Opportunities Within Existing Policies to Support Shellfish Growers' Adaptive Capacity to Ocean Acidification on the U.S. West Coast

KEY MESSAGES

- Authors found an evolution of policy over time from a focus primarily on collecting information through science and monitoring, to taking more direct actions to aid marine and coastal communities in responding to OA through permitting, networking, and education.
- Existing U.S. State and Federal policies that pertain to OA may enhance the adaptive capacity of shellfish growers to rapid environmental change (e.g., Oregon H.B. 2209 and Infrastructure Investment and Jobs Act (2022), respectively).
- There are opportunities to support and advance adaptive strategies without policy action or change, from within existing policies, and potential with new policies (e.g., renewal of the Agriculture Improvement Act of 2018 to improve crop insurance for shellfish growers). Furthermore, not every strategy needs to be addressed with policy (e.g. networking within the shellfish industry and through academic partnerships).
- It is necessary to collaborate and consult with agency staff to determine if there are additional opportunities outside of written policy and to arrive at a set of actionable recommendations to advance shellfish grower adaptive strategies.

Many commercially-important shellfish species are sensitive to ocean acidification (OA), the decline in ocean pH levels caused by increased anthropogenic carbon absorption.[1] Coastal communities in California and Oregon are particularly vulnerable to OA due to their socioeconomic dependence on marine resources as well as their geographic location along OA "hot spots".[3] As OA continues to threaten coastal economies and livelihoods, policy interventions may be needed to address the impacts of OA and to support coastal communities in adapting to and coping with its consequences.

Federal and state decision-makers have already implemented several policies to address OA. Federal OA policies, such as those included in the Magnuson-Stevens Fishery Conservation and Management Act of 1976 and the Federal Ocean Acidification Research and Monitoring Act, improved monitoring of OA and coastal community impacts, disaster relief for impacted fisheries, and established the Interagency Working Group on Ocean Acidification (to coordinate OA research and monitoring).[4] State governments have also initiated their own policies to address OA.[5] As founding member states of the Pacific Coast Climate leadership and International Alliance to Combat Ocean Acidification (OA Alliance), both California and Oregon became some of the first states in the OA Alliance to develop statewide OA Action Plans in 2018 and 2019, respectively.[6,7] Both California and Oregon are currently implementing such action plans through funding research and supporting communities and industries facing OA impacts. Given increasing levels of OA and associated impacts on coastal communities, it is imperative to identify opportunities where existing policies could continue to support shellfish growers' **adaptive capacity (*i.e., the ability to respond and adapt)*** to OA. Moreover, recognizing opportunities for policy expansion is crucial to enhance the ability of shellfish growers to adapt to OA.

Previous work by Ward et al. (2022) and Green at el. (2023) identified shellfish grower adaptive strategies that were classified into three main categories: (1) **science** (2) **farm management** and (3) **policy and networking**.[8,9] Researchers from Oregon State University and San Diego State University (Wolters et al. 2025) developed an analytical framework **to determine alignment between existing state and federal policies (e.g. legislation, action plans, task forces) and those previously identified adaptive capacity strategies of shellfish growers**. Authors compiled a dataset of written policies related to OA through searching legislative databases and reviewing OA action plans and task force documents from federal and state levels (California and Oregon). Keywords like "ocean acidification" and "acidifying" were used to identify relevant bills. Further searches within these documents for terms like "coastal community" or “coastal stakeholder” helped pinpoint policies that mentioned communities. Federal legislation such as the Clean Water Act was also intentionally included for its direct and indirect impact on OA. Finally, the identified documents were reviewed to align policy with the adaptive strategies identified by shellfish growers.

ALIGNMENT OF ADAPTATION STRATEGIES WITH EXISTING POLICIES

Wolters et al. 2025 linked the adaptive strategies identified by growers to existing federal and state policies related to OA, organized by the three main categories of strategies identified by growers as important for adaptive capacity: (1) **science** (2) **farm management** and (3) **policy and networking** (see Appendix). Their review demonstrates the **progression of policy over time** from a focus primarily on collecting information through science and monitoring, to taking **more direct actions** to aid marine and coastal communities in responding to OA through permitting, networking, and education. Below are existing policies where adaptive strategies are currently supported according to Wolters et al. 2025.

Science

There are multiple federal and state legislation that promote OA monitoring and research, either through the direct investment of science or the creation of entities to administer funds for research.

- Executive Order 13547 (2010) created U.S. National Ocean Policy, promoting a science-based planning approach to build capacity to address climate change and OA.
- Inflation Reduction Act (2022) allocated $14 million to research OA and mitigation of impacts on coastal economies and communities.
- California OA and Oregon OAH action plans aim to build scientific understanding of OA to support shellfish industries, with entities like the California Ocean Protection Council and Oregon Ocean Science Trust funding scientific efforts to build that understanding and promoting partnerships with shellfish growers.

Farm Management

Wolters et al. 2025 did not identify any federal policies pertaining to farm management. However, California and Oregon shellfish growers frequently mentioned flexibility in culture methods, species or life stages, or culture location as potential strategies to bolster adaptive capacity to OA. Oregon OAH Action Plan and California OA Action Plan both suggest integrating shellfish farming with submerged aquatic vegetation (e.g., coupling oyster farming with

seagrass) for carbon sequestration, with ongoing research aimed at establishing best management practices for this co-production approach.[6,7]

Policy & Networking

Authors suggest that legislative support, real-time data access, collaborative efforts (e.g., among industry, community, academics, and agencies), and addressing permitting challenges will enhance the resilience and adaptive capacity of shellfish growers. Table 1, below, includes a subset of identified policies and potential adaptive capacity alignment. Note that the table does not include federal funding that has allowed for the creation of supportive programs like Oregon Sea Grant and California Sea Grant, both of which provide extension agents to share research and information with local communities. Furthermore, in 2023, NOAA and the National Oceanic Partnership Program announced $24.3 million for academic, agency, and industry collaboration on reducing carbon dioxide in marine environments.

Table 1: A subset of existing state and federal policies that align with and support grower-identified adaptive strategies.

Guiding document	Potential Adaptive Capacity Alignment
Executive Order 13921 (2020)	Requires the National Oceanic and Atmospheric Administration (NOAA) to identify and address aquaculture permitting barriers.
Infrastructure Investment and Jobs Act (2022)	Allocated $3.9 million to the West Coast Ocean Alliance (WCOA). Funds will be used to create an aquaculture inventory and an ocean health dashboard and data portal to aid in decisions about new siting, or relocation of current farms, and provide an accessible data portal for real-time ocean health information.
Oregon's H.B. 2784 of 2017, California's Fish and Game Code §15502 et seq. 2022	Ongoing efforts to simplify permitting through the designation of lead agencies and reduction of administrative barriers.
2018 State of California Ocean Acidification Action Plan 5.1 (CA) 2018 OAH Report Action 2019 OAH Action Plan Steps 4.2.2, 4.2.b	Both plans focus on networking (connecting industry, community, academic, and agencies) and shellfish industry engagement (promoting partnerships, monitoring capacities, and science-based practices) to help shellfish growers quickly adapt to OA conditions.[6,7] This includes establishing advisory boards, sharing information, and providing technical support to communities affected by OA.

OPPORTUNITIES TO SUPPORT ADAPTIVE STRATEGIES

Adaptive capacity can be supported by federal and state policy efforts through legislation, action plans, councils, and task forces. As Wolters et al. 2025 suggests, there are additional opportunities at the federal and state level that can further support the adaptive capacity of shellfish growers in California and Oregon beyond what is currently being done. Below is a summary of opportunities suggested by Wolters et al. 2025.

Directed OA Funding
Directing funding and resources to OA, such as directed funding in legislation, can help overall adaptive capacity of shellfish growers via research and monitoring (e.g., the proposed Federal Coastal and Ocean Acidification Stressors and Threats Research Act of 2021 would have come with funding and creation of an advisory board to aid in coordination and networking).

Expand Existing Programs
The authors suggested that legislative efforts could be proactive in providing safeguards against the impact of OA on shellfish aquaculture. Insurance programs and disaster relief programs offer financial security against acute natural disasters, thus increasing shellfish grower resilience. However, there are opportunities to continue to expand the following programs to address chronic OA impacts:

- Emergency Assistance for Livestock, Honey Bees and Farm-raised Fish Program (ELAP)
- Noninsured Crop Disaster Assistance Program (NAP)

There have also been efforts to expand crop insurance for shellfish grouping (e.g., Agriculture Improvement Act of 2018, USDA pilot crop insurance program).

Renew Legislation
Along with potential expansion of existing programs, authors suggest that renewal of legislation pertaining to OA would bolster shellfish grower adaptive capacity. Taking advantage of the renewal of the Farm Bill would increase financial security for national shellfish aquaculture. Although not active and would need to be reintroduced, the Sustaining Healthy Ecosystems, Livelihoods, and Local Seafood Act (SHELLS) Act (H.R. 3951) would create an Office of Aquaculture within the USDA and set up an advisory committee of policy makers, tribal representatives, producers, and scientists. If enacted, SHELLS could provide more flexibility in shellfish farm management.

Continued State Level Action
It is evident that state level actions have been vital in addressing OA in their coastal communities through policy, networking, and funding. The California Ocean Acidification Action Plan and Oregon Ocean Acidification and Hypoxia Action Plan address numerous adaptive capacity tools that may improve shellfish grower adaptive capacity to OA such as networking to integrate science, farm management, and policy. Funding examples include:

- California A.B. 65 (2019) which provides funding for coastal climate change adaptation strategies including projects promoting OA adaptive capacity
- Oregon H.B. 3114 provides over $1 million in grants for OAH monitoring, workshops, and seminars for shellfish proliferation, etc.

Continued funding for implementation of state OA action plans would contribute to sustained action and resilience to OA.

Promote Networking and Information Sharing
As stated by the authors, not every strategy needs to be addressed by policy. Networking is a viable strategy that will encourage collaboration within the shellfish industry, scientific

organizations, and agencies to share information. Authors also stressed that it is imperative to address the gap between science and practical application. Practical adaptation for shellfish growers can be supported by more effective translation to grower adaptation, information dissemination, and greater compatibility between scientific monitoring scales and farm operation monitoring needs. Data accessibility may include distributing lists of resources, developing a centralized repository for real-time OA information, and facilitating quick access for growers to adapt to changing conditions. Supporting monitoring networks like the U.S. Integrated Ocean Observing System (IOOS) can also provide timely data on ocean conditions, allowing growers to adjust practices accordingly.

CONCLUSION

With anthropogenic carbon emissions on the rise, it is important to act on existing policy to support the adaptive capacity of shellfish growers in California and Oregon in the face of increasing OA. Overall, adaptive capacity is built by fostering community resiliency and reducing vulnerability to change. Enhancing adaptive capacity to OA and its impacts through policy, management, and science will enable growers to adapt more effectively and sustain an important economic sector in California and Oregon.

This paper was a review of existing written OA-specific policies and demonstrated that there are notable opportunities to support adaptive strategies using these policies, with some initiatives already in progress. However, additional opportunities to advance strategies within the framework of current policies remain underutilized. Furthermore, it is worth noting that some effective strategies might not require formal policy changes and should be explored further. To fully leverage potential policy opportunities, it is crucial to engage directly with state agency staff to uncover insights and possibilities that extend beyond the written policies analyzed in this study.

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APPENDIX:

Grower Adaptation strategies and Legislative, Executive Order, Agency, Council, or Task Force Adaptive Capacity alignment. From Wolters et al. 2025.

Grower Adaptation Strategies	State	Guiding Document	Potential Adaptive Capacity Alignment
Science	OR	2017 Relating to Ocean Chemistry (S.B. 1039)	Created the Ocean Coordinated Council on Ocean Acidification and Hypoxia (OAH Council). Declares state policy on OAH; supports science and monitoring
Science	OR	2020 Oregon Executive Order 20-04	Directs Oregon State Agencies to work to reduce and regulate greenhouse gas emissions to mitigate climate and ocean change, including Ocean Acidification and Hypoxia (OAH)
Science	OR	2021 Relating to ocean chemistry; and declaring an emergency (H.B. 3114)	Provides funding for purposes related to ocean chemistry, including over $1 million in competitive grants for OAH monitoring, workshops, and seminars for shellfish proliferation, etc.
Science	CA	2008 California Ocean Protection Act (S.B. 1319)	Established a permanent Ocean Protection Council that conducts research, funds science, and develops strategic plans
Science	CA	2016 Ocean Protection Council: Ocean Acidification and Hypoxia (S.B. 1363) Amended	Early progress on SB 1363 included OPC investments in OA monitoring in seagrass beds and convening of an OPC Science Advisory Team working group to explore the use of seagrass as an ocean acidification management tool in CA
Science	CA	2016 Ocean Protection Council: Ocean Acidification and Hypoxia (A.B. 2139) Amended	Develop an Ocean Acidification and Hypoxia task force to address OAH science and monitoring
Science	Fed	2009 Federal Ocean Acidification Research and Monitoring Act (FOARAM)	Created an Interagency Working Group on Ocean Acidification (IWGOA) to coordinate OA research and monitoring across federal agencies
Science	Fed	2010 Executive Order 13547	Created the U.S. National Ocean Policy (NOP) that seeks a science-based holistic planning approach to address climate change and ocean acidification
Science	Fed	2022 Inflation Reduction Act	Allocated $14 million to research OA and mitigation of impacts on coastal economies and communities
Farm management	OR	2018 OAH Report Action Steps 3.1, 3.3 (Research and Monitoring, Farm Management)	Research on maintaining shellfish farm resiliency through co-production/growth of submerged aquatic vegetation (SAV), develop best management practices (BMPs)
Farm	CA	2018 State of California Ocean	Provide “extension-type” of technical support that could

Grower Adaptation Strategies	State	Guiding Document	Potential Adaptive Capacity Alignment
management		Acidification Action Plan 5.1.4 (Farm Management)	accelerate OA into operations of shellfish communities.
Farm management	CA	2018 State of California Ocean Acidification Action Plan 5.2 (Research and Monitoring, Farm Management)	Build resiliency of the aquaculture community by working on solutions to OA induced problems, improve, and enhance monitoring of OA at shellfish farms to allow industry to respond, and provide greater access to OA information at state and federal level.
Farm management	CA	2018 State of California Ocean Acidification Action Plan 5.3 (Research and Networking, Farm Management)	Build resilience into shellfish aquaculture by improving knowledge of how OA impacts industry, and how to respond, integrate into management decisions, and provide information to shellfish farms in a useful, applied manner.
Policy and networking	OR	2019 OAH Action Plan Theme 4 – Step 4.2.2 (Networking)	OAH Council convenes "State of OAH" workshops for communities on OAH science, impacts, and solutions with policy makers as well as communities and at-risk industries
Policy and networking	OR	2018 OAH Report Action 4.2.b At-risk industries and professions (Networking)	Report that guides the State to: 1. Communicate with industries affected by OAH to improve collaborative solutions 2. Facilitate round tables and workshops with seafood industry processors, producers, fishermen, and retailers 3. Create outreach materials highlighting OAH science
Policy and networking	OR	H.B. 2209 (2015) (Networking) (Permitting)	Created a Joint Interim Task Force on Oregon Shellfish to develop the Oregon Shellfish Initiative that established the ODA as the lead state agency for permitting and advanced networking opportunities through education
Policy and networking	CA	Fish and Game Code §15502 et seq. (Permitting)	Established an aquacultural coordinator within the California Department of Fish and Wildlife, also created the Aquaculture Development Committee (ADC) as a multiagency, academic and industry committee to assist with aquaculture opportunities and barriers
Policy and networking	CA	2018 State of California Ocean Acidification Action Plan Action 5.1 (Networking)	Engage interested parties from across the public and private sectors to share learning and take action to address OA
Policy and networking	Fed	1997 National Oceanographic Partnership Act (H.R. 3303)	Funds ocean science research pertaining to climate changes and marine health
Policy and networking	Fed	EO 13921 (2020) Section 6(i) (Permitting)	Establishes NOAA as the lead agency for federal permits of shellfish aquaculture
Policy and	Fed	Inflation Reduction Act (IRA)	Allocated $14 million to research ocean acidification and

Grower Adaptation Strategies	State	Guiding Document	Potential Adaptive Capacity Alignment
networking		(Fund)	mitigation of impacts on coastal economies and communities