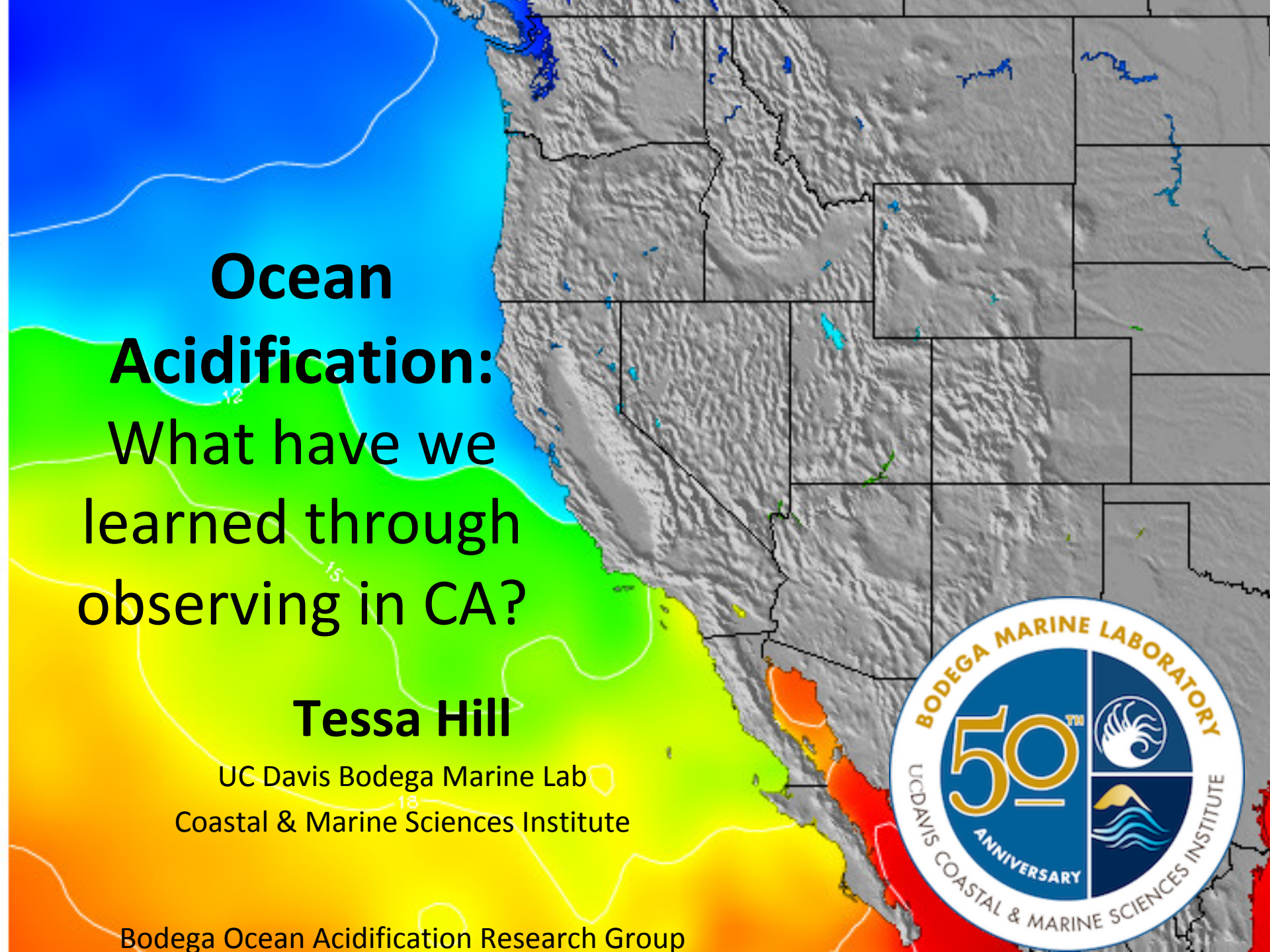


Ocean Acidification: What have we learned through observing in CA?

Tessa Hill

UC Davis Bodega Marine Lab

Coastal & Marine Sciences Institute

Bodega Ocean Acidification Research Group

Take home ideas

- There will be variability in response to ocean acidification – the ocean, especially the coastal ocean – is complex & dynamic

- Novel partnerships can maximize our ability to understand and respond to this problem

- Long term studies of the ocean are essential to place today's changes in context

Climate Variability and Change

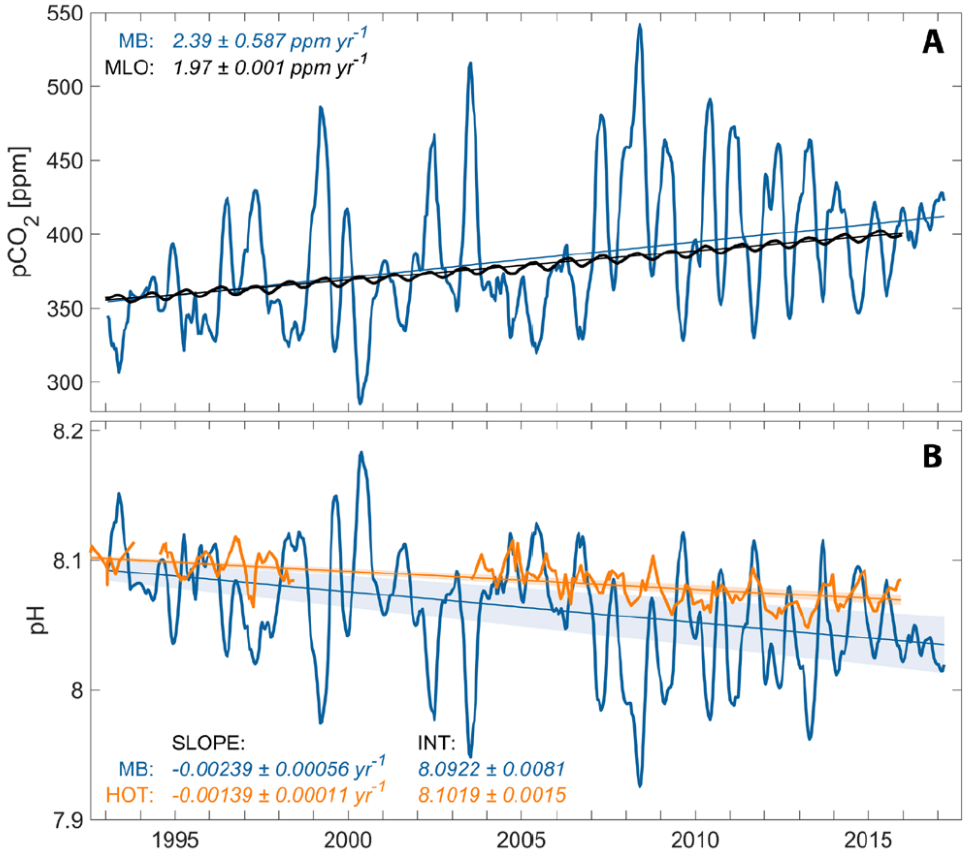
Response of a Coastal Ocean Ecosystem

By Francisco P. Chavez, J. Timothy Pennington, Reiko P. Michisaki, Marguerite Blum, Gabriela M. Chavez, Jules Friederich, Brent Jones, Robert Herlien, Brian Kieft, Brett Hobson, Alice S. Ren, John Ryan, Jeffrey C. Sevadjian, Christopher Wahl, Kristine R. Walz, Kevan Yamahara, Gernot E. Friederich, and Monique Messié

Chavez et al., 2018, *Oceanography*

Longest time series in CA – MBARI measurements – show increase in pCO2 and decreasing pH since 1990's

NOAA moorings – CE1 and CE2 offshore Central CA show similar trends



Climate Variability and Change

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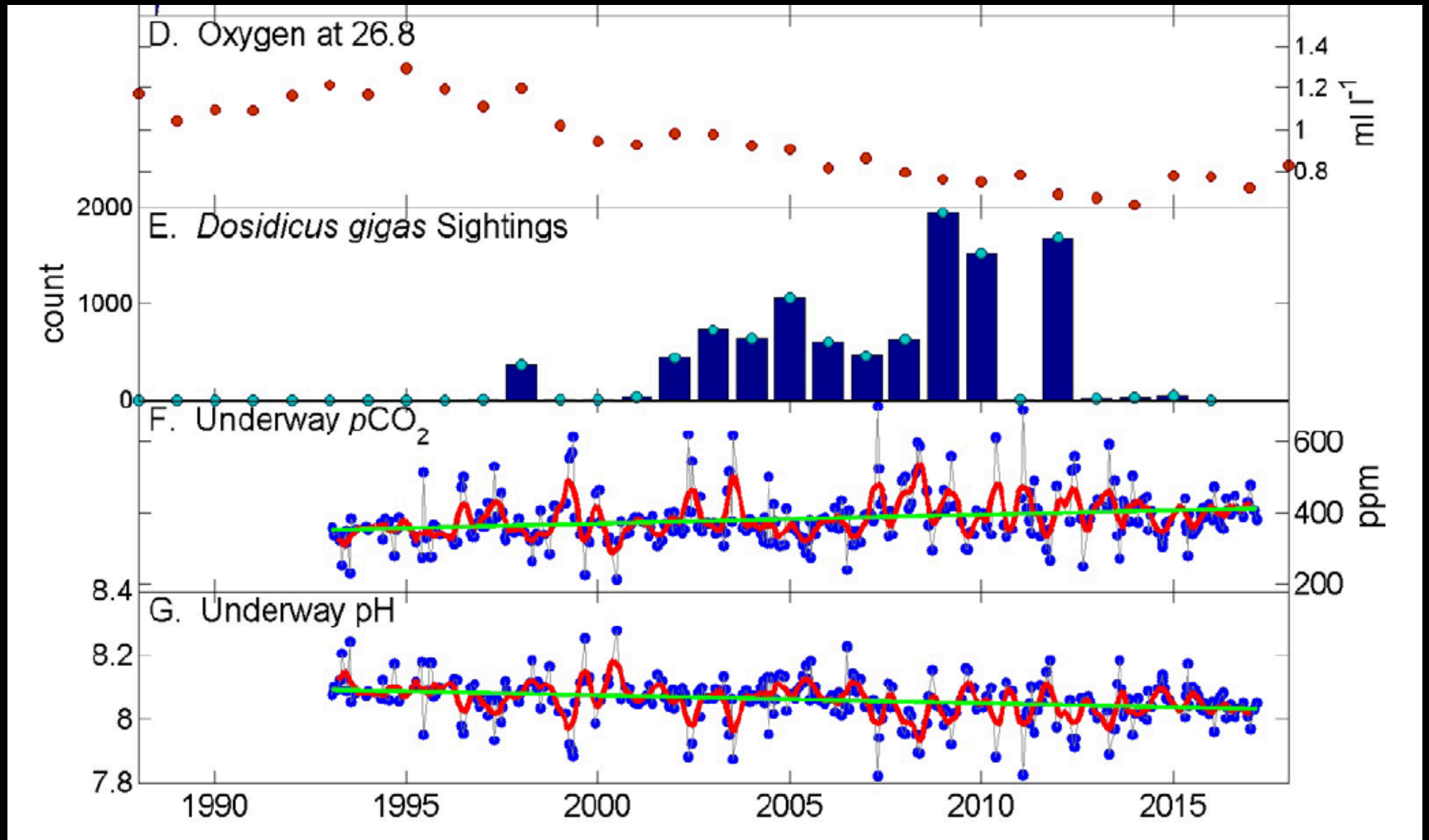
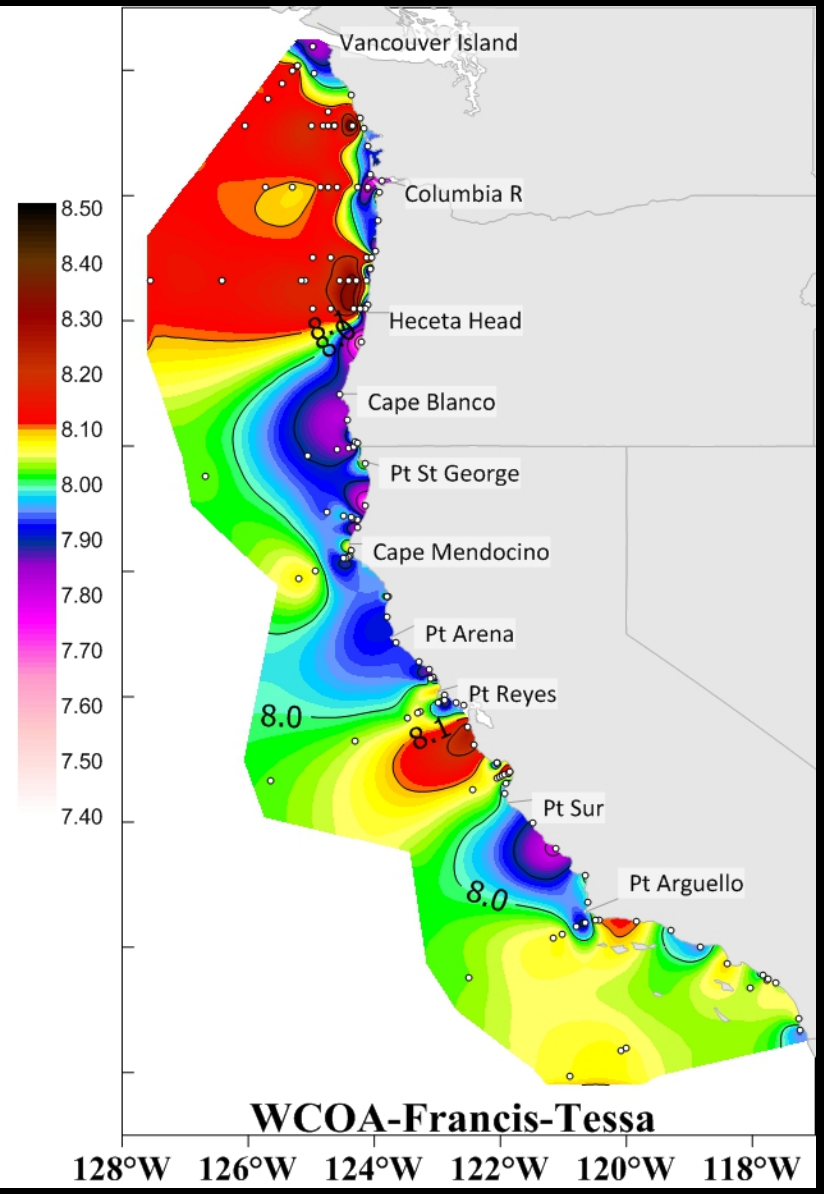


We observe large variability in pH within this dynamic, complex system

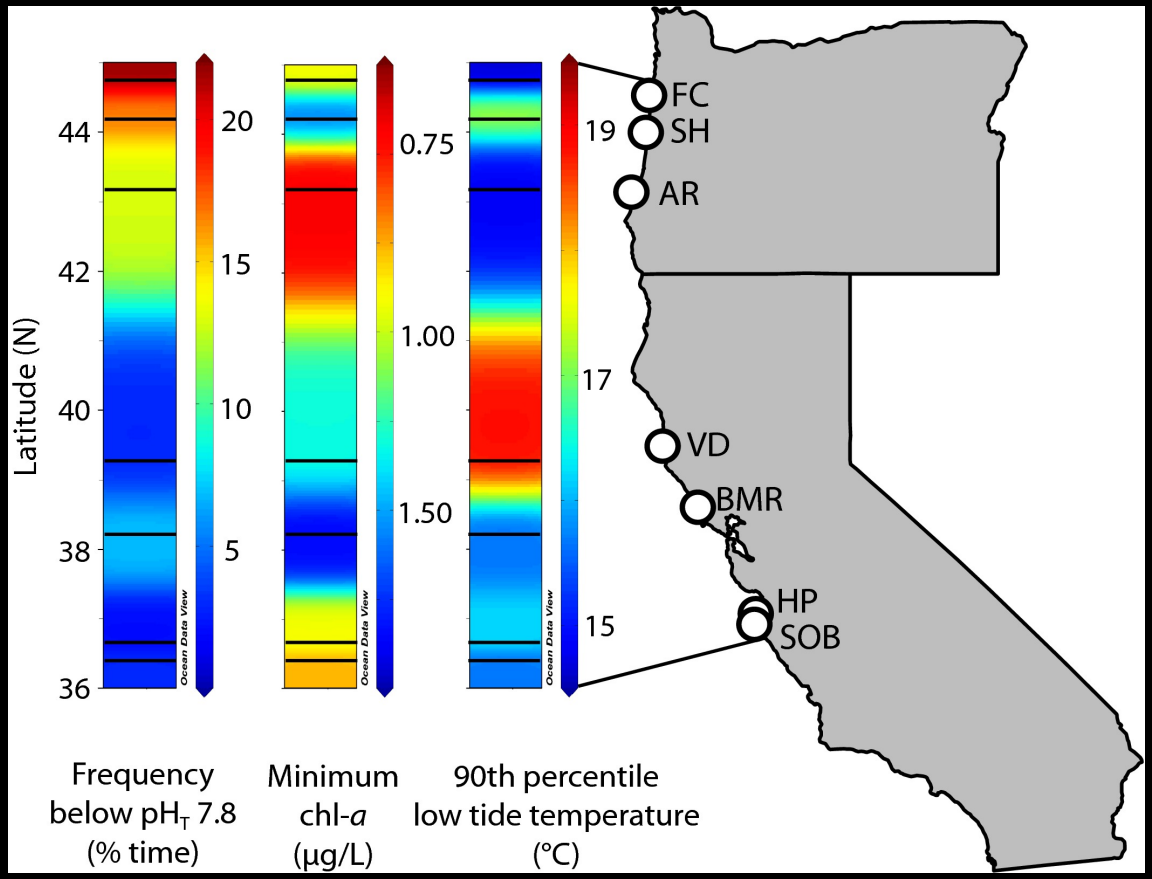


Natural laboratory and opportunities to understand adaptation

'Mosaic' of pH elucidated by partnerships between Federal Agency & University Researchers

Data from: NOAA (R. Feely), NSF-OMEGAS and UCDavis; Feely et al., 2016; Hill et al. in prep.

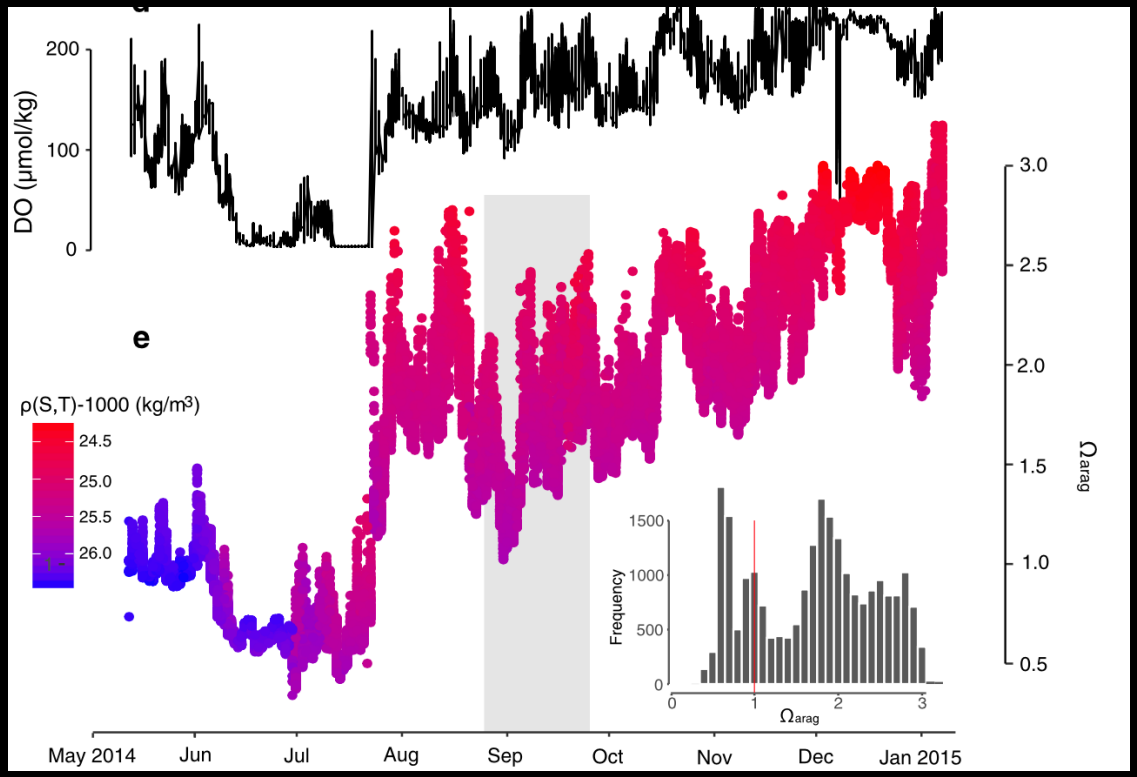
Environmental mosaics matter – conditions along the coast are patchwork of exposure to stress



Kroeker et al., 2016; also see Chan et al 2017

Reconstructing ocean acidification using empirical relationships w/ T, S, DO

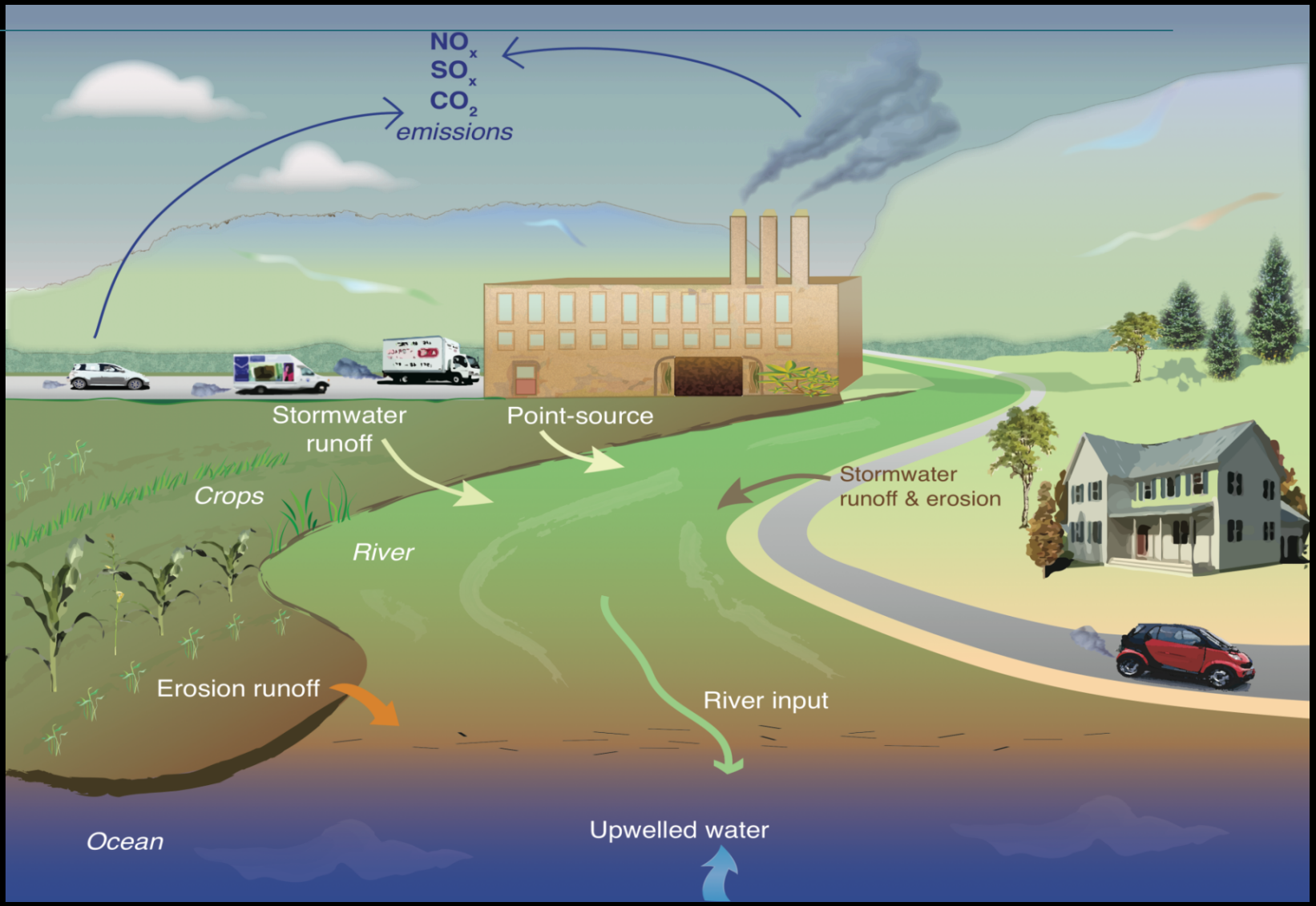
Aragonite saturation and DO at BML Mooring, 2014



Measured T, S, DO and carbonate chemistry used to develop relationships; reconstruct past OA trends (see papers by Juranek, Alin, and Davis)

Catherine Davis et al., 2018, *Estuaries and Coasts*

Nutrient inputs to the coast exacerbate OA

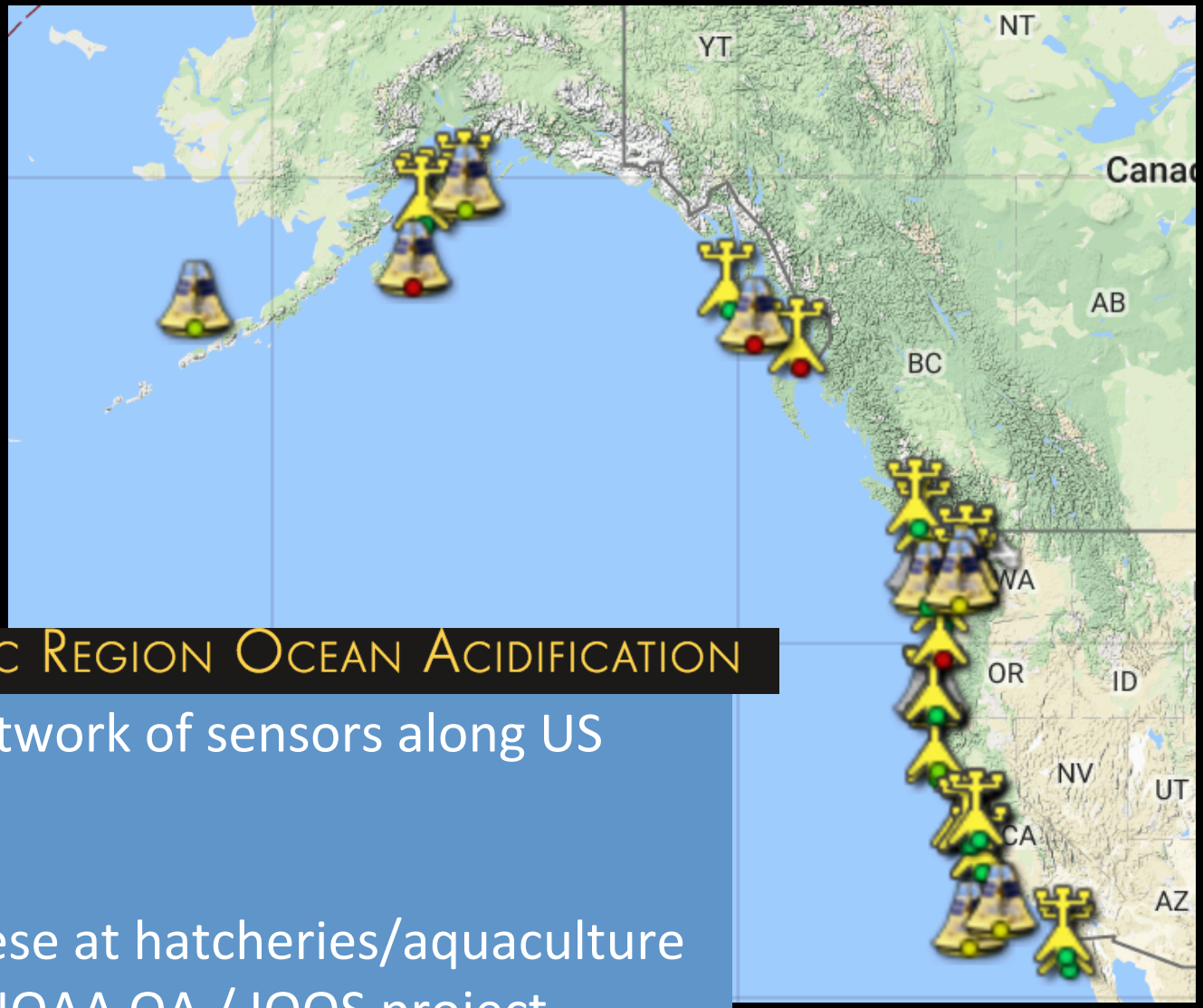


Modified after Kelly et al. (2011) *Science*

A need for a network of observations

Despite the central importance of data for detecting long-term changes in the ocean's carbon system, coordinated observing networks in the US coastal and estuarine waters did not exist until recently. Historically, assessments of changes to the carbonate system relied on a handful of data records worldwide (none of which operated in California waters, and the longest of which began only in the early 1980's) (Bates et al., 2014).

IOOS Network



IOOS Pacific Region Ocean Acidification

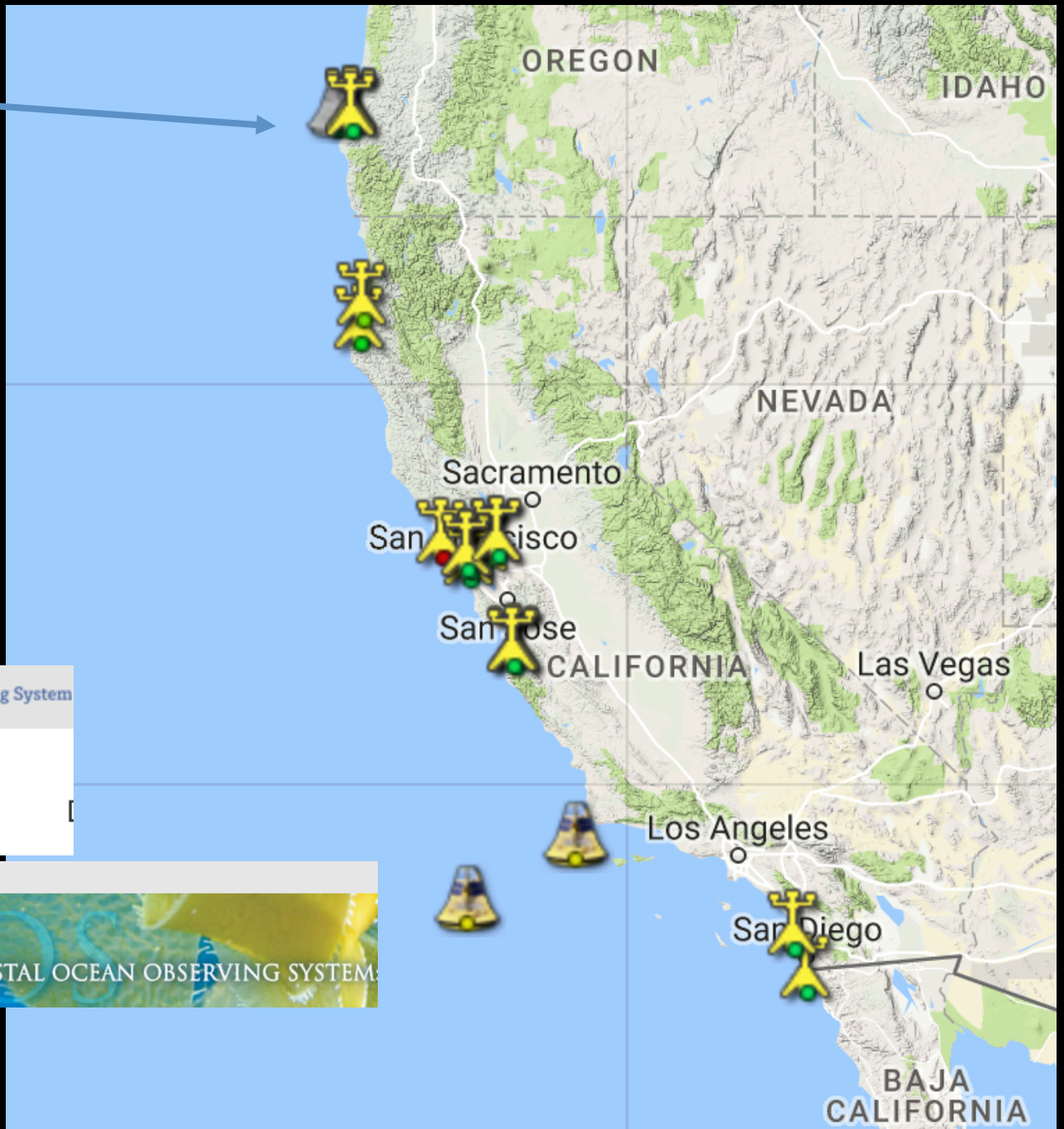
Growing network of sensors along US West Coast

Many of these at hatcheries/aquaculture facilities - NOAA OA / IOOS project

http://www.ipacoa.org/

Sea Grant California

State of California
Ocean Protection Council



IOOS | Integrated Ocean Observing System

CeNCOOS

IOOS | Integrated Ocean Observing System

SCCOOS

SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM

OA Monitoring: Chemical, Physical, Biological

- Co-location provides direct measure of biological impact of changes due to OA
- Processes are likely complex (O_2, pH, pCO_2, Ω), so impacts will be too
- Biological monitoring provides 'real world' and ecological relevance to observed chem/phys change
- *Consider: ENSO and PDO discoveries & investigation!*

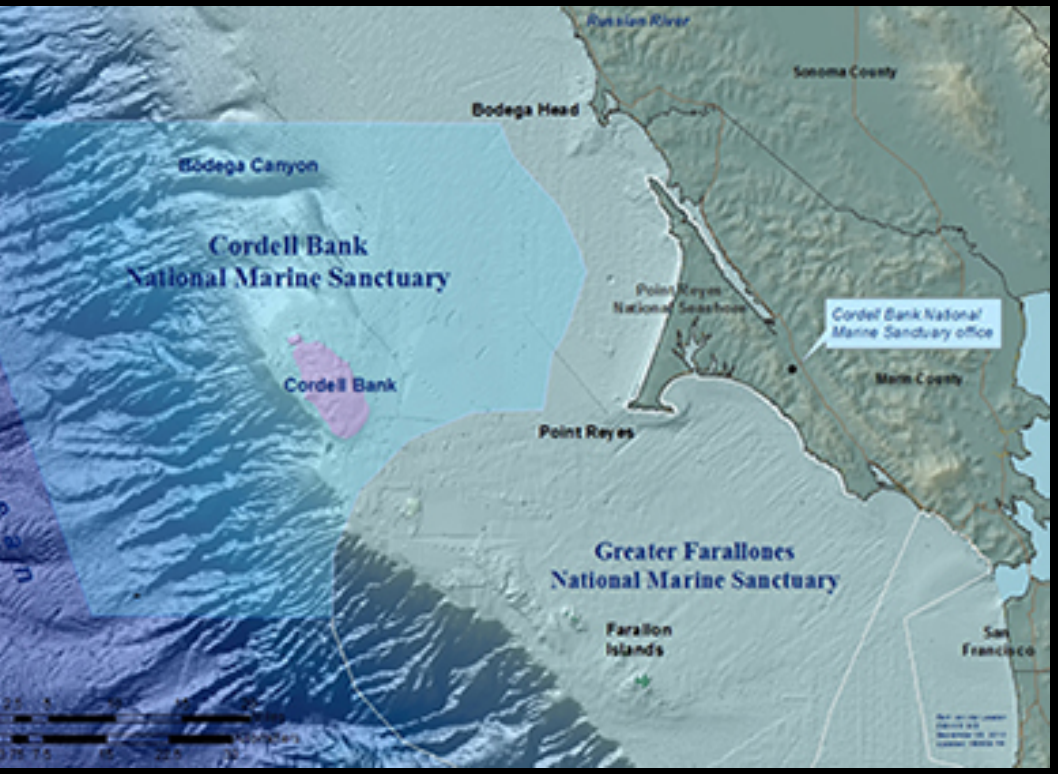
Combining oceanographic monitoring & biological indicators

Shell dissolution under high CO_2; already considered an indicator of change in California waters (Bednarsek et al., 2014)

Reduced calcification & rebuilding of shell under high CO_2 (Davis et al 2017)

Slower growth under high CO_2 (Cooper et al., 2016)

Ocean Climate Indicators: A Monitoring Inventory and Plan for Tracking Climate Change – Greater Farallones National Marine Sanctuary
(Duncan et al., 2013)



Indicators for a variety of habitats in North-Central CA

Developed through an expert judgement process, with over 100 suggested indicators – selection criteria narrowed to physical (10) and biological (13) final indicators

CALIFORNIA
OCEAN
SCIENCE
TRUST

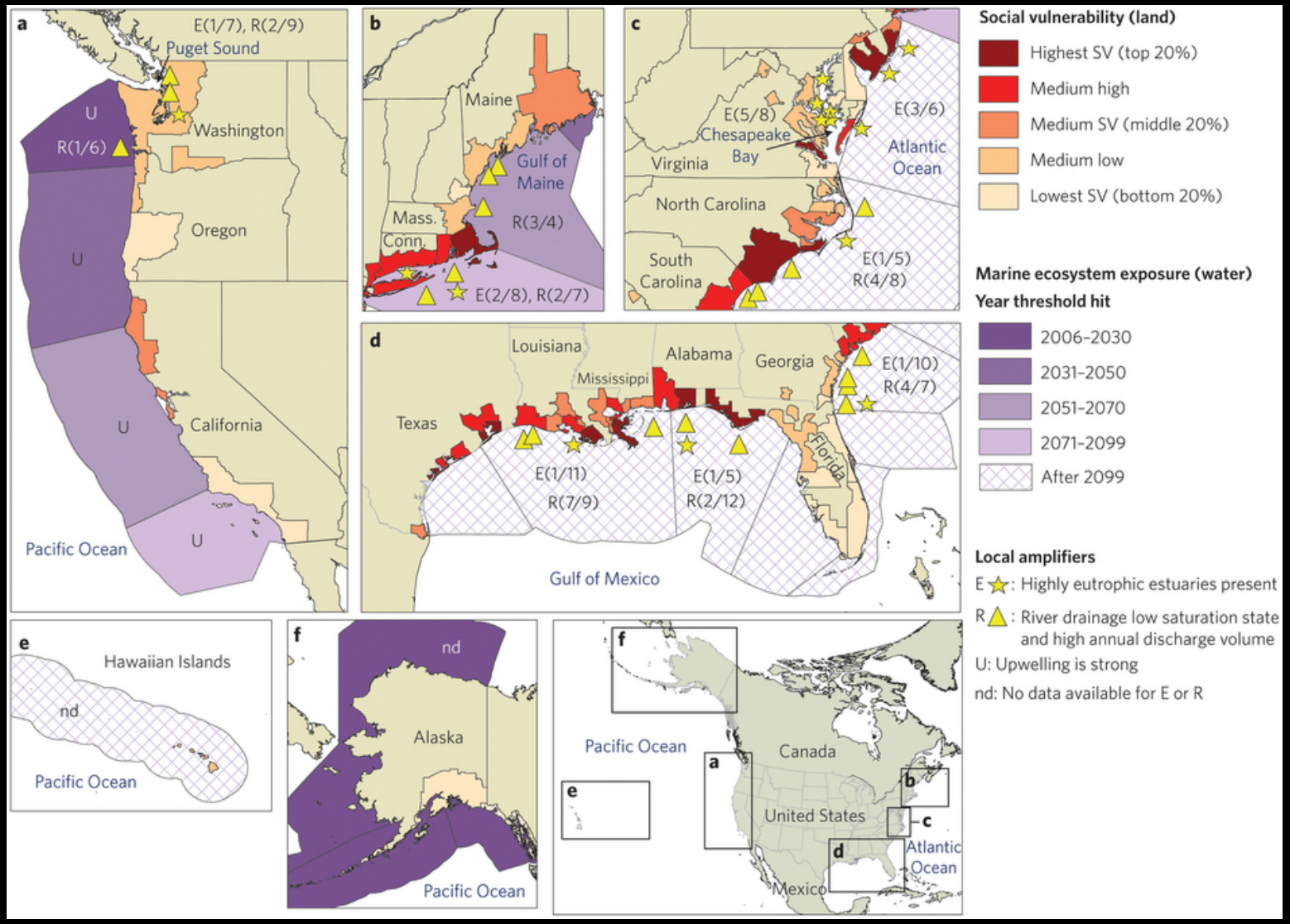
Biological & chemical monitoring

NSF-supported OMEGAS Consortium: OSU, UCSB, UCSC, UC Davis, Univ Hawaii, Stanford, MBARI

Combined laboratory & field observations (e.g., mussels, urchins) with oceanographic sensors

Consider: CA MPA monitoring, NERR, LTERs in CA!

Our vulnerability to ocean acidification = oceanography + economics



Ekstrom et al, 2015

Needs & visions for CA

Investments in monitoring from surface to subsurface

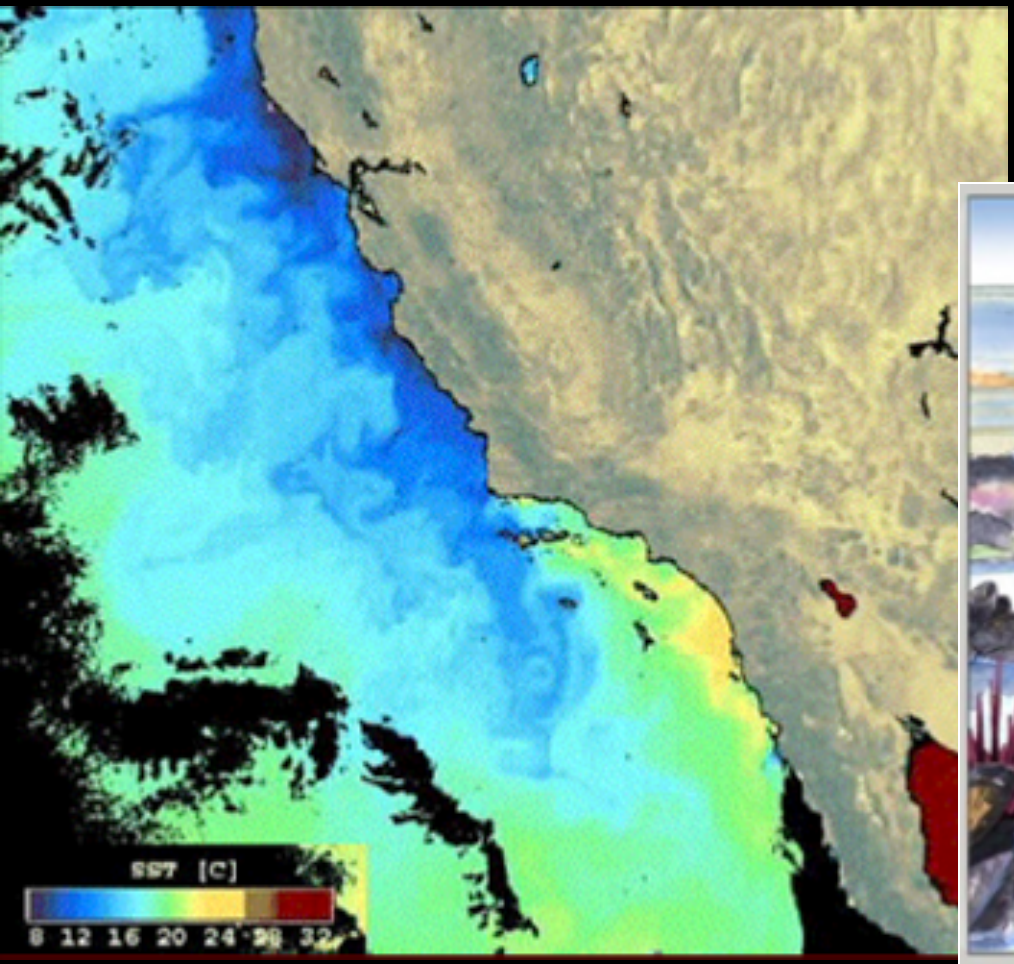
Expanded partnerships – local communities, tribes, aquaculture/fisheries, regional & local management agencies, scientists

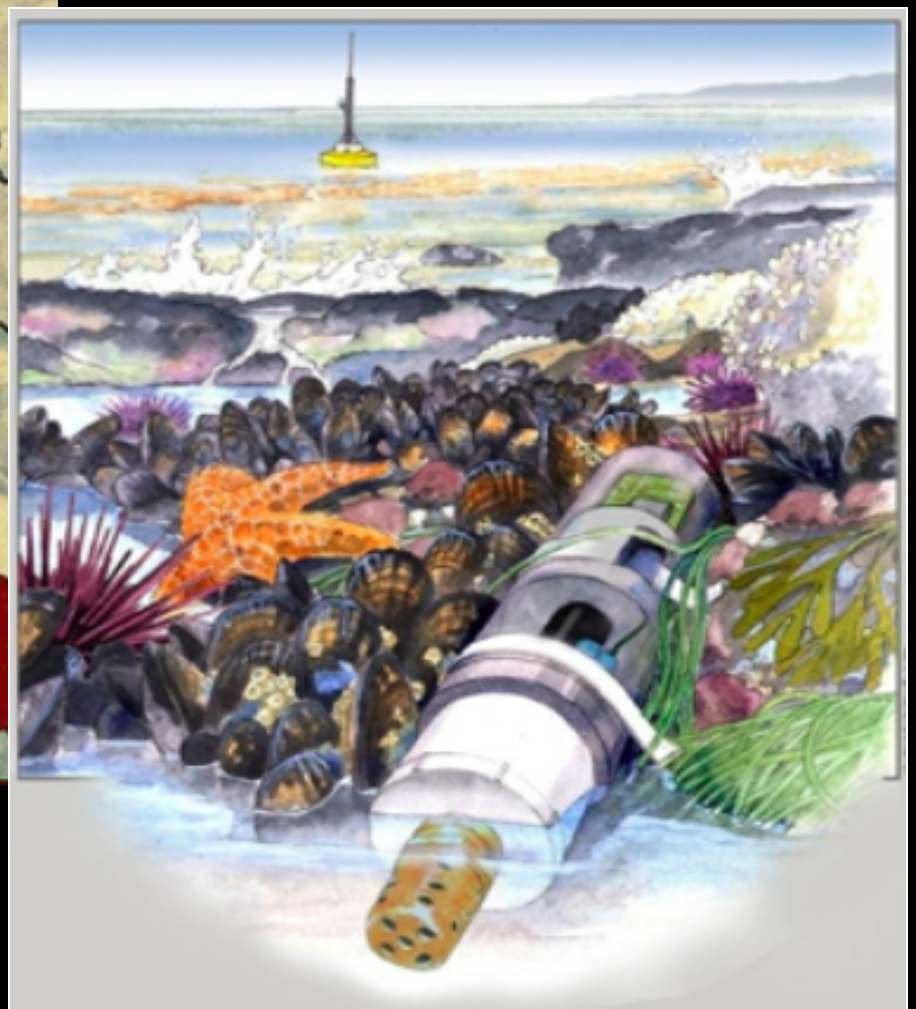
Co-location of biological & chem/physical monitoring

Synthesis of modeled progression/ thresholds and field observations

Linkages between the mosaic of oceanographic impacts and human impacts along the coast

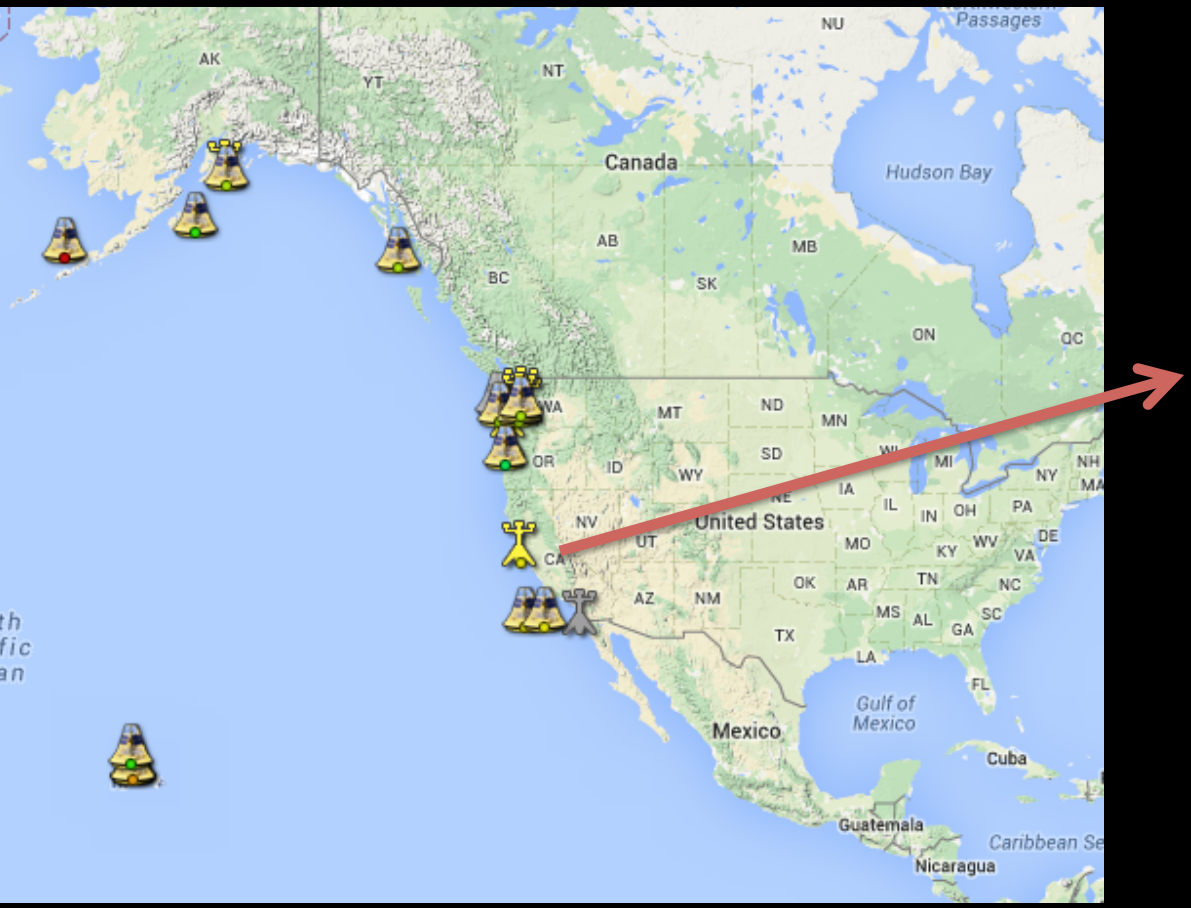
There will be variability in response to ocean acidification: this is a complex environment





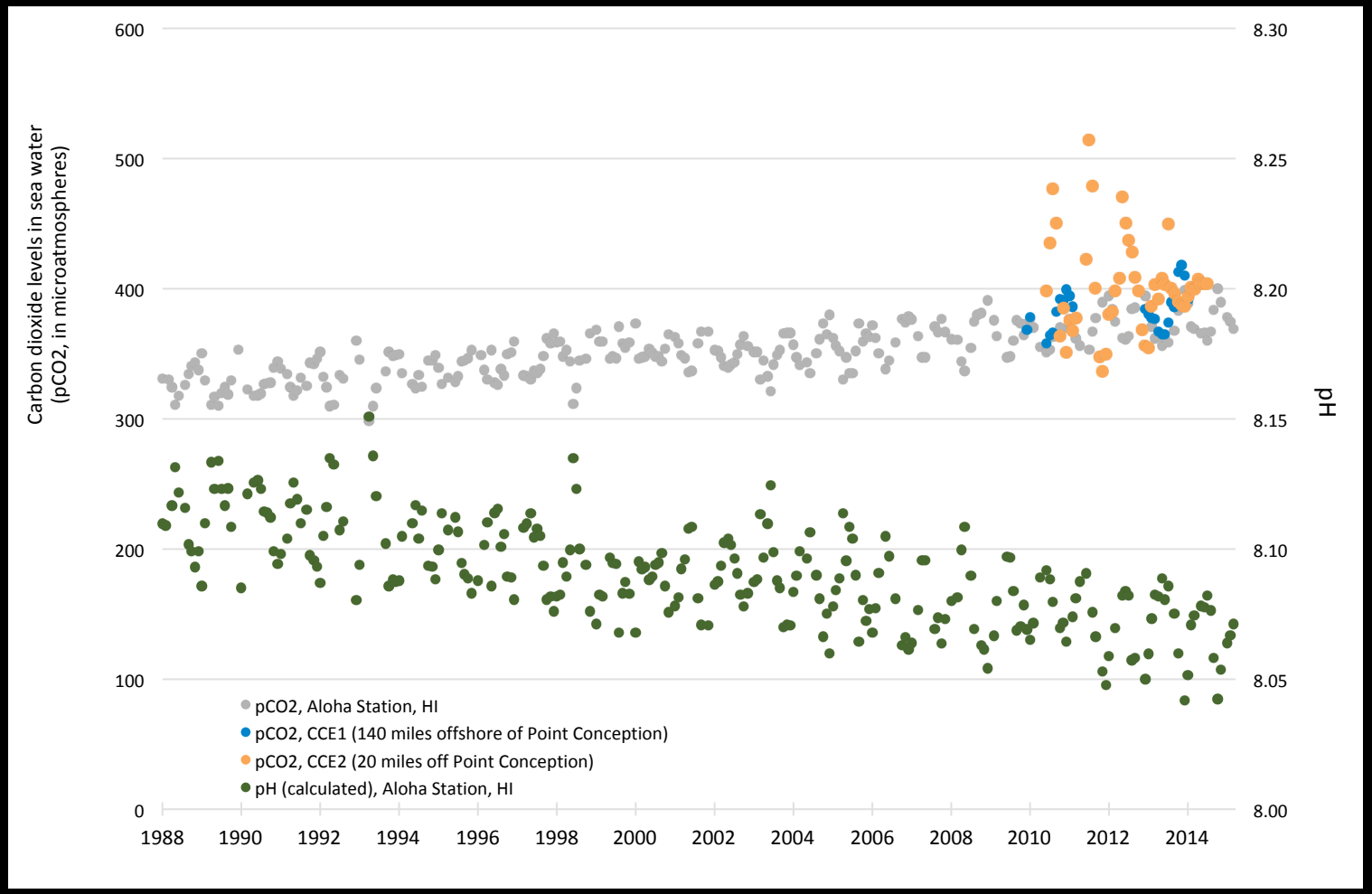
INTEGRATED OCEAN OBSERVING SYSTEM

NOVEL PARTNERSHIPS CAN MAXIMIZE OUR UNDERSTANDING OF IMPACTS

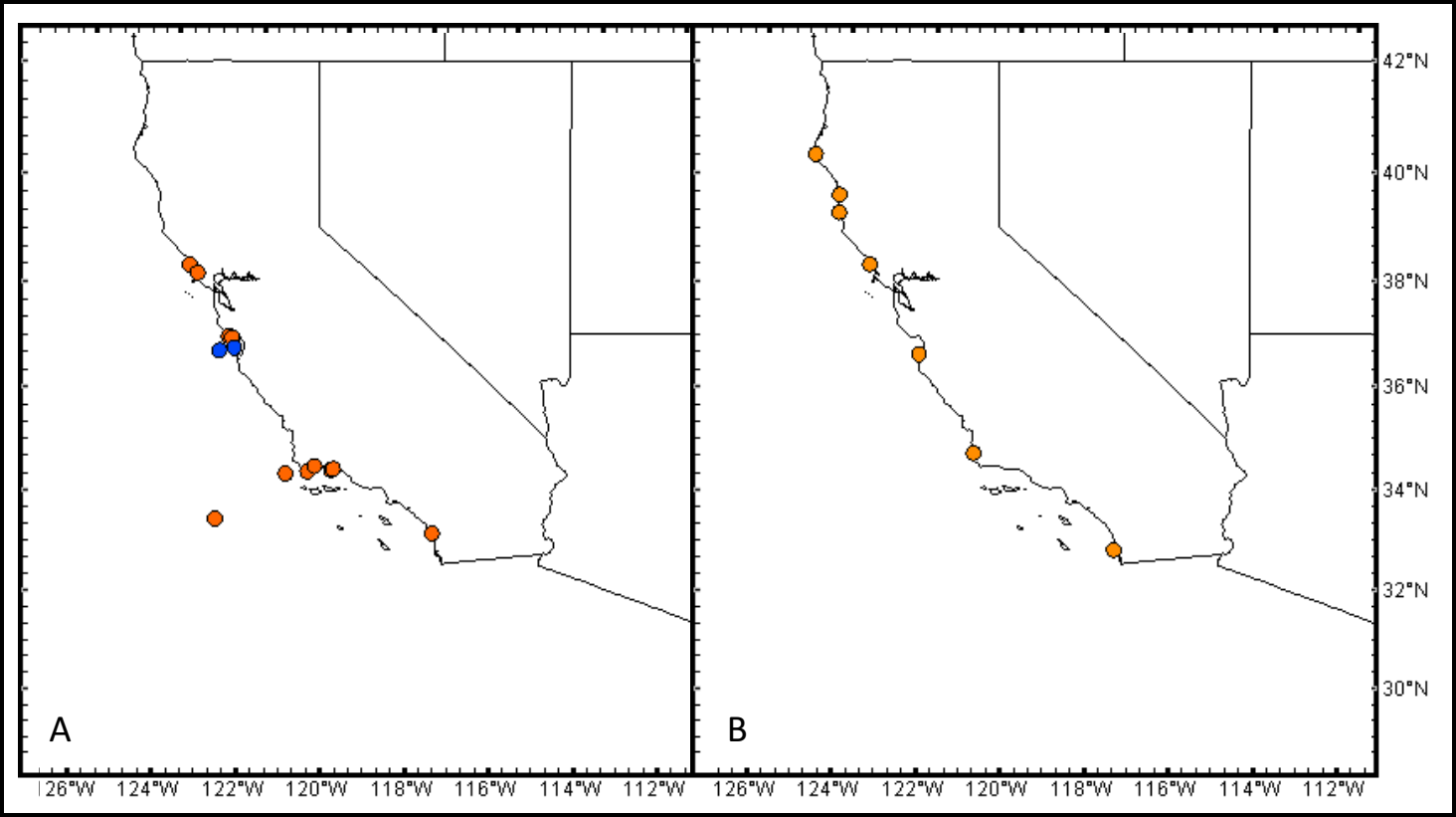


T. Sawyer, Hog Island Oyster Company & OA sensors

UNDERSTANDING CHEMICAL, PHYSICAL, BIOLOGICAL CHANGE IS CRITICAL TO DOCUMENT *AND RESPOND* TO ACIDIFICATION


Carbon dioxide levels in sea water (pCO2, in microatmospheres)
600
500
400
300
200
100
0
8.30
8.25
8.20
8.15
8.10
8.05
8.00
pH
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
pCO2, Aloha Station, HI
pCO2, CCE1 (140 miles offshore of Point Conception)
pCO2, CCE2 (20 miles off Point Conception)
pH (calculated), Aloha Station, HI

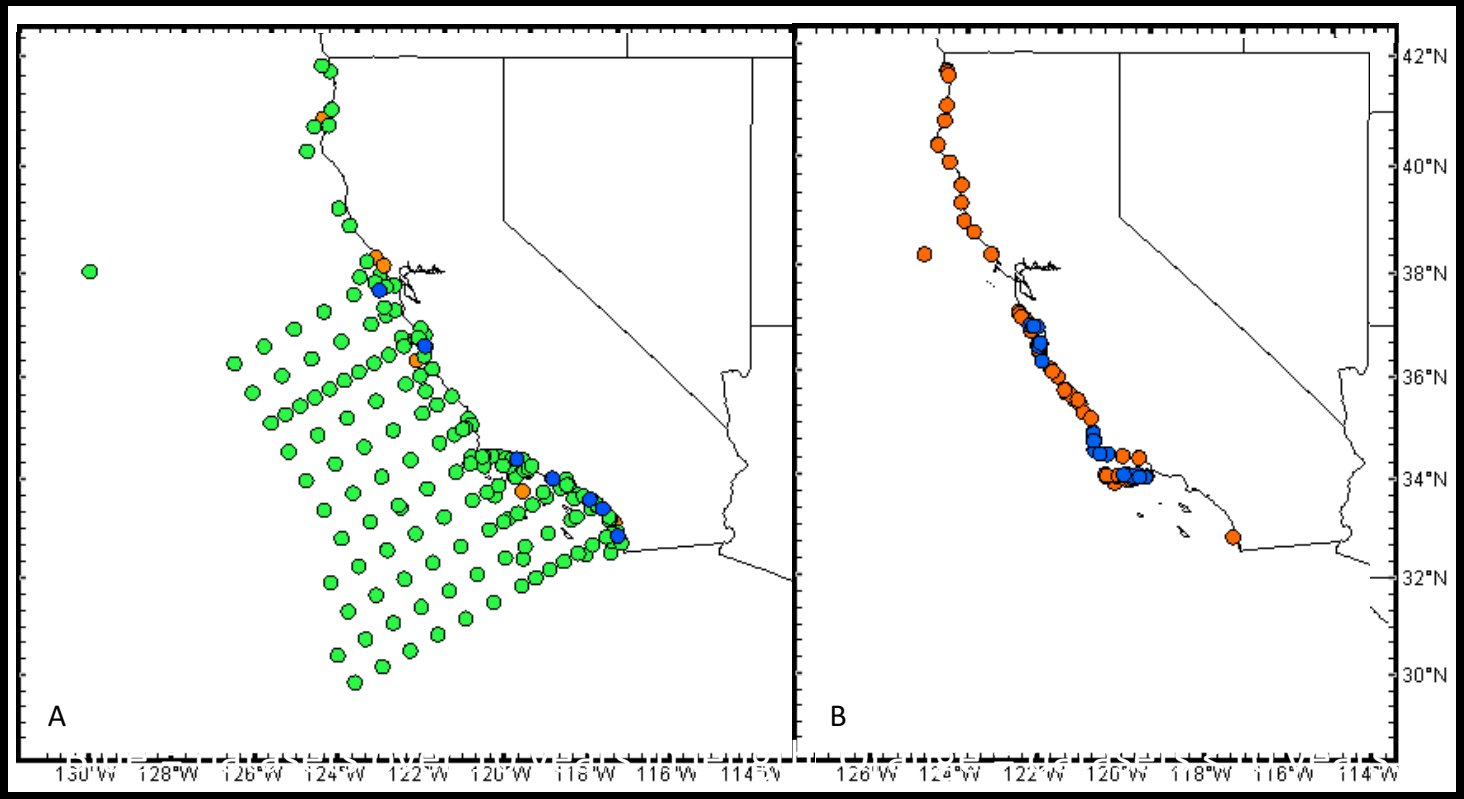
Ongoing (Left) and past (Right) ocean acidification monitoring in CA – limited to datasets that were made public as of 2016



Blue = datasets over 10 years in length; Orange = datasets <10 years.

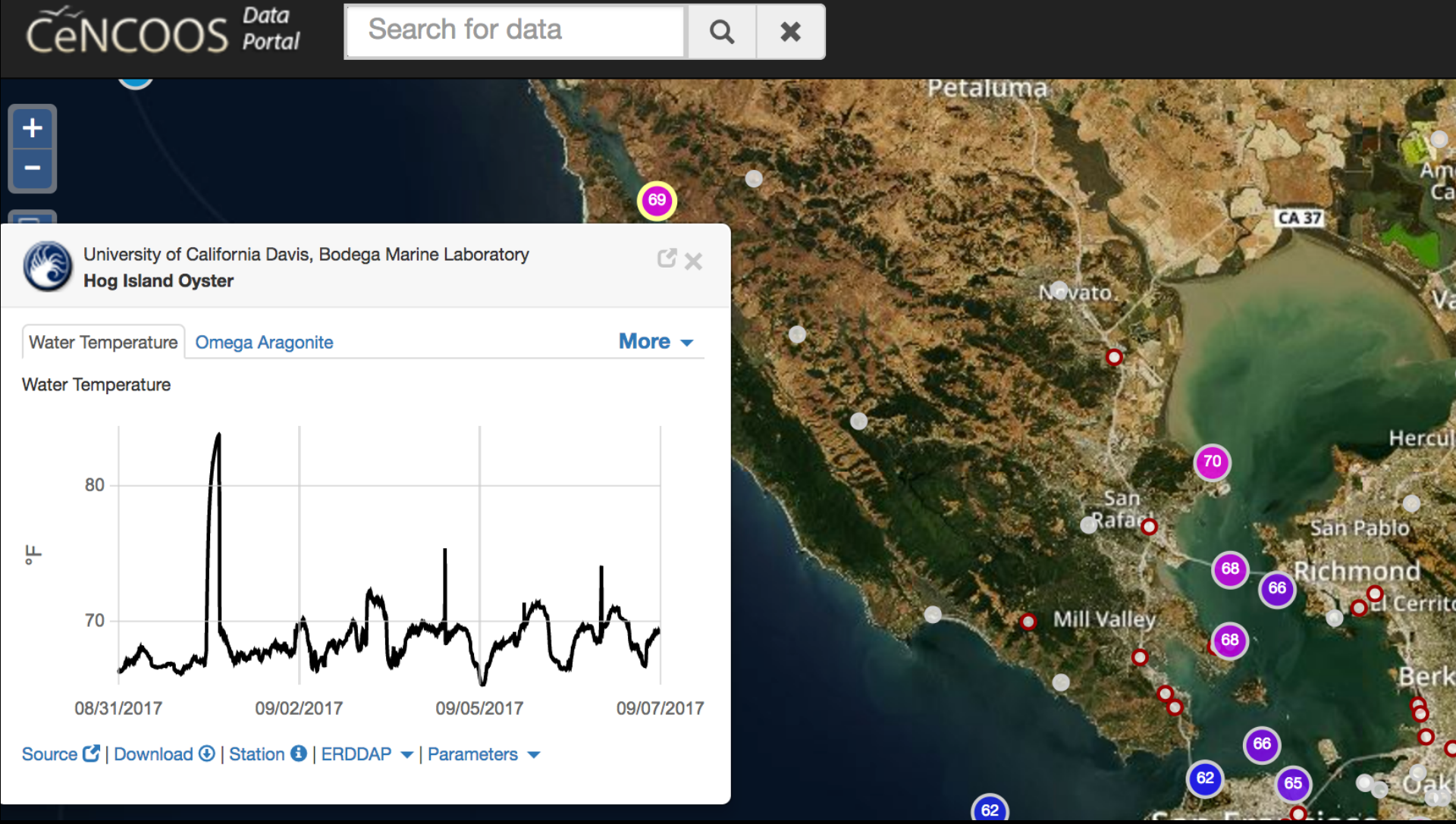
Rivest et al., Indicators of Climate Change in California

Ongoing (Left) and past (Right) temperature monitoring in CA – limited to datasets that were made public (as of 2016)



Blue = datasets over 50 years in length; Green = 11-50 years; Orange = datasets <10 years.

Rivest et al., Indicators of Climate Change in California



CeNCOOS data portal – also ”Connecting the Dots on Ocean Acidification” story on CeNCOOS website