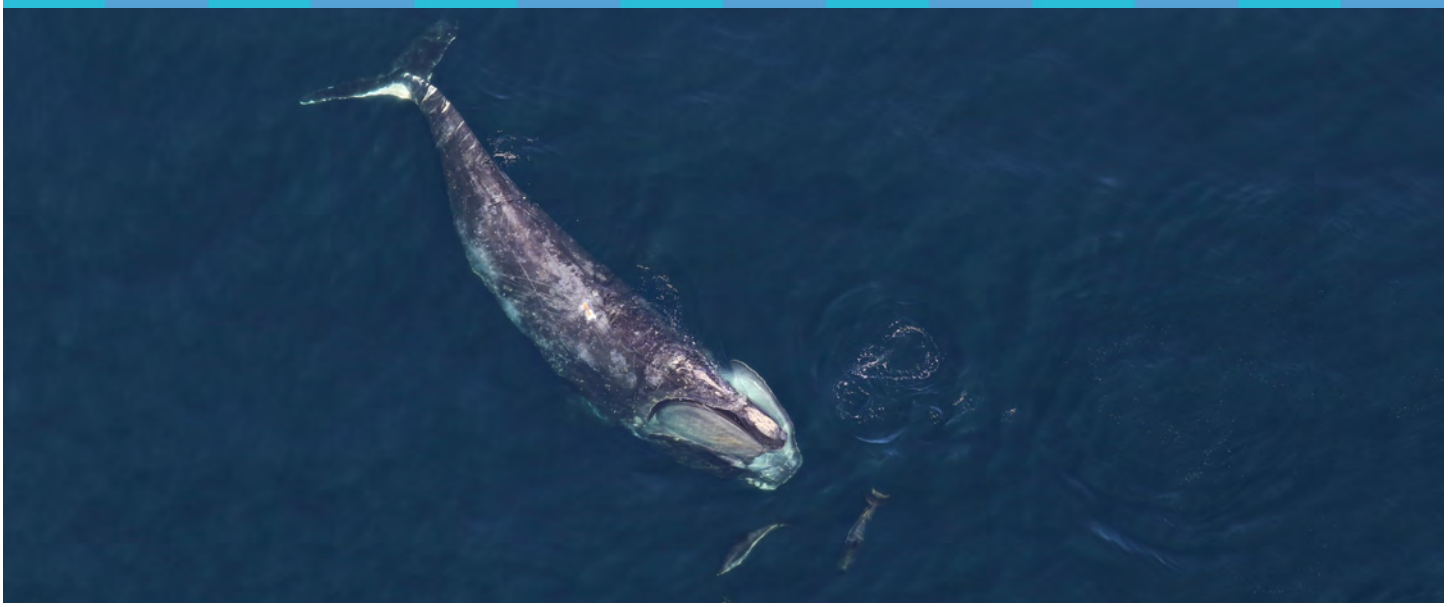
Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Climate Change Impacts

Stellwagen Bank National Marine Sanctuary

May 2020



An endangered North Atlantic right whale feeds in Stellwagen Bank National Marine Sanctuary. *Photo: Allison Henry/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.

Stellwagen Bank National Marine Sanctuary

Stellwagen Bank National Marine Sanctuary contains 842 square miles of protected ocean at the mouth of Massachusetts Bay. Located between Cape Ann and Cape Cod, the sanctuary is centered around Stellwagen Bank, an underwater plateau bathed by cold, nutrient-rich waters, transported from the deep by tides, which fuel a diverse biological community. Designated by Congress on November 4, 1992, the sanctuary protects waters vital for whales, seabirds, and economically important species such as lobster, sea scallops, and cod. These resources in turn have supported local and regional economies through activities like whale watching, fishing, recreation, and many others.

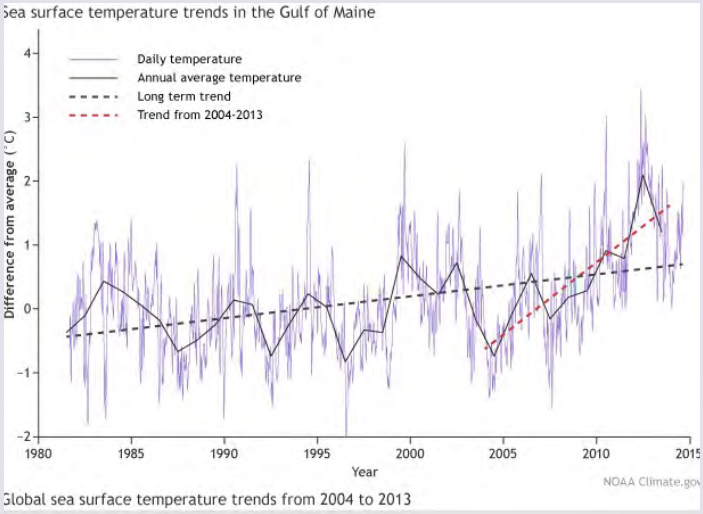
Increasing Water Temperatures

As global temperatures rise, the ocean absorbs much of the heat. While the average ocean temperature is rising world-wide,[1] water temperatures in the region of Stellwagen Bank are increasing three times faster than the global average[1-3] (Case Study 1), partly due to changing currents.[3] The water is already 4.3°F warmer in autumn and 2.2°F warmer in spring than 1968 and could rise another 6.7°F by 2100.[4]

Warming Gulf of Maine waters may force cod in the sanctuary to deeper or more northern waters. *Photo: NOAA*

Rising water temperatures are affecting the wildlife of the sanctuary. As temperatures rise, some species move deeper or northward to cooler waters.[5] Studies suggest southern species will move into the sanctuary while other species will move out, with unknown consequences for the ecology and economy of the region.[4] Several fishery species such as hake and sea scallops are expected to move north and decline in

Case Study 1—A Warming Gulf of Maine



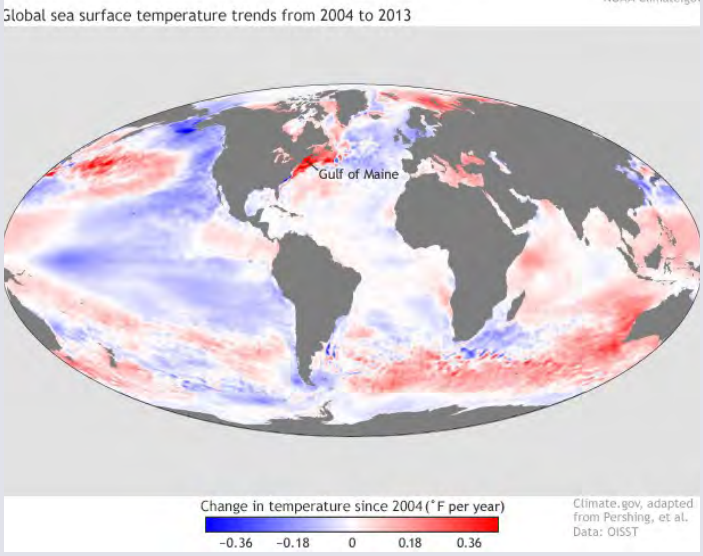


Photo: Climate.gov adapted from Pershing et al. 2015[2] with data derived from the Optimum Interpolation Sea Surface Temperature (OISST)

The Gulf of Maine, which contains the sanctuary, is one of the fastest warming bodies of water on Earth. Between 2004 and 2013, it warmed faster than 99.9% of the ocean, largely due to the northward shift in the Gulf Stream Current and changes to large scale climate-cycles known as the Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO).[2] Warming waters have even been implicated in the collapse of the Atlantic cod stock in the region[2] and an increase in the number of sea turtle cold-stunning events.[29] While it is unclear if this rate of warming will continue, the Gulf of Maine is expected to continue to warm through the coming century.[1,4] Given the impacts that warming waters are already having on the ecology and economy of the region, future warming is likely to create continued management challenges for sanctuary and fisheries managers alike.

Number.[4] Some species, like Atlantic cod, may even disappear from the region.[4] In contrast, rising temperatures may provide more habitat for some species, like black sea bass, and others may appear in the region for the first time.[4,6] Warming waters could also facilitate the northward spread of epizootic shell disease, which can devastate lobster populations.[7,8] In addition, warming waters in the Gulf of Maine have been implicated in increased numbers of cold-stunned endangered Kemp's ridley sea turtles by allowing them to travel further north during the summer without providing sufficient time to return south before cold weather develops.[9]

Perhaps the greatest impact of increasing ocean temperatures in the sanctuary is to one of its smallest inhabitants (Case Study 2). Copepods are nearly microscopic animals that are the foundation of the food web and the preferred prey of endangered North Atlantic right whales[10] and northern sand lance, which are in turn prey for many other species. Changes in copepods could impact the type and number of species supported in the sanctuary.[1,11] Increasing temperatures are predicted to cause one very important copepod to move north, leading to decreased abundance in the sanctuary.[12] Past copepod reductions have been associated with lower reproductive success in both American lobsters[13] and right whales.[10,14] Further, right whales are following copepods north, forcing this endangered species into new territory[15-17] and possibly out of the sanctuary.[17]

The American lobster is one of the many sanctuary species that may be impacted by climate change. *Photo: Matthew Lawrence/NOAA*

Case Study 2—Copepods, climate change, and the North Atlantic right whale

Copepods and other zooplankton are important prey for North Atlantic right whales. *Photo: NOAA*

Copepods are tiny crustaceans that feed on microscopic algae. The copepod species *Calanus finmarchicus* is vital to the Stellwagen Bank National Marine Sanctuary ecosystem and a major food source for many species.[11] In fact, *C. finmarchicus* is the primary prey of endangered North Atlantic right whales, which return every spring to the sanctuary and surrounding waters to feed on over 100 million copepods a day.[10,18]

While many crustaceans are impacted by ocean acidification, *C. finmarchicus* appears resistant to acidic waters.[19] However, at high temperatures (such as those seen in 2012) *C. finmarchicus* fails to reproduce[11,20] and its abundance is already decreasing in much of the Gulf of Maine.[21] In recent years, record numbers of *C. finmarchicus* have been recorded near the sanctuary,[20,21] and right whales have followed. This recent increase in *C. finmarchicus* near the sanctuary is a result of currents transporting copepods from cooler waters and suggests that the sanctuary may provide a foraging refuge for right whales.[20,21] Eventually, increasing temperatures are expected to force *C. finmarchicus* farther north, which may reduce the flow of copepods into the sanctuary.[12] This could result in a decrease of *C. finmarchicus* abundance in the region up to 25% by 2060 and 50% by 2100.[12] As the primary prey of North Atlantic right whales and northern sand lance, decreases in the abundance of *C. finmarchicus* could have large, cascading impacts on the ecology of the sanctuary. In fact, low *C. finmarchicus* abundance in the Gulf of Maine may already be leading to declines in North Atlantic right whale health and reproduction.[10,14-17] With less than 420 North Atlantic right whales remaining in the population, further reductions in *C. finmarchicus* abundance could be devastating to the recovery and persistence of this endangered species.

Endangered North Atlantic right whales are susceptible to climate change due to the impacts on *Calanus finmarchicus*. *Photo: NOAA*

Ocean Acidification

About 30% of the carbon dioxide (CO_2) released into the atmosphere is absorbed by the ocean,[22] causing a chemical reaction that leads to ocean waters becoming more acidic. In fact, the ocean has become 30% more acidic since the beginning of the industrial revolution.[23,24] Acidic waters make it difficult for shellfish such as lobsters, scallops, and ocean quahog to make and maintain their shells. While the chemical and oceanographic properties of Stellwagen Bank appear to somewhat buffer the effects of acidification,[25] the wider Gulf of Maine region is considered highly vulnerable to future acidification due to predicted increases in river runoff and hypoxia (low oxygen conditions).[1]

Populations of sea scallop and other shellfish are predicted to decline under levels of acidification expected by 2100.[26,27] The situation is especially dire for scallops as the waters of the sanctuary are also expected to be too warm for the species.[6] Given the economic importance of the sea scallop fishery, the impacts of ocean acidification are both ecologic and economic. Acidification may also have impacts to predators such as humpback whales and greater shearwaters through their prey. In particular, acidic conditions have been shown to reduce the reproductive success of northern sand lance,[28] an important forage fish. Sand lance serve as prey for numerous species within the sanctuary and represent an important trophic link. In fact, there is often a strong relationship between the number of sand lance in the sanctuary and the number of predators like whales and seabirds.[29] Sand lance are also affected by impacts of climate change to *C. finmarchicus*, their primary prey, exacerbating the influence of climate change on this keystone forage fish.

Many different sanctuary species may be affected by climate change.
Species IDs (top to bottom): sea scallop, *photo: USGS*; sand lance, *photo: USGS;* great shearwater, *photo: Elliott Hazen/NOAA*

Species like this harbor seal may be indirectly impacted by climate change.
Photo: Elliot Hazen/NOAA, under NOAA Fisheries permit #14245

Changing Ocean Currents

Changes to global ocean currents can have direct impacts on conditions in Stellwagen Bank National Marine Sanctuary. Large currents like the Gulf Stream move water and heat around the ocean like a giant conveyer belt. Even relatively small changes in the paths of these currents can lead to big changes in water properties like temperature and salinity for entire oceanic regions, like the Gulf of Maine. The most important currents affecting the Gulf of Maine are the Labrador Current, which brings cold, relatively fresh water from the Arctic, and the Gulf Stream, which brings warm salty water from the south.[3] Warming conditions in the Arctic are causing the flows of these currents to shift north of their historic locations.[3] These shifts are bringing more warm, salty Gulf Stream water into the Gulf of Maine, which in turn is affecting Stellwagen Bank National Marine Sanctuary.[3,25] This increase in Gulf Steam water is the reason that the Gulf of Maine is one of the fastest warming regions of the global ocean.[3,25]

The smaller currents of the Gulf of Maine, such as the Maine Coastal Current, directly affect the sanctuary by transporting water from the north. This flow also brings *C. funmarchicus* copepods into the sanctuary from cooler, northern waters. This is especially important during warm years when these copepods are otherwise unable to breed in the waters surrounding Stellwagen Bank.[20,21]

Changing Weather and Storms

Weather patterns throughout the world are being affected by climate change. In the Northeast, the frequency and intensity of storms (and rainfall in general) is projected to increase throughout the region leading to higher river discharge into the waters of the sanctuary.[1] The number of large rivers that drain into the Gulf of Maine make the region particularly vulnerable to the impacts of increased river discharge. River water is more acidic than ocean water and large amounts of river water can lower the pH of parts of the ocean. The Gulf of Maine is considered particularly vulnerable to accelerated acidification due to increased precipitation and river discharge.[1]

Shearwaters and other seabirds may be affected by the impacts of climate change on their prey.
Photo: Peter Flood

In addition to being more acidic than the ocean, river water also carries high levels of nutrients from land. This is especially true of rivers that run through populated areas before discharging into the ocean, such as the Merrimack River. High levels of nutrients can cause algal blooms that, along with increased water temperature, can lead to hypoxic (low oxygen) conditions that negatively impact wildlife and further accelerate acidification.[1,30]

A Sentinel for a Changing Ocean Climate

The sanctuary incorporates climate change into its research and monitoring programs. The sand lance is a pencil-sized forage fish and essential prey for whales, bluefin tuna, cod, and many other species. The sanctuary and University of Connecticut researchers are studying the little-known ecology of this fish including its susceptibility to ocean acidification. Seabirds are the watery equivalent of the "canary in the coal mine" because of their sensitivity to changing ocean conditions. The sanctuary's seabird research and monitoring program allows managers to understand how climate change is impacting the ecology of these important species. These programs and others have made Stellwagen Bank National Marine Sanctuary an important sentinel site in the Gulf of Maine.

Communicating about climate change is important to build understanding of threats and changing conditions in the sanctuary. The sanctuary works with whale watch naturalists to help them communicate climate impact information to the over 500,000 people each year who go on whale watch tours. Further, sanctuary volunteers are trained to communicate climate change messages to visitors. Climate change will also be a theme in the sanctuary's condition report and the update of the management plan. In addition to the ways the sanctuary is addressing the impacts of climate change, there are many ways you can help.

As top predators, humpback whales are likely to be impacted by climate change, as a changing ocean may impact their prey availability within the sanctuary. *Photo: NOAA*

Photo: NOAA, under NOAA Fisheries permit #14245

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. Pershing et al. (2015) Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science*.
3. Saba et al. (2016) Enhanced warming of the Northwest Atlantic Ocean under climate change. *J. Geophys Res-Oceans*
4. Kelisner et al. (2017) Marine species distribution shifts on the U.S. Northeast Continental Shelf under continued ocean warming. *Prog Oceanogr*
5. Poloczanska et al. (2013) Global imprint of climate change on marine life. *Nature*
6. Hare et al. (2016) A vulnerability assessment of fish and invertebrates to climate change on the northeastern U.S. continental shelf. *PLoS One*
7. Greene (2016) North America's iconic marine species at risk due to unprecedented ocean warming. *Oceanography*
8. Maynard (2016) Improving marine disease surveillance through sea temperature monitoring, outlooks and projections. *Philos T R Soc B*
9.Griffin et al. (2019) Warming seas increase cold-stunning events for Kemp's ridley sea turtles in northwest Atlantic. PLoS One
10. Meyer-Gutbrod et al. (2015) Climate-associated changes in prey availability drive reproduction dynamics of the North Atlantic right whale population. *MEPS*
11. Preziosi & Runge (2014) The effect of warm temperatures on hatching success of the marine planktonic copepod, *Calanus finmarchicus*. *J Plankton Res*
12. Grieve, et al. (2017) Projecting the effects of climate change on *Calanus finmarchicus* distribution within the U.S. northeast continental shelf. *Sci Rep*
13. Carloni et al. (2017) Bridging the spawner-recruit disconnect: trends in American lobster recruitment linked to the pelagic food web. *Bull Mar Sci*
14. Meyer-Gutbrod & Greene (2014) Climate-associated regime shifts drive decadal-scale variability in recovery of North Atlantic right whale population. *Oceanography*
15. Davis et al. (2017) Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004-2014. *Sci Rep*
16. Meyer-Gutbrod & Greene (2018) Uncertain recovery of the North Atlantic right whale in a changing ocean. *Glob Change Biol*
17. Meyer-Gutbrod et al. (2018) Marine species range shifts necessitate advanced policy planning: The case of the North Atlantic right whale. *Oceanography*
18. Kenney et al. (1986) Estimation of prey densities required by western North Atlantic right whales. *Mar Mammal Sci*
19. Runge, et al. (2016) End of the century CO2 concentrations do not have a negative effect on vital rates of *Calanus finmarchicus*, an ecologically critical planktonic species in North Atlantic ecosystems. *ICES J Mar Sci*
20. Runge et al. (2015) Persistence of *Calanus finmarchicus* in the western Gulf of Maine during recent extreme warming. *J Plankton Res*
21. Record et al. (2019) Rapid climate-driven circulation changes threaten conservation of endangered North Atlantic right whales. *Oceanography*
22. DeVries et al. (2017) Recent increase in oceanic carbon uptake driven by weaker upper-ocean overturning. *Nature*
23. Haugan,& Drange (1996) Effects of CO2 on the ocean environment. *Energy Conv Manag*
24. Doney et al. (2009) Ocean acidification: The other CO2 problem? *Annu Rev Mar Sci*
25. Salisbury & Jönsson (2018) Rapid warming and salinity changes in the Gulf of Maine alter surface ocean carbonate parameters and hide ocean acidification. *Biogeochemistry*
26. Cooley et al (2015) An integrated assessment model for helping the united states sea scallop (*Placopecten magellanicus*) fishery plan ahead for ocean acidification and warming. *PLoS One*
27. Rheuban et al. (2018) Projected impact of future climate change, ocean acidification, and management on the US Atlantic sea scallop (*Placopecten magellanicus*) fishery. *PLoS One*
28. Murray et al. (2019) High sensitivity of a keystone forage fish to elevated CO2 and temperature. *Conserv Physiol*
29. Nelson and Ross (1991) Biology and population changes of northern sand lance (*Ammodytes dubius*) from the Gulf of Maine to the Middle Atlantic Bight. *J Northwest Atl Fish Sci*
30. Cai et al. (2011) Acidification of subsurface waters enhanced by eutrophication. *Nature Geosci*

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