Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Climate Change Impacts

Hawaiian Islands Humpback Whale National Marine Sanctuary

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Photo: NOAA Permit #15240

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A humpback whale and her calf swim through sanctuary waters. *Photo: Ed Lyman/NOAA Permit #14682-37906*

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 marine national monuments must face these global effects of climate change, each is affected differently.

Hawaiian Islands Humpback Whale National Marine Sanctuary

Hawaiian Islands Humpback Whale National Marine Sanctuary was designated by Congress in 1992 to protect North Pacific humpback whales and their habitat. Covering 1,400 square miles of shallow waters in the main Hawaiian Islands, the focus of the sanctuary is on the protection and monitoring of the Hawaiian Discrete Population Segment (HDPS) of North Pacific humpback whales. The sanctuary encompasses the main breeding grounds of these whales, which migrate to Southeast Alaska, British Columbia, and other parts of the North Pacific to feed during the spring and summer months.

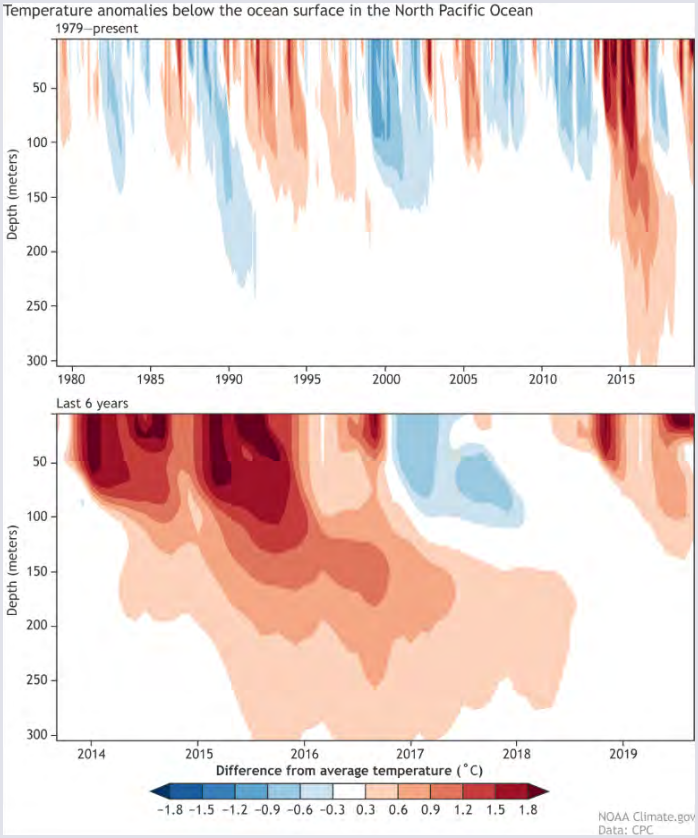
Increasing Water Temperatures

As global temperatures rise, the ocean absorbs much of the heat. The average ocean temperature is rising worldwide,[1] and recent water temperatures in the sanctuary are the highest on record. In fact, the average water temperature of the Hawaiian Islands is projected to increase by as much as 5°F by 2100.[2,3] Further, the waters of the HPDS' Alaskan feeding grounds have been warming by 1.25°F per decade, one of the fastest warming rates on Earth.[4,5]

While humpback whales are unlikely to be directly impacted by increased temperatures, there is evidence they are being affected by temperature-driven changes to their prey. Warmer waters reduce upwelling, decreasing productivity and leading to fewer krill,[4,6] a primary prey item. Increasing water temperatures have also allowed less nutritious zooplankton to shift northwards into the feeding grounds, reducing the energy available to the food web and the whales.[7-9]

The humpback whales in the sanctuary feed off the coast of Alaska, exposing them to climatic changes in these northern waters. *Photo: NOAA*

Case Study 1—A trifecta of warming waters



Subsurface temperature anomalies were averaged in the North Pacific Ocean. *Photo: Climate.gov based on figure provided by Caihong Wen*

The 2013-2018 decline in humpback whale sightings corresponded to a "trifecta" of warm water events in their Alaskan feeding grounds.[4] In 2013, a marine heat wave known as "The Blob" formed in the North Pacific. The Blob persisted until 2016 and resulted in water temperatures more than 5°F above normal.[4] The next year, in 2014, the large-scale climate cycle known as the Pacific Decadal Oscillation (PDO) switched to a pronounced positive phase.[4] A positive PDO is associated with higher ocean temperatures and weakened upwelling, which impacts the forage fish that whales depend on by reducing biological productivity.[4] Finally, a strong El Niño event began in 2015 and persisted through 2016, further encouraging warmer waters in the Alaskan feeding grounds. While neither the El Niño nor the shift in the PDO can be definitively tied to climate change, climate models suggest both of these processes will be altered, with El Niño becoming more extreme.[16,17] Further, climatological modelling suggests that The Blob could not have formed without climate change.[7] A reduction in food due to this trifecta may have reduced the ecosystem carrying capacity of the HDPS, resulting in the observed declines in whale sightings and health.[4]

There is some evidence that these effects of warmer waters on prey may already be impacting the HDPS. Since 2013, emaciated whales have been reported in Alaska and Hawai'i[10] and sightings of humpback whales and mother-calf pairs in Hawai'i fell by as much as 76% between 2013 and 2018.[4] Scientists suggest this decline was triggered by a "trifecta" of warm water events: the 2013 formation of a persistent marine heat wave called "The Blob," a switch to a positive phase in the Pacific Decadal Oscillation (PDO) in 2014, and the strong 2015-2016 El Niño[4] (Case Study 1). These events created water temperatures up to 5°F above normal in the Alaska feeding grounds of the HDPS, negatively impacting the prey of humpback whales.[4]

Warmer temperatures are also expected to lead to larger and longer lasting harmful algal blooms (HABs). HABs release toxins dangerous to whales and their prey, and have been implicated in mass whale mass mortality events.[11-14] HABs that spread along the North American west coast during The Blob may have contributed to declining whale sightings, either by directly impacting whales or by reducing prey.

The sanctuary is also home to vibrant coral reefs. Ocean heat waves, when combined with increasing average temperatures, can cause corals to become stressed and expel the algae that provides their food. This phenomenon, known as "bleaching" because corals appear white due to the loss of algae, can lead to death. Reefs in the sanctuary could experience yearly bleaching by 2045[15] with major consequences for sanctuary ecosystems.

Corals in the sanctuary are expected to be exposed to an increasing number of bleaching events. *Photo: NOAA*

Case Study 2—Climate Change, Humans, and Humpback Whales


Interactions with humans, such as entanglement, may increase as the climate changes. *Photo: Ed Lyman NOAA/MMHSRP Permit #932-1905*

Interactions with humans are the primary cause of whale injury and death.[11] Ship strikes and entanglement in fishing gear can injure and kill whales, while human-caused noise can interfere with communication and cause stress or injury.[11]

The increasing navigability of the Arctic[18] is likely to result in greater human activity in the feeding grounds of the HDPS.[11] Increased shipping could lead to more ship strikes[19] while noise associated with heightened human activity could disturb or injure whales.[11] Further, as temperatures rise, some valuable fish stocks are expected to shift northward, increasing fishing pressure and the risk that whales will become entangled in fishing gear.[11] Changes in whale behavior due to climate change could also raise the risk of entanglement. During The Blob marine heatwave, changes in the distribution of prey due to altered upwelling in parts of the North American west coast drove humpback whales closer to shore to feed and resulted in record numbers of reported entanglements in the region.[20] Entanglement risk was further exacerbated by a change in the timing of fisheries due to a harmful algal bloom (HAB) fueled by The Blob, which led to an increased overlap between fishery and whale feeding seasons.[20] Separately, whale watching may increase as climate change makes other forms of ocean tourism less viable.[11] Whale watching can cause harmful stress if whales are crowded or harassed, particularly in breeding areas like Hawaiʻi, where calves and mothers are especially vulnerable to increased stress and harassment.[11]

While human impacts can be mitigated to an extent within the sanctuary, humpback whales are wide-ranging and susceptible to changes in human behavior throughout their range. This is especially true of their feeding grounds as increasing industrial interest in the nearby Arctic has and will continue to increase.[19]

A team of specially trained NOAA-led responders work to free a whale entangled in gear. *Photo: R. Finn/NOAA MMHSRP Permit #932-1905*

Ocean Acidification

About 30% of the carbon dioxide (CO_2) released into the atmosphere is absorbed by the ocean[21] causing a chemical reaction that leads to ocean waters becoming more acidic. The ocean has become 30% more acidic since the beginning of the industrial revolution.[22,23] Due to its chemistry, such as particularly low levels of dissolved minerals like calcium, the ocean water of Hawaiʻi may be more vulnerable to acidification than other parts of the Pacific.[24] The chemical properties of the high-latitude waters where the HDPS feeds also make those waters vulnerable to acidification.[25,26] Upwelling, which fuels blooms of prey in the Alaskan feeding grounds, also brings acidic deep water to the surface, further increasing the susceptibility of this area to acidification.[26]

While ocean acidification is unlikely to directly impact whales, they are expected to be indirectly affected through their prey. Acidification in Alaskan waters is projected to negatively impact organisms at the base of the food chain such as phytoplankton with stony shells and pteropods, small sea snails which are highly vulnerable to ocean acidification.[1,19, 27]

Pteropods are an important component of the food web in Alaskan waters and a critical food source for the forage fish on which humpbacks depend.[1,19] Acidification may also directly impact prey species. The reproduction of a sister species of sand lance, an important HDPS prey species, is highly susceptible to acidification.[28] Similarly, krill, a vital prey for the HDPS, display reduced reproductive success under acidic conditions.[29] If the populations of these or other important prey species are reduced due to ocean acidification, it could have large impacts on humpback whales. In fact, acidification has already been identified as a possible indirect cause of the nutritional stress and reduced reproduction observed in the HDPS from 2013-2018.[10]

In addition to humpback whales, many other species in the sanctuary are impacted by climate change. Species IDs (top to bottom): Hawaiian monk seal, spinner dolphins, green sea turtle. *Photo: Ed Lyman/NOAA Permit #15240; Claire Fackler/NOAA; Ed Lyman/NOAA*

Kōʻieʻie Loko Iʻa (Maui) and other ancient Hawaiian fish ponds are threatened by sea level rise and other impacts of climate change. *Photo: NOAA*

Rising Ocean Waters

Numerous factors contribute to rising global sea levels including melting glaciers and thermal expansion of seawater. Differences in factors such as currents and the Earth's gravitational field cause sea levels to rise at different rates in different locations.[1,30] In the next century, Hawaiʻi is expected to experience large changes in sea level with a potential rise of 3.2 ft by 2060 and 8 ft by 2100.[1,31] While rising waters will not impact humpbacks, they pose a threat to cultural heritage sites within the sanctuary and throughout the Hawaiian Islands.

A historical fishpond, named Kōʻieʻie Loko Iʻa, fronts the sanctuary property on Maui. This and other fishponds (loko iʻa) are often brackish water and were built and maintained by native Hawaiians to naturally raise and harvest fish. Many loko iʻa were built over 500 years ago, providing an important physical and cultural tie to the past. It is estimated that at the establishment of sustained contact with Europeans in 1778, there were almost 500 loko iʻa across the islands, with the potential to produce over 900 metric tons of fish per year.[32-34] Now, only about 50 of these ponds remain,[32-34] and they are threatened by sea level rise.[35-37] Rising waters have the potential to overtop loko iʻa, causing damage to the walls and salinizing the brackish waters. Even those loko iʻa that are not directly overtopped could be impacted by salinization of freshwater springs which are vital to their proper functioning.

Changing Weather and Storms

Weather patterns around the world are being altered by climate change. Changes to wind and evaporation impact rainfall while rising ocean temperatures fuel stronger storms.[1,38] While the number of factors impacting weather in Hawaiʻi make changes difficult to predict, there is evidence that rainfall will decrease[1,39,40] but that extreme rainfall events will occur more frequently.[1] Periods of drought could lead to the salinization of historic fishponds (loko iʻa) while extreme rain events may cause coastal erosion, threatening their structural integrity.[36,37] Hawaiʻi is also projected to experience an increased number of tropical storms and hurricanes, which are also expected to be stronger.[41,42] While these storms generally have little effect on whales, storm surge, wind, and waves can damage loko iʻa and coral reefs in the sanctuary.

The coastline, beaches, and cultural resources of the sanctuary are threatened by sea level rise and coastal erosion. *Photo: Matt McIntosh/NOAA*

In the Alaskan feeding grounds, models project increases in rainfall and glacial runoff.[1,42] These impacts have been linked to declines in herring, an important prey species for humpback whales.[4,43] Further declines due to projected rainfall and runoff could have indirect impacts on the nutrition of the HDPS. In addition, increased runoff can bring nutrients from land, potentially fueling HABs and other algae blooms.[44,45]

A Hope for the Future

The yearly and seasonal migrations of humpback whales suggests an ability to respond to environmental variation and that they may possess some potential for an adaptive response to climate change, such as migrations to areas that contain more prey if traditional feeding areas become less productive.[16] Thus, while increasing temperatures, ocean acidification, and other climate change impacts threaten humpback whales through changes to their prey, it is possible that if we sustain areas with minimal climate and non-climate stressors, these animals may be able to successfully respond and adapt to life under future climate conditions.

Reducing these non-climate stressors is one of the many ways that NOAA is working to address the impacts of climate change on humpback whales and other resources. Sanctuary managers work with researchers around the globe to track and understand changes in the humpback whale population. This work increases our understanding of how whales are impacted by climate change and may reveal ways in which we can help them adapt to these challenges. NOAA is also active in investigating the ways climate change impacts other resources including cultural resources, such as historic fishponds (loko i‘a), and the natural resources that make up the ecosystem of the sanctuary. Further, sanctuary staff, managers, and volunteers actively participate in climate change outreach and education throughout the Hawaiian Islands.

While humpback whales face many challenges from climate change, their ecology suggests they may be resilient to climate impacts *Photo: NOAA Permit #14097*

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