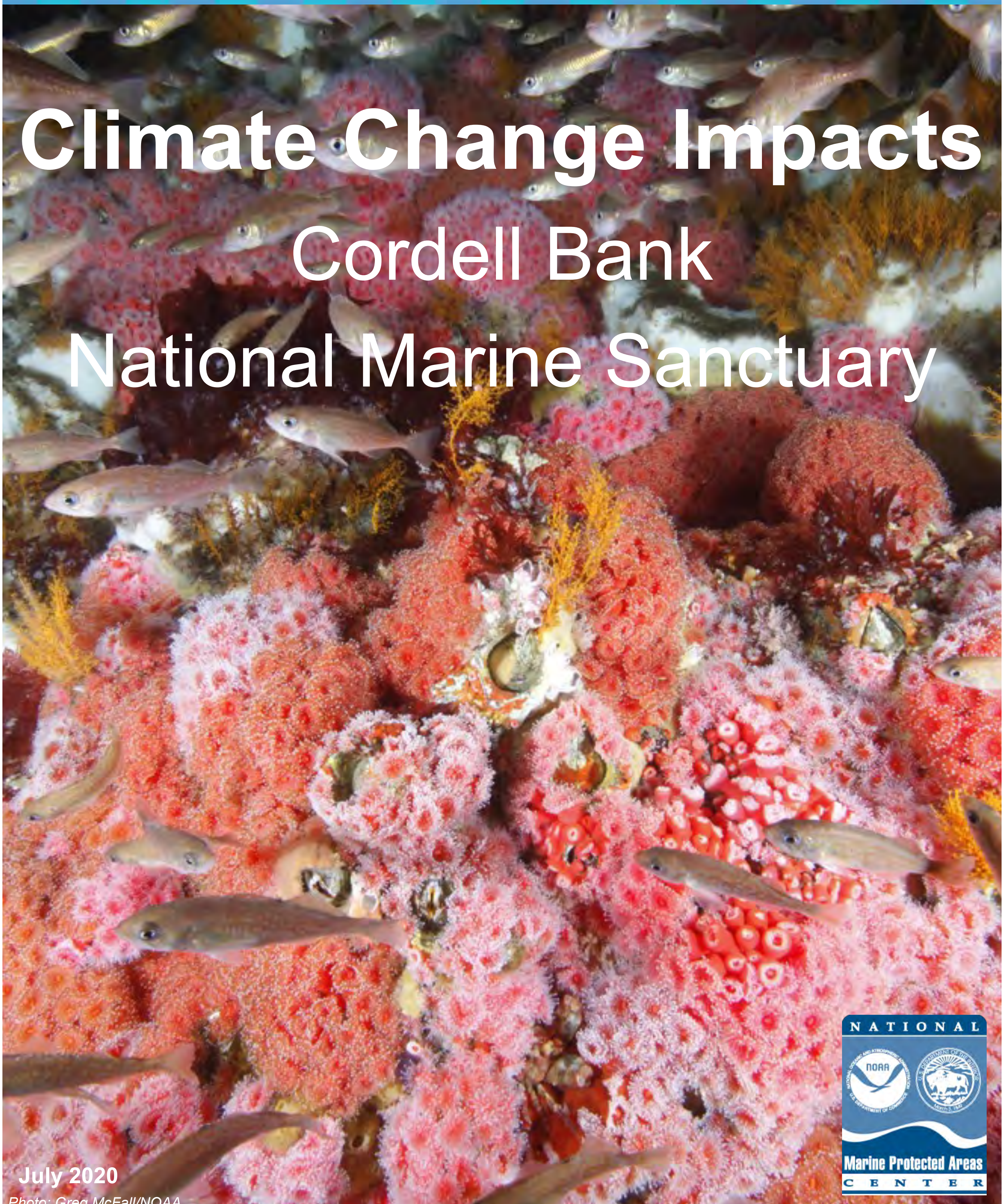
Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration



Climate Change Impacts

Cordell Bank
National Marine Sanctuary

July 2020

Photo: Greg McFall/NOAA

Cordell Bank National Marine Sanctuary protects a vibrant marine ecosystem home to hundreds of diverse species. *Photo: NOAA*

Our Changing Ocean

The impacts of climate change are intensifying both globally and locally, threatening America's physical, social, economic, and environmental well-being.[1] National marine sanctuaries and marine national monuments must contend with rising water temperatures and sea levels, water that is more acidic and contains less oxygen, shifting species, and altered weather patterns and storms.[1] While all of our sanctuaries and national monuments must face these global effects of climate change, each is affected differently.

Cordell Bank National Marine Sanctuary

Cordell Bank National Marine Sanctuary, established in 1989 and expanded in 2015, protects 1,286 square miles of ocean offshore of the north-central coast of California. Cordell Bank rises from the soft sediment of the continental shelf to within 115 feet of the surface, with rocky substrate providing habitat for invertebrates, algae, and fishes. Another prominent seafloor feature, Bodega Canyon, cuts into the continental shelf providing soft and rocky habitat for deep water corals, sponges, and fishes. Cool, nutrient-rich waters, transported from the deep, drive a dynamic food web and vibrant sanctuary ecosystem that supports abundant marine mammals, sponges and deep water corals, krill, seabirds, and economically and ecologically important fish species.

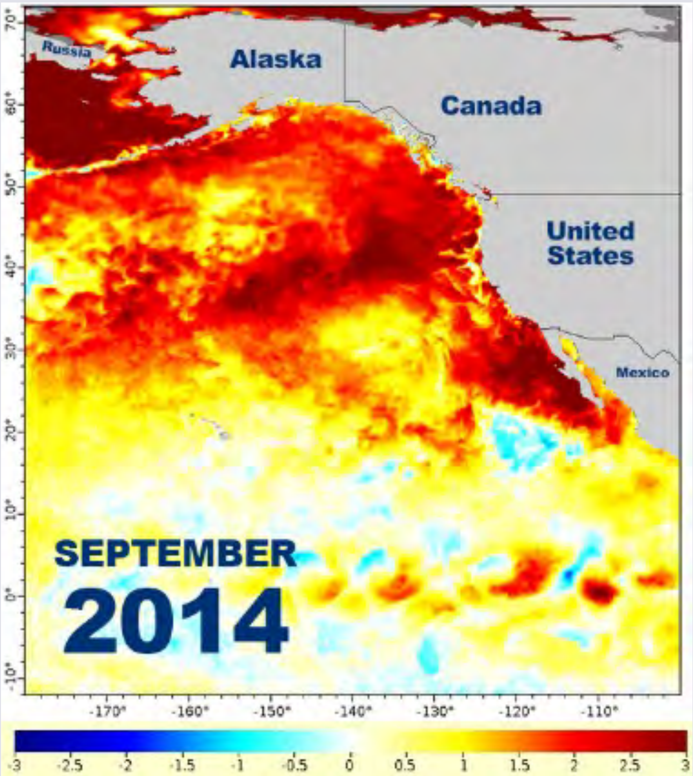
Changes to Upwelling

Alongshore winds and the rotation of the Earth cause cool, nutrient-rich deep waters to rise to the surface in a process called upwelling, fueling the food web of the sanctuary. While upwelled waters are rich in nutrients, they are also lower in oxygen and are more acidic than surface waters, properties that influence the ecological community of the sanctuary.

Changes to upwelling could affect the zooplankton prey of predators like Laysan albatross and other migratory birds. *Photo: Laura Morse/NOAA*

Upwelling is a major oceanographic and ecological process in the sanctuary and is responsible for the high productivity of the ocean in this region. The productivity driven by upwelling influences many aspects of the sanctuary's ecosystem from the timing and success of seabird nesting[2,3] to the presence of migratory species. Species such as blue and humpback whales travel from Mexico and Central America to feed in the sanctuary while seabirds arrive from as far

Case Study 1—The 2014-16 Marine Heatwave



Sea surface temperature anomaly (°C above average temperature) along the west coast on September 1, 2014 during the 2014-16 marine heatwave. *Photo: NOAA Fisheries, data from NOAA Coral Reef Watch*

In 2013, a system of persistent, unusually high atmospheric pressure formed south of the Gulf of Alaska.[17-19] This high pressure system reduced the amount of heat transferred from the ocean to the atmosphere, in part by weakening wind, which eventually led to a pool of persistent warm water forming off the coast of Alaska.[17,18] This warm water anomaly, dubbed "The Blob," eventually spread from the Gulf of Alaska to Southern California, creating a marine heatwave along the entire Pacific coast that persisted from 2014 to 2016. This heatwave drove water temperatures over 7°F above normal in some locations;[20] resulted in large numbers of southern species moving north;[11,21] fueled a large harmful algal bloom (HAB) that killed fish, birds, and marine mammals;[9] delayed the opening of the Dungeness crab fishery;[9,11] and had impacts on prey species that altered the food web.[7] A similar marine heatwave formed in 2019 but mostly stayed north and west of the sanctuary and dissipated over the winter. It is too early to tell if warm water anomalies will become a recurring phenomenon, but as climate change continues, large-scale changes to oceanic and atmospheric processes may create more events like the 2014-16 warm water anomaly.

as Papahānaumokuākea Marine National Monument,[4] New Zealand,[5] and South America[6] to take advantage of upwelling-driven blooms of prey. Due to its importance to the ecology of the region, changes in upwelling timing or intensity have consequences for the sanctuary's ecosystem.

Warm water events like those that occur during El Niño events and marine heatwaves can reduce upwelling by creating distinct layers in the ocean, a process called stratification, or force it closer to shore and away from the majority of the sanctuary.[7,8] When this occurs, sanctuary waters receive less nutrients, leading to lower biological productivity as well as smaller and less abundant zooplankton.[9,10] Such changes can lead to cascading effects on species throughout the food web, affecting fish, seabirds, and marine mammals.[2,9-12] Low-upwelling events could become more common in the future as the frequency and intensity of both marine heatwaves and El Niño events are expected to increase.[13,14]

Despite periodic decreases in upwelling due to El Niño and other warm water events, increases in alongshore winds in recent decades have resulted in a rise in upwelling duration and intensity,[15] which is projected to continue in the coming century.[16] While an increase in upwelling may enhance biological productivity in the sanctuary, it could also lead to decreases in oxygen, increases in acidity, and a slowing of ocean warming. These changes, which are discussed in depth later in this report, could have impacts on sanctuary resources.

Elephant seals and other marine mammals that feed in the sanctuary depend on upwelling-driven productivity. *Photo: Peter Pyle/NOAA*

Case Study 2—Zooplankton and Climate Change

Zooplankton are a critical part of the food web in the sanctuary and may be impacted by climate change *Photo: Russ Hopcroft/UAF*

Zooplankton, small, sometimes microscopic animals, are a critical part of the sanctuary ecosystem and food web. The zooplankton community in the sanctuary is typically dominated by copepods and krill[22] that feed on the phytoplankton, microscopic algae that thrive on the high nutrient waters provided by upwelling. The zooplankton of the sanctuary are nutritious prey that are high in fats. Fish, seabirds, and mammals feed on zooplankton or forage fish like anchovy, which themselves prey on zooplankton, making these tiny animals critical links in the food web.

Climate change and ocean acidification may have adverse impacts on many zooplankton species in the sanctuary. Krill have reduced reproductive success under acidic conditions[23] and the shells of pteropods, small sea snails that are important prey for fish such as salmon, thin under acidic conditions.[24,25] Zooplankton are also affected by warmer waters. During past El Niño events and heatwaves in the California Current, the zooplankton community shifted to smaller, less nutritious southern species,[9,10,22,26] the krill population declined,[7] and the overall biomass of zooplankton fell as much as 90%.[27] During the 2014-2016 warm water anomaly, these changes disrupted the food web and were partly responsible for mass mortalities of seabirds[2,9] and marine mammals[11,12] throughout the California Current ecosystem. Further, during the heatwave, reductions in krill in offshore areas such as the sanctuary forced humpback whales to feed on fish that were closer to shore, resulting in record numbers of whale entanglements in fishing gear across the West Coast in 2015 and 2016.[7]

While there is no danger of zooplankton disappearing entirely from the waters of the sanctuary, climate change will likely continue to alter the zooplankton community in ways that will have consequences for the number and types of species that the ecosystem can support.

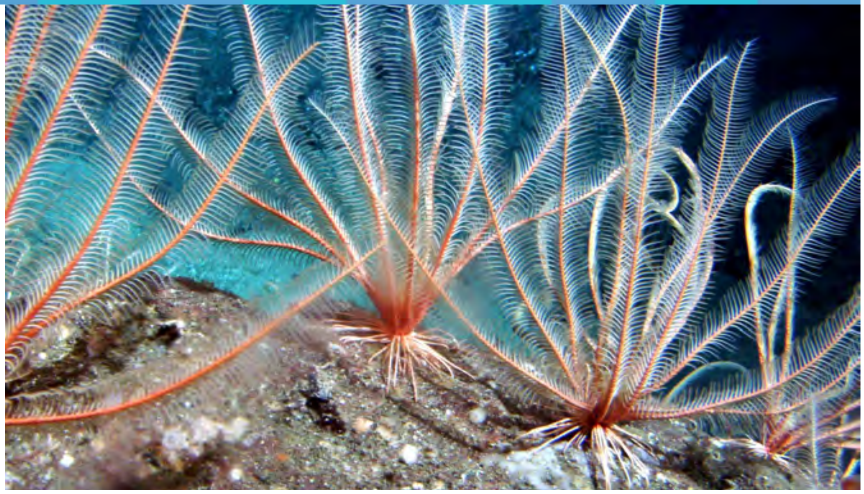
Krill are a zooplankton of particular importance as prey to whales, seabirds, and other marine mammals and fish. *Photo: Shannon Lyday/NOAA*

Deoxygenation and Hypoxia

As waters warm, the ability of the ocean to hold oxygen decreases.[28] Warming waters also cause the ocean to form distinct layers, reducing mixing and limiting the exchange of oxygen and nutrients.[28] The global ocean has already experiences a 2% decline in oxygen since 1960 and is predicted to decline up to another 3-4% by 2100.[29]

Low oxygen conditions, called hypoxia, have become increasingly common in the ocean off California in recent years.[28,30] Ocean oxygen concentrations off California have fallen 20% since 1980[31,32] and may fall below the range of natural variability by 2030.[33] The deepest parts of the sanctuary are naturally low in oxygen, but shallow areas are also experiencing low oxygen events for short periods in some years.[30] Upwelling brings low oxygen water to the surface and plankton blooms fueled by upwelled nutrients can further reduce oxygen levels when they use oxygen at night or decay.[34] Decreased ocean oxygen globally, and changes to the supply of oxygen to deep waters as a result of climate change, are producing upwelled water that is even lower in oxygen than in the past with direct impacts on oxygen concentrations in the sanctuary.[35,36]

Direct effects from hypoxia to organisms in the deep sea are less well understood but could increase stress and shrink available habitat.[37] Economically important species like Dungeness crab and rockfish have been shown to move away from hypoxic areas and future conditions could reduce the available habitat for these species.[31,38-42] Decreased oxygen could also lead to an increase in species that can thrive in these conditions such as Humboldt squid, which prey on economically important species.[43] As hypoxic conditions become more widespread in the coming century,[34] effects such as these are likely to become more common in the sanctuary.



Many deep water and bottom-dwelling species in the sanctuary could be affected by lower oxygen levels. Species IDs (top to bottom): crinoids, China rockfish, swiftia coral and brittle stars. *Photos: Michael Carver/NOAA; NOAA/MARE; NOAA*

Ocean Acidification

Pink hydrocoral and other species with stony skeletons and shells are likely to be impacted by ocean acidification. *Photo: NOAA*

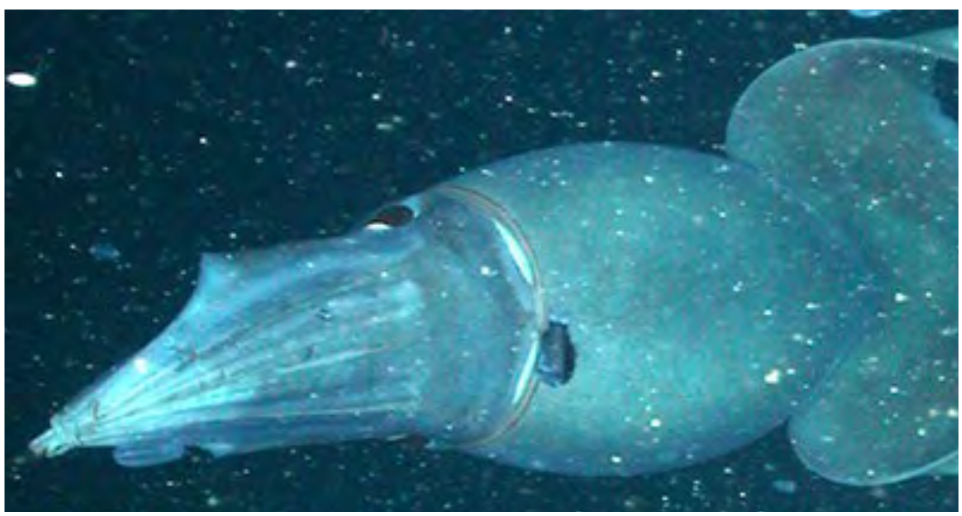
On average, the global ocean has become 30% more acidic since the beginning of the industrial revolution.[44,45] Due in part to upwelling, the acidity of U.S. West Coast waters has risen faster than other regions, up to 60% since 1895, and will continue to rise.[46,47] The sanctuary is located in an area of persistent high acidity.[28]

Increasingly acidic waters make it difficult for shell-forming animals like Dungeness crab and deep water coral to make and maintain shells and stony skeletons.[34] Deep water corals are particularly susceptible as deep waters are naturally more acidic than the surface and some areas are already acidic enough slow their growth.[48] Further, acidification could reduce larval survival in Dungeness crab[49] and krill[23] while also increasing stress and decreasing larval survival in rockfish and other species without shells.[39,40,50,51]

Fish, birds, mammals, and coral can also be indirectly affected by acidification through adverse impacts on their prey.[23,24,52] More acidic waters could adversely affect zooplankton, a critical link in the food web, potentially reducing their numbers. Pteropods, important prey for fish, are particularly susceptible to increasingly acidic waters,[24] and krill, prey for salmon, seabirds, and whales, may experience reduced larval survival as acidity increases.[23] Due to these effects, Dungeness crabs may be more negatively affected by reductions of prey driven by acidification than its direct impacts.[52] The effects of ocean acidification on prey species could have consequences for the entire food web from corals to blue whales.[21-23]

Rising Water Temperatures and Multiple Stressors

As global temperatures rise, the average ocean temperature is increasing world wide.[1] Water temperatures in the region of the sanctuary have risen slightly over the past century[53] and could warm 7°F by 2100.[54]



Humboldt squid and other southern species could become more common in the sanctuary as waters warm. *Photo: Kevin L Stierhoff/NOAA*

Warming waters hold less oxygen, contributing to hypoxia, and could lead to more frequent and intense harmful algal blooms (HABs).[55,56] HABs produce toxins that can harm wildlife, causing mass mortalities of whales, birds, and other animals.[57,58] Warming waters may also allow species to move northward or force them deeper to cooler waters.[59] As a result, southern species could become more common in the sanctuary while others may decline in number.[28,42,60]

The stressors highlighted in this report are affecting the sanctuary simultaneously. The ways in which these multiple stressors interact to affect wildlife and other resources are often complex and difficult to predict. For example, while recruitment of some rockfish species may increase during warm years,[9] they could be negatively affected by lower oxygen and higher acidity.[40,41] Understanding how individual factors are expected to change, interact, and affect sanctuary resources provides the basic information needed to begin to understand and address the multiple interacting stressors of climate change.

Some Ways the Sanctuary Staff Is Responding to Climate Change

NOAA is working to understand how the sanctuary is affected by climate change in order to better manage for ecological resilience. NOAA scientists and sanctuary staff have identified potential climate impacts and climate indicators and are monitoring a suite of indicators through partnerships with non-profits and universities in long term projects. These include the sanctuary's benthic science program, Applied California Current Ecosystem Studies ecosystem monitoring, and hypoxia monitoring.

The sanctuary staff is evaluating and working to reduce its greenhouse gas emissions and is collaborating with others to address emissions in the sanctuary. For example, a project encouraging shipping companies to voluntarily slow ship speeds to reduce whale strikes resulted in reduced air emissions. Managers and partners also work to reduce non-climate stressors, like disturbance to sensitive seafloor habitats, to maintain a healthy ecosystem that may be more resilient to climate change.

Climate change information is included in many sanctuary outreach and education initiatives and at sanctuary advisory council meetings. As an example, NOAA developed an ocean acidification curriculum, including a communication toolkit featuring a Dungeness crab case study, to help teachers, advisory council members, and others communicate the causes and consequences of ocean acidification.

Cordell Bank National Marine Sanctuary protects a unique, vibrant, and thriving ecosystem. *Photo: Jess Morten/NOAA*


Photo: Jamie Jahnke/NOAA/Point Blue Conservation Science

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