California Current Acidification Network: Leadership And Coordination to Combat OAH on the US West Coast

27 Jun 2023

Alex Harper
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OCEAN PROTECTION COUNCIL

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

OAP NOAA OCEAN ACIDIFICATION PROGRAM

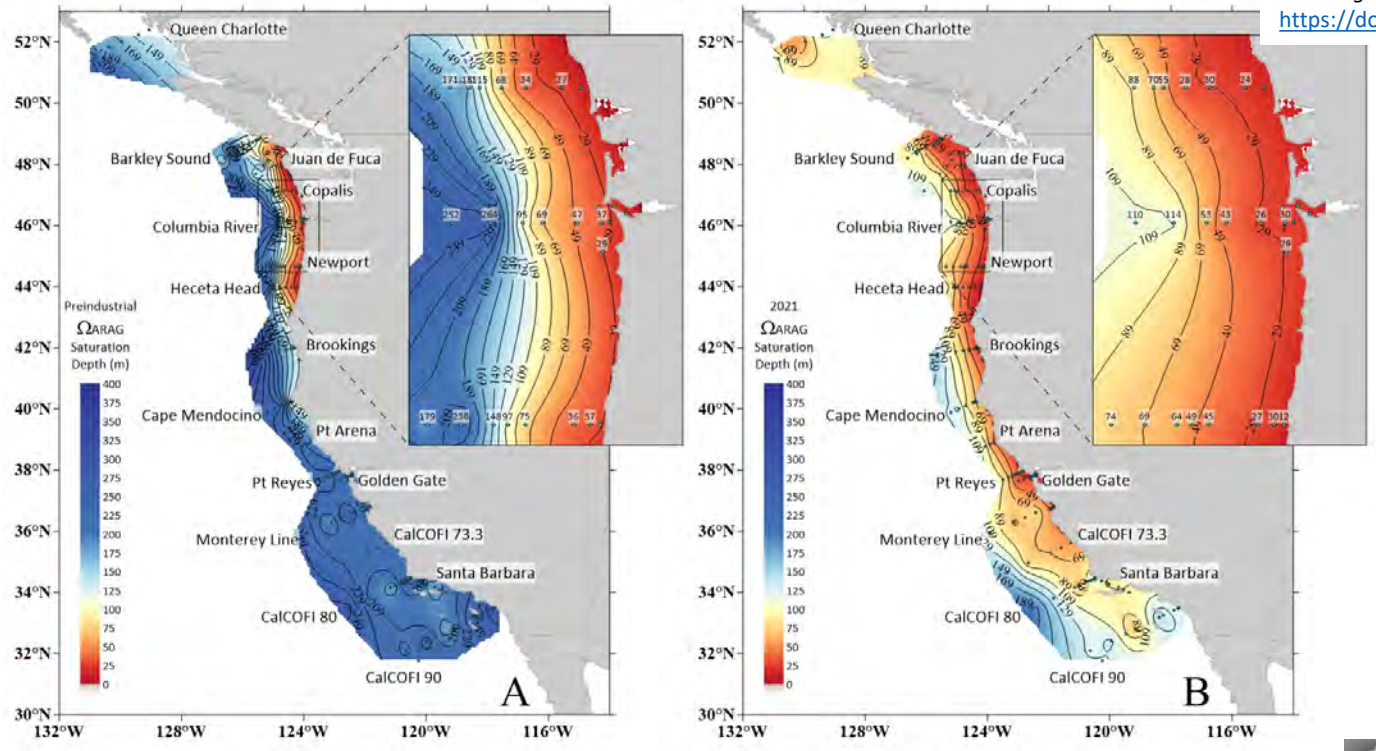
C-CAN California Current Acidification Network

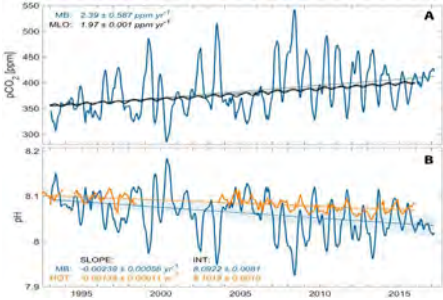
Sea Grant California

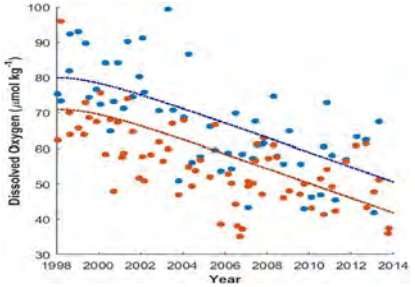
CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

OAH Pre- and post-industrial

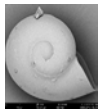
Celebrating 30 Years of Ocean Science and Technology at the Monterey Bay Aquarium Research Institute. Climate Variability and Change. Ecosystem. F. Chavez et al, *Oceanography.* https://doi.org/10.5670/oceanog.2017.429



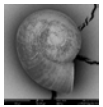




Pre-industrial and 2021 Aragonite Saturation Horizon (Depth in meters) Feely et al.



No dissolution



Moderate dissolution

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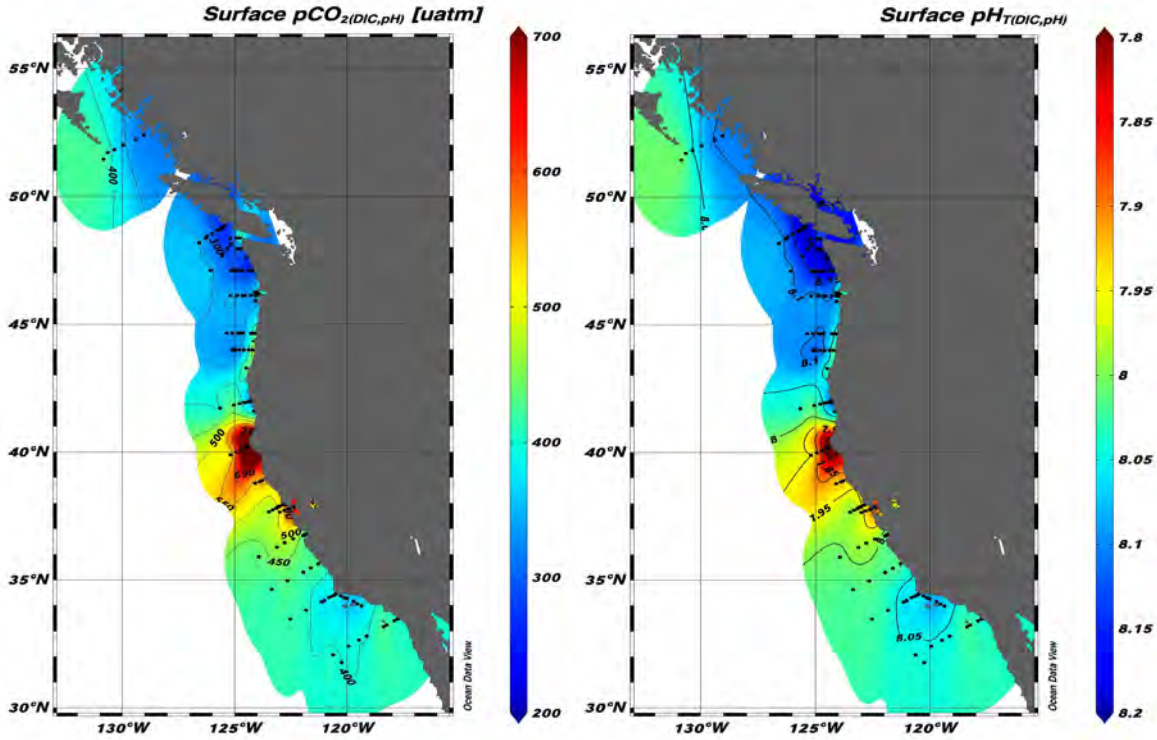
Acidification & Hypoxia – Upwelling



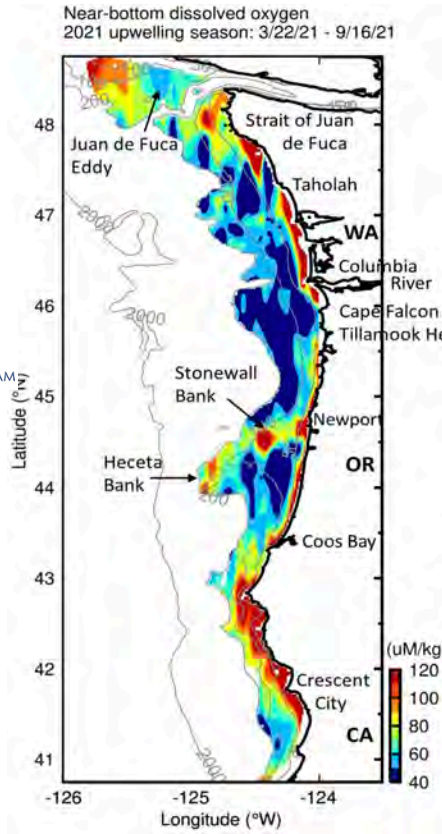
Surface pCO_2 [µatm]

Surface pH_T

Feely et al (in prep)

PMEL

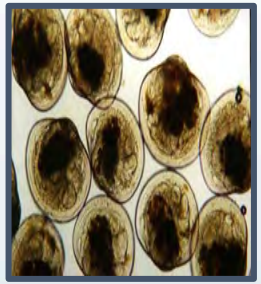
NOAA OCEAN ACIDIFICATION PROGRAM



Barth et al (in prep)

IOOS West – Headlights project

Pacific Northwest hatchery failures



Photos: Taylor Shellfish

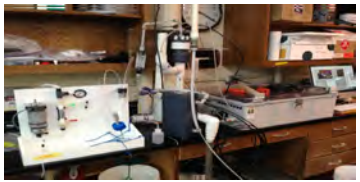
"Between 2005 and 2009, disastrous production failures at Pacific Northwest oyster hatcheries signaled a shift in ocean chemistry that has profound implications for Washington's marine environment." *Washington Blue Ribbon Panel on Ocean Acidification 2012*

Turning the headlight on 'high'

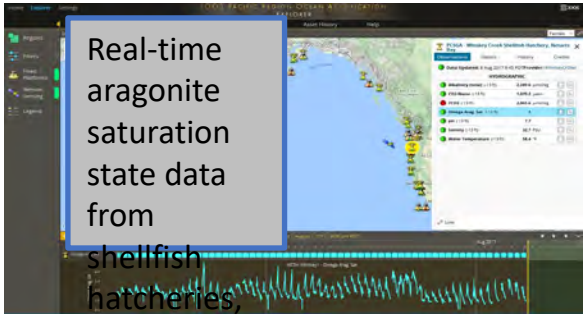
*"Putting an IOOS buoy in the water **is like putting headlights on a car**. It lets us see changing water conditions in real time,"*

-Mark Wiegardt, co-owner of Whiskey Creek Shellfish Hatchery.

Burke-o-Lator



ACDC

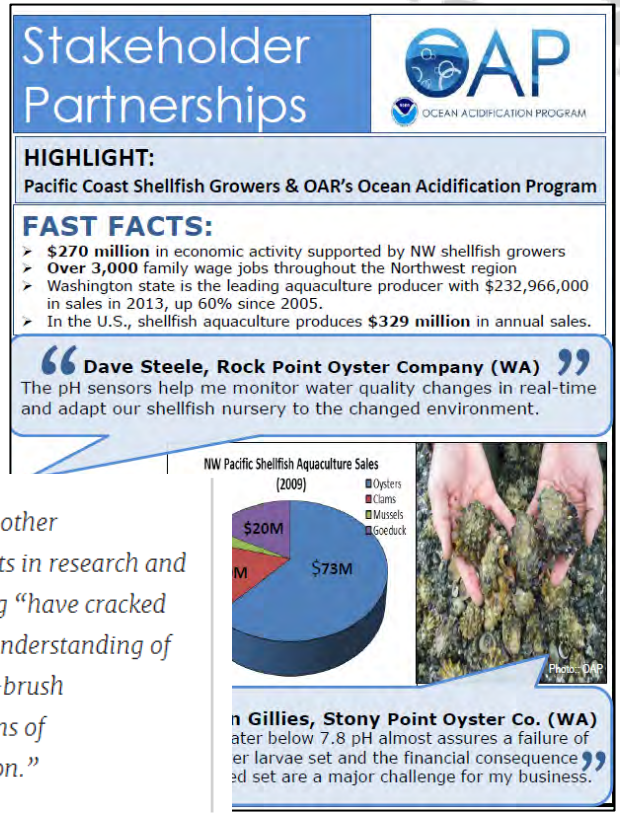


Shellfish Growers as Ocean Advocates

Developing Ocean Acidification "Champions" in Congress

Ocean acidification "provides a case study of a way that we can drive forward bipartisan action on an environmental issue," says an Ocean Conservancy scientist.

These and other investments in research and monitoring "have cracked open our understanding of the broad-brush implications of acidification."



Alutiiq Pride Shellfish Hatchery Seward, AK

Taylor Shellfish Hatchery Quilcene, WA

Whiskey Creek Shellfish Hatch Tillamook, OR

Hog Island Oyster Company Tomales Bay, CA

Carlsbad Aquafarm Carlsbad, CA

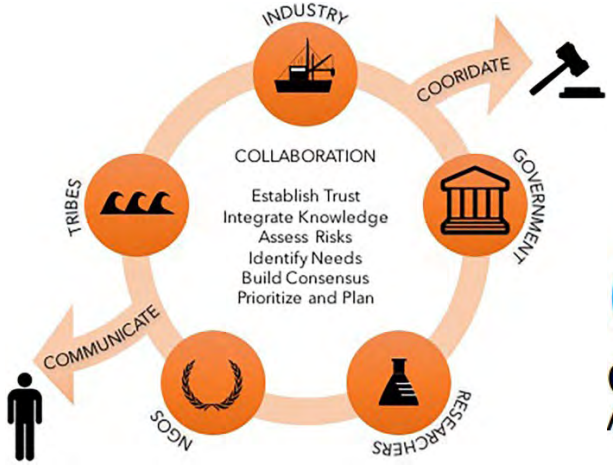
Showstack, R. (2018), Developing ocean acidification "champions" in Congress, *Eos, 99,* https://doi.org/10.1029/2018EO111659. 10 Dec 2018.

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

California Current Acidification Network

The C-CAN Mission is to:

- Coordinate and encourage development of an ocean acidification monitoring network for the west coast that serves publicly available data;
- Improve understanding of linkages between oceanographic conditions and biological responses;
- Facilitate and encourage the development of causal, predictive and economic models that characterize these linkages and forecast effects; and
- Facilitate communication and resource / data sharing among the many groups, organizations and entities that participate in C-CAN or utilize C-CAN as an informational resource.



C-CAN
California Current Acidification Network

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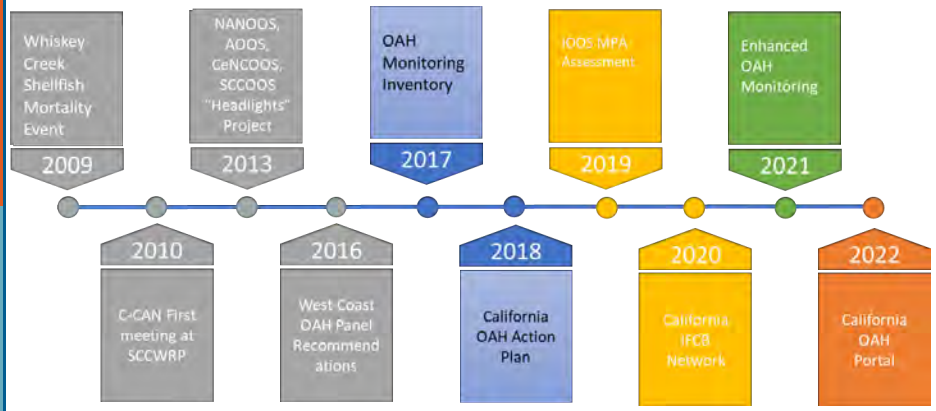
Decision-relevant OA information



Observations

Engagement & Products

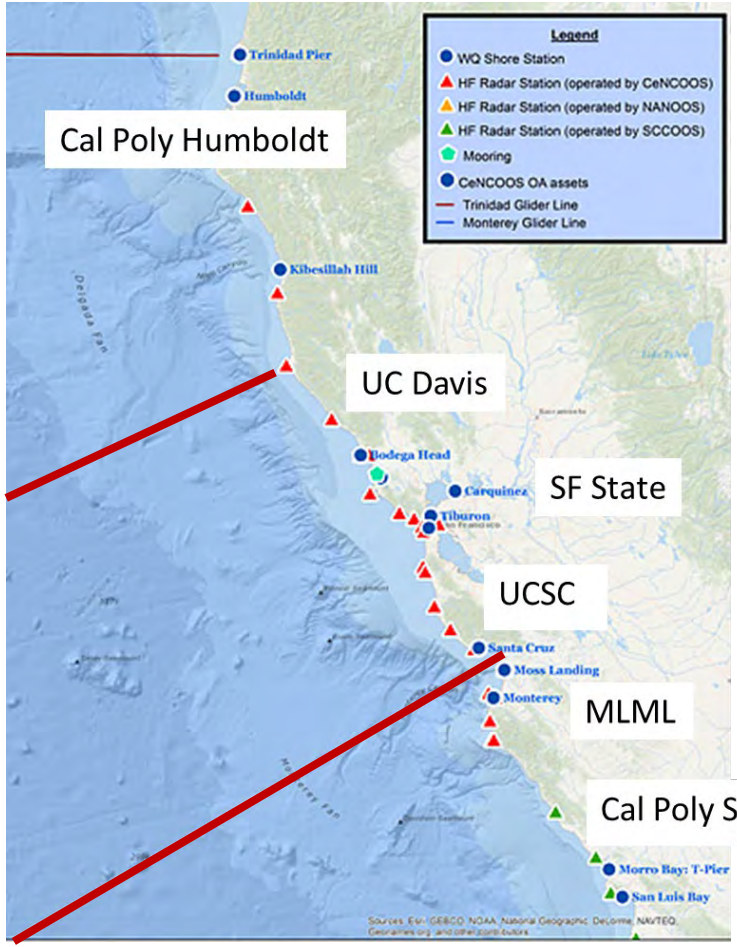
Data Management & Cyberinfrastructure

Modelling & Analysis

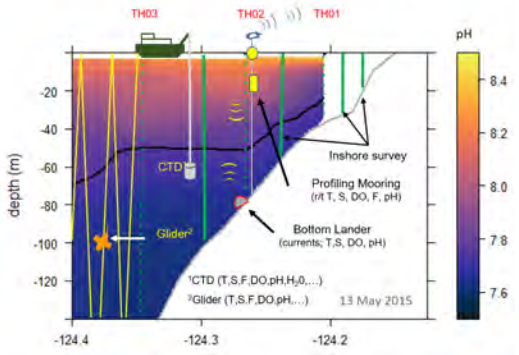
CeNCOOS Responding to State and National Priories

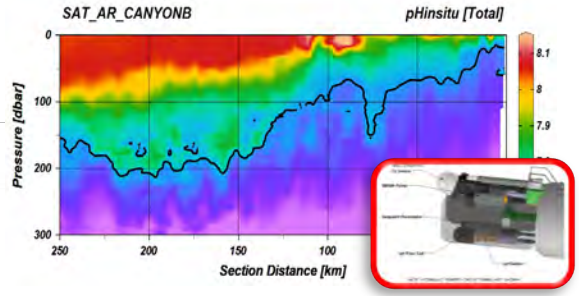
- Standardizing data collection across monitoring programs
- Improving data quality, accessibility, and interoperability
- Investing in subsurface, offshore, and joint bio-chem observations
- Filing geographic gaps to address ecosystem and human vulnerabilities
- Building centralized information hub (California OA Portal) to streamline access to data, forecasts, and indicators

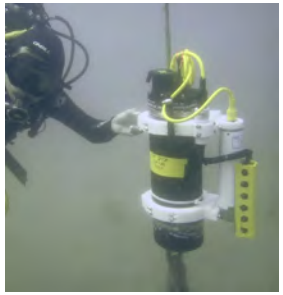
CeNCOOS OAH Investment - Observing



Shore station recap
Mooring support
ACCESS Surveys
BGC Gliders





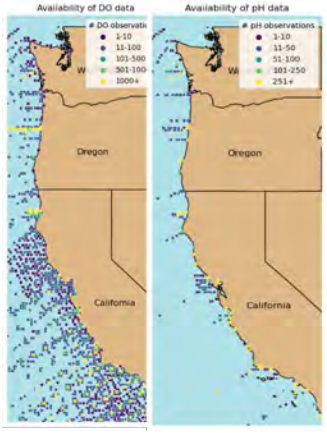


Leveraging existing CHEM monitoring programs

We are working to better connect biological and chemical monitoring across ongoing monitoring programs by standardizing the collection and delivery of OAH variables across programs:

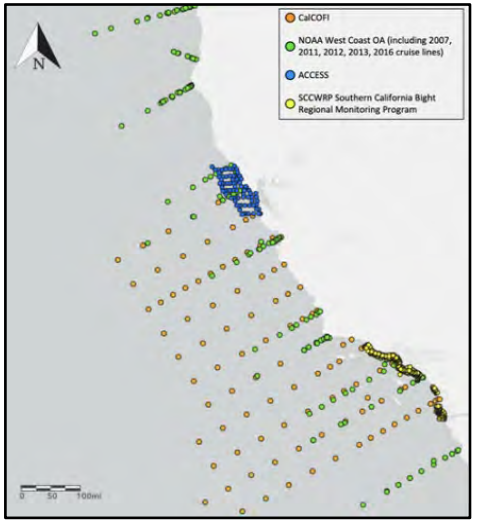
- Applied California Current Ecosystem Studies (ACCESS)
- California Cooperative Fisheries Investigation (CalCOFI)
- California Current Ecosystem Long-term Ecological Research (CCE LTER)
- The NOAA West Coast Ocean Acidification Regional Survey Cruises
- Southern California Coastal Water Research Project Southern California Bight Regional Monitoring Program

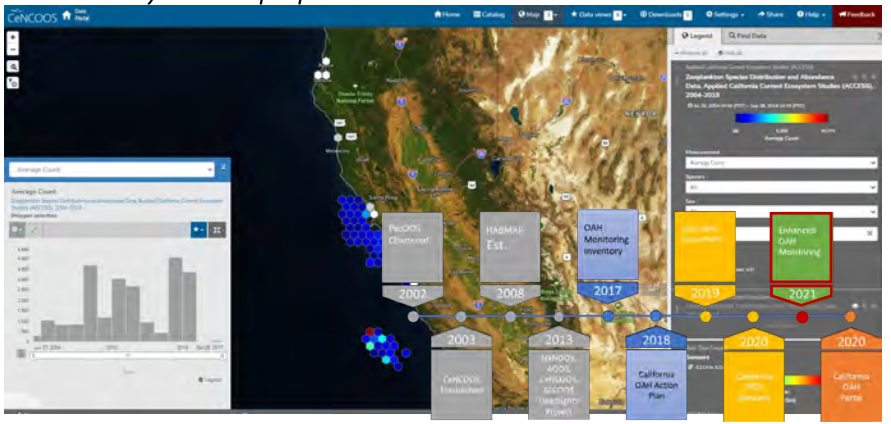
CeNCOOS is leading the data management, aggregation, and curation across monitoring programs to ensure data is interoperable, accessible and visualized in the Cal OOS Portal.



Data Paper coming soon!

Kennedy et al. in prep





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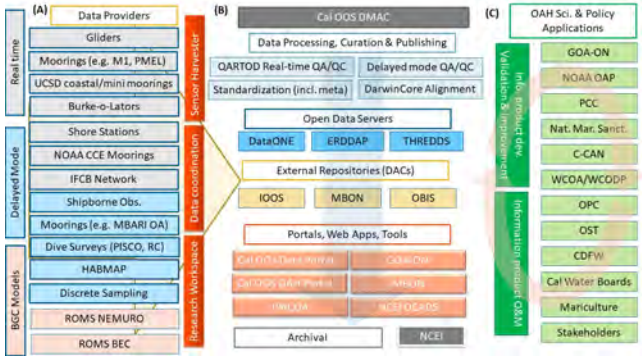
Data quality and interoperability

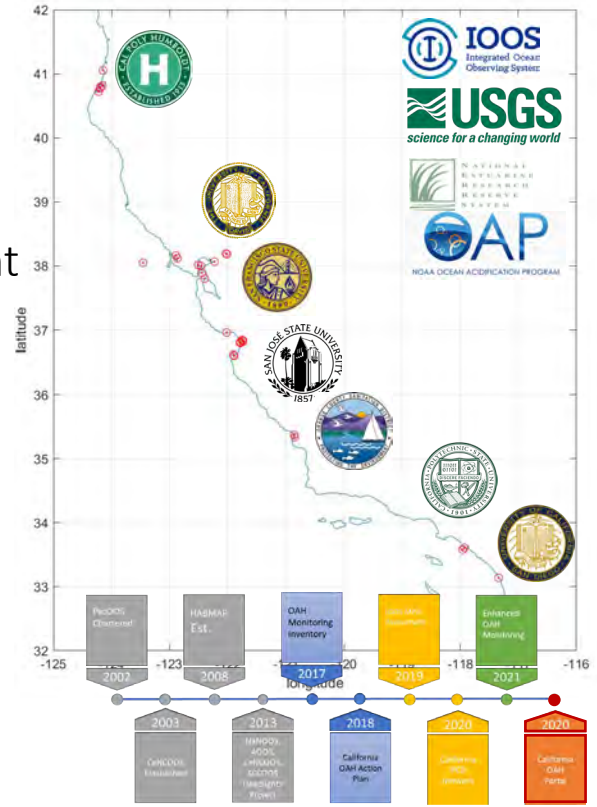
Establish a nearshore data quality working group improve data quality through standardize calibration and QC to deliver high-quality, comparable nearshore sensor-borne data to the new Cal OAH Data Portal.

Objectives: Convene managers of shore station, NERRS water quality monitoring, and diver-deployed sensor programs to:

- Share challenges, best practices, and lessons learned
- Create community for learning and data quality enhancement

Outcome: Develop community driven shared SOPs and best practices to improve nearshore OAH data quality.





Cal OAH Portal: Curated obs and models

Visit oah.caloos.org to explore and provide feedback!

The primary audience for this work are state managers.

Management applications addressed within this work include:

1. visualization of multiple stressors in the coastal environments
2. exploration of spatial and temporal scales to assess whether anthropogenic or other input are likely to exasperate OAH impacts and to what degree
3. use of synthesis products and model outputs for vulnerability assessments
4. identify the places most at risk of multiple stressor impacts, and the timing and scope of that impairment.

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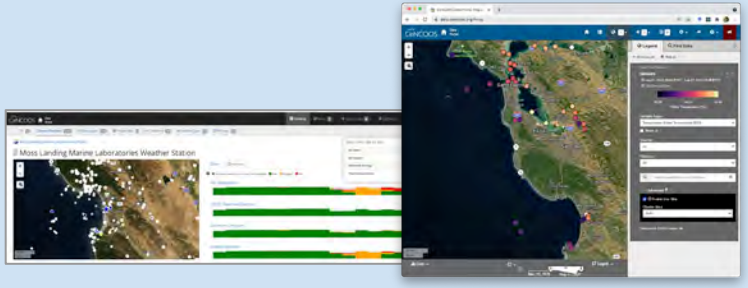
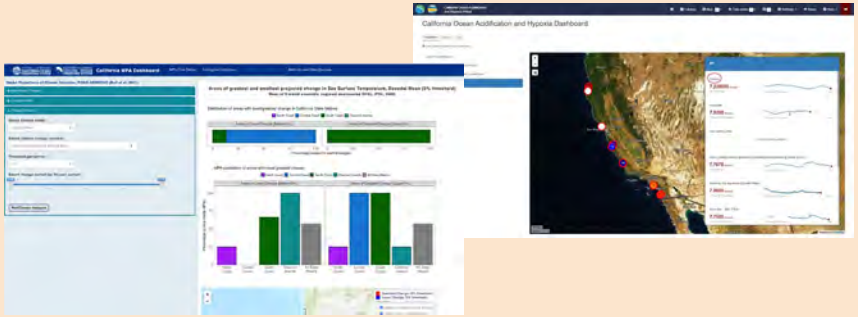
A ‘toolkit’ of Information Solutions

Portals, port-lets, and curated dataviews



- **Discover/Access/Download** data
- **Monitor real-time** data
- Develop **routine analysis**
- Can be too technical / overwhelming for some users

Dashboards for synthesis and threshold application



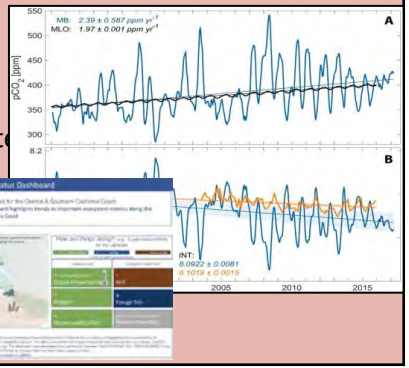
- Easy way to access and visualize data
- Can include synthesis capabilities
- Still requires some user engagement

Web Apps, Mobile Apps, Data Snapshots

- Discrete, user-driven products
- Convenient if out of cellular range
- Served via cencoos.org “Your Ocean” product portal and/or portal landing page

Indicators and infographics

- Synthesized or representative datasets
- Visually simplified for ease of access and Int
- Can include narrative and be Distributed directly to users



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Marine Carbon Dioxide Removal (mCDR)

NOAA Mission and Values

•*Science.* NOAA CDR research must be **transparent** and verifiable (e.g. what works and what doesn't).

•*Service.* NOAA CDR research should support evidence-based decisions with **actionable** knowledge, information, and tools.

•*Stewardship.* NOAA CDR research should supporting a broad constellation of **collaborative** efforts with targeted opportunities to advance effective (efficient and durable) and accountable (safe, sustainable, and fair) CDR research.

Proposal title: mCDR 2023 - Engaging the U.S. Commercial Fishing Community to Develop Recommendations for Fishery-Sensitive mCDR Governance, Collaborative Research and Monitoring, and Outreach to Fishing Communities

NEW PROJECT

Collaborating Institutions and Investigators: Fiona Hogan,[1] PI; Roger Griffis[2], co-PI; Sarah Schumann, co-PI[3]; Mike Conroy[1]; Brad Warren[4]; Alex Harper[5]; Darcy Dugan[6]; and others TBD.

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

NOPP

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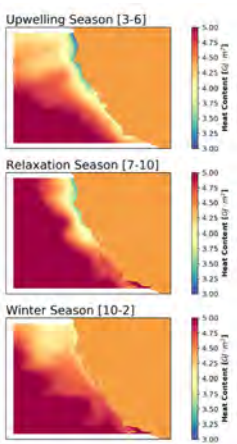
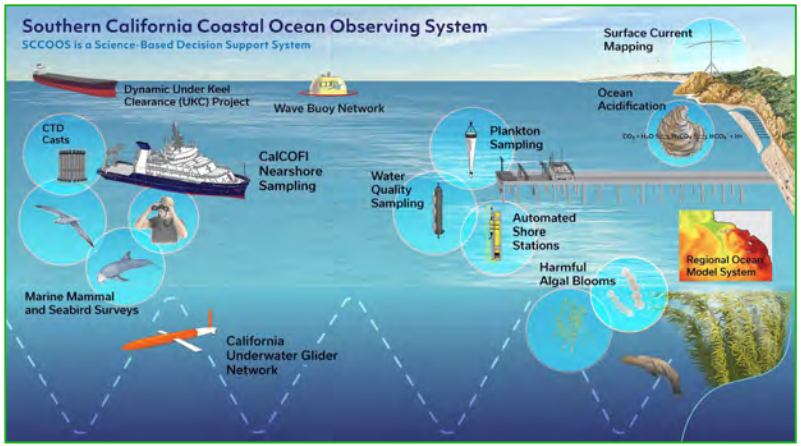
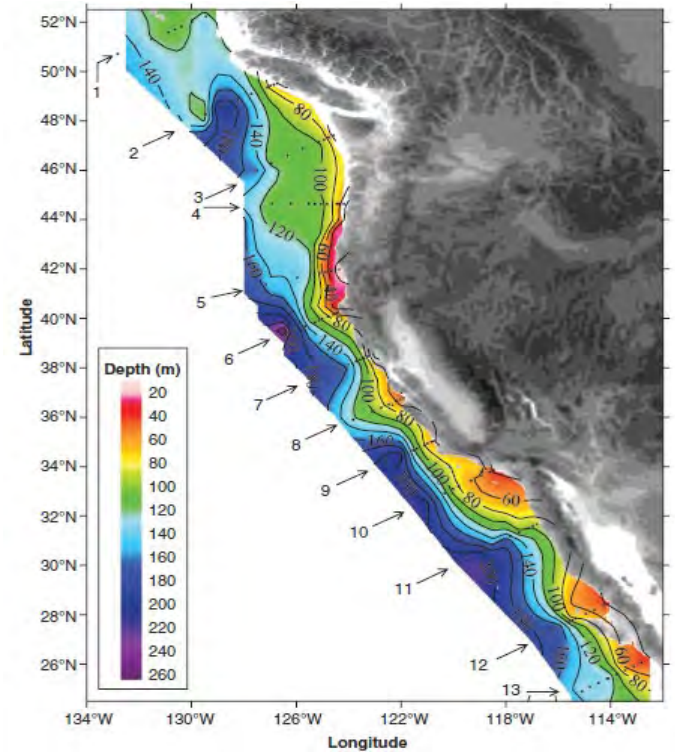
CALIFORNIA OCEAN
OBSERVING SYSTEM

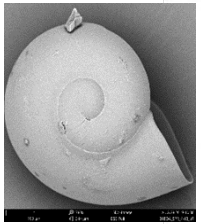
Thank you!



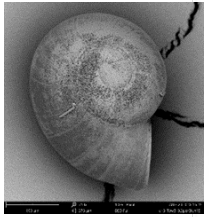


Acidification & Hypoxia – Exposure & Sensitivity

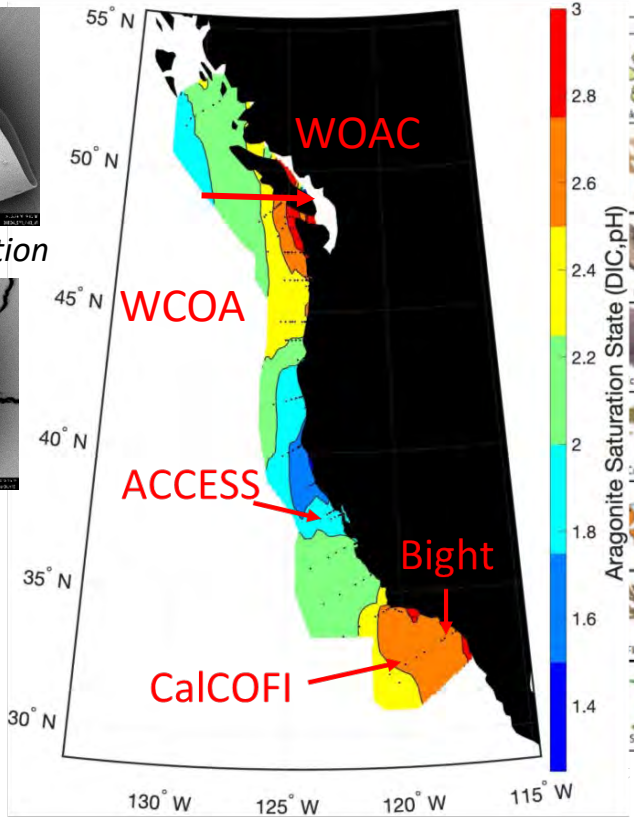




No dissolution



Moderate dissolution



WCOA 21 Aragonite Saturation State

Taxa	Response	Mean Effect
Calcifying algae	Survival	
	Calcification	
	Growth	
	Photosynthesis	−28%
	Abundance	−80%
Corals	Survival	
	Calcification	−32%
	Growth	
	Photosynthesis	
	Abundance	−47%
Molluscs	Survival	−44%
	Calcification	−40%
	Growth	−17%
	Development	−25%
	Abundance	
Echinoderms	Survival	
	Calcification	
	Growth	−10%
	Development	−11%
	Abundance	
Crustaceans	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
Fish	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
Fleshy algae	Survival	
	Calcification	
	Growth	+22%
	Photosynthesis	
	Abundance	
Seagrasses	Survival	
	Calcification	
	Growth	
	Photosynthesis	
	Abundance	

al. (2013, *Glob. Change Biol.*)

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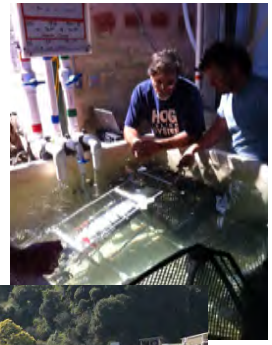
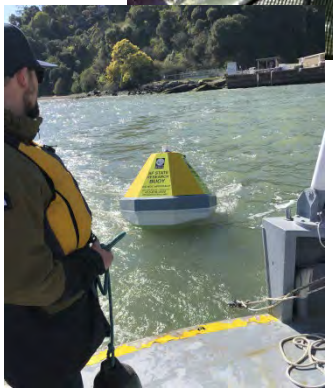
PMEL





Strengths of shore station monitoring

- Close to where the impacts of OAH are most likely to be felt, as well as interested users, stakeholders and biological time series
- Observations needed to test the next generation of high-resolution nearshore and estuarine models with biogeochemical coupling
- Build off existing infrastructure and expertise for monitoring, less effort than establishing brand-new sites
- Relatively easy and inexpensive access for cleaning and calibration compared with offshore surveys and buoys, great technology testbed
- PIs have leveraged funding to study offshore OAH thanks in large part to the presence of near-shore stations

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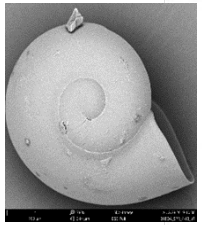
Monitoring biological impacts

- West Coast OA monitoring are collaborating to monitor biological impacts using a similar set of metrics
  - West Coast Wide: WCOA
  - California: ACCESS, Bight and CALCOFI
  - Washington: WOAC
- Key metric: pteropod and larval crab shell dissolution
- Generating comparable datasets for biological impacts west-coast wide
  - Working towards an assessment framework which will allow for a common currency to describe "how bad is it?“
  - Workshop will be organized within the year



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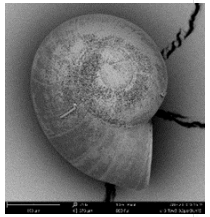
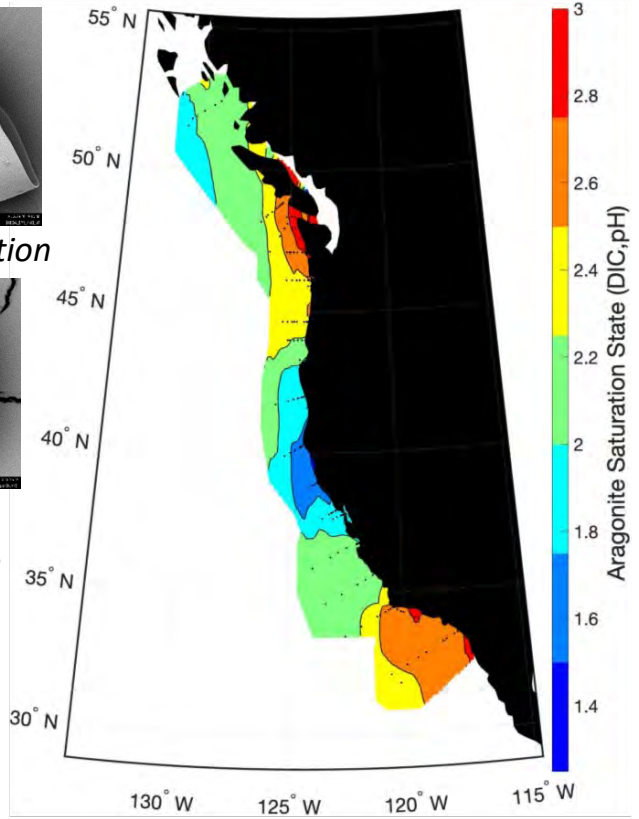


Moderate dissolution



WCOA 21 Aragonite Saturation State

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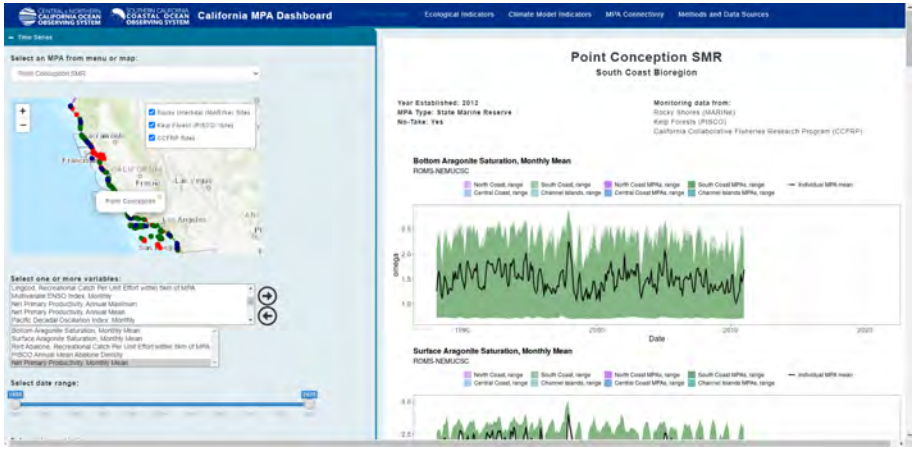
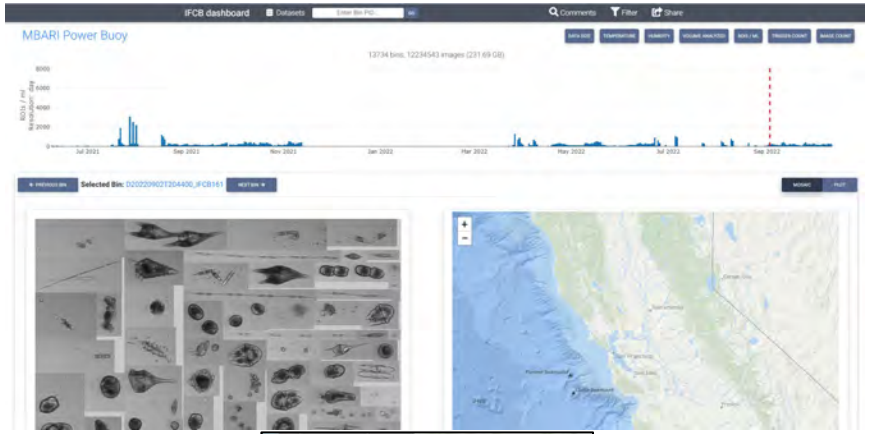
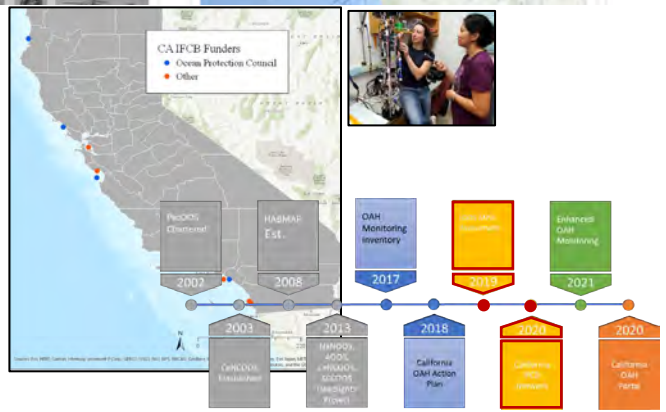
Expanding biological observing capability

MPA Long-term Monitoring Programs



California IFCB Network





CA OA Action Plan Action 1.2.7. Enhance and expand coupled environmental and biological monitoring across the statewide MPA network to provide essential baseline information for understanding OA ecosystem impacts.

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Opportunities for continued progress

- Entrain industry (commercial and recreational shellfish, finfish and aquaculture) in the collection of OAH and relevant biological data
- Build stronger partnerships with kelp monitoring and reforestation efforts
- Co-design observing systems with offshore wind industry
- Help lead climate solutions using marine CDR
- Continue to connection with Oregon, Washington, Canada and beyond
- In-region interagency collaboration (e.g. NPS, PNNL)
- Support Indigenous communities in reclaiming management of coastal lands through information sharing and partnership

C-CAN

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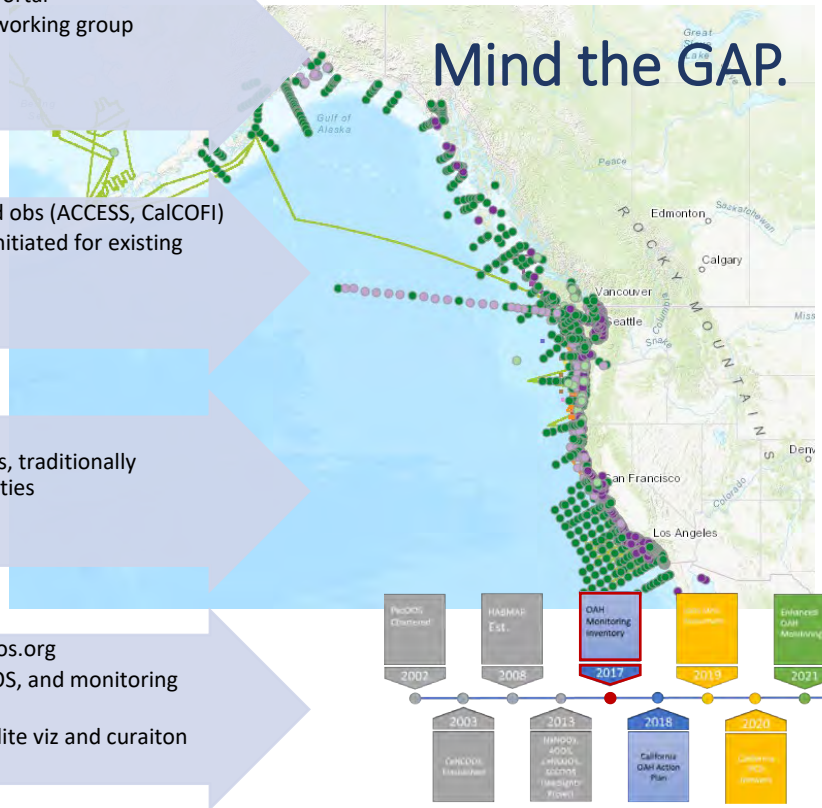
West Coast OAH Inventory and data gaps

What we heard.	How we responded.
Data quality, accessibility, and integration issues	•Further implement QARTOD via the Cal OOS Portal •OAH Portal: Establish nearshore data quality working group
Subsurface and offshore obs lacking	•Targeted investments in moorings, ship-based obs (ACCESS, CalCOFI) •Data handling, processing, and access effort initiated for existing moorings
Geographic gaps & Vulnerabilities	•California's North Coast / Southern Oregon •Communication issue – messaging, Indigenous, traditionally underserved and underrepresented communities
"One-stop shop" for data access, forecasts	•Developed statewide information center caloos.org •Further unified delivery with SCCOOS, NANOOS, and monitoring partners •Enhanced portal capabilities for model / satellite viz and curaiton



A California OAH Portal

Our goal:

Build a centralized information access hub, the *California OAH Portal, to* serve automated, high-quality and interoperable data and synthesis products

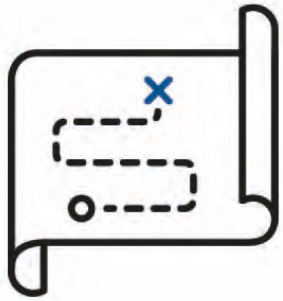
Project objectives

Objective 1. Improve data quality, interoperability, and access.

Objective 2. Streamline data ingestion for enhanced visualization and synthesis.

Objective 3. Establish a state-wide information HUB for managers and stakeholders.

Objective 4. Develop and automate synthesis products and biological indicators.



CA OA Action Plan: OOS Perspective

Decision-relevant monitoring information about OA is widely available, delivered in a usable form, and routinely applied to decisions across the public and private sectors. [5-year goal]

Provide ***open access to information*** developed through the monitoring and observation system ***via existing or new web-based platforms and data portal(s)*** that allow the OA information to be viewed and analyzed in ***combination with other environmental information.*** [5-year goal]

Action 1.2. . The monitoring and observation system design should be informed by an assessment of user needs and should:

- encompass ***near- and off-shore areas***…;
- ***couple environmental and biological monitoring***…;
- strategically ***integrate existing monitoring and observation assets***,,,;
- provide sufficient ***quality assurance/quality control***…;
- include industry (e.g., fishing) and citizen science where feasible and beneficial

Modeling to evaluate nutrient inputs and climate change

ROMS-BEC (regional ocean modeling system with biogeochemical elemental cycling)

A coupled physical-biogeochemical model of Southern California Bight is being used to simulate algal blooms, acidification and hypoxia (OAH).

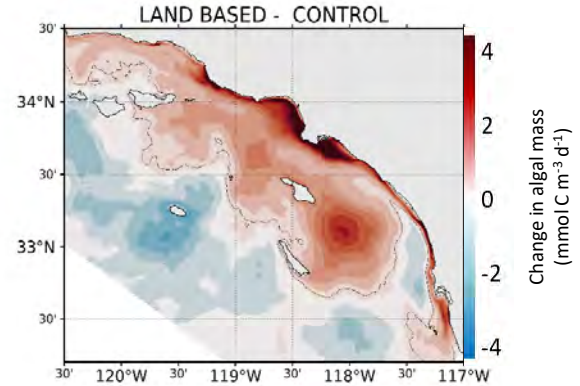
That model has been applied to estimate effects of anthropogenic nutrients.

- 700 million gallons of effluent discharge with 1 x 10^5 kg N per day (Howard et al. 2014 L&O)

Algal Production

red = increase

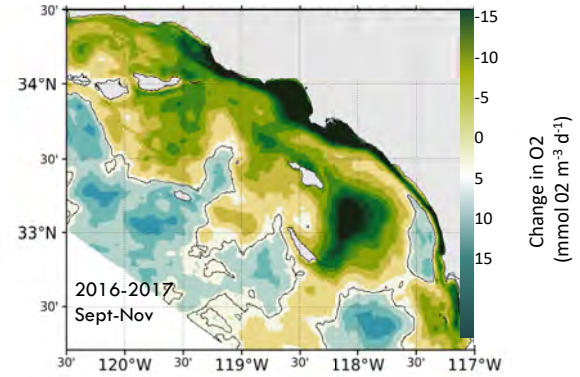
blue = decrease



Oxygen

green = loss

blue = gain



Performance/Validation Publications

Renault et al. 2021 *Progress in Oceanography*

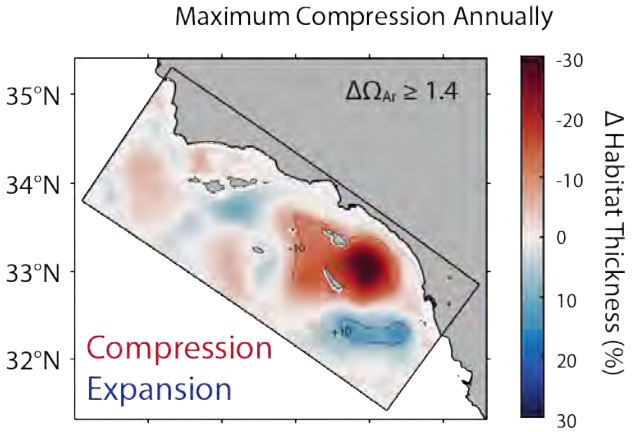
Deutsch et al. 2021 *Progress in Oceanography*

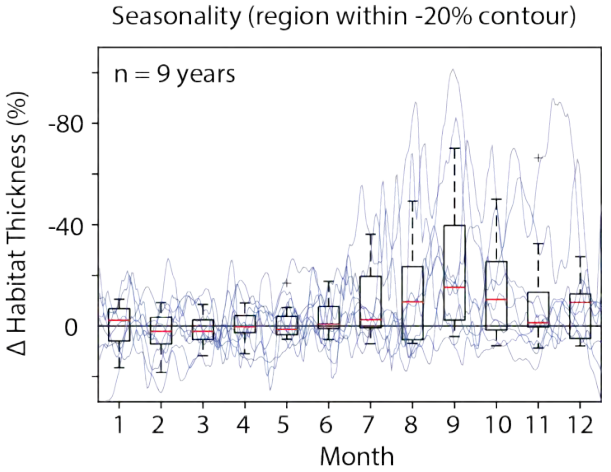
Kessouri et al. 2021 *Journal of Advances in Modeling Earth Systems*

Ho et al. 2021 *Journal of Hydraulic Engineering*

OAH-relevant changes in habitat emerge from eutrophication in the Bight

- Assessed as difference between a model simulation with anthropogenic nutrient inputs and the other without
- Region of maximum habitat compression is not coastal (where increased phytoplankton production is greatest), rather it is offshore, expressed southeast of Catalina Island
- It is a seasonal phenomena; lasting 2-4 months in late summer-early fall
- Habitat outcomes for both oxygen and acidification metrics largely consistent (aerobic habitat not shown here)





Frieder et al., in prep

CeNCOOS DMAC Subsystem

DMAC – **D**ata **M**anagement **A**nd **C**yberinfrastructure

IOOS DMAC philosophy

- Distributed thematic and regional data assembly centers
- Develop and manage technical design & standards
- Standardize & integrate data delivery from multiple sources
- Leverage existing capabilities
- Enhance value to agencies and societal needs

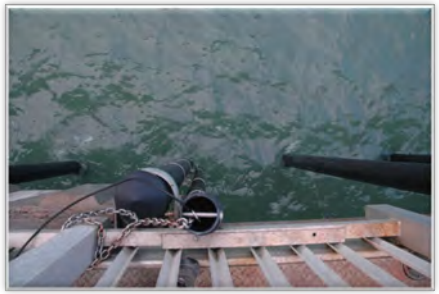
Core Principals (that we strive for):

- **FAIR**: Findable, Accessibility, Interoperability, Reusability
- **Timely**: Data Value can diminish over time (Operational)
- **Reliability**: Having data available when it is needed
- **Open Data**: Available for anyone, for any use

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

Objective 1: Improve data quality

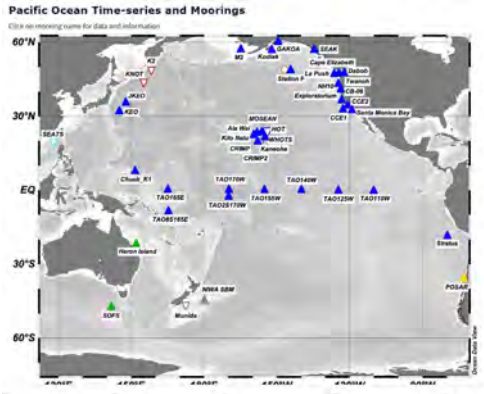
- **Description:** Standardize and build automated data QA/QC, standardization, and submission processes (including best practices and SOPs for data QA/QC, metadata, submission and long-term archival) for priority long-term monitoring programs
- **Near-term actions:** Develop SOPs for shore-based stations (Cal OOS, NERRS, diver-deployed sensors), moorings, ship-based data (e.g. Trinidad Head Line cruise data), and explore access and visualization for BGC model data (e.g. ROMS-BEC and ROMS-NEMURO outputs)
- **CO-Is/Collaborators:** CeNCOOS, SCCOOS, Axiom, SCCWRP


CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

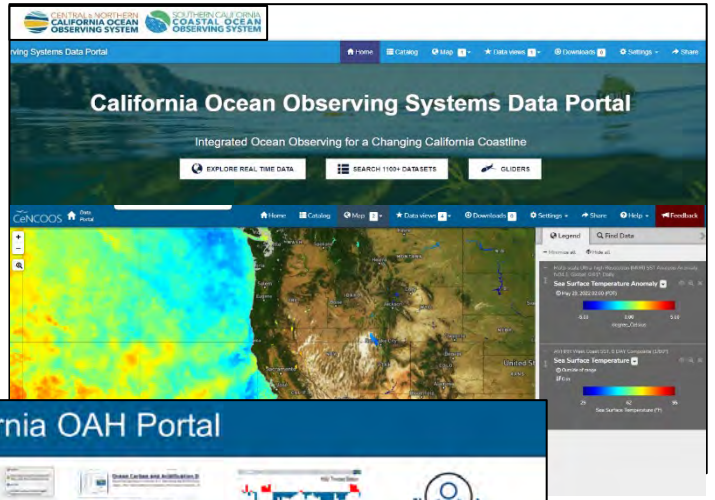
Objective 2: Streamline data ingestion

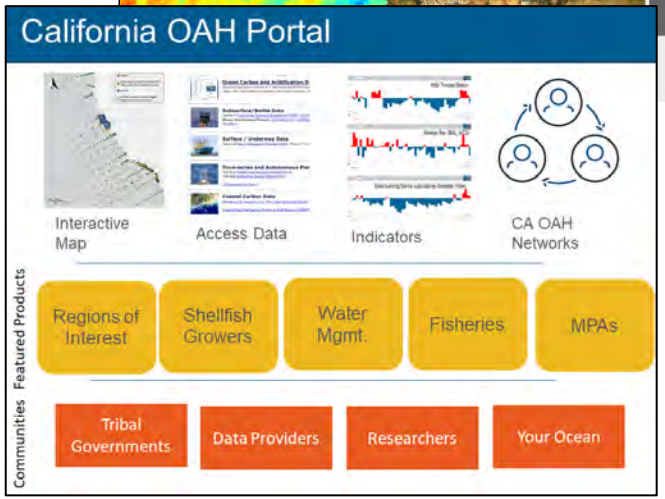
- **Description:** Provide standardized metadata and automated data submission pipelines to high-priority long-term monitoring data streams to ensure OAH and biological indicators are reliable, timely, and based on the best available science.
- **Near-term actions:** Data mining and exploration with UC Davis and "Enhancing OAH Monitoring" partners, establishing collaborative venues e.g. github and Research Workspace
- **CO-Is/Collaborators:** CeNCOOS, SCCOOS, Axiom



Objective 3: Establish statewide info hub

- **Description:** Launch a new California OAH Portal user interface (e.g. landing page branding, search tags, curated maps and data views) co-developed with managers and stakeholders.
- **Near-term actions:** Launch (internal) beta data.caloos.org/OAH landing page and portal, get community input (Y1 Q3-4) and begin to iterate; hiring new junior programmer for web app development needs.
- **CO-Is/Collaborators:** CeNCOOS, SCCOOS, NANOOS, UCSD/CalCOFI, SCCWRP





Objective 4: Develop automated products

- **Description:** Develop derived, synthesis datasets to generate a suite of automated indicators (new and developing) using both model and derived observational datasets (e.g. pH, temperature, oxygen, and plankton assemblages).
- **Near-term actions**: Continue to aggregate and explore data via “Enhancing OAH Monitoring” Project; meet with indicator development team.
- **CO-Is/Collaborators:** CeNCOOS, NANOOS, UCSD/CalCOFI, SCCWRP