Juvenile rockfish show resilience to CO2-acidification and hypoxia across multiple biological scales

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Conservation Physiology, Volume 6, Issue 1, 1 July 2018, coy038, https://doi.org/10.1093/conphys/coy038
Published: 10 July 2018

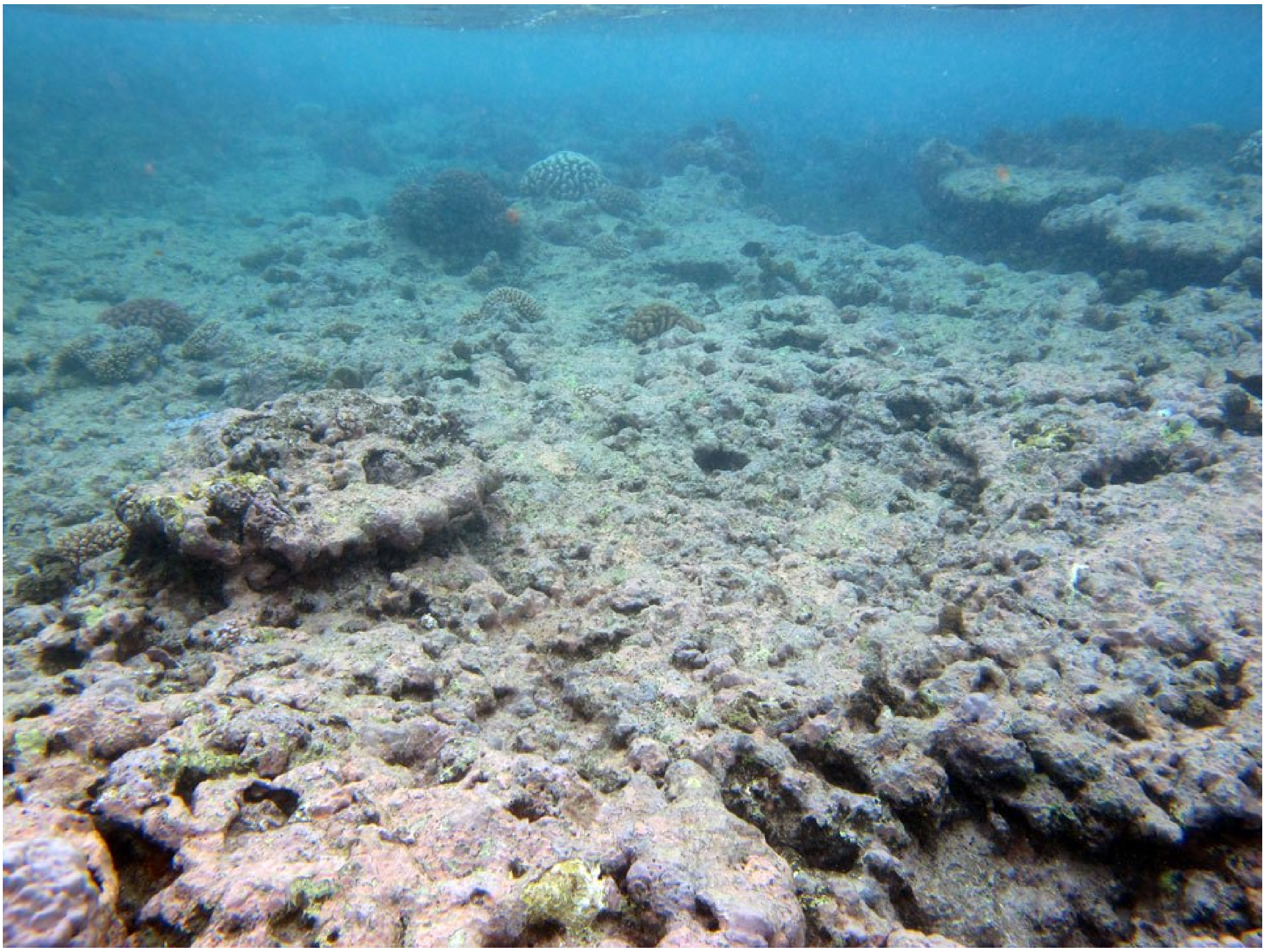
Abstract

California's coastal ecosystems are forecasted to undergo shifting ocean conditions due to climate change, some of which may negatively impact recreational and commercial fish populations. To understand if fish populations have the capacity to respond to multiple stressors, it is critical to examine interactive effects across multiple biological scales, from cellular metabolism to species interactions. This study examined the effects of CO_2-acidification and hypoxia on two naturally co-occurring species, juvenile rockfish (genus *Sebastes)* and a known predator, cabezon (*Scorpaenichthys marmoratus*). Fishes were exposed to two PCO_2 levels at two dissolved oxygen (DO) levels: ~600 (ambient) and ~1600 (high) µatm PCO_2 and 8.0 (normoxic) and 4.5 mg l^{-1} DO (hypoxic) and assessments of cellular metabolism, prey behavior and predation mortality rates were quantified after 1 and 3 weeks. Physiologically, rockfish showed acute alterations in cellular metabolic enzyme activity after 1 week of acclimation to elevated PCO_2 and hypoxia that were not evident in cabezon. Alterations in rockfish energy metabolism were driven by increases in anaerobic LDH activity, and adjustments in enzyme activity ratios of cytochrome c oxidase and citrate synthase and LDH:CS. Correlated changes in rockfish behavior were also apparent after 1 week of acclimation to elevated PCO_2 and hypoxia. Exploration behavior increased in rockfish exposed to elevated PCO_2 and spatial analysis of activity indicated short-term interference with anti-predator responses. Predation rate after 1 week increased with elevated PCO_2; however, no mortality was observed under the multiple-stressor treatment suggesting negative effects on cabezon predators. Most noteworthy, metabolic and behavioral changes were moderately compensated after 3 weeks of acclimation, and predation mortality rates also decreased suggesting that these rockfish may be resilient to changes in environmental stressors predicted by climate models. Linking physiological and behavioral responses to multiple stressors is vital to understand impacts on populations and community dynamics.

Climate change is predicted to have profound implications for marine ecosystems, with adverse ramifications expected for species abundance and diversity, and the sustainability of commercial fisheries (Brander, 2007; Wood and McDonald, 1997). Shifts in multiple environmental factors such as elevated dissolved carbon dioxide (CO_2, hereafter CO_2-acidification), low dissolved oxygen (DO, hereafter hypoxia) and increased temperature (Crain *et al.*, 2008; Keeling *et al.*, 2010; Doney *et al.*, 2011) have the potential to threaten individual species and communities by negatively affecting animal physiology and behavior (see reviews Heuer and Grosell, 2014; Nagelkerken and Munday, 2016; Tresguerres and Hamilton, 2017). While the organismal responses to CO_2-acidification and hypoxia have individually been explored, in nature these factors can change in concert. In particular, in highly productive, midlatitude coastal systems with seasonal upwelling, seawater can be both high in partial pressure of CO_2 (PCO_2) and low in DO due to expansion of oxygen minimum zones (Chan *et al.*, 2008; Largier *et al.*, 2015). This results in dynamic changes in both pH and oxygen in coastal habitats (Feely *et al.*, 2008).

Full Article: https://academic.oup.com/conphys/article/6/1/coy038/5051719

New study explores the role nitrogen plays in coral reef fight against ocean acidification



Crustose coralline algae build a shallow ridge (algal ridge) on a coral reef in Moorea, French Polynesia. CSUN marine biologist Robert Carpenter and a former student, Maggie Johnson, found that increasing the amount of nitrogen helps the algae fight off the negative effects of ocean acidification. Photo by Maggie Johnson.

A new study by California State University, Northridge marine biologist Robert Carpenter and a former student, Maggie Johnson, now with the Smithsonian Institution, found that increasing the amount of nitrogen helps crustose coralline algae — which often serves as a cementing element for coral reefs around the world — fight off the negative effects of ocean acidification.

Carpenter and Johnson called their study one more piece in the larger puzzle that scientists are trying to assemble as they look for ways to preserve the world's coral reefs. They cautioned that their findings do not offer a simple solution to the damage being done to reefs by ocean acidification.

“When we do single-species experiments,” Carpenter said, “we are hoping to establish a baseline so we don’t have to do the same experiment for every single species in a coral reef, of which there are millions. We take species that are important for the coral reef – in this case, crustose coralline algae, which help bind the reef together, help calcify the reef and serve as food for other organisms – and hope that what we learn can contribute a base of knowledge for further research.”

Robert Carpenter injects nutrients into laboratory aquaria to test the combined effects of nutrient enrichment and ocean acidification on a crustose coralline alga. Photo by Maggie Johnson.

Their paper, “Nitrogen enrichment offsets direct negative effects of ocean acidification on a reef-building crustose coralline alga,” was published this week in the scientific journal Biology Letters. Nitrogen, along with other chemicals, is used in fertilizers. The chemicals used in fertilizers are found in nutrient pollution runoff from the land, which has been cited as accelerating the negative impact of ocean acidification on the world’s coral reefs.

Carpenter and Johnson chose to examine how nitrogen alone might impact one key component of coral reefs – crustose coralline algae.

"What this experiment did was document the effect of adding nitrogen to a single organism," said Johnson, who started working on the project while a master's candidate in marine biology at CSUN from 2008-11. "But what happens in the real world is hard to say because the nitrogen will be fertilizing the growth of other types of algae, other types of organisms and sea life. While it may help one aspect of a coral reef, it may also have a detrimental impact on another aspect. Also, in the real world, nitrogen is not introduced to corals through runoff by itself.

Maggie Johnson collects crustose coralline algae from a shallow coral reef using an underwater drill and scuba tank. Photo by Stella Hein, courtesy of Maggie Johnson.

"There are a lot of complicating factors that need to be taken into consideration when we consider ocean acidification and temperature warming when it comes to coral reefs," said Johnson, who is now conducting post-doctoral research at the Smithsonian Marine Station in Florida. "The answers aren't as simple as we would like. Scientists need to be thinking about the local environment. What's happening locally can impact how these ecosystems respond to global pressures."

Johnson and Carpenter conducted their experiment in a set of same-sized tanks – each stocked with crustose coralline algae – to assess how the alga responded to nitrogen enrichment in a variety of conditions designed to mimic various levels of ocean acidification.

"Half those tanks had an ambient pH (acidity)that represents the ocean right now, and in the other half, we decrease the pH to simulate what the pH would be at the end of the century if ocean acidification continues," Carpenter said. "We introduced nitrogen enrichment on a daily basis over the course of three weeks. Half received nitrogen enrichment, half did not."

Carpenter said algae receiving nitrogen enrichment were able to partially mitigate the effects of ocean acidification than those that did not receive nitrogen.

"This is not a simple solution to saving the world's coral reefs from the effects of ocean acidification," Carpenter said. "But it is something that we need to think about as we move forward."

Johnson said she wishes there were simple answers to the questions around how to save the world's coral reefs.

"But there aren't," she said. "Hopefully, the work that we did can contribute to the dialogue and help move the research forward. I don't think the outlook is completely bleak when it comes to the world's coral reefs, but where we end up may be quite different than what we are used to predicting."

California State University Northridge, 11 July 2018. Press release.

Original post: https://news-oceanacidification-icc.org/

An Acidified San Francisco Bay? No One's Studied That Yet

This buoy measures seawater chemistry near the Estuary & Ocean Science Center in Tiburon. (Photo by Eric Simons)

Ocean acidification and the effect it will have on the San Francisco Bay hasn't received the scientific study you might imagine, given how frequently climate change comes up in discussions of the Bay.

To date there has been almost no long-term monitoring of the Bay’s carbon chemistry, for example. Ocean acidification is “expected to impact estuaries on the West Coast,” one scientific report concluded in 2016, but “chemical and biological data on acidification threats and impacts are lacking.”

There are a lot of basic questions. Does ocean upwelling bring acidified—CO2-rich and oxygen-poor—water into the Bay? Does acidification threaten the Bay’s marine life, and which life, and how much? Do restored tidal marshes soak up or burp out carbon? How much carbon, and are all estuaries like that? Could local projects to capture and store CO2 before it’s emitted become part of the carbon offset market?

“You can’t do adaptive management if you don’t have a baseline,” says Karina Nielsen, director of San Francisco State’s Estuary & Ocean Science Center (EOS). “If you don’t measure, you’re operating blind.”

This past winter, scientists from SFSU, UC Davis, and the National Oceanic and Atmospheric Administraton–backed Central and Northern California Ocean Observing System (CeNCOOS) dropped a seawater-chemistry-monitoring buoy and companion mooring into the deep green water just behind the EOS in Tiburon. The buoy and mooring are intended to continue operating for decades as part of NOAA’s global ocean monitoring system, meaning scientists will operate blindly no longer.

You can follow two of the buoy’s measurements in real time: CO2 in the air, and in the water at its surface. All other things being equal, water and air will exchange gases while moving toward equilibrium, so you’d expect the two numbers to be pretty close if they were near equilibrium.

But seawater can change rapidly, and in the new Bay buoy, the first months were characterized by differences between CO2 concentration in the air and water. The air held mostly steady at around 400 parts per million, basically the global atmospheric level. But the seawater CO_2 level has fluctuated, spiking to nearly 900 ppm. Water in the Bay is somehow finding a lot of CO_2 from somewhere. But where?

One influx, according to UC Davis ocean scientist John Largier, comes from the ocean. The natural phenomenon of ocean upwelling is constantly flooding offshore areas with cold, acidic water from the deep. Some have questioned whether that dense upwelled water can slither over the sandbar just outside the Golden Gate and so enter the Bay. Largier has argued it can and does, magnifying the importance of the Pacific as a watershed for the Bay. Largier now wants to determine the influence of the ocean watershed relative to the Bay’s various terrestrial watersheds and internal cycling as sources of CO_2. So he was interested to see that over the buoy’s first few months of operation, active upwelling periods offshore corresponded to the new buoy’s recording of very high CO_2 concentration in the seawater relative to the air. Further solidifying the case that the CO_2 is coming in from the ocean, the Bay water CO_2 peaks around the high tide and drops during the ebb.

And that’s just a few months of information on a single data point. The buoy and mooring are designed to capture much more, including chemistry at depth, pH, salinity, and temperature. Largier says scientists will start to be able to answer some of the basic Bay questions after they’ve watched for at least a year, through cycles of strong and weak ocean upwelling, through summer and winter, dry and wet weather, perhaps through an algal bloom or other low-oxygen event. That long-term view, absent so far when it comes to water chemistry, can help scientists make meaning of the millions of dollars spent improving the Bay in anticipation of climate change.

“It’s sort of catching up a little bit, isn’t it,” Largier says. “You’d think by now, given the intensity of this issue, that people, somebody, would have invested already in knowing what's going on."

Full article: https://baynature.org/article/acidified-sf-bay/

Mechanisms to explain the elemental composition of the initial aragonite shell of larval oysters

Abstract

Calcifying organisms face increasing stress from the changing carbonate chemistry of an acidifying ocean, particularly bivalve larvae that live in upwelling regions of the world, such as the coastal and estuarine waters of Oregon (USA). Arguably the first and most significant developmental hurdle faced by larval oysters is formation of their initial prodissoconch I (PDI) shell, upon which further ontological development depends. We measured the minor metal compositions (Sr/Ca, Mg/Ca) of this aragonitic PDI shell and of post-PDI larval *Crassostrea gigas* shell, as well as the water they were reared in, over ~20 days for a May and an August cohort in 2011, during which time there was no period of carbonate under-saturation. After testing various methods, we successfully isolated the shell from organic tissue using a 5% active chlorine bleach solution. Elemental compositions (Sr, Mg, C, N) of the shells post-treatment showed that shell Sr/Ca ranged from 1.55 to 1.82 mmol/mol; Mg/Ca from 0.60 to 1.11 mmol/mol, similar to the few comparable published data for larval oyster aragonite compositions. We compare these data in light of possible biomineralization mechanisms: an amorphous calcium carbonate (ACC) path, an intercellular path, and a direct-from-seawater path to shell formation via biologically induced inorganic precipitation of aragonite. The last option provides a mechanistic explanation for: (1) the accelerated precipitation rates of biogenic calcification in the absence of a calcifying fluid; (2) consistently elevated precipitation rates at varying ambient-water saturation states; and (3) the high Ca-selectivity of the early larval calcification despite rapid precipitation rates.

Plain Language Summary

Larval oysters are particularly susceptible to changes in ocean water chemistry thought to result from the increasing concentration of atmospheric carbon dioxide. Here, we use trace element concentrations measured in larval shells and the water in which the larvae were reared in order to investigate how and why the larvae are so sensitive to these small chemical changes in their environment. We suggest that the way in which larval oysters make their shells is inherently prone to these changes in water chemistry, but once past an initial phase of shell growth, the juvenile oysters may become more resilient.

Haley B. A., Hales B., Brunner E. L., Kovalchik K. & Waldbusser G. G., 2018. Mechanisms to explain the elemental composition of the initial aragonite shell of larval oysters. *Geochemistry, Geophysics, Geosystems* 19 (4): 1064–1079. [Article](#) (subscription required).

[Mechanisms to explain the elemental composition of the initial aragonite shell of larval oysters](#)

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

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Abstract

Marine ecosystems are experiencing rapid changes driven by anthropogenic stressors which, in turn, are affecting human communities. One such stressor is ocean acidification, a result of increasing carbon emissions. Most research on biological impacts of ocean acidification has focused on the responses of an individual species or life stage. Yet, understanding how changes scale from species to ecosystems, and the services they provide, is critical to managing fisheries and setting research priorities. Here we use an ecosystem model, which is forced by oceanographic projections and also coupled to an economic input-output model, to quantify biological responses to ocean acidification in six coastal regions from Vancouver Island, Canada to Baja California, Mexico and economic responses at 17 ports on the US west coast. This model is intended to explore one possible future of how ocean acidification may influence this coastline. Outputs show that declines in species biomass tend to be larger in the southern region of the model, but the largest economic impacts on revenue, income and employment occur from northern California to northern Washington State. The economic consequences are primarily driven by declines in Dungeness crab from loss of prey. Given the substantive

revenue generated by the fishing industry on the west coast, the model suggests that long-term planning for communities, researchers and managers in the northern region of the California Current would benefit from tracking Dungeness crab productivity and potential declines related to pH.

Access to full article can be found here: https://www.sciencedirect.com/science/article/pii/S0304380018301856