# California Shellfish Farmers: Perceptions of Changing Ocean Conditions and Strategies for Adaptive Capacity

Photo: Remy Hale

## Highlights

- California shellfish growers expressed concern for ocean acidification, yet were often unable to detect if or how it impacts their operations, making them vulnerable.
- Shellfish growers identified adaptive strategies to respond to ocean acidification and environmental change, categorized broadly as: (1) policy, regulations, & network development, (2) farm management practices, and (3) scientific needs & knowledge gaps.
- These strategies highlight the need to bring scientists, decision-makers, and growers together to discuss socioeconomic, political, and scientific avenues to facilitate the aquaculture industry's adaptation to ocean acidification and other environmental stressors.

## The Need to Adapt

Decreasing ocean pH due to ocean absorption of excess carbon dioxide, ("ocean acidification"), threatens shell-forming species by hindering shell development, growth, and survival. In California, ocean acidification threatens coastal economies and livelihoods that depend upon these species, such as the state's aquaculture industry. Given expected changes in ocean chemistry, there is an urgent need to understand the vulnerability of California's sustainable shellfish aquaculture industry and facilitate its adaptation in the face of climate change.

*"We are not currently using any kid of instrument or observations to look for acidification because number one, we don't know how to do that."*

- Quote from grower

## Our Approach

We interviewed shellfish growers from over half of California's farms from the Humboldt Bay, Point Reyes, and Central Coast regions, which included in-bay and land-based culture of primarily oysters, mussels, clams, and abalone. These interviews aimed to understand (1) environmental changes or impacts growers were experiencing or aware of, and (2) adaptive strategies growers were using (or wanting to use) to respond to environmental change, including ocean acidification.

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# Findings

Shellfish growers identified 17 environmental factors and 18 adaptive strategies (categorized in Fig. 1; Appendix A). Growers were concerned about ocean acidification (i.e., carbonate chemistry), and noted many other environmental factors (in particular, marine pathogens, rainfall, and species populations), but were typically unable to detect if ocean acidification was impacting their in-bay operations. Permitting and regulatory changes were the most cited adaptive strategy.

> *"We just had a big die off...where we lost about half of our year-old oysters, and I have no idea what caused it or why."*
>
> \- Quote from grower

Growers noted proposed changes could simplify or clarify permitting requirements, as well as reduce regulatory burdens and increase flexibility to implement other strategies. Other common strategies included developing and leveraging networks to share best practices, communicate needs, and advancing scientific knowledge (Fig. 1).

> *"The regulations have gotten tighter", "It takes so long, it's so expensive, and it's such a black box. There's no programmatic approach to projects."*
>
> \- Quote from grower

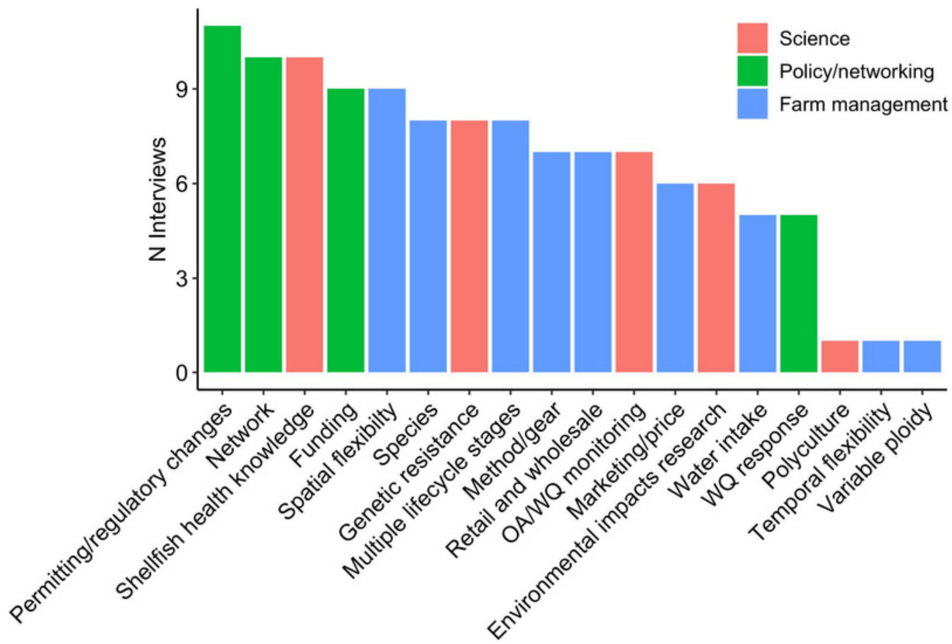


Figure 1. Total number of aquaculture operators who mentioned each identified adaptive strategy. Descriptions of each strategy are detailed in Appendix 1.

# Implications

No single adaptive strategy will address all the challenges California's aquaculture industry faces; this will likely require a multidisciplinary, and multi-institutional approach. Developing and leveraging networks with growers, decision-makers, and scientists, can facilitate implementation of this portfolio of strategies. Scientists can address key knowledge gaps identified by growers, such as developing genetically-resistant broodstock. Many of the strategies proposed by growers suggest value in input from scientists and decision-makers on the resources, data, and tools to support growers in detecting and responding to ocean acidification and environmental change, and thereby reducing their vulnerability.

Other strategies (e.g., 'Farm Management'), may require policy changes. Decision-makers can aid in aligning expectations around potential changes, and clarifying and communicating permitting and regulatory requirements to reduce growers' time and costs in navigating these processes. Decision-makers can also advise on the social, economic, and political feasibility of implementing other strategies (e.g., identifying funding opportunities).

# Future Work

Collaborations between growers, scientists, and decision-makers will help identify solutions that facilitate adaptation of California's aquaculture industry. Our ongoing research will expand analyses to all California and Oregon growers, paired with an analysis of policies that may support adaptation to ocean acidification. Please see: https://www.oceansciencetrust.org/projects/oavulnerability/


Reference

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Photo: Ed Anderson

**APPENDIX 1. Adaptive capacity strategies identified by California shellfish growers. Strategies (left-hand column) correspond to strategies labeled on the X-axis in Figure 1.**

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|---|---|
| **Policy & Networking Strategies** | |
| Permitting/Regulatory Changes | Permitting new operations and simplifying or clarifying permit changes for existing operations can reduce regulatory burdens, allowing for increased flexibility and allocation of resources towards other strategies. |
| Network | Developing and leveraging networks of other growers, managers, policymakers, and scientists to share information, build best practices, and communicate policy and scientific needs. |
| Funding | Access to funding opportunities can serve numerous purposes including improved ability to attain permits or insurance, conduct research, etc. |
| Water Quality (WQ) Response | A timely WQ regulatory response to allow operations to open more quickly after a WQ-induced closure and avoid economic losses (i.e., monitoring conditions and allowing a prompt reopening if criteria are met). |
| **Farm Management Strategies** | |
| Spatial Flexibility | For in-bay culture, growing in multiple locations and moving product within leased areas can allow real-time responses to environmental stressors (e.g., moving away from a run-off source, out of the intertidal, towards the mouth of the bay, etc.). |
| Species | Culturing numerous, additional, or alternative species diversifies growers' products and can open up new markets or help ensure product is available if one species does poorly or is more impacted by a mortality event. |
| Multiple Life Stages | Having multiple life cycle stages and size classes (broodstock, seed, small adults, and large adults) in-house can reduce reliance on outside operations and provide market diversification and flexibility. Self-operated hatcheries can reduce negative impacts of regional seed shortages. |
| Method & Gear Type | Employing multiple or new methods or gear types (or switching between them) can allow growers to use the best-available and most suitable methods and technology to effectively grow their product. |
| Retail & Wholesale | Having both a retail and wholesale business can allow diversification of customers and sales. Wholesale typically allows access to restaurant markets, while retail is direct to customers. Having both can make operations more resilient if for example, the restaurant industry suffers (as was the case during the COVID-19 outbreak). |
| Marketing & Price | Changing marketing strategies or product prices (e.g., raising the price of shellfish) can help growers keep pace with other costs of business up-keep, cost-of-living, market shifts, etc. |
| Water Intake | For land-based culture, altering water upon intake, turning pumps off at strategic times, or altering the intake location can allow manipulation of water quality and/or carbonate chemistry towards favorable conditions. |
| Temporal Flexibility | For in-bay culture, altering the timing of shellfish outplanting or harvesting around anticipated environmental stress events can allow growers to avoid mortality and loss of product. |
| Variable Ploidy | Having access to both triploid and diploid oysters can diversify growers' products and help reduce risk of product loss due to possible differential environmental effects between the two. |
| **Science Strategies** | |
| Shellfish Health Knowledge | Identifying drivers of shellfish mortality and health can allow growers to recognize and respond to environmental conditions likely to lead to shellfish mortality. |
| Genetic Resistance | Developing broodstock that is genetically resistant to environmental stressors can yield a greater quality or quantity of product. |
| Monitor OA & Water Quality (WQ) | Improving water quality monitoring, including carbonate chemistry data, can inform growers of environmentally stressful conditions. This can allow for adaptive responses and lead to greater understanding of how water quality affects shellfish health and mortality. |
| Environmental Impacts Research | Advancing research on the environmental impacts of new methods, species, or gear types can lead to easier permit approvals when growers seek to make such changes. |
| Polyculture | Exploring and researching the benefits of co-culturing shellfish with other species may be a highly sustainable way for operations to expand, with possible ocean acidification amelioration benefits from co-culture with algae/marine plants. |