Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Climate Change Impacts

Gray's Reef National Marine Sanctuary

July 2020

NATIONAL Marine Protected Areas CENTER

Gray's Reef provides habitat for a diverse ecological community of temperate and tropical species. *Photo: Greg McFall/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.

Gray's Reef National Marine Sanctuary

Gray's Reef National Marine Sanctuary protects 22 square miles of ocean 19 miles off the coast of Georgia. Designated in 1981, the sanctuary protects Gray's Reef, one of the largest live bottom reefs in U.S. waters. Gray's Reef is the only protected natural reef on Georgia's continental shelf and sits at the transition of the tropical and temperate seas, making it important to many species. The reef's diverse assemblage of sponges and soft corals provide habitat for economically and ecologically important species such as lobsters, shrimp, black sea bass, snappers, and groupers. The sanctuary also protects habitat used year-round by threatened loggerhead sea turtles and is near the only known calving ground of endangered North Atlantic right whales.

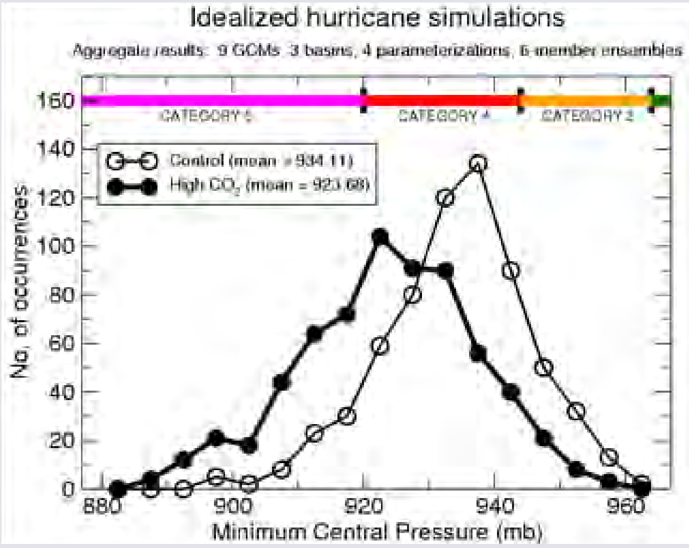
Changing Weather and Storms

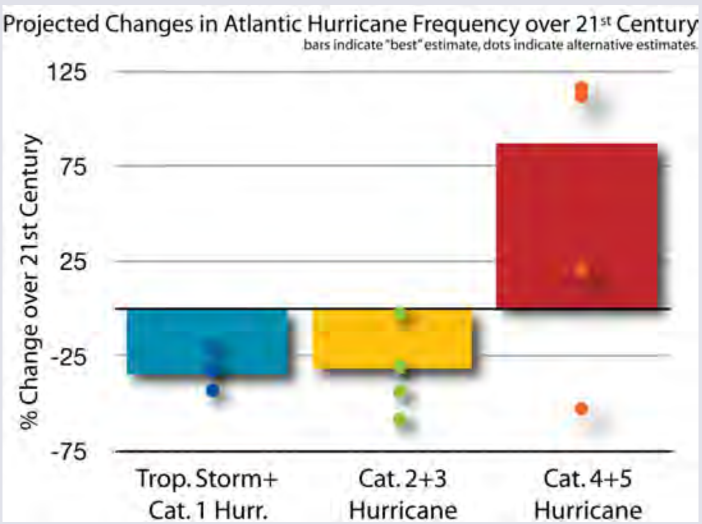
Weather patterns around the world are being altered by climate change. Changes to wind and evaporation impact rainfall while rising ocean temperatures fuel stronger storms.[1,2] In the region of the sanctuary, the frequency of extreme rainfall events has increased in recent years[1,3] and is expected to continue to increase in the coming century.[1,3,4]

Sponges, important habitat-builders in the sanctuary, could be impacted by changes to rainfall and storms. *Photo: Greg McFall/NOAA*

Runoff associated with increasingly frequent extreme rain events can have a number of impacts on the living resources of the sanctuary. Runoff from rivers is more acidic than ocean water, exacerbating the effects of ocean acidification.[5] Pulses of sediment can clog the pores of sponges,[6] important habitat-builders within the sanctuary, and the increased turbidity can reduce light levels, further impacting photosynthetic sponges and corals.[6] The high level of nutrients often found

Case Study 1— Changing Hurricanes





Modeled future air pressure (strength) of Atlantic hurricanes (top) and the percent change in the frequency of Atlantic storms of each intensity (bottom). *Photo: gfdl.noaa.gov adapted from Knutson et al. 2019*[2]

Tropical cyclones (tropical storms and hurricanes) are expected to be altered by climate change. In the Atlantic Ocean, higher ocean temperatures are projected to result in stronger storms while warmer, moister air is expected to cause these storms to produce more rainfall.[2] Further, the frequency of the most intense storms, category 4 and 5 hurricanes, is expected to increase.[2] However, climate change could also cause changes that discourage the initial formation of Atlantic hurricanes. Projected increases in vertical wind shear (the change in the wind's speed and direction with height) and warming atmospheric temperatures could make it more difficult for hurricanes to form.[2] Ultimately, the combination of these climate change impacts is expected to result in fewer Atlantic hurricanes.[2] However, those storms that do form are projected to be stronger and produce more rainfall.[2]

in riverine runoff can fuel algal blooms that eventually lead to low dissolved oxygen levels.[7,8] Low dissolved oxygen can be particularly dangerous to bottom-dwelling animals like corals, sponges, and lobsters. Higher nutrient input could also lead to increases in the number, size, and duration of harmful algal blooms (HABs) that produce toxins dangerous to living resources and humans.[9]

In addition to rainfall, tropical storms and hurricanes are expected to be altered by climate change. Over the past 500 years, the tracks of these storms have slowly shifted northward towards the sanctuary.[10] In fact, 47 tropical storms and hurricanes have passed within 25 miles of the sanctuary since 1853,[11] with three doing so in 2016 alone. The wind, waves, and storm surge driven by these storms can directly damage sponges, corals, and other habitat-forming invertebrates while the rainfall they produce can result in extreme runoff events that further impact these animals.[4,6] Moreover, warming water temperatures are projected to result in an increase in the number of the strongest tropical storms and hurricanes[1,2,12] and to cause these storms to intensify more rapidly.[1,13] In addition, the rainfall associated with Atlantic hurricanes is expected to increase by 10-15%,[2] further exacerbating the impacts of associated runoff events. While the storms that do form are expected to be stronger and produce more rainfall, the overall number of tropical storms and hurricanes in the region of the sanctuary is projected to decrease due to changes in wind, currents, and atmospheric circulation.[2]

Changing rainfall and storms impact bottom-dwelling invertebrates in the sanctuary. *Photo: Greg McFall/NOAA*

Case Study 2—Climate Change and Habitat-Forming Invertebrates

While they face challenges, sponges in the sanctuary are largely expected to be resistant to climate change. *Photo Greg McFall/*

Sponges and non-reef building corals provide complex habitat for hundreds of species in the sanctuary. Climate change may impact these habitat-forming invertebrates. While bleaching (the loss of algae that provide food to some corals and sponges) due to high temperatures is a danger, it is not expected to impact the survival of sponges and corals at Gray's Reef due to their relatively low dependence on photosynthesis.[4,14]

The ocean has become more acidic in the past 250 years.[15,16] Under acidic conditions, corals and some sponges can have difficulty building stony skeletons, compromising their growth and increasing their vulnerability to storms.[1,16-19] Separately, sponges could be impacted by sediment runoff associated with increases in extreme rainfall.[1,4,6] Sediment can decrease sponge growth by clogging pores and reducing the light available for photosynthesis.[4,6] Nutrients in runoff have also been associated with coral and sponge bleaching and disease[20] and can lead to low-oxygen conditions[1,7,8] that can stress or kill bottom-dwelling invertebrates.

While climate change may have some impacts on the habitat-forming invertebrates of Gray's Reef, sponges, which dominate the community, are often beneficiaries of climate change.[21] Sponges are generally more tolerant of warming waters and ocean acidification than other habitat-forming invertebrates.[21,22] In some photosynthetic sponges, acidification may even counter the effects of warming by increasing the ability of the symbiotic algae to provide food.[21,22] The ultimate response to climate change impacts will differ from species to species[21,22] but, in general, sponges are thought to be resilient to many of the impacts of climate change.[21] This could allow the sanctuary, as a healthy reef, to be a source of climate-tolerant sponges in the future.

The habitat-forming invertebrates of Gray's reef provide the foundation for a thriving and diverse ecosystem. *Photo: NOAA*

Warming Waters

As global temperatures rise, the ocean absorbs much of the heat, causing the average ocean temperature to rise world wide.[1] In the sanctuary, average sea surface temperature has risen 2°F since 1824[4,23] and could increase another 5.4°F by 2100.[4,24] Extreme temperature events have also increased in frequency and intensity in past decades and are projected to continue to do so in the coming century.[1] When combined with increased average temperatures, ocean heatwaves can cause photosynthetic sponges and corals to become stressed and expel the algae that provide their food. This phenomenon, known as "bleaching" because sponges and corals appear white due to the loss of algae, can decrease their growth and reproduction.[4,25] However, unlike on tropical reefs, bleaching is unlikely to kill the invertebrates of Gray's Reef as they can sustain themselves on zooplankton prey alone.[4,14] Warming waters can still impact sponges and corals in other ways, such as increasing disease.[6,26,27]

Increasing temperatures can also impact sanctuary resources indirectly. As temperatures rise, many species are moving northward or deeper to cooler waters.[1,28] This could cause southern species, like red snapper,[4,29] to become more common in the sanctuary while species like black sea bass may become less abundant.[4,29,30] Separately, warm water, which holds less oxygen, is one contributor to a projected 1% decline in dissolved oxygen content within the sanctuary by 2050.[31] While low-oxygen conditions can stress and kill bottom-dwelling invertebrates, it is unlikely that oxygen will drop to harmful levels in the sanctuary.[4] Higher temperatures will likely also increase the size and duration of harmful algal blooms (HABs).[32-34] These blooms release toxins that can be damaging to invertebrates, fish, mammals, and even humans.

Many species in the sanctuary may be impacted by climate change. Species IDs (top to bottom): North Atlantic right whales, black sea bass and vase sponge, regal sea goddess nudibranch. *Photo: Sea to Shore Alliance/NOAA; Greg McFall/NOAA; Greg McFall/NOAA*

Shellfish, like this lion's paw scallop, can have difficulty building and maintaining shells under acidic conditions. *Photo: Greg McFall/NOAA*

Ocean Acidification

About 30% of the carbon dioxide (CO_2) released into the atmosphere by humans is absorbed by the ocean,[35] 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,[15,16] and the waters of the sanctuary could become another 26% more acidic by 2050.[4,36] Increasingly acidic waters decrease the concentration of carbonate, the mineral animals use to make shells, making it difficult for coral, shellfish, and some sponges to make and maintain their shells and stony skeletons. In the sanctuary, carbonate concentrations are projected to decrease up to 40% by 2100.[4,36] This decrease is expected to be exacerbated by an influx of low-carbonate water due to changing currents[36] and increased bursts of high-acidity river water from extreme rainfall events.[2,4]

Increased acidification and lower carbonate concentrations could reduce the growth of corals and shellfish, such as shrimp and lobsters, by making it more difficult to make and maintain their shells. Acidification also impacts the larvae of economically and ecologically important species, including lobsters and fish, by decreasing growth, survival, and their ability to find their way back to the reef.[37-41] Some corals in the sanctuary show resilience to acidification but could show decreased growth by the end of the century.[42] While sponges are generally more resistant to ocean acidification than other invertebrates,[21,22] they could experience reductions in their zooplankton prey, which are directly affected by acidification, decreasing growth and reproduction.[43,44]

Changing Ecological Communities

Together, exotic species and climate change are creating communities in many places that are ecologically different from those that existed in the past, altering ecosystem functions and services.[45,46] Sitting at the transition of the temperate and tropical oceans, Gray's Reef typically hosts a temperate community in winter and a tropical community in summer.[4] As winter temperatures increase, tropical species may become established year-round[47] while temperate species like black sea bass[4,29,30] and sheepshead[47] could become less common.[48] This shift to a more tropical community could have unexpected consequences.

Lionfish is a tropical invasive species that could benefit from climate change and contribute to the changing ecological community at Gray's Reef. *Photo: NOAA*

Invasive species can also alter ecological communities. While the presence of invasive species is not necessarily a direct result of climate change, climate impacts such as warming waters, can allow invasion of new areas or give invaders advantages over native species.[24,49-52] The lionfish has been documented at Gray's Reef since 2003[4] and is an invasive species of particular concern. Lionfish prey heavily on native species, competing with native predators, and are expected to become more established in the sanctuary as its waters warm.[24,52] While invasive species and other changes to ecological communities are difficult to predict, they are likely to continue as climate change progresses.

What Is Being Done?

Climate change is an issue that cuts across all aspects of the sanctuary's work. NOAA uses research, monitoring, education, and outreach to understand and address the impacts of climate change. In collaboration with numerous partners, NOAA seeks to better understand the impacts of climate change, the first step in addressing its effects. A scientific buoy stationed at Gray's Reef measures and records data such as water temperature, pH, oxygen concentration, and CO_2 concentration to track and better understand how these values are being altered by climate change. In partnership with NOAA's Pacific Marine Environmental Laboratory, Gray's Reef National Marine Sanctuary managers are using data from this buoy to examine differences in CO_2 concentration at the surface and bottom of the sanctuary, as well as long-term trends. Gray's Reef National Marine Sanctuary managers are also studying ancient scallop beds to better understand how Earth's climate has changed in the past. All of this research will help scientists and sanctuary managers better forecast and understand how the bottom-dwelling community of the Atlantic Ocean will adapt to climate change.

In addition to research, NOAA actively participates in outreach and education with students, teachers, and the public throughout the region. This outreach is critical to increase understanding of climate change and begin to address its effects.

Blue angelfish are just one of the hundreds of species that make up the great diversity of life at Gray's Reef. *Photo: Greg McFall/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. Knutson et al. (2019) Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming. *Bull. Am. Mar. Sci.*
3. Easterling et al. (2017a) Precipitation change in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program*
4. Shein et al. (2019) Rapid vulnerability assessment or Gray's Reef National Marine Sanctuary. *National Marine Sanctuaries Conservation Series ONMS-19-01*
5. Reimer et al. (2017) Time series pCO_2 at a coastal mooring: Internal consistency, seasonal cycles, and interannual variability. *Con.t Shelf. Res.*
6. Bell et al. (2015) Sediment impacts on marine sponges. *Mar. Poll. Bull.*
7. Scavia et al. (2003) Predicting the response of Gulf of Mexico hypoxia to variations in Mississippi River nitrogen load. *Limnol. Ocean.*
8. Justić et al. (2003) Simulated responses of the Gulf of Mexico hypoxia to variations in climate and anthropogenic nutrient loading. *J. Mar. Sys.*
9. Anderson et al. (2008) Harmful algal blooms and eutrophication: Examining linkages from selected coastal regions of the United States. *Harmful Algae*
10. Baldini et al. (2016) Persistent northward North Atlantic tropical cyclone track migration over the past five centuries. *Sci. Rep.*
11. Knapp et al. (2010) The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bull. Am. Meteorol. Soc.*
12. Kossin et al. (2017) Extreme storms. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program*
13. Emanuel (2017) Will global warming make hurricane forecasting more difficult? *Bull. Am. Meteorol. Soc.*
14. Miller (1995) Growth of a temperate coral: effects of temperature, light, depth, and heterotrophy. *Mar. Ecol. Prog. Ser.*
15. Haugan & Drange (1996) Effects of CO2 on the ocean environment. *Energy Conv. Manag.*
16. Doney et al. (2009) Ocean acidification: The other CO2 problem? *Annu. Rev. Mar. Sci.*
17. Doney et al. (2012) Climate change impacts on marine ecosystems. *Annu. Rev. Mar. Sci.*
18. Kleypas & Yates (2015) Coral reefs and ocean acidification. *Oceanography*
19. Bates & Bell (2017) Responses of two temperate sponge species to ocean acidification. *New Zeal. J. Mar. Fresh.*
20. Lapointe et al. (2019) Nitrogen enrichment altered stoichiometry and coral reef decline at Looe Key, Florida Keys, USA: A 3-decade study. *Mar. Biol.*
21. Bell et al. (2018) Sponges to be winners under near-future climate scenarios. *BioSci.*
22. Bennett et al. (2018) Interactive effects of temperature and pCO_2 on sponges from the cradle to the grave. *Glob. Change Biol.*
23. Freeman et al. (2017) ICOADS Release 3.0: a major update to the historical marine climate record. *In. J. Climatol.*
24. Grieve et al. (2016) Range expansion of the invasive lionfish in the Northwest Atlantic with climate change. *Mar. Ecol. Prog. Ser.*
25. Ramsby et al. (2018) Elevated seawater temperature disrupts the microbiome of an ecologically important bioeroding sponge. *Molec. Ecol.*
26. Di Camillo et al. (2013) Sponge disease in the Adriatic Sea. *Mar. Ecol.*
27. Bruno et al. (2007) Thermal stress and coral cover as drivers of coral disease outbreaks. *PLoS Biol.*
28. Poloczanska et al. (2013) Global imprint of climate change on marine life. *Nature*
29. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. *PLoS One*
30. Hare et al. (2016) A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. continental shelf. *PLoS One*
31. Schmidtko et al. (2017) Decline in global oceanic oxygen content during the past five decades. *Nature*
32. Jönk et al. (2008) Summer heatwaves promote blooms of harmful cyanobacteria. *Glob. Change Biol.*
33. Moore et al. (2008) Impacts of climate variability and future climate change on harmful algal blooms and human health. *Environ. Health*
34. 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*
35. DeVries et al. (2017) Recent increase in oceanic carbon uptake driven by weaker upper-ocean overturning. *Nature*
36. Feely et al. (2009) Present conditions and future changes in a High-CO_2 world. *Oceanography*
37. Ross & Behringer (2019) Changes in temperature, pH, and salinity affect the sheltering responses of Caribbean spiny lobsters to chemosensory cues. *Sci. Rep.*
38. Munday et al. (2009) Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. *PNAS*
39. Munday et al. (2010) Replenishment of fish populations is threatened by ocean acidification. *PNAS*
40. Baumann et al. (2012) Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. *Nat. Clim. Change*
41. Kroeker et al. (2010) Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. *Ecol. Lett.*
42. Varnerin et al. (2020) Recruits of the temperature coral *Oculina arbuscula* mimic adults in their resilience to ocean acidification. *Mar. Ecol. Prog. Ser.*
43.Garzke et al. (2016) Combined effects of ocean warming and acidification on copepod abundance, body size and fatty acid content. *PLoS One*
44. Smith et al. (2016) Ocean acidification reduces demersal zooplankton that reside in tropical coral reefs. *Nat. Clim. Change*
45. Charles & Dukes (2008) Impacts of invasive species on ecosystem services. *Biol Invasions*
46. Salvaterra et al. (2013) Impacts of the invasive alga *Sargassum muticum* on ecosystem functioning and food web structure. *Biol. Invasions*
47. Morley et al. (2017) Marine assemblages respond rapidly to winter climate variability. *Glob. Change. Biol.*
48. Vergés et al. (2014) The tropicalization of temperate marine ecosystems: Climate-mediated changes in herbivory and community phase shifts. *Proc. Roy. Soc. B.*
49. Byers (2002) Impacts of non-indigenous species on native enhanced by anthropogenic alteration of selection regimes. *Oikos*
50. Stachowicz (2002) Linking climate change and biological invasions: Ocean warming facilitates nonindigenous species invasions. *Proc. Nat Acad. Sci.*
51. Crickenberger & Moran (2013) Rapid range shift in an introduced tropical marine invertebrate. *PLoS One*
52. Whitfield et al. (2014) Native fish community structure and Indo-Pacific lionfish *Pterois volitans* densities along a depth-temperature gradient in Onslow Bay, North Carolina, USA. *Mar. Ecol. Prog. Ser.*

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