Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Climate Change Impacts

Channel Islands National Marine Sanctuary

NATIONAL Marine Protected Areas CENTER

May 2020

Garibaldi, the state marine fish of California, is just one of the great diversity of species supported by the sanctuary *Photo: Claire Fackler/NOAA*

Our Changing Ocean

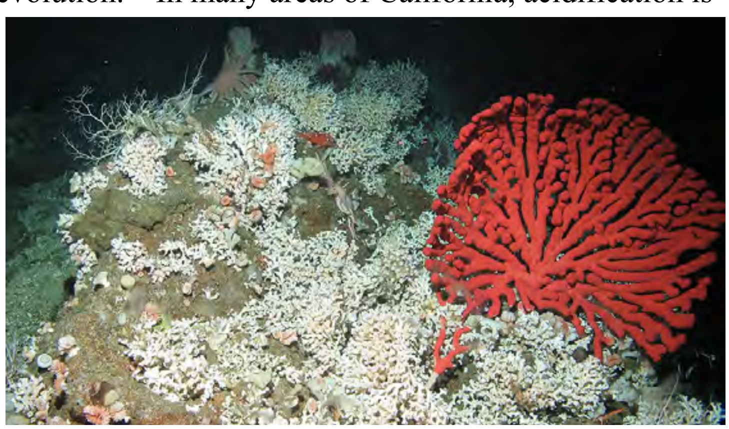
The impacts of climate change are intensifying both globally and locally, threatening America's physical, social, economic, and environmental well-being[1]. National marine sanctuaries and marine national monuments must contend with rising water temperatures and sea levels, water that is more acidic 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.

Channel Islands National Marine Sanctuary

Channel Islands National Marine Sanctuary protects 1,470 square miles of ocean around five of southern California's Channel Islands, surrounding and partially overlapping Channel Islands National Park. Established in 1980, the sanctuary protects vibrant ecosystems from kelp forests to deep sea coral gardens. These waters provide habitat for ecologically, economically, and culturally important species like market squid and rock crab, while hosting a number of endangered species from abalone to whales. The sanctuary supports a variety of recreational uses, supports prime commercial fishing grounds, and is a place of important cultural heritage, protecting over 150 historic shipwrecks and containing waters of immeasurable value to the Chumash people.

Ocean Acidification

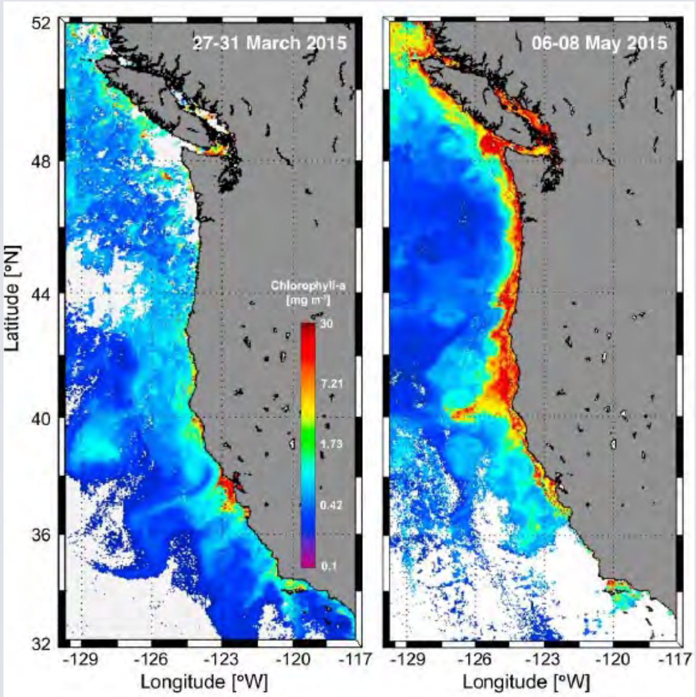
About 30% of the carbon dioxide (CO_2) released into the atmosphere by humans is absorbed by the ocean,[2] causing a chemical reaction that leads to ocean waters becoming more acidic. Globally, the ocean has become 30% more acidic since the beginning of the industrial revolution.[3,4] In many areas of California, acidification is exacerbated by upwelling. Cool, nutrient-rich upwelled water fertilizes the region's ecosystems but is more acidic than surface waters. Due in part to the influence of upwelling, which is expected to increase in intensity in the coming century,[5,6] the acidity of California's waters has increased by up to 60% since 1895 and will continue to rise.[7,8]



Deep sea coral communities in the sanctuary are threatened by ocean acidification. *Photo: NOAA*

Increasingly acidic waters make it difficult for organisms like rock crab and deep water coral to make and maintain stony skeletons and shells. Deep water corals, which provide important habitat for many

Case Study 1—Harmful Algal Blooms



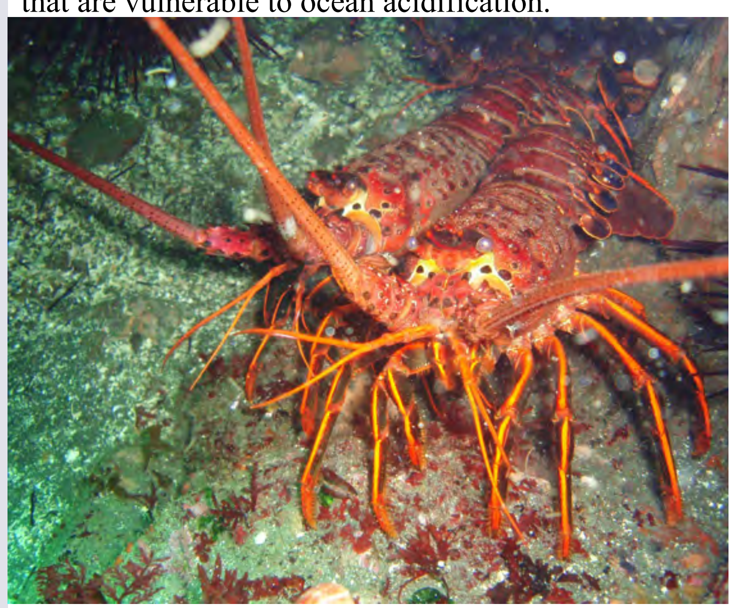
Chlorophyll levels, a measure of algae growth, along the U.S. west coast before (left) and during (right) the 2015 harmful algal bloom. *Photo: ONMS 2019,[27] adapted from McCabe et al. 2016.[22]*

Harmful algal blooms (HABs) produce toxins that can harm animals and humans. These toxins are produced by phytoplankton that are eaten by zooplankton and small fish, which are in turn prey for larger animals. In this way, toxins work their way up the food web and can sicken or kill animals and poison seafood. In recent decades, HABs on the west coast of North America have been responsible for mass mortalities of seabirds,[22] whales,[22-24] and other marine mammals,[22,24,25] as well as closures and delays of valuable fisheries such as Dungeness crab and rock crab.[22,26,27] Climate change is altering the frequency and intensity of these natural disasters along the entire west coast. The Santa Barbara Channel has been a known hot spot for HABs since 1998.[27] Increasing water and air temperatures create conditions that may favor larger, longer lasting HABs,[28,29] and ocean acidification may cause phytoplankton to produce more toxins, leading to blooms that are more toxic.[30] Further, projected increases in storm intensity and extreme rainfall events could lead to increases in coastal runoff events that introduce large loads of nutrients into the ocean, sustaining blooms and potentially increasing their toxicity.[31,32] As climate change progresses, HABs are likely to increase in size, intensity, and frequency with widespread potential impacts for the ecology and economy of the west coast.

species,[9] are particularly vulnerable as deeper habitats are naturally more acidic than surface waters.[9] The low oxygen and high acidity conditions of the sanctuary's deep waters are at the edge of suitable conditions for some corals to grow and survive.[9,10] Some areas are already acidic enough to slow coral growth and cause their skeletons to dissolve.[9]

Acidification also affects other species. Increasing acidity could reduce breeding habitat for market squid[11] while increasing stress and decreasing larval survival in rockfish and other species.[12-16] The prey of fish, seabirds, and marine mammals may also be impacted.[17-19] More acidic waters could affect zooplankton with consequences for the entire food web from corals and rock crabs to seabirds and whales. For example, past decreases in zooplankton have reduced the number of fish in the sanctuary.[20]

Preliminary research suggests that the northern shores of the northern Channel Islands may provide some partial refuge from acidification because they experience high-acidity conditions less frequently.[21] The east-west orientation of the coast in this area and shallower depths of the Santa Barbara Channel reduce local upwelling compared to elsewhere in California.[21] As water upwelled north of Point Conception flows south, it becomes less acidic while bathing the islands with nutrients, allowing them to receive the benefits of upwelling without as much increased acidity.[21] Therefore, some portions of the sanctuary experience relatively lower acidity within a rapidly acidifying region, and may provide a local refuge to organisms that are vulnerable to ocean acidification.[21]



Spiny lobsters are vulnerable to ocean acidification but may find refuge within the sanctuary. *Photo: Claire Fackler/NOAA*

Case Study 2—Kelp Forests and Climate Change

Blue and olive rockfish are some of the more than 1,000 species found in Channel Island kelp forests. *Photo: Yasmeen Smalley/NPS*

The vibrant kelp forests of the sanctuary are home to over 1,000 ecologically, economically, and culturally important species including sheephead, spiny lobster, and abalone. Kelp forests also act as "blue carbon" ecosystems. As kelp grows, it stores carbon in its structures and as pieces break off, they can float up to 150 miles offshore.[33] Tens of thousands of tons of kelp is transported through offshore canyons to the deep sea each year, where it can be buried for millennia.[34,35] Globally, kelp and other macroalgae could sequester up to 200 million tons of carbon annually,[34] 13% more than the annual emissions of Los Angeles.[36]

Warming waters can reduce kelp survival and reproduction,[37,38] and kelp can be removed by the strong waves and currents associated with El Niño and extreme weather events,[37] which are both projected to increase in frequency and intensity.[39] Kelp can also be impacted by ecological changes that may be triggered by climate change, like sea urchin population booms.[40]

Despite these threats, when compared to kelp elsewhere in California, the kelp forests of the Channel Islands appear more resilient to climate change. The reproduction of kelp in the sanctuary is more resilient to high temperatures[38] and while kelp forests in the sanctuary did show some die-off during the warm water anomalies of 2013-2016, they regrew more quickly and more completely than those to the north and south.[37] The ability of Channel Islands kelp to better survive, recover from, and reproduce in high temperatures could increase the adaptation of kelp throughout California through the spread of resilient kelp from the sanctuary.[38] Given their apparent resilience to climate change, kelp forests in the sanctuary are an important habitat not only for the ecology and economy of the region, but for mitigating the impacts of climate change on the California coast.

The vibrant kelp forests of the Channel Islands are particularly resilient to climate change. *Photo: Robert Schwemmer/NOAA*

Increasing Water Temperatures

Average ocean temperature is rising world-wide.[1] Water temperatures in the sanctuary increased slightly over the past century,[1,41] and could warm up to 7°F by 2100.[42] In addition to rising average temperatures, warm water anomalies are expected to increase in frequency and intensity.[43]

Rising temperatures and warm water anomalies can cause mortality events of intertidal species, and could create conditions that are too warm for some deep water corals.[44] Higher temperatures are also expected to lead to more frequent and intense HABs,[26,29] and have caused changes in nutrients and zooplankton that alter the food web.[45-48] Warmer waters also hold less oxygen. Oxygen in California marine waters has decreased 20% since 1980[49,50] and may fall below the range of natural variability by 2030.[1,51] Lower oxygen could decrease rockfish habitat in the sanctuary by 50%,[12] reduce breeding habitat for market squid,[11] and impact deep water corals.[52]

Warming waters also encourage species to move north or deeper to cooler waters.[53] Southern species, like Humboldt squid and brown booby, could become more common in the sanctuary while others, like market squid, may become less abundant.[34,42,54] These shifts are particularly relevant to the sanctuary as the confluence of warm and cool currents results in the western islands hosting a community of cool water species while the eastern islands host warm water species.[55,56] The transition point between these communities is sensitive to changes in temperature. In the 1970s, warming waters caused a change in the marine community of Santa Cruz Island along with a decrease in the number of fish due to reduced zooplankton prey.[20] A similar shift towards a warm water community occurred during the 2013-2016 warm water anomalies.[57] Such changes to ecological communities are expected to continue as waters warm.[57]

The sanctuary protects a great diversity of life, much of which could be affected by climate change. Species IDs (top to bottom): Black and yellow rockfish, Spanish shawl nudibranch, blue whales. *Photo: Claire Fackler/NOAA; Claire Fackler/NOAA; Jessica Morten/NOAA*

The diverse ecological communities of the sanctuary could be impacted by changes to ocean currents. *Photo: NOAA*

Changing Oceanographic Processes

Globally, climate change is altering large scale oceanographic processes such as ocean currents, atmospheric circulation, and El Niño.[39,58,59] These changes can have direct impacts on the sanctuary.

Oceanic currents are of particular importance to the Channel Islands ecosystem. The interaction of the warm Davidson Current and cool California Current creates a high-diversity ecological transition in the sanctuary.[55,56] While it is uncertain if climate change will alter these currents, changes could have impacts on sanctuary ecosystems.

During El Niño events, the region of the sanctuary experiences large waves, wet conditions, reduced upwelling, and warmer water.[60,61] These effects could intensify in the future as the frequency and intensity of El Niño events are expected to increase.[39] Climate change is also projected to cause increases in the winds that drive upwelling.[6] Overall, despite periodic decreases during El Niño, this is expected to increase the frequency and intensity of upwelling in the coming century, which could exacerbate the impacts of ocean acidification.[5,6]

Changes to atmospheric circulation also affect the sanctuary. In 2013, an area of unusually high pressure south of the Gulf of Alaska led to the formation of a coast-wide marine heatwave.[62,63] In the sanctuary, this led to the 2013-2016 warm water event with ocean temperatures up to 11°F above normal,[64] causing many species, like market squid, to move northward,[45,46,54] fueling a large HAB,[46] and reducing zooplankton prey.[45,46]

Rising Ocean Waters

Numerous factors contribute to rising global sea levels including melting glaciers and thermal expansion of seawater. Factors such as currents and changing land height cause sea level to rise at different rates in different locations.[1,65] Along the mainland shoreline in the region of the sanctuary, sea level has been rising at about 1.2 inches per decade[66] and could rise another 2 feet in the next 50 years.[67]

The habitats of many species in the sanctuary, such as northern elephant seals, could be degraded by sea level rise. *Photo: Robert Schwemmer/NOAA*

Although it's unclear how this projection will affect the Channel Islands, sea level rise could drown beaches and rocky intertidal habitats. This could inundate critical nesting, pupping, and haul-out habitat for mammals, such as northern elephant seals and California sea lions, and sea birds like the western snowy plover.[68] However, the lack of development on the islands will likely allow many of these habitats to move up shore. Rising sea level also reduces intertidal habitat for mussels, oysters, and other intertidal species by exposing them to more predation from oceanic predators at the same time that warming air temperatures limit their ability to move higher in the intertidal zone. Further, deeper waters could "drown" eelgrass meadows, by reducing available light, shrinking this ecologically important habitat that sequesters carbon.[69] Rising waters could also increase coastal erosion in combination with projected increases in storm and wave intensity.[70,71]

What is Being Done?

To gain a better understanding of how conditions are changing, NOAA scientists track climate indicators such as water temperature and acidity. They have also developed indicators to track changes in ecological communities, such as monitoring of deep sea corals. Sanctuary staff have also established and enhanced partnerships with other researchers at NOAA, the University of California Santa Barbara, the U.S. National Park Service, and others to research and address the impacts of climate change in the region. Detecting, assessing, and tracking the impacts of climate change was also a clear theme throughout the sanctuary's 2016 Condition Report. Building on that report, in 2020 NOAA staff began developing an updated sanctuary management plan. As supported by the condition report, public comments, and advisory council input, the new plan is expected to include a climate change action plan.

Recognizing the importance of sharing this important information, NOAA has also developed a regional an educational website that teachers can use to help students gain a better understanding of ocean acidification. Through this website, teacher workshops, volunteer trainings, and outreach demonstrations, NOAA is increasing public understanding and awareness of the impacts of climate change.

Teacher workshops are an integral part of the sanctuary's climate change outreach and education activities. *Photo: Laura Francis/NOAA*

Citations

1. USGCRP (2018) Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. *U.S. Global Change Research Program*
2. DeVries et al. (2017) Recent increase in oceanic carbon uptake driven by weaker upper-ocean overturning. *Nature*
3. Haugan & Drange (1996) Effects of CO2 on the ocean environment. *Energy Conv. Manag.*
4. Doney et al. (2009) Ocean acidification: The other CO2 problem? *Annu. Rev. Mar. Sci.*
5. Garcia-Reyes and Largier (2010) Observations of increased wind-driven coastal upwelling off central California. *J. Geophys. Res. Oceans*
6. Xiu et al. (2018) Future changes in coastal upwelling ecosystems with global warming: The case of the California Current System. *Sci. Rep.*
7. Gruber et al. (2012) Rapid progression of ocean acidification in the California Current System. *Science*
8. Osborne et al. (2020) Decadal variability in twentieth-century ocean acidification in the California Current Ecosystem. *Nature Geosci.*
9. Gómez et al. (2018) Growth and feeding of deep-sea coral *Lophelia pertusa* from the California margin under simulated ocean acidification conditions. *PeerJ*
10. Wickes (2014) The effect of acidified water on the cold-water coral, Lophelia pertusa: Distribution in the Southern California Bight and analysis of skeletal dissolution. *PQDT Open*
11. Navarro et al. (2018) Development of Embryonic Market Squid, *Doryteuthis opalescens*, under Chronic Exposure to Low Environmental pH and [O_2]. *PLoS One*
12. McClatchie et al. (2010) Oxygen in the Southern California Bight: Multidecadal trends and implications for demersal fisheries. *Geophys. Res. Lett.*
13. Hamilton et al. (2017) Species-specific responses of juvenile rockfish to elevated pCO_2: From behavior to genomics. *PLoS One*
14. Munday et al. (2010) Replenishment of fish populations is threatened by ocean acidification. *Proc. Nat. Acad. Sci. US*
15. Rossi et al. (2016) Lost at sea: ocean acidification undermines larval fish orientation via altered hearing and marine soundscape modification. *Biol. Lett.*
16. Murray et al. (2019) High sensitivity of a keystone forage fish to elevated CO_2 and temperature. *Conserv. Physiol.*
17. McLaskey et al. (2016) Development of *Euphausia pacifica* (krill) larvae is impaired under pCO_2 levels currently observed in the Northeast Pacific. *Mar. Ecol. Prog. Ser.*
18. Bednaršek et al. (2017) Exposure history determines pteropod vulnerability to ocean acidification along the US West Coast. *Sci. Rep.*
19. Hodgson et al. (2018) 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. *Ecol. Model.*
20. Holbrook et al. (1997) Changes in an assemblage of temperate reef fishes associated with a climate shift. *Ecol. Appl.*
21. Kapsenberg and Hofmann (2016) Ocean pH time□series and drivers of variability along the northern Channel Islands, California, USA. *Limnol. Oceranogr.*
22. McCabe et al. (2016) An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophys. Res. Lett.*
23. Geraci et al. (1989) Humpback Whales (*Megaptera novaeangliae*) fatally poisoned by dinoflagellate toxin. *An. J. Fish. Aquat. Sci.*
24. Alther et al. (2010) Forecasting the consequences of climate-driven shifts in human behavior on cetaceans. *Mar. Pol.*
25. Scholin et al. (2000) Mortality of sea lions along the central California coast linked to a toxic diatom bloom. *Nature*
26. McKibben et al. (2017) Climatic regulation of the neurotoxin domoic acid. *Proc. Nat. Acad. Sci. US*
27. Office of National Marine Sanctuaries (2019) Channel Islands National Marine Sanctuary 2016 Condition Report. *US Department of Commerce. NOAA*
28. Jӧnk et al. (2008) Summer heatwaves promote blooms of harmful cyanobacteria. *Glob. Change Biol.*
29. Gobler et al. (2017) Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans. *Proc. Nat. Acad. Sci. US*
30. Tatters et al. (2012) High CO2 and silicate limitation synergistically increase the toxicity of *Pseudo-nitzschia fraudulenta*. *PLoS One*
31. Anderson et al. (2002) Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries*
32. Anderson et al. (2008) Harmful algal blooms and eutrophication: Examining linkages from selected coastal regions of the United States. *Harmful Algae*
33. Hobday et al. (2016) A hierarchical approach to defining marine heatwaves. *Prog. Oceangr.*
34. Krause-Jensen and Duarte (2016) Substantial role of macroalgae in marine carbon sequestration. *Nature Geosci.*
35. Harrold and Lisin (1989) Radio-tracking rafts of giant kelp: local production and regional transport. *J. Exp. Mar. Biol. Ecol.*
36. Gurney et al. (2019) The Hestia fossil fuel CO2 emissions data product for the Los Angeles megacity (Hestia-LA). *Earth Syst. Sci. Data*
37. Cavanaugh et al. (2019) Spatial variability in the resistance and resilience of giant kelp in Southern and Baja California to a multiyear heatwave. *Front. Mar. Sci.*
38. Hollarsmith et al. (2020) Varying reproductive success under ocean warming and acidification across giant kelp (*Macrocystis pyrifera*) populations. *J. Exp. Mar. Biol. Ecol.*
39. Cai et al. (2014) Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature Climate Change*
40. Hohman et al. (2019) Sonoma-Mendocino bull kelp recovery plan. *Plan for the Greater Farallones National Marine Sanctuary and the CA Department of Fish and Wildlife*
41. Johnstone and Mantua (2014) Atmospheric controls on northeast Pacific temperature variability and change, 1900–2012. *Proc. Nat. Acad. Sci. US*
42. Chavez et al. (2017) Readying California fisheries for climate change. *California Ocean Science Trust*
43. Frölicher et al. (2018) Marine heatwaves under global warming. *Nature*
44. Gugliotti et al. (2019) Depth-dependent temperature variability in the Southern California bight with implications for the cold-water gorgonian octocoral *Adelogorgia phyllosclera*. *J. Exp. Mar. Biol. Ecol.*
45. Sanford et al. (2019) Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. *Sci Rep*.
46. Cavole et al. (2016) Biological impacts of the 2013-2016 warm-water anomaly in the northeast Pacific: Winners, losers, and the future. *Oceanography*
47. DiLorenzo and Mantua (2016) Multi-year persistence of the 2014/15 north Pacific marine heatwave. *Nature Climate Change*
48. Kahru et al. (2018) CCE1: Decrease in the frequency of oceanic fronts and surface chlorophyll concentration in the California Current System during the 2014–2016 north east Pacific warm anomalies. *Deer Sea Res. I*
49. Bograd et al. (2015) Changes in source waters to the Southern California Bight. *Deep Sea Res. II*
50. Ito et al. (2017) Upper ocean O_2 trends: 1958–2015. *Geophys. Res. Lett.*
51. Long et al. (2016) Finding forced trends in oceanic oxygen. *Glob. Biogeochem. Cyc.*
52. Dodds et al. (2007) Metabolic tolerance of the cold-water coral *Lophelia pertusa* (*Scleractinia*) to temperature and dissolved oxygen change. *J. Exp. Mar. Biol. Ecol.*
53. Poloczanska et al. (2013) Global imprint of climate change on marine life. *Nature*
54. Thompson et al. (2019) State of the California Currrent 2018-19: A novel anchovy regime and a new marine heatwave? *CalCOFI*
55. Caselle et al. (2015) Recovery trajectories of kelp forest animals are rapid yet spatially variable across a network of temperate marine protected areas. *Sci. Rep.*
56. Allen et al. (2006) Ecology of marine fishes: California and adjacent waters. *Berkley: University of California Press*
57. Freedman (2019) Understanding the Efficacy of Spatial Management on Emerging Threats. *PhD Dissertation. UC Santa Barbara Ecology Evolution and Marine Biology Department*
58. Luo et al. (2009) Response of Pacific subtropical□tropical thermocline water pathways and transports to global warming. *Geophys. Res. Lett.*
59. Luo and Rothstein (2011) Response of the Pacific Ocean circulation to climate change. *Atmosphere-Ocean*
60. Allen and Komar (2006) Climate controls on US west coast erosion processes. *J. Coast. Res.*
61. Jacox et al. (2016) Impacts of the 2015–2016 El Niño on the California Current System: Early assessment and comparison to past events. *Geophys. Res. Lett.*
62. Bond et al. (2015) Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophys. Res. Lett.*
63. Walsh et al. (2018) Explaining extreme events of 2016 from a climate pperspective. *Bull. Am. Meterol. Soc.*
64. Gentemann et al. (2016) Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. *Geophys. Res. Lett.*
65. Slagen et al. (2014) Projecting twenty-first century regional sea-level changes. *Clim. Changes*
66. Pendleton et al. (2005) Coastal vulnerability assessment of Channel Islands National Park (CHIS) to sea-level rise. *US Geological Survey*
67. Griggs et al. (2017) Rising Seas in California: An Update on Sea-Level Rise Science. *California Ocean Science Trust.*
68. Funayama et al. (2011) Effects of sea-level rise on northern elephant seal breeding habitat at Point Reyes Peninsula, California. *Aquat. Conserv,*
69. Short and Neckles (1999) The effects of global climate change on seagrasses. *Aquat. Bot.*
70. Dettinger (2011) Climate change, atmospheric rivers, and floods in California—A multimodel analysis of storm frequency and magnitude changes. *J. Am. Water Res.As.*
71. Erikson et al. (2015) Projected wave conditions in the eastern North Pacific under the influence of two CMIP5 climate scenarios. *Ocean Model.*

To view the full report online visit: https://sanctuaries.noaa.gov/management/climate/impact-profiles.html