Understanding Ocean Acidification Impacts to California’s Living Marine Resources

HELPING THE STATE VISUALIZE WHAT’S AT STAKE AS OCEANS ACIDIFY

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Motivation

I. OA is a complex issue for a variety of reasons

II. Scientists have learned A LOT over 15 years
   i. There is still much to be discovered

III. Newest scientific data often not available to managers in accessible format

IV. This makes management around OA challenging

V. California policy-makers are starting to act on OA
Project Overview

**Project Goal:**
Help California understand the potential impacts of ocean acidification to marine resources to inform relevant and impactful management and policy actions.

Support resource managers in addressing **WHERE** and on **WHAT** to act:
- Which California marine species are most at risk with OA?
- Where geographically are these impacts most likely to manifest?
Impacts of Ocean Acidification on California Living Marine Resources

Ocean acidification is already impacting important species and ecosystems in California. Visualizing these impacts can help state resource managers understand what's at stake as oceans acidify.

### Benthic Invertebrates

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Calcification</th>
<th>Growth</th>
<th>Reproduction</th>
<th>Survival</th>
<th>Behavior</th>
<th>Ecosystem Role</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Mussel</td>
<td>U</td>
<td>NE</td>
<td>M</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Dungeness Crab</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
<tr>
<td>Ochre Sea Star</td>
<td>M</td>
<td>M</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Olympia Oyster</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
<tr>
<td>Pacific Oyster</td>
<td>M</td>
<td>M</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Purple Sea Urchin</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
<tr>
<td>Red Sea Urchin</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Red Abalone</td>
<td>M</td>
<td>M</td>
<td>NE</td>
<td>I</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
</tbody>
</table>

**Key**
- Increase: ▲
- Decrease: ▼
- Mixed Results: ● (unknown, insufficient data)
- No Effect: △
- Unknown (not studied): *

**Ecosystem Role**
- Predator: ▲
- Engineer: ●
- Food Web Link: ▲

**Economic Importance**
- Commercial: C
- Recreational: R

### Pelagics

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Calcification</th>
<th>Growth</th>
<th>Reproduction</th>
<th>Survival</th>
<th>Behavior</th>
<th>Ecosystem Role</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krill (CA spp)</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
<tr>
<td>Market Squid</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>M</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
<tr>
<td>Ptenosud (CA spp)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>I</td>
<td>U</td>
<td>▲ ▲</td>
<td>C</td>
</tr>
</tbody>
</table>

**Ecosystem Role**
- Biogenic: ▲
- Phytoplankton: ●
- Food Web Link: ▲

**Economic Importance**
- Commercial: C

### Finfish

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Activity</th>
<th>Calcification</th>
<th>Growth</th>
<th>Reproduction</th>
<th>Survival</th>
<th>Behavior</th>
<th>Ecosystem Role</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabezon</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Blue Rockfish</td>
<td>NE</td>
<td>NE</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Copper Rockfish</td>
<td>NE</td>
<td>NE</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Gopher Rockfish</td>
<td>NE</td>
<td>NE</td>
<td>U</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
</tbody>
</table>

**Ecosystem Role**
- Predator: ▲
- Engineer: ●
- Food Web Link: ▲

**Economic Importance**
- Commercial: C

### Submerged Aquatic Vegetation

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Photosynthesis</th>
<th>Calcification</th>
<th>Growth</th>
<th>Reproduction</th>
<th>Survival</th>
<th>Behavior</th>
<th>Ecosystem Role</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eelgrass</td>
<td>NE</td>
<td>M</td>
<td>M</td>
<td>NE</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
<tr>
<td>Giant Kelp</td>
<td>NE</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>U</td>
<td>U</td>
<td>▲ ▲</td>
<td>C, R</td>
</tr>
</tbody>
</table>

**Ecosystem Role**
- Predator: ▲
- Engineer: ●

**Economic Importance**
- Commercial: C

**Funding Provided by**
- Ocean Protection Council
- S.C. Davis Science and Marine Sciences Institute
- Monterey Bay Aquarium Foundation

**References**

**Further Information**
http://www.oceansciencetrust.org/projects/oactionplan

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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 change, like OA (MLMA Master Plan, Chapter II). 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 S.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 OA Advisory Group 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.

Understanding of OA is in early stages. The nascentness 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.
Annaliese Hettinger

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Whitney Berry Kerry Nickols
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Impacts of Ocean Acidification on Alaska Fish & Shellfish

Ocean acidification is expected to negatively impact species in Alaska. This research reflects results from peer reviewed literature.

Resident Alaska species whose responses to ocean acidification have not been studied:

- Top commercial value
  - Pacific cod
  - Sockeye salmon
  - Snow crab
  - Pink salmon
  - Pacific halibut
  - Sablefish
  - Chinook salmon
  - Alaska pollock
  - Yellowfin sole
  - Pacific rockfish
  - Black cod
  - Rock halibut
  - Pacific scallop

- Highest biomass in bottom trawl surveys
  - Pacific ocean perch
  - Giant redleg
  - Abalone
  - Pacific sleeper shark
  - Yelloweye sole
  - Redmouth rockfish
  - Gooney rockfish
  - White sea urchin
  - Arrowtooth flounder
  - Pacific kelp
  - Okkiskol rockfish
  - Doradito orange sole
  - Sharpnose rockfish
  - Blue rockfish

- Other important species
  - Braided salmon
  - Giltweed
  - Crescent gaper
  - Dulcy vire
  - Longnose mackerel
  - Snowy whitefish
  - Pacific sand lance
  - Rainbow trout
  - Threespine stickleback
  - Sabletile shrimp

Ecosystem Role

<table>
<thead>
<tr>
<th>Ecosystem Role</th>
<th>Resident marine species</th>
<th>Response to Ocean Acidification</th>
<th>Economic Importance/ Food Security</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Calcification</td>
<td>Growth</td>
</tr>
<tr>
<td>Predator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Tanner crab</td>
<td></td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>Red king crab</td>
<td></td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>Pink salmon</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Dungeness crab</td>
<td></td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>Blue king crab</td>
<td></td>
<td>Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>Northern rock sole</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>WALLEYE POLLOCK</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Northern shrimp</td>
<td></td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>Pteropod</td>
<td></td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>BALTIC CLAM</td>
<td></td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>Pinto abalone (EM)</td>
<td></td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>Common cockle</td>
<td></td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>Red sea urchin</td>
<td></td>
<td>U</td>
<td></td>
</tr>
</tbody>
</table>

*Non-Alaska populations studied

KEY: Increase, Decrease, Equilibrium, N/A, Not applicable, Unknown, Only current populations

NOTE: The species listed in the table above are the only Alaska species that have been studied to date.

References:
Commercial, recreational, and subsistence fishing: ADFG Subsistence Reporting 2014

Acknowledgements:
Results from peer reviewed literature. Data compiled by the Kelley Lab at the University of Alaska Fairbanks.
Partners: Alaska Ocean Acidification Network, Oregon Acidification Research Center, Alaska Fisheries Science Center (NOAA Fisheries)

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