Considering Ocean Acidification Impacts In California Fisheries

SUMMARY OF A SCIENCE AND MANAGEMENT WORKSHOP

NOVEMBER 29, 2018 OAKLAND, CA

OCEAN ACIDIFICATION (OA) is a complex issue that has the potential to alter marine food webs and ecosystems in California, with direct and indirect impacts to valuable marine fisheries and industries.

In response to mounting evidence of long-term ecosystem and economic impacts, fishery managers understand the urgency of addressing the impacts of ocean changes like OA (MLMA Master Plan, Chapter 11). The newly adopted *State of California Ocean Acidification Action Plan* (OA Action Plan) highlights the need to prepare for the full range of risks and impacts, as well as build resilience of affected communities, industries, and interests. However, the complex and dynamic nature of OA, coupled with nascent scientific understanding and existing resource management frameworks, make it difficult to determine where and how to act. California fisheries managers and decision-makers are currently working to understand and address the potential risks OA poses to coastal species, ecosystems, and human communities. This workshop, supported by a synthesis of species-specific impacts which outlines the current understanding of OA impacts in California, aimed to frame information in a way that is useful to decision-makers.

To advance understanding and impactful action to address effects of OA, meaningful collaboration and coordination between scientists, decision-makers, and stakeholders will be invaluable (OA Action Plan, Action 5.1). Working together they can more efficiently fill management relevant gaps in knowledge and identify effective management solutions.

KEYWORDS:
Vulnerability, Scale, Partnerships, Dynamic, Nascent, Engage, Communities

About the Workshop

Ocean Science Trust, with support from California Ocean Protection Council, convened a workshop to bring together scientists and marine resource managers to explore the concept of spatial and temporal OA "hotspots". While "hotspots" was indicated as a concept of interest in the *West Coast OAH Panel Recommendations*, a formal definition does not exist in relation to OA, and thus the term is often used and defined in different ways. The goal of this workshop was to explore the utility of "hotspots" and discuss how information about ocean chemistry change and OA vulnerability across time and space may be useful to inform fisheries management and support resilient systems in California. Participants explored practical opportunities to incorporate the current understanding of OA impacts in fisheries, and identified barriers and information needs to help us better anticipate and respond to potential changes to ecosystems, communities, and industries. As identified during the workshop, this summary presents challenges and data gaps, as well as opportunities for California natural resource managers to consider as they continue to explore ways to incorporate OA into their decision making.

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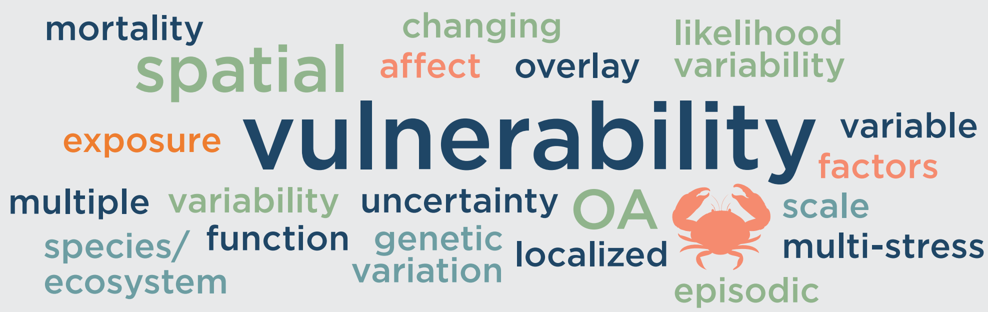


Figure 1.
Visual representation of workshop participants' electronically submitted responses to "What does OA 'hotspots' mean to you?"

Challenges and Gaps

Participants identified several challenges to acting on potential impacts of OA in a fisheries management context.

Differences in management and vulnerability among fisheries. The management structure, depth of understanding, and vulnerability to OA will vary among fisheries, and therefore the most impactful solutions will likely differ among them. This can make it challenging to prioritize where to act first and where to allocate resources. Dungeness crab and rockfish will likely experience OA very differently, have varying levels of data on population dynamics and trends, and involve a different suit of management bodies.

Differences in scales of fisheries management and scientific data. Scientific data collection and analyses, such as local monitoring and modeling, often occur at different geographic and time scales than are relevant to fisheries data and management. In addition to aligning resolution of scientific data and management, alignment and co-location of chemical and biological data collection will be necessary to address challenging questions regarding where the impacts of OA will be most intense and warrant management action, and where solutions are most likely to be effective.

Need to balance priorities and allocate limited resources. Fisheries managers must consider how to weigh short-term mandates, priorities and management needs (e.g. addressing harmful algal bloom impacts), with planning for long-term shifts, including where to allocate limited resources to begin addressing OA now. Partnerships will be critical for leveraging limited resources.

Dynamic nature of OA makes it hard to pinpoint impacts. OA is dynamic and "hotspots" may not be stable in space and time. Similarly, a location or "hotspot" due to physical conditions (e.g. low pH) may not directly translate into impacts on organisms and communities as the pH thresholds at which negative impacts manifest will likely vary among species. What may be considered a "hotspot" for one species may not be for another. OA must also be considered in combination with other interacting environmental stressors. Therefore, "hotspots" are inherently challenging to define and identify, which makes the term less meaningful in the fisheries management context. *Vulnerability* to ocean chemistry changes was a more helpful phrase in understanding the impacts and potential solutions to OA.

Understanding of OA is in early stages. The nascency of the science regarding OA impacts can make further planning for long-term changes challenging. While scientists are learning more about the direct impacts to select species, indirect ecosystem and food web impacts are less understood. Some of the key research gaps that were identified during the workshop can be found below. Additionally, the general public lacks an understanding of the potential impacts from OA and how communities will be affected. As a result, the limited interest and engagement from stakeholders around OA can make it difficult for decision-makers to act. As our understanding of the broader direct and indirect impacts of OA increases, and communication of this information increases the public's understanding, the constituency around this issue will continue to grow.

ILLUSTRATING CHALLENGES: Dungeness Crab

During the workshop, participants discussed Dungeness crab as an example of the above challenges and a case study of where and how OA considerations could be incorporated into management. Dungeness crab regulation and management is shared between the Fish and Game Commission, California Department of Fish and Wildlife (CDFW), and State Legislature. In addition to a unique management structure, Dungeness crab already face serious impacts from other environmental stressors, including harmful algal blooms (HABs). While there is evidence that suggests there will be negative impacts to crab survival due to OA, population level impacts are not fully understood. In addition to more research on OA specific impacts, understanding how growth, reproduction and survival are impacted by changing environmental conditions will allow a more comprehensive management response to the full suite of stressors. Underlying the above information needs is expanded knowledge on population status and dynamics that can help link landings data to abundance estimates (e.g. through catch per unit effort calculations), to provide a baseline for better understanding OA and other impacts.

Opportunities

As science on OA continues to advance, coordinated conversations among scientists, policy-makers, resource managers, and communities will help accelerate understanding and identify the most impactful management responses. California has the opportunity to continue it's bold leadership in addressing the impacts of OA and applying new management strategies. Workshop participants identified the following opportunities:

Adapting existing tools and actionable processes. Resource managers have existing tools that can be used to manage species vulnerable to OA impacts. These tools can be adapted and applied, individually or in unison, based on the anticipated impacts. For example, spatial management within individual fisheries (e.g. reducing/increasing fishing in certain locations, spot closures, regulations within Areas of Special Biological Significance, etc.) can help management be responsive to changing ocean chemistry. Managers could also integrate relevant OA information into Enhanced Status Reports and Fishery Management Plans (FMPs) to identify tools that will be most effective for particular fisheries. This will help managers understand how to adapt fishing regulations based on species specific impacts (e.g. size distribution and recruitment), buffer against unknown impacts, and tailor approaches for each species (e.g. stock assessments and environmental indicators that inform harvest control rules). It will also be valuable to explore how fishing communities can maintain access to fishery resources as productivity and distribution change. This may involve adjusting the regulations around permitting and access, and removing barriers to community adaptation. Management Strategy Evaluations and scenario planning are additional tools that can help managers hone in on and prioritize which management strategies will be most effective under OA and climate change. As impacts of OA will likely simultaneously affect multiple fisheries and the ecosystems on which they rely, ecosystem based management may be useful in managing the impacts across fisheries. For example, an exploration of how marine protected areas (MPAs) contribute to ecosystem resilience in the face of OA and other stressors could be incorporated into the 2022 10-year management review of marine protected areas.

Relevant research gaps and questions:

- How will OA impact specific fish stocks? What are the OA thresholds for various important species? How can we use current population estimates and OA thresholds to manage important species?
- Where and how can MPAs help build resilience to OA and other climate stressors? If species size structure increases inside an MPA, does vulnerability to climate impacts decrease? Can you model which MPAs will have an increased size structure and/or predict which will be most resilient?
- Can we model what impacts to populations will be West-coast wide?
- What portals and tools exist and where should managers and stakeholders go for information?

Strategic alignment of monitoring.
Prioritizing research projects that connect biological and chemical monitoring will aid managers in drawing more localized and direct connections about impacts to fisheries and communities, and will illuminate opportunities to build resilience and respond effectively. For upcoming scientific projects to be relevant to decision making, it is essential that they are coordinated with management to ensure the scale at which data are collected (i.e. how many sites? where? in real time?) and the measurements used align with management (i.e. is size or fecundity more informative to management?)

Relevant research gaps and questions:

- How can we effectively pair chemical and biological monitoring alongside habitat suitability modeling to understand where species might move and where impacts will be felt in the future?
- Will larvae distribution and recruitment change in space and time under climate change? How? (discussed for Dungeness crab specifically, but important in many other species)
- What is missing in the West Coast OA monitoring inventory (e.g. gaps analysis)?
- What measures of stress are most helpful for the management of different species and ecosystems (i.e. is using the mean or maximum/minimum of OA measurements most impactful to fisheries? over what time periods)?

Understanding vulnerability and multi-stressor impacts to species of management concern.
Understanding where and when chemical changes are likely to be most intense, and the resulting impacts of these changes, could help managers prioritize which species are most at risk and inform spatial fisheries decisions (e.g. closures, adjusting take, adapting communities, etc.). Scientists, resource managers, and communities can collaborate to identify high priority local case studies - locations or specific fisheries - for which to develop a synthesis of current understanding, decision support tools, and management strategies. In addition, developing vulnerability and risk assessments - of species and communities - that incorporate uncertainty and can be updated as new science is conducted, will be highly valuable in honing in on where to act in the face of uncertain and complex ocean changes. Even with growing understanding of processes and drivers, we are entering an era where uncertainties should be expected. Risk assessments can aid management in a way that buffers the unexpected when it happens. Making progress towards understanding spatial considerations of multiple stressors (e.g. OA and HABs overlaps and linkages) will more holistically address fisheries vulnerabilities. Access to in-depth information and diverse perspectives, including community perspectives and traditional and indigenous knowledge, will help support identifying important vulnerabilities and crafting more robust solutions.

Relevant research gaps and questions:

- What species and communities are most likely to experience negative consequences or have access to new opportunities? Does California have enough data to manage them sustainably from both a species and human community perspective?
- What are the locations of highest vulnerability to OA impacts or highest probability of experiencing OA outside of “normal” variation? Where are there locations that experience confluence of multiple climate stressors? What is the natural variability of OA along the coast?
- How will OA impacts to species and ecosystems manifest in the field and in combination with other environmental stressors?
- What are the synergistic effects of climate stressors and fishing pressure changes? Will there be extra pressure put on fisheries which are not as impacted by OA when others show declines due to climate impacts? Can OA impacts be mediated through the management of other climate impacts (e.g. HABs)?
- Can understanding one environmental stressor (e.g. HABs) help us understand another (e.g. OA)? Are there similar spatial impacts and/or are they linked in when and where they occur?

Preparing and engaging communities.
Establishing preparedness and understanding of vulnerability in communities can help managers respond more efficiently. Building on current partnerships and discussions between resource managers, decision-makers, scientists, and other partners regarding scenario planning and community impacts will be a key next step in addressing the social and economic impacts of OA and other climate driven ocean changes. Engagement and knowledge built through upcoming projects identifying the "geography of stress" will also help identify vulnerable communities. Through these efforts, as well as others (e.g. public communications around new scientific knowledge, legislative briefings, and sharing with groups like the Dungeness crab Task Force), communications with stakeholders will be invaluable in building a constituency around the issues of OA in fisheries and potential implications. This constituency is an essential tool for the success of future efforts to develop thoughtful and impactful action.

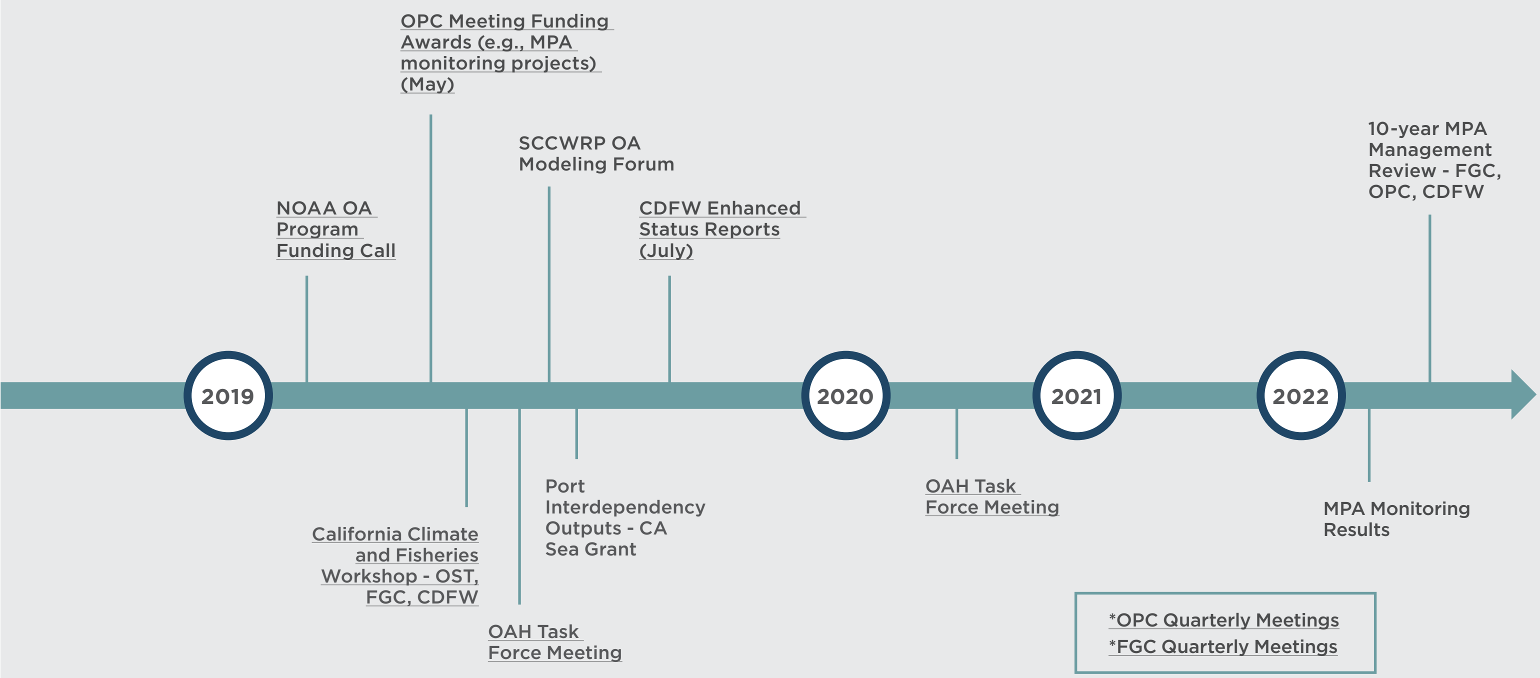
Relevant research gaps and questions:

- What are the social and economic impacts to fisheries from OA and other climate stressors, especially for economically and culturally important species like Dungeness crab?
- What communities are going to be most sensitive to climate change?

Guiding policies, scientific support, and coordination.
California has been a leader in building momentum around the issue of OA and developing science-based actions to mitigate and manage for impacts, resulting in the newly adopted *OA Action Plan*. Through the Action Plan's guidance and implementation, the State will actively work to integrate these actions into public agency operations and decisions made by members of the private sector and scientific community. California is also uniquely positioned to link science and management needs through the *California OAH Science Task Force*. This body will continue to serve as a venue for tracking evolving OA science and building capacity and readiness for emerging science through connecting findings with fisheries managers, decision-makers, and other end users. Continued coordination will help guide science to ensure relevance to management priorities and future planning, helping California to be proactive as opposed to reactive. It would be valuable to convene a regular meeting or forum (including scientists, managers, policymakers, tribes, etc.) to share updates on lessons learned, discuss the current state of knowledge and management actions, consider integration across efforts, and to explore how to make new learning actionable.

Moving Forward

We are likely entering an era where uncertainties should be expected and successful management buffers the unexpected when it happens. Science is constantly evolving and we now know more than we did just a few years ago, but the challenge of OA continues to build. Continuing the conversations that occured during this workshop, regularly and with a diverse set of participants, will be necessary to identify the most impacted species and communities, and to tackle fisheries management questions under OA and other changing ocean conditions. Understanding vulnerabilities and addressing impacts at the appropriate scale will require forging new partnerships and building on existing ones, while allocating resources and answering questions strategically. While there are still many questions left to answer, this workshop provided a venue for scientists and marine resource managers to advance the discussions around potential actions and needed information to address OA impacts in fisheries management.



ONGOING PROJECTS (1-3 YEARS)

- NOAA OA Program Projects
- Climate Vulnerability Assessments: *Federally Managed Species*
- Dungeness Crab Lab Work
- MPA Effectiveness
- Geography of Stress
- Santa Barbara Channel: *OA in Aquaculture & Fisheries*
- Seagrass (statewide, Humboldt)
- Southern California Coastal Water Research Project (SCCWRP) OA Models
- West Coast OA Monitoring Inventory

RELEVANT OPC FUNDING

- MPA Monitoring
- Once Through Cooling Mitigation
- Prop 68
- Find current opportunities here

Figure 2.
Timeline of OA relevant scientific research projects, meetings and management activities (2019-2022) discussed during the workshop, not a comprehensive list.

Workshop Participants

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Resources

Projects discussed during the workshop.

- Impacts of ocean acidification on California's living marine resources
- Geography of stress: Impacts of ocean acidification along the California Coast
- MPA effectiveness and ecological responses in the face of changing ocean conditions
- Integrated modelling of California's coastal ocean to inform ocean acidification and hypoxia policy (more here)
- Risks of ocean acidification in the California Current food web and fisheries: ecosystem model projections (accompanying infographic)
- Consequences of spatially variable ocean acidification in the California Current: Lower pH drives strongest declines in benthic species in southern regions while greatest economic impacts occur in northern regions (accompanying presentation and infographic)
- Estimates of the direct effect of seawater pH on the survival rate of species groups in the California current ecosystem
- Elevated CO_2 impairs olfactory-mediated neural and behavioral responses and gene expression in ocean-phase coho salmon *(Oncorhynchus kisutch)*
- Ocean acidification monitoring - including Burkeolators
- C-HARM model for domoic acid monitoring