Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Climate Change Impacts

Mallows Bay-Potomac River National Marine Sanctuary

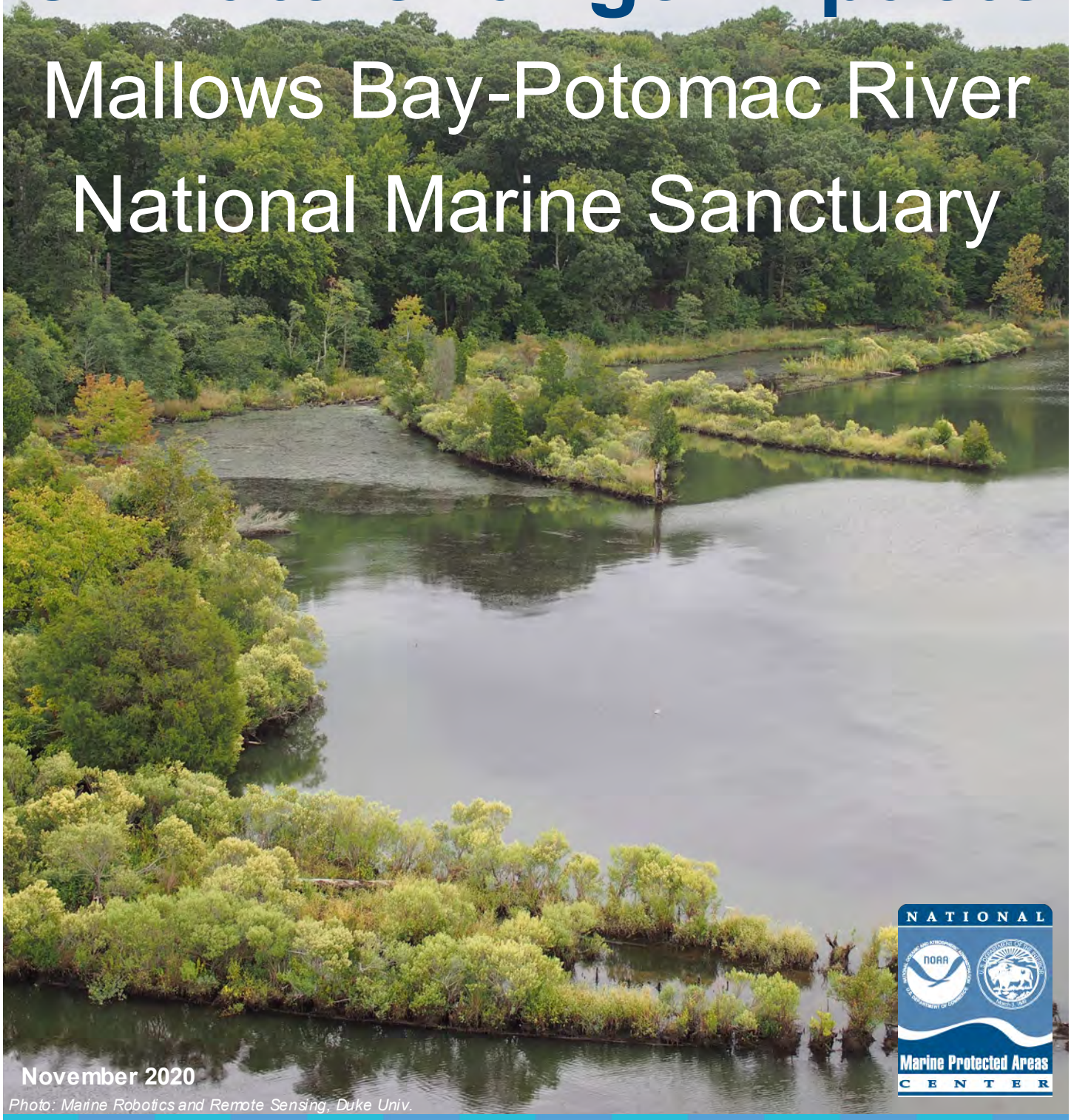

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Photo: Marine Robotics and Remote Sensing, Duke Univ.

Mallows Bay-Potomac River National Marine Sanctuary protects a unique and diverse collection of over 100 shipwrecks. *Photo: Donald G Shomette*

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.

Mallows Bay-Potomac River National Marine Sanctuary

Mallows Bay-Potomac River National Marine Sanctuary encompasses 18 square miles of the Potomac River about 30 miles south of Washington, D.C. Designated in 2019, the sanctuary protects a diverse collection of shipwrecks and cultural heritage dating back nearly 12,000 years. The sanctuary is most recognized for the remains of over 100 wooden steamships: the "ghost fleet of Mallows Bay." Built for the U.S. Shipping Board Emergency Fleet Corporation between 1917 and 1919 as part of U.S. involvement in World War I, but never used in the theater of war, these ships were brought to Mallows Bay for salvage and were eventually abandoned. In addition to their historical value, natural processes have transformed these ships into unique and ecologically valuable habitat.

Increasing Temperatures

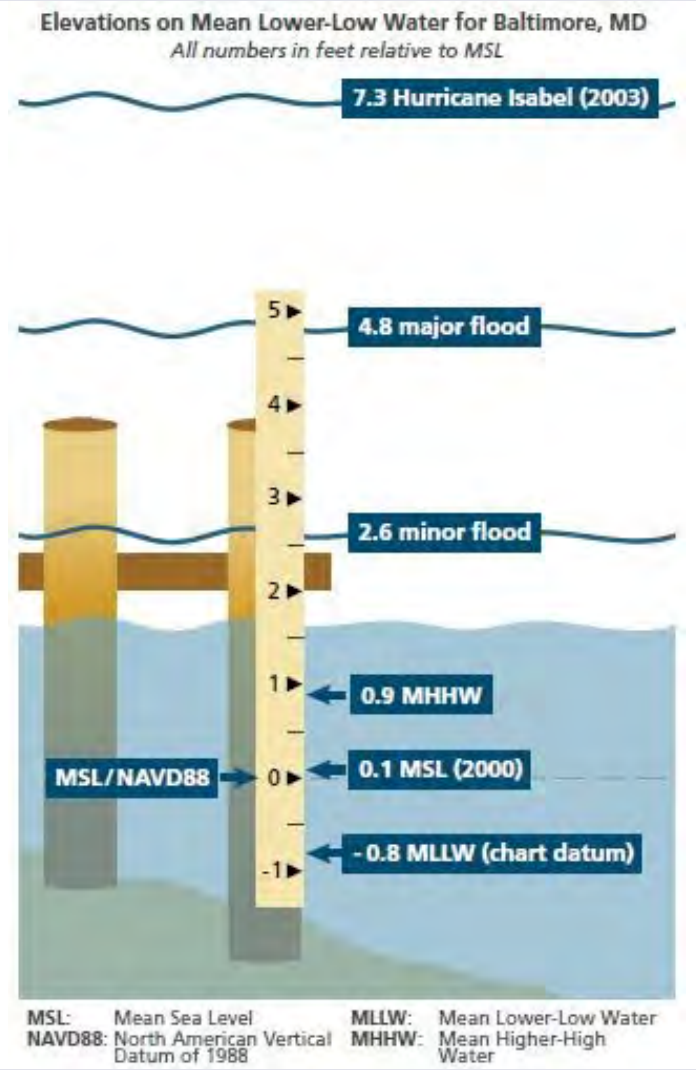
As global temperatures rise, the ocean absorbs much of the heat, causing the average ocean temperature to rise worldwide.[1] The waters of the sanctuary are affected by both the influence of rising air temperatures on upstream waters and increasing ocean temperatures of tidal waters including the Chesapeake Bay and tidal Potomac. As they are partially submerged, the cultural resources and shipwrecks in the sanctuary will be affected by both increasing water and air temperatures.

The shipwrecks of the sanctuary provide a habitat for many birds, including osprey. *Photo: Matt McIntosh/NOAA*

By 2035, the average air temperature in the region could be 3.6°F warmer than pre-colonial temperatures, the largest projected increase of any region in the country.[2] In addition, Atlantic ocean temperatures in and near the Chesapeake could rise faster than almost any other area of the ocean,[1,3,4] up to 10°F by 2100.[5]

Warming air and water could increase the degradation of shipwrecks in the sanctuary as higher temperatures

Case Study 1—Threats to infrastructure



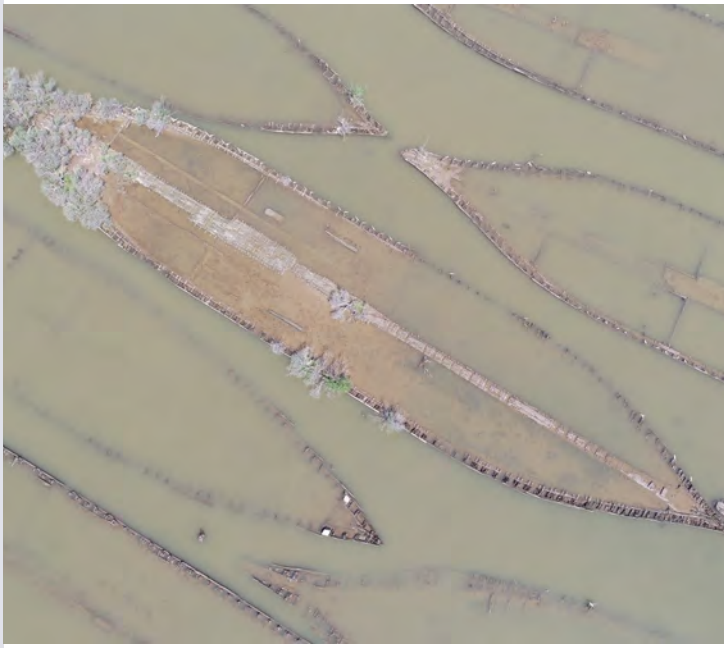
Water levels during flood and storm events in Baltimore, which is expected to experience similar levels of sea level rise as the sanctuary. *Photo: Maryland Commission on Climate Change*[16]

While sea level rise could impact the cultural resources in the sanctuary, it is also likely to affect sanctuary infrastructure. The boat ramp and kayak launch at the sanctuary, as well as a local beach, are often used as access points for the public and sanctuary managers alike. In combination with sea level rise, projected regional increases in rainfall,[12,13] storm surge,[6,17] and the strength of tropical storms and hurricanes[9-11] could increase the chance that sanctuary infrastructure is damaged by flooding. Further, nuisance flooding (waters 1.75 feet above mean higher-high water) in the region currently occurs less than 10 days per year, but, due to sea level rise and increased tidal heights, could occur nearly 100 days a year by 2050 and be a near daily occurrence by the end of the century.[16] Such flooding could damage access points and other infrastructure making the sanctuary less accessible.

increase the rate of both chemical and biological deterioration.[6-8] Organic materials, such as the wooden hulls of the ghost fleet, are particularly vulnerable.[6]

Rising temperatures may also indirectly affect the cultural resources in the sanctuary through its impacts on large-scale processes such as storms and rainfall. Warming oceans fuel stronger tropical storms and hurricanes. In the coming century, these storms are expected to strengthen and intensify more rapidly.[9-11] Higher sea levels, another expected impact of climate change, make these storms more likely to damage shipwrecks through waves and storm surge.[6] Further, as a result of higher temperatures, the rainfall associated with these storms is expected to increase in coming decades,[10] potentially contributing to the recent trend of increasing rainfall in the region.[1,12,13] Flooding from extreme rain events has the potential to damage shipwrecks and other cultural resources through fast water flow, debris carried by floodwaters, and by lifting and moving shipwrecks.[14]

The overall number of tropical storms and hurricanes in the Atlantic is projected to decrease in the coming century, while their strength, intensity, and rainfall are projected to increase.[10] In addition, the impacts of these storms on the Chesapeake region could increase as a result of a projected northward shift in the path of storms.[15] Ultimately, whether through direct or indirect effects, rising temperatures could have many impacts on the cultural resources protected by the sanctuary.



Wooden shipwrecks are particularly susceptible to degradation from rising temperatures. *Photo: Marine Robotics and Remote Sensing, Duke Univ.*

Case Study 2— Climate Change and the *Benzonia*

Benzonia was burned to the waterline before salvage and is now threatened by climate change. *Photo: National Archives*

Perhaps the most prominent wreck of the ghost fleet is the USS *Benzonia*. A wooden steamship with steel bolts and cross-strapping, *Benzonia* was built in Washington state in 1919. It was later brought to Mallows Bay where it was burned to the waterline and stripped for salvage. In 2003, the storm surge from Hurricane Isabel lifted *Benzonia* on top of the wreck of *Caribou*, where it sits today, making it the most easily visible member of the ghost fleet. This unique positioning has allowed *Benzonia* to become an important habitat for birds, but also exposes it to a combination of stressors from both water and air, many of which are likely to be exacerbated by climate change.

Today, the threats of climate change to *Benzonia* are representative of those faced by many wrecks in the sanctuary. Chemical degradation of the wreck could be accelerated by ocean acidification, an increase in the acidity of water due to the uptake of carbon dioxide.[6,7,18] Metallic portions of the wreck, such as the steel bolts and cross-strapping that secure the wooden hull, are the most likely to be impacted by acidification.[6,18] Warming air and water temperatures also increase the rate of chemical reactions, accelerating chemical and biological degredation.[6] Expected increases in tide strength as a result of sea level rise[17,19,20] could also accelerate degradation by exposing the wreck to increased wetting and drying, which can damage historic wood.[6] *Benzonia* has also burned twice since being lifted to its current location, causing substantive damage and exposing more area of the wreck to the impacts of climate change now and in the future.

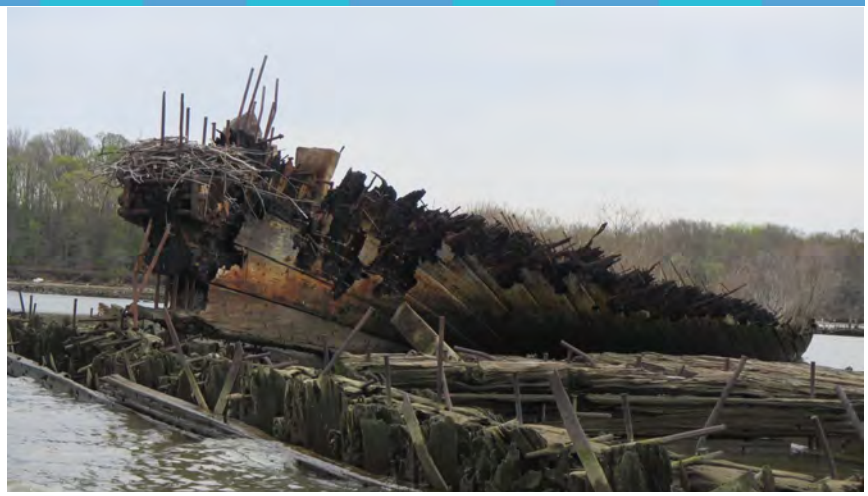
Benzonia, pictured before recent fires, represents many ways the ghost fleet may be affected by climate change. *Photo: Donald Shomette*

Rising Waters

Average sea level is rising worldwide.[1] However, differences in factors like winds, currents, and changing land height cause sea level to rise at different rates in different locations.[1,21] In the Chesapeake region, the land itself is sinking due to geological changes.[16,22,23] Other factors, including changing wind and current patterns in the Atlantic,[16,24,25] also contribute to the rapid rate of sea level rise in the region, which is higher than the global average[20,26] and among the fastest in the country.[27] Under a "business as usual" scenario, Potomac water levels could rise up to 7.9 feet by 2100.[16]

Increased time submerged could help preserve cultural resources. However, higher sea levels also increase the potential for damage from waves and storms[6] while enhancing the possibility that shipwrecks are moved by floods and storm surge.[14] Sea level rise also increases the risk of flooding due to storm surge and rainfall,[28,29] which is expected to increase in the Chesapeake watershed in coming decades.[30,31] Further, as waters rise, the height of storm surge in the sanctuary is likely to increase at an even faster rate.[16,17] The combination of sea level rise with increased rainfall and storm surge is expected to result in 100-year floods occurring yearly by 2100.[16,32] Flooding can increase erosion and damage cultural resources through currents, scouring, and debris. Erosion has already led to fallen trees and shifting sediment in the sanctuary. Shifting sediments can aid preservation by burying cultural resources or accelerate their degradation by uncovering them.[6]

Sea level rise is also causing tides in the Chesapeake to rise higher and fall further.[20] Areas further from the mouth of the Bay, like the sanctuary, are expected to see the greatest change in tidal height.[17,33] Three feet of sea level rise could increase tidal height in the sanctuary by 6 inches.[17] Increased wetting and drying brought by higher and lower tides could damage the historic wood of shipwrecks in the sanctuary.[6]



Top to bottom: metal bolts and cross-strapping hold together wooden hulls; shipwrecks make unique habitat; changing water levels can move shipwrecks. *Photos: Marlies Tumolo/NOAA; Marine Robotics and Remote Sensing, Duke University (mid and bottom).*

The steel hull of the *Accomac* makes it particularly susceptible to the affects of ocean acidification. *Photo: Mariles Tumolo/NOAA*

Ocean Acidification

The absorption of carbon dioxide (CO_2) causes a chemical reaction that leads to waters becoming more acidic and has resulted in the ocean becoming 30% more acidic since 1750.[34,35] The chemistry of estuarine waters, such as the sanctuary, make them particularly susceptible to acidification.[36] However, the future level of acidification in the sanctuary is difficult to predict as it will be determined by a combination of ocean acidification and runoff from upstream, which can raise or lower acidity.[37]

While more information is needed to better understand the exact impacts of acidification on cultural resources, its known effects on the materials that make up shipwrecks suggest it will increase their deterioration.[6,38] Ultimately, increased acidity is likely to accelerate the corrosion of cultural resources in the sanctuary.[6] This is particularly true of metal materials such as the steel hull of the wreck of the *Accomac* and the metal cross-strapping and bolts that hold together the wooden hulls of the ghost fleet.[6,18] This weakening of structural integrity can also increase the susceptibility of wrecks to damage from waves and currents. However, the dense beds of submerged aquatic vegetation (SAV) in the sanctuary could buffer the wrecks against some of these impacts as they take up large amounts of CO_2 through photosynthesis, reducing the acidity of the surrounding waters.[39]

Changing Ecological Communities

Invasive species and climate change are changing ecological communities worldwide, altering ecosystem functions and services.[40,41] Climate change can lead to the invasion of new areas or give invaders advantages over native species.[42-44]

Hydrilla forms thick beds in the sanctuary. Photo: *Kayla do Cuoto/NOAA*

Of particular concern are species of shipworm, which burrow into wood and are major contributors to shipwreck degradation worldwide. While not yet in sanctuary waters, shipworm has been found in the Chesapeake since 1878.[45] As its habitat is limited by temperature and salinity,[46-48] shipworm may spread as waters warm and higher sea levels raise salinity. There is also evidence that shipworm is becoming more tolerant of fresher and colder water.[47,48] Though it is unlikely shipworm will colonize the sanctuary, its impacts on shipwrecks make it prudent to monitor for its possible arrival.

Many of the submerged aquatic vegetation (SAV), underwater plants, in the sanctuary are invasive.[39] Climate change could further alter the SAV community as increased CO_2 concentrations benefit SAV[39,49] while warmer waters are expected to favor invasives.[39] The plant *Hydrilla* invaded the Potomac River in the 1980s[39] and is particularly prevalent in the sanctuary where it forms thick beds, outcompeting native species[39,50] and obscuring cultural resources. While SAV can obscure resources, it may also play a role in protecting them from some of the effects of climate change. Thick beds of SAV can slow water flow, potentially reducing damage from powerful currents and waves. Further, SAV can reduce the effects of acidification by taking up large amounts of CO_2 through photosynthesis.[39] Thus, whether native or invasive, SAV may be beneficial to the preservation of cultural resources in the sanctuary and changes to the SAV community could have unexpected consequences.

What Is Being Done?

The sanctuary management plan, which will govern the activities and programs in the sanctuary while laying out its management priorities, will explicitly address climate change and actions that NOAA can take to assess and address its impacts. NOAA also works with state partners at the Maryland Department of Natural Resources and Maryland Department of the Environment who are researching and working to address the impacts of climate change. These partnerships resulted in the installation of a buoy in Mallows Bay, funded by the National Marine Sanctuary Foundation, that collects data on water parameters as part of a larger network that monitors the Chesapeake and creates the baseline needed to track climate change impacts. NOAA is also working with other researchers to study the impacts of climate change and other stressors in the sanctuary.

The sanctuary serves as a focal point for education and outreach to students, teachers, and local communities throughout the region. This outreach focuses on a wide range of topics, including climate change, and is critical to increase public understanding of climate change and begin to address its effects. By providing a way to get into nature and experience history up close, the sanctuary can familiarize local communities with the natural world and instill a sense of wonder and stewardship in children and adults alike. This step is critical to creating support to address climate change in order to preserve the sanctuary and the resources it protects.

The sanctuary is an important focal point for education and outreach to local communities in Maryland and Virginia. *Photo: Matt McIntosh/NOAA*

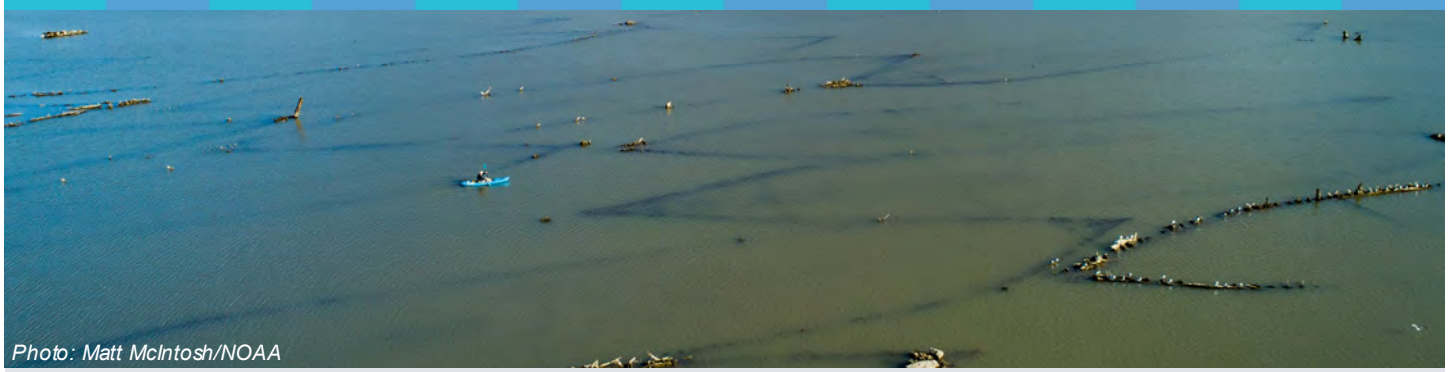


Photo: Matt McIntosh/NOAA

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. Karmalkar & Bradley (2017) Consequences of global warming of 1.5°C and 2°C for regional temperature and precipitation changes in the contiguous United States. *PLoS One*
3. Saba et al. (2015) Enhanced warming of the Northwest Atlantic Ocean under climate change. *J. Geophys. Res. Oceans*
4. Alexander et al. (2018) Projected sea surface temperatures over the 21st century: Changes in the mean, variability and extremes for large marine ecosystem regions of Northern Oceans. *Elementa Sci. Anthrop.*
5. Muhling et al. (2017) Potential salinity and temperature futures for Chesapeake Bay using a statistical downscaling disaggregation framework. *Estuar. Coasts*
6. Wright (2016) Marine archaeology and climate change: An invitation. *J. Mari. Arch*
7. Perez-Alvaro (2016) Climate change and underwater cultural heritage: Impacts and challenges. *J. Cult. Herit.*
8. North & Macleod (19887) Corrosion of metals. In: *Conservation of marine archaeological objects*
9. Kossin et al. (2017) Extreme storms. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program*
10. Knutson et al. (2019) Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming. *Bull. Am. Mar. Sci.*
11. Emanuel (2017) Will global warming make hurricane forecasting more difficult? *Bull. Am. Meteorol. Soc.*
12. Thibeault & Seth (2014) Changing climate extremes in the Northeast United States: observations and projections from CMIP5. *Climatic Change*
13. Hoerling et al. (2016) Characterizing recent trends in U.S. heavy precipitation. *J. Climate*
14. Office of National Marine Sanctuaries (2016) Mallows Bay-Potomac River National Marine Sanctuary Designation Draft Environmental Impact Statement. *U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries*
15. Baldini et al. (2016) Persistent northward North Atlantic tropical cyclone track migration over the past five centuries. *Sci. Rep.*
16. Boesch et al. (2018) Sea-level rise: Projections for Maryland 2018. *University of Maryland Center for Environmental Science*
17. Boesch et al. (2013) Updating Maryland's sea-level rise projections. Special report of the Scientific and Technical Working Group to the Maryland Climate Change Commission. *University of Maryland Center for Environmental Science*
18. Spalding (2011) Perverse sea change: underwater cultural heritage in the ocean is facing chemical and physical changes. Cultural and heritage arts review. *The Ocean Foundation*
19. Rhamstorf et al. (2012) Testing the robustness of semi-empirical sea level projections. *Clim. Dynam.*
20. Ross et al. (2017) Fingerprints of sea level rise on changing tides in the Chesapeake and Delaware Bays. *J. Geophys. Res. Oceans*
21. Slagen et al. (2014) Projecting twenty-first century regional sea-level changes. *Clim. Change*
22. Love et al. (2016) The contribution of glacial isostatic adjustment to projections of sea□level change along the Atlantic and Gulf coasts of North America. *Earth's Future*
23. Sweet et al. (2017) Global and regional sea level rise scenarios for the United States. *NOAA Technical Report NOS CO-OPS 083*
24. Ezer et al. (2013) Gulf Stream's induced sea level rise and variability along the U.S. mid□Atlantic coast. *J. Geophys. Res. Oceans*
25. Little et al. (2017) On the relationship between the meridional overturning circulation, alongshore wind stress, and United States East Coast sea level in the Community Earth System Model Large Ensemble. *J. Geophys. Res. Oceans*
26. Miller et al. (2013) A geological perspective on sea□level rise and its impacts along the U.S. mid□Atlantic coast. *Earth's Future*
27. Sallenger et al. (2012) Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature. Clim. Change*
28. Ezer & Atkinson (2014) Accelerated flooding along the U.S. East Coast: On the impact of sea□level rise, tides, storms, the Gulf Stream, and the North Atlantic Oscillations. *Earth's Futrure*
29. Woodruff et al. (2013) Coastal flooding by tropical cyclones and sea-level rise. *Nature*
30. Najjar et al. (2010) Potential climate-change impacts on the Chesapeake Bay. *Estuar. Coast Shelf Sci.*
31. Guilbert et al. (2015) Characterization of increased persistence and intensity of precipitation in the northeastern United States. *Geophys. Res. Lett.*
32. Marsooli et al. (2019) Climate change exacerbates hurricane flood hazards along US Atlantic and Gulf Coasts in spatially varying patterns. *Nat. Commun.*
33. Rhamstorf et al. (2012) Testing the robustness of semi-empirical sea level projections. *Clim. Dynam.*
34. Doney et al. (2009) Ocean acidification: The other CO2 problem? *Annu. Rev. Mar. Sci.*
35. Haugan & Drange (1996) Effects of CO2 on the ocean environment. *Energy Conv. Manag.*
36. Hu and Cai (2013) Estuarine acidification and minimum buffer zone—A conceptual study. *Geophys. Res. Lett.*
37. Wallace et al. (2014) Coastal ocean acidification: The other eutrophication problem. *Estuar. Coast. Shelf. Sci.*
38. Dunkley (2015) Climate is what we expect, weather is what we get: managing the potential effects of climate change on underwater cultural heritage. In: *Water and Heritage: material, conceptual, and spiritual connections*
39. Arnold et al. (2017) Twenty-first century climate change and submerged aquatic vegetation in a temperate estuary: the case of Chesapeake Bay. *Ecosyst. Health. Sustain.*
40. Charles & Dukes (2008) Impacts of invasive species on ecosystem services. *Biol Invasions*
41. Salvaterra et al. (2013) Impacts of the invasive alga *Sargassum muticum* on ecosystem functioning and food web structure. *Biol. Invasions*
42. Byers (2002) Impacts of non-indigenous species on native enhanced by anthropogenic alteration of selection regimes. *Oikos*
43. Stachowicz (2002) Linking climate change and biological invasions: Ocean warming facilitates nonindigenous species invasions. *Proc. Nat Acad. Sci.*
44. Crickenberger & Moran (2013) Rapid range shift in an introduced tropical marine invertebrate. *PLoS One*
45. Scheltma & Truitt (1956) The shipworm *Toredo Navalis* in Maryland coastal waters. *Ecology*
46. Paalvast & Van der Velde (2011) New threats of an old enemy: The distribution of the shipworm *Toredo navalis* L. (Bivalvia: Teredinidae) related to climate change in the Port of Rotterdam areas, the Netherlands. *Mar. Poll. Bull.*
47. Borges et al. (2014) Diversity, environmental requirements, and biogeography of bivalve wood-borers (Teredinidae) in European coastal waters. *Front. Zool.*
48. Lippert et al. (2017) *Toredo navalis* in the Baltic Sea: Larval dynamics of an invasive wood-boring bivalve at the edge of its distribution. *Front. Mar. Sci.*
49. Zimmerman et al. (2015) Predicting effects of ocean warming, acidification, and water quality on Chesapeake region eelgrass. *Limnol. Oceanogr.*
50. Haller & Sutton (1974) Community structure and competition between *Hydrilla* and *Vallisneria*. *Hyacinth Control Journal*

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