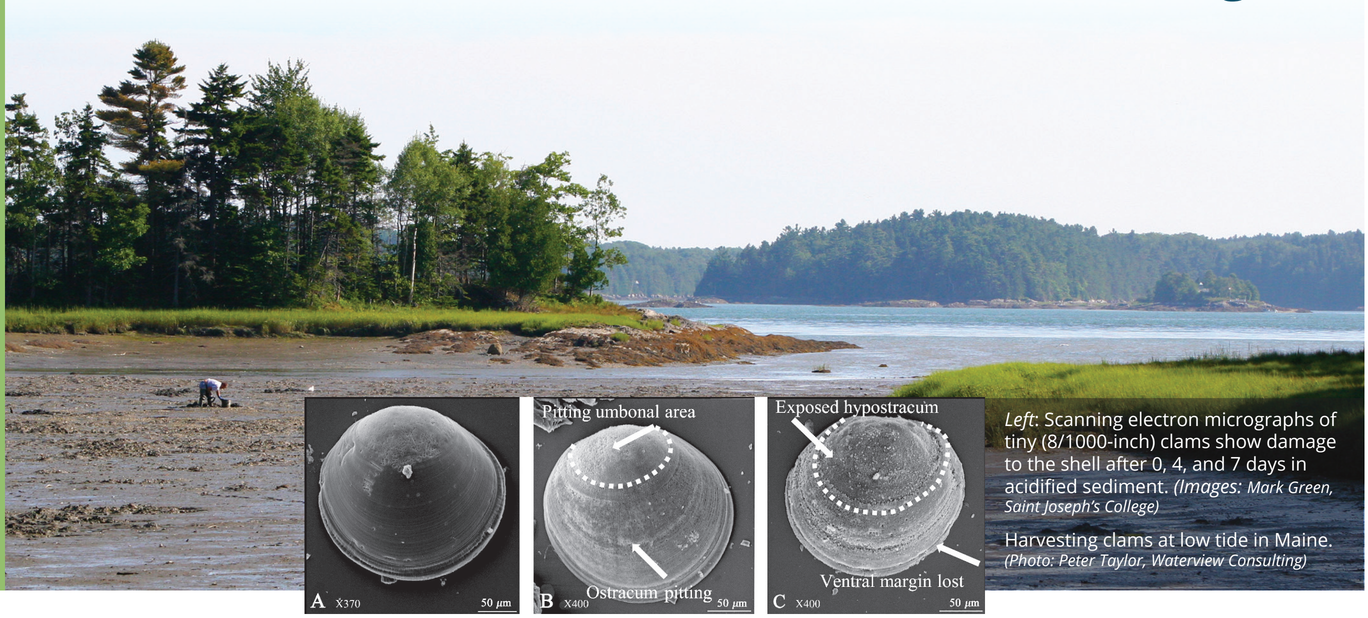
NORTHEAST **COASTAL ACIDIFICATION** NETWORK

Overview *of* Acidification *in the* Northeast Region



Left: Scanning electron micrographs of tiny (8/1000-inch) clams show damage to the shell after 0, 4, and 7 days in acidified sediment. *(Images: Mark Green, Saint Joseph's College)*

Harvesting clams at low tide in Maine. *(Photo: Peter Taylor, Waterview Consulting)*

Ocean Acidification Is Happening on a Global Scale

Historically, the world's ocean has been on the basic side of the acid-base scale of pH. But decades of scientific monitoring show that seawater pH is dropping toward the acidic side, as carbon dioxide is being emitted into the atmosphere more rapidly than any period over the past 300 million years.

Seawater absorbs approximately 25 percent of atmospheric carbon dioxide. This spurs a series of chemical reactions that result in more carbonic acid in the ocean. These reactions—known as **ocean acidification**—also reduce the amount of dissolved calcium carbonate mineral. Many species of marine life rely on calcium carbonate to build skeletons and shells.

Since the beginning of the industrial revolution, the pH of the ocean's surface waters has dropped from 8.2 to 8.1—an acidification of 30 percent. Estimates based on business-as-usual carbon emission scenarios indicate that by 2100 surface waters could plummet to approximately pH 7.9. That would be the lowest ocean pH in more than 20 million years.

Local Factors Can Worsen Acidification Along Coast

While carbon dioxide emissions into the atmosphere are the driving force behind ocean acidification, additional factors can cause greater acidification near the coast. Scientists refer to these local processes as **coastal acidification** to distinguish them from the global process of ocean acidification.

Rivers and other sources, such as wastewater treatment plants and storm water discharges, strongly influence the chemistry of coastal waters by bringing fresh water, nutrients, and carbon into the ocean. Excessive nutrients promote acidification by fueling growth of algae and phytoplankton, which then die and decay. Carbon dioxide released during decay has the same effect on pH as carbon dioxide from the atmosphere. Freshwater inputs are increasing as climate change brings more intense precipitation.

New England Is Particularly Vulnerable

New England faces an elevated risk for ocean and coastal acidification because its coastal waters are not well buffered

THE NORTHEAST COASTAL ACIDIFICATION NETWORK (NECAN) is a nexus of scientists, resource managers, and industry partners dedicated to coordinating and guiding regional observing, research, and modeling focused on coastal and ocean acidification along the coast and offshore of New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia. The purpose is to better identify critical vulnerabilities to acidification, particularly with respect to regionally important and economically significant marine resources.

against acidification compared to many other places, such as the southeastern U.S. coast. Seawater with reduced buffering capacity exhibits a more pronounced pH change for a given input of carbon dioxide, making corrosion more likely for shells and skeletons of marine life. Buffering capacity is low in the Northeast primarily because of the cold water, which affects carbonic acid chemistry, and because of the many rivers that flow into the ocean. Already, plumes of water outside river mouths sometimes become so acidified that shells and skeletons may begin to dissolve (see map, next page).

How Does Ocean and Coastal Acidification Affect Marine Life?

Ocean and coastal acidification pose a severe threat to sea urchins (left) and scallops (right), according to laboratory studies.

A Range of Impacts Are Possible

Ocean and coastal acidification can affect marine life in myriad ways, which the scientific community is just beginning to understand. Mollusks, crustaceans, corals, and some algae have greater difficulty forming hard parts such as shells and skeletons when seawater pH declines, and the hard structures may even dissolve. Metabolic rate, immune response, organ development, acid-base regulation, and sense of smell may also be harmed. Alternatively, increased levels of carbon dioxide in seawater can benefit seaweeds and other algae by enabling them to photosynthesize and grow more quickly.

Shell and Skeleton Growth May Be Impeded

Calcium carbonate is the main building block of shells of mollusks, sea urchins, and calcifying plankton. It is a minor albeit critical component of the carapaces of lobsters and shrimp. Normally, calcium carbonate is abundant in seawater, enabling calcifying species to readily build and maintain their body structures. Ocean and coastal acidification, however, make seawater less saturated with calcium carbonate. This means calcifying animals must devote greater energy to building shells and skeletons, leaving them less energy for feeding, reproduction, and other essential activities. Eventually, if calcium carbonate becomes undersaturated, seawater may become corrosive, meaning shells, skeletons, and other calcareous body parts begin to dissolve, especially those of young individuals still building their calcium carbonate-dependent shells or skeletons.

Overview of Effects on Marine Life

Scientific research into effects of ocean and coastal acidification on marine life is a new and rapidly advancing field. Below are summaries of the latest science. For references, visit **necan.org**.

Ecosystem

Little is known yet about how acidification affects the food web and other aspects of the ocean ecosystem. Most studies to date have been done in the **laboratory**, have focused on **single species**, and have used specimens from **places outside the Northeast**. Information below is drawn from existing studies.

Fish

Only a few fish species of New England have been studied. One study found summer flounder embryos had **lower survival** rates. Other studies found cod larvae and Atlantic silverside had **variable responses** depending on the population source.

Crustaceans

Few studies have been conducted, and the findings are mixed.

Mollusks

Mollusks are comparatively well studied, and the research shows they are **highly vulnerable**. Shells **grow more slowly**, and larvae and juveniles suffer **higher mortality**.

Other Invertebrates

Effects on the green sea urchin are overwhelmingly **negative** at all stages from larva to adult. Among other bottom-dwelling invertebrates, a general trend is that noncalcifying species fare better than calcifying species.

Seaweed and Seagrasses

Calcareous algae tend to be affected **negatively**. Fleshy algae and marine plants such as eelgrass tend to respond positively through **increased productivity**.

Zooplankton

Pteropods, which underpin key food webs for pink salmon, mackerel, herring, seabirds, whales, and other species, are **highly sensitive** to acidification and suffer **high mortality**. In the Pacific Northwest the percentage of pteropods with dissolving shells due to ocean acidification has doubled in the nearshore habitat since the pre-industrial era. Copepods appear relatively **robust** to acidification. Little information is available about other types of zooplankton.

Phytoplankton

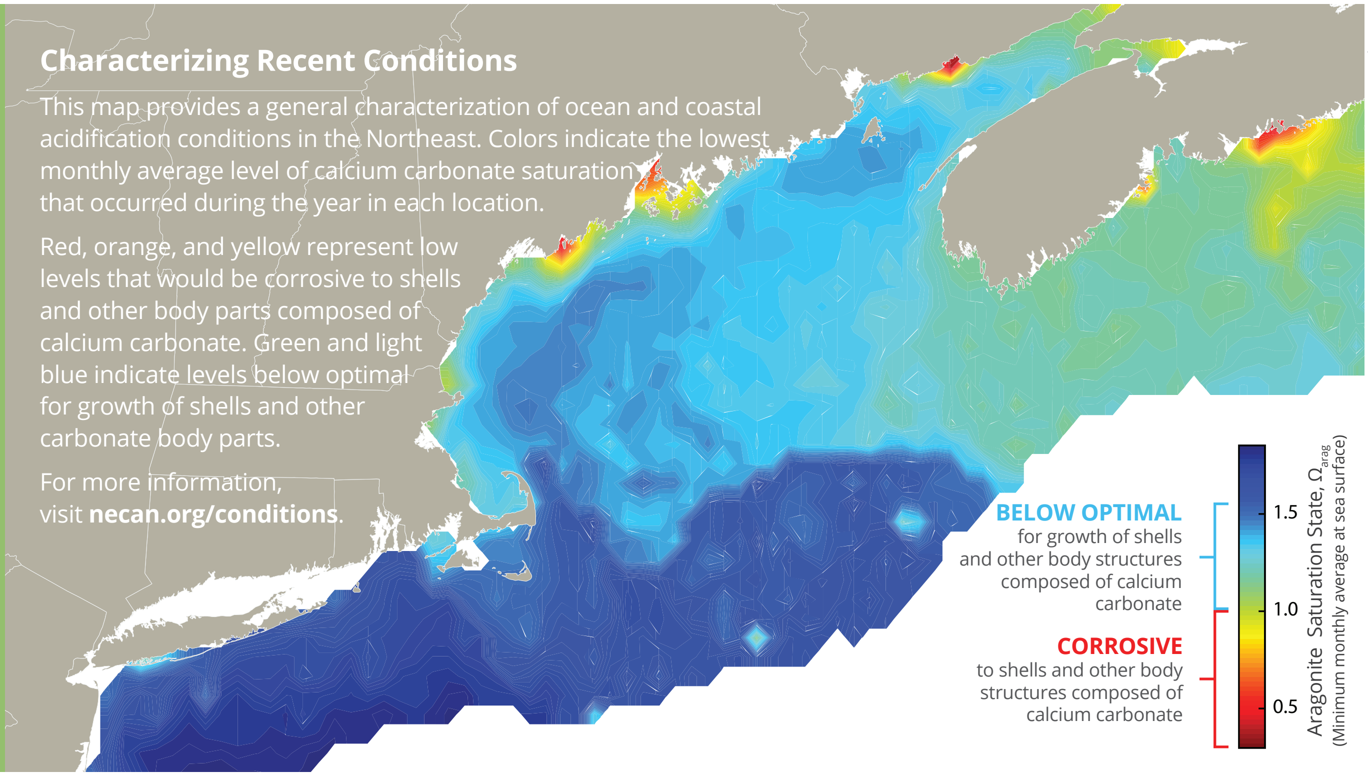
Phytoplankton vary greatly in their responses to acidification. Some **grow more slowly** and/or have **less nutritional value**, while others have the **opposite response** or **no change** at all.

Characterizing Recent Conditions

This map provides a general characterization of ocean and coastal acidification conditions in the Northeast. Colors indicate the lowest monthly average level of calcium carbonate saturation that occurred during the year in each location.

Red, orange, and yellow represent low levels that would be corrosive to shells and other body parts composed of calcium carbonate. Green and light blue indicate levels below optimal for growth of shells and other carbonate body parts.

For more information, visit **necan.org/conditions**.



Data: Minimum monthly averaged sea surface aragonite saturation state (Ω_{arag}) per Signorini *et al.* (2013) and Gledhill *et al.* (2015).ß

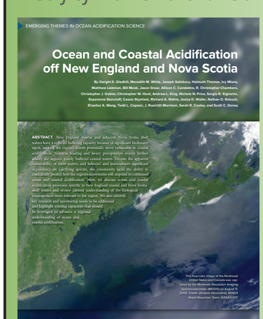
Businesses and Policymakers Need Information

Among the many industries that could be affected by ocean and coastal acidification are commercial fishing, shellfish harvesting, aquaculture, and seafood distribution. People operating businesses in those industries need objective information to help them prepare for and respond to the impacts. Policymakers and resource managers are beginning to address ocean and coastal acidification, and they require high-quality scientific information for decision-making. In turn, the scientific community needs input from stakeholders and decision-makers to design effective monitoring and research strategies for the region. NECAN holds workshops, offers state-of-the science webinars, publishes reports, and conducts other initiatives to inform and build partnerships among stakeholders, policymakers, and resource managers.

Lobster fishing and shellfish aquaculture are among the industries threatened by ocean and coastal acidification.

Below left: NECAN published "Ocean and Coastal Acidification off New England and Nova Scotia" in the June 2015 issue of *Oceanography*. *Below right:* NECAN supported production of *A Climate Calamity in the Gulf of Maine Part 2: Acid in the Gulf*, a short animated video that tells the story of ocean and coastal acidification in the Northeast.

Both are available online at necan.org.



Outlook: What Lies Ahead?

The ocean ecosystem of the northeastern U.S. faces an elevated risk for continued ocean and coastal acidification. The region's poorly buffered waters will likely grow more sensitive to changes in carbonate chemistry because of increasing amounts of fresh water. The fresh water will come from two sources, both associated with climate change: (1) more precipitation falling onto land and draining into the ocean, and (2) relatively fresher ocean water flowing from the Arctic. These changes could result in larger, more frequent plumes of corrosive water in the Northeast.

Urgent scientific priorities include greatly expanded, high-quality monitoring of ocean and coastal acidification, conducting biological studies in the region, and integrating those studies to characterize present-day conditions and forecast future changes.

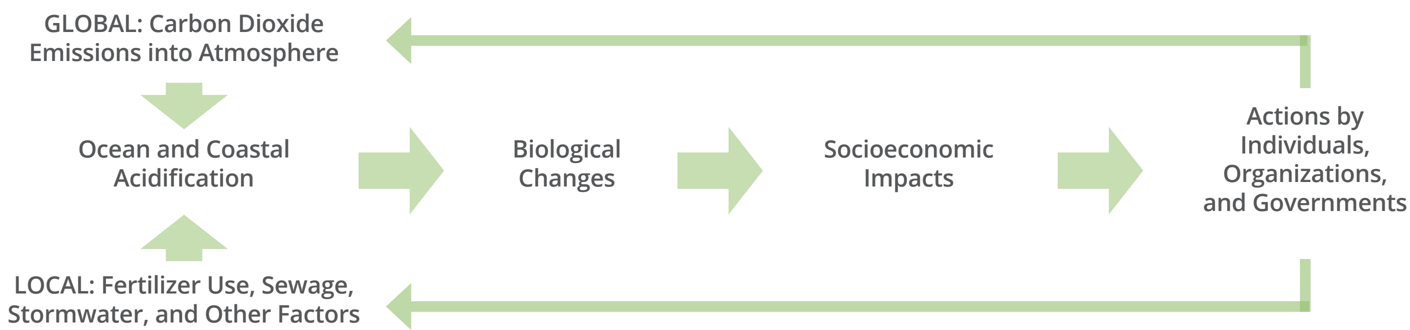
Research Priorities for the Northeast

Scientists are working to develop accurate projections of ocean and coastal acidification and its likely effects on the ecosystem and ocean-related economy in the Northeast. To advance those efforts, NECAN convened experts who identified the following priorities for research:

- **Studies of commercially important species**—including American lobster, blue crab, Jonah crab, rock crab, horseshoe crab, sea scallop, and many species of finfish—to evaluate their sensitivity to acidification, using populations from within the Northeast
- **Multiple-stressor studies** that investigate the impact of acidification in combination with other stressors such as temperature, hypoxia, salinity, ultraviolet radiation, and trace metals specific to this region
- **Multiple life-stage and multi-generational studies** that follow organisms from younger to older life stages and from parent to offspring, as they are exposed to increased carbon dioxide
- **Food web and other indirect effect studies** that consider how species' interactions with other species and the environment may change as a result of acidification
- Studies of how species respond to **variable levels of acidification**, rather than stable levels, to better reflect real-world conditions, and of whether shellfish, which are already exposed to high variability in estuaries, can adapt to changing conditions
- **Investigations of key processes**—air-sea exchange, upwelling, river/stream flow, estuary conditions, benthic/pelagic biology, and vertical mixing—to determine influences on calcium carbonate dynamics and trends across the region
- **Monitoring of carbonate chemistry** using a strategic design to quantify the changing conditions of the Scotian Shelf, upwelling areas, and rivers
- **Identification of long-term carbonate chemistry trends** for the region: hindcasting to the pre-industrial period, forecasting at weekly to seasonal scales, and projecting long-term changes under Intergovernmental Panel on Climate Change (IPCC) scenarios
- **Field studies** that build on single-species laboratory studies to understand real-world ecosystem changes and the effects on organisms in their natural environments

Buoys with sensors that monitor ocean chemistry provide critical data for studying acidification.

Links Between People and Coastal Acidification



What Can You Do?

Many people ask, "What can I do about coastal acidification?" The causes of coastal acidification are localized, and actions to reduce it can be taken rapidly by citizens and government (see box at right). A key step is to learn about its causes, effects on marine life, regional conditions, and the latest research. That knowledge equips people to take practical steps and to help others take action. The NECAN website at **necan.org** provides educational and scientific information resources. Addressing the global issue of ocean acidification will take many decades of collective effort to reduce carbon emissions. It is essential to ensure that all policy makers, from local to national levels, are informed about the potential effects of increasing ocean and coastal acidification.

Take Action Against Ocean and Coastal Acidification

Experts recommend people take the following steps to reduce acidification of their local coastal waters:

- Cut down or eliminate **fertilizers** on lawns, gardens, and farms.
- Make sure **septic systems** are doing their job.
- Reduce **stormwater runoff** and improve **sewage treatment**.
- Protect and restore **eelgrass beds** and **salt marshes** because they absorb and sequester carbon dioxide.
- **Join** and/or **volunteer** with organizations to monitor coastal waters and educate the public.

Visit the NECAN website for information about ocean and coastal acidification in the Northeast | **www.necan.org**

Much of the text in this document is adapted from Gledhill, D.K., M.M. White, J. Salisbury, H. Thomas, I. Mlsna, M. Liebman, B. Mook, J. Grear, A.C. Candelmo, R.C. Chambers, C.J. Gobler, C.W. Hunt, A.L. King, N.N. Price, S.R. Signorini, E. Stancioff, C. Stymiest, R.A. Wahle, J.D. Waller, N.D. Rebuck, Z.A. Wang, T.L. Capson, J.R. Morrison, S.R. Cooley, and S.C. Doney. 2015. Ocean and coastal acidification off New England and Nova Scotia. *Oceanography* 28(2):182–197, http://dx.doi.org/10.5670/oceanog.2015.41.