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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Ocean Science Trust

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 aid state resource managers in understanding what's at stake as oceans acidify.

Benthic Invertebrates

SPECIES COMMON NAME	RESPONSE TO OCEAN ACIDIFICATION: Calcification	Growth	Reproduction	Survival	Behavior	ECOSYSTEM ROLE	ECONOMIC IMPORTANCE
California Mussel	↓	↓	U	↓	U	■	R
Dungeness Crab	U	NE	M	↓	U	▲ ●	C, R
Ochre Sea Star	↓	↓	U	U	U	▲	
Olympia Oyster	↓	↓	U	↓	U	■	C, R
Pacific Oyster	↓	↓	U	↓	U		C
Purple Sea Urchin	M	↓	M	M	U	■ ●	C, R
Red Sea Urchin	U	↓	↓	↓	U	■ ●	C, R
Red Abalone	U	↓	↓	M	U	●	R

Pelagics

SPECIES COMMON NAME	RESPONSE TO OCEAN ACIDIFICATION: Calcification	Growth	Reproduction	Survival	Behavior	ECOSYSTEM ROLE	ECONOMIC IMPORTANCE
Krill (CA spp)	U	M	U	M	U	●	
Market Squid	↑	U	↓	↓	U	▲ ●	C
Pteropod (CA spp)	↓	U	↓	↓	I	●	

Finfish

SPECIES COMMON NAME	RESPONSE TO OCEAN ACIDIFICATION: Activity	Growth	Reproduction	Survival	Behavior	ECOSYSTEM ROLE	ECONOMIC IMPORTANCE
Cabezon	U	NE	U	NE	U		C, R
Blue Rockfish	NE	NE	U	NE	NE	▲	C, R
Copper Rockfish	↓	NE	U	NE	I	▲	C, R
Gopher Rockfish	↓	NE	↓	NE	I	▲	C, R

Submerged Aquatic Vegetation

SPECIES COMMON NAME	RESPONSE TO OCEAN ACIDIFICATION: Photosynthesis	Growth	Reproduction	Survival	ECOSYSTEM ROLE	ECONOMIC IMPORTANCE
Eelgrass	↑	M	↑	U	■	
Giant Kelp	NE	M	M	NE	■	C, R

KEY

- ↑ Increase
- ↓ Decrease
- M Mixed Results (Increased, Decreased, No Effect)
- NE No Effect
- U Unknown (Not Studied)
- I Impacted
- ▲ Predator
- ■ Engineer
- ● Food Web Link
- C Commerical
- R Recreational

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REFERENCES
http://bit.ly/OAReferences

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

- California Spiny Lobster*
- Pacific/Ocean Pink Shrimp*
- California Spot Prawn
- Brown/Pacific/California Rock Crab
- Red Rock Crab
- Warty Sea Cucumber
- Giant Red Sea Cucumber
- Giant Keyhole Limpet
- Purple Hinged Rock Scallop*
- Pacific Geoduck*
- Lingcod
- California Sheephead
- Chinook Salmon
- Steelhead (Coastal Rainbow Trout)
- Coho Salmon*
- California Halibut
- Pacific Jack Mackerel
- Pacific Herring
- Night Smelt
- Shiner Surfperch
- California Grunion*

** indicates work in progress.*

NOTE: This is not an exhaustive list.

FURTHER INFORMATION
http://bit.ly/OAimpacts

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UC DAVIS Coastal and Marine Sciences Institute Bodega Marine Laboratory

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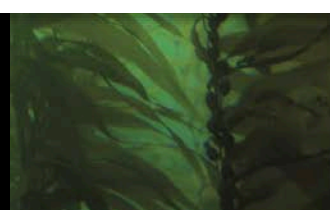

development of a comprehensive inventory of areas in California vulnerable to OA.

Learn more about OA in CA:
http://www.oceansciencetrust.org/projects/oaactionplan

1. Eastern Research Group, Inc (2016) The national significance of California's ocean economy. NOAA. https://coast.noaa.gov/data/digitalcoast/pdf/california-ocean-economy.pdf.

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?"

ng on potential impacts of OA in a

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.

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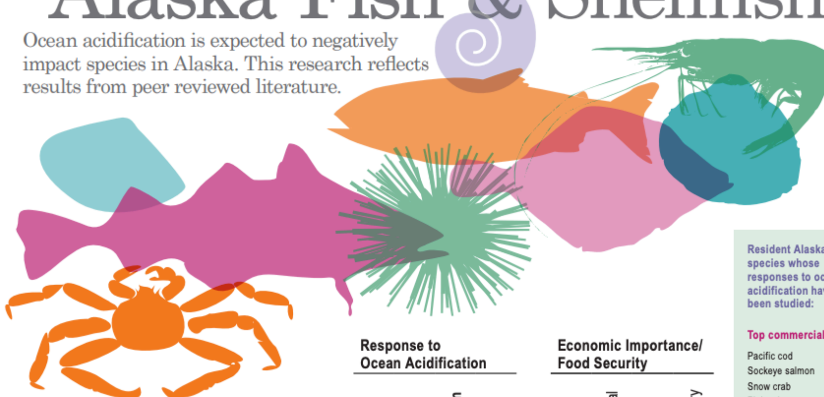
Alaska Ocean Acidification Network

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.



Ecosystem Role	Resident marine species	Calcification	Growth	Reproduction	Survival	Commercial	Sport/personal	Subsistence	Closed Fishery
Predator	Southern Tanner crab	↓	↓	↓	↓	●	●	●	◒
Predator	Red king crab	↓	↑	↓	↓	●	●	●	◒
Predator	Pink salmon*	N/A	↓	↓		●	●	●	
Predator	Dungeness crab*	U	↓	—	↓	●	●	●	
Predator	Blue king crab		↓	U	↓	●		●	◒
Food Web Link	Northern rock sole*	N/A	↓	U	↓	●		●	
Food Web Link	Walleye pollock*	N/A	—	U	—	●		●	
Food Web Link	Northern shrimp*	U	↓	U	↓	●		●	
Food Web Link / Chemical / Nutrient Cycling	Pteropod*	↓	↓	U	U				
Habitat Forming	Baltic clam*	↓	↓	↓	↓		●	●	
Chemical / Nutrient Cycling	Pinto abalone* (endangered)	U	U	U	↓				●
Chemical / Nutrient Cycling / Habitat Forming	Common cockle*	↓	↓	U	U		●	●	
Ecosystem Engineer	Red sea urchin*	U	U	↓	U			●	

Columns grouped as: Response to Ocean Acidification (Calcification, Growth, Reproduction, Survival); Economic Importance/ Food Security (Commercial, Sport/personal, Subsistence, Closed Fishery)

Non-Alaska populations studied

KEY: ↑ Increase ↓ Decrease — Equilibrium N/A Not applicable U Unknown ◒ Only certain populations

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

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
- Chum salmon
- Atka mackerel
- Yellowfin sole
- Pacific rockfish
- Chinook salmon
- Coho salmon
- Rock sole
- Rockfishes
- Pacific herring

Highest biomass in bottom trawl surveys

- Pacific ocean perch
- Giant grenadier
- Atka mackerel
- Pacific sleeper shark
- Salmon shark
- Yellowfin sole
- Redstripe rockfish
- Canary rockfish
- White sea urchin
- Arrowtooth flounder
- Pacific hake
- Shortaker rockfish
- Clonal plumose anemone
- Sharpshin rockfish
- Silvergray rockfish

Other important species

- Broad whitefish
- Capelin
- Crescent gunnel
- Dolly varden
- Longfin smelt
- Ninespine stickleback
- Pacific sand lance
- Rainbow smelt
- Threespine stickleback
- Sidestriped shrimp

References:

Commercial, recreational, and subsistence listing: ADFG Subsistence Reporting 2014 Statewide: http://www.adfg.alaska.gov/sb/CSIS/index.cfm?ADFG=main.home.
Commercial value data: NMFS. 2015 Fisheries of the United States. Current Fishery Statistics No. 2015. National Marie Fisheries Service Office of Science and Technology. Alan Lowther & Michael Liddel, Editors. Silver Spring, MD.
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