Trophic State of Coastal Waters

While the presence of many water pollutants can lead to decreases in coastal water quality, four interlinked components related to trophic state are especially critical: nutrients (nitrogen and phosphorus), chlorophyll-*a*, dissolved oxygen, and water clarity. "Trophic state" generally refers to aspects of aquatic systems associated with the growth of algae, decreasing water transparency, and low oxygen levels in the lower water column that can harm fish and other aquatic life. Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle (https://www.epa.gov/nutrientpollution/issue). Nitrogen and phosphorus can come from point sources, such as wastewater treatment plants and industrial effluents, and nonpoint sources, such as runoff from farms, over-fertilized lawns, leaking septic systems, and atmospheric deposition. Chlorophyll-*a* is a surrogate measure of phytoplankton abundance in the water column. Chlorophyll-*a* levels are increased by nutrients and decreased by filtering organisms (e.g., clams, mussels, or oysters). High concentrations of chlorophyll-*a* indicate overproduction of algae, which can lead to surface scums, fish kills, and noxious odors. Low dissolved oxygen levels and decreased clarity caused by algal blooms or the decay of organic matter from the watershed are stressful to estuarine organisms. Reduced water clarity (usually measured as the amount and type of light penetrating water to a depth of 1 meter) can be caused by algal blooms, sediment inputs from the watershed, or storm-related events that cause resuspension of sediments, and can impair the normal growth of algae and other submerged aquatic vegetation.

This indicator, developed as part of EPA's National Coastal Condition Assessment (NCCA), is based on an index constructed from probabilistic survey data on five components: dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll-*a*, daytime dissolved oxygen in bottom or near-bottom waters (where benthic life is most likely to be affected), and water clarity. The results for this indicator are presented in EPA's 2015 National Coastal Condition Assessment (U.S. EPA, 2021). The survey was designed to provide a national picture of water quality by sampling sites in coastal waters throughout the contiguous United States. Each site was sampled during the summer months; thus the indicator reflects a snapshot of conditions from the period of June through September in each survey year. Comparable data were collected three times: 2005–2006, 2010, and 2015. Data are sufficient to show differences in trophic condition over time for four regions: Northeast Coast, Southeast Coast, Gulf Coast, and West Coast.

Key factors like sediment load, mixing processes, and ecosystem sensitivity naturally vary across biogeographic regions and even within regions. Thus, benchmarks for nutrients, water clarity, and chlorophyll-*a* were established based on variable expectations for conditions in different biogeographic regions. For example, due to Pacific upwelling during the summer, higher nutrient and chlorophyll-*a* concentrations are expected along the West Coast than in other regions. Water clarity thresholds are lower for coastal waters that support seagrass than for naturally turbid waters. A single national reference range of 2–5 milligrams per liter (mg/L) was used for dissolved oxygen, because concentrations below 2 mg/L are almost always harmful to many forms of aquatic life and concentrations above 5 mg/L seldom are (Diaz and Rosenberg, 1995; U.S. EPA, 2000). The process of classifying individual sites varies by region and is described in detail, along with the regionally relevant benchmarks, in the Technical Support Document for the 2015 National Coastal Condition Assessment (U.S. EPA, 2020).

The overall water quality index is a compilation of the five components. For each site, the index is rated high if none of the five components received a score that would be considered environmentally unfavorable (high concentrations of nitrogen, phosphorus, or chlorophyll-*a* levels or low concentrations of dissolved oxygen or reduced water clarity), and no more than one component was rated moderate. Overall water quality is low if two or more components received the most unfavorable rating. All other sites receive a moderate index score. If two or more components are missing, and the available components do not suggest a moderate or low index rating, the site is classified as "unsampled."

What the Data Show

Water quality along the Southeast Coast has remained relatively stable over time (Exhibit 1). A substantial portion of the Southeast Coast had low or moderate water quality. The West Coast and Northeast Coast saw an increase in high water quality between 2005–2006 and 2015, while the Gulf Coast had an increase in low water quality.

Nitrogen concentrations were low in almost all coastal waters sampled throughout the period of record (Exhibit 2). The Gulf Coast had the largest percentage of area with high concentrations in 2015 (8 percent). All regions have

experienced an increase in prevalence of low nitrogen concentrations over time.

Most regions had low to moderate phosphorus concentrations throughout the timeframe shown (Exhibit 3). The West Coast had predominantly low concentrations, while the Northeast and Southeast had largely moderate concentrations. The largest proportion of area with high phosphorus concentrations was in the Gulf Coast in 2010 (45 percent of coastal area). Some regions have experienced fluctuations in quality over time—most noticeably the West Coast and Gulf Coast.

Chlorophyll-*a* concentrations have varied over time and by region (Exhibit 4). High chlorophyll-*a* concentrations were most prevalent along the Gulf Coast in 2015 (32 percent of coastal area). Low chlorophyll-*a* concentrations along the Southeast Coast decreased from 24 percent of coastal area in 2005–2006 to 11 percent in 2015. The West Coast saw a decrease in percent of area with low concentrations of chlorophyll-*a* and an increase in moderate concentrations. A significant decrease in percent of unsampled area was accompanied by increases in percent of area with high, moderate, and low concentrations of chlorophyll-*a* for the Northeast Coast.

While effects vary with temperature and salinity, as a general rule, concentrations of dissolved oxygen above 5 mg/L are considered supportive of marine life, concentrations below 5 mg/L are potentially harmful, and concentrations below 2 mg/L—a common threshold for hypoxia—are associated with a wider range of harmful effects (e.g., some juvenile fish, crustaceans, and mollusks that cannot leave the area may die). All four regions had dissolved oxygen levels above 5 mg/L in at least 65 percent of their coastal waters in 2015, with the West Coast having the highest rate at 84 percent of the area (Exhibit 5).

Water clarity has varied over time and by region (Exhibit 6). Water clarity surpassed reference conditions (i.e., higher clarity) in more than 90 percent of the coastal waters of the West Coast in 2015. The Southeast Coast and Gulf Coast had the largest proportion of area with low clarity. The Northeast Coast and Southeast Coast both showed an increase in clarity in 2015 compared with 2005–2006.

Limitations

- Comparable data have not been collected over the same timeframes in Alaska, Hawaii, or U.S. territories.
- The NCCA survey target population includes estuarine waters. It does not include observations of dissolved oxygen concentrations in offshore coastal shelf waters, such as the hypoxic zone in Gulf of Mexico shelf waters.
- At each sample location, the components of this indicator may have a high level of temporal variability. This survey is intended to characterize the typical distribution of water quality conditions in coastal waters during the summer. It does not consistently identify the "worst-case" condition for sites experiencing occasional or infrequent hypoxia, nutrient enrichment, or decreased water clarity at other times of the year.

Data Sources

This indicator is based on an analysis published in EPA's 2015 National Coastal Condition Assessment (U.S. EPA, 2021). These data are available on EPA's website at https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys.

References

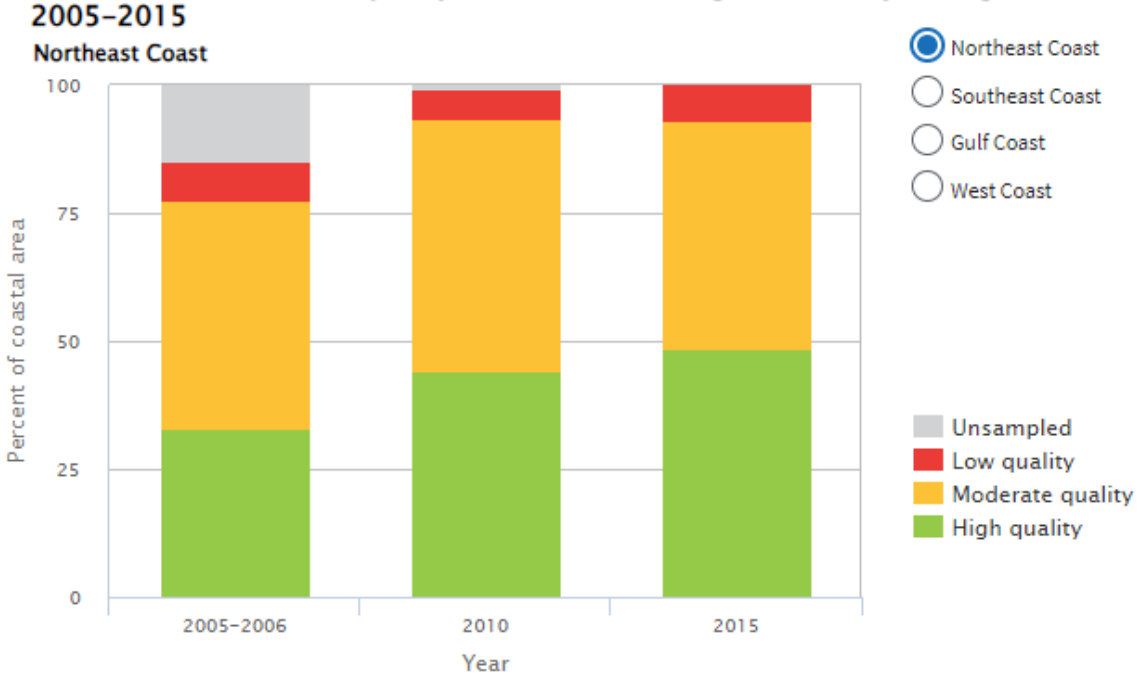
Diaz, R.J., and R. Rosenberg. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioral responses of benthic macrofauna. Oceanogr. Mar. Biol. Ann. Rev. 33:245-303.

U.S. EPA (United States Environmental Protection Agency). 2021. National Coastal Condition Assessment 2015 report. EPA-841-R-21-001. https://www.epa.gov/national-aquatic-resource-surveys/national-coastal-condition-assessment-2015-report.

U.S. EPA. 2020. National Coastal Condition Assessment 2015 technical support document. EPA-841-R-20-002. https://www.epa.gov/national-aquatic-resource-surveys/national-coastal-condition-assessment-2015-technical-support.

U.S. EPA. 2000. Ambient aquatic life water quality criteria for dissolved oxygen (saltwater): Cape Cod to Cape Hatteras. EPA/822/R-00/12.

Exhibit 1. Coastal water quality index for the contiguous U.S. by ecoregion, 2005–2015



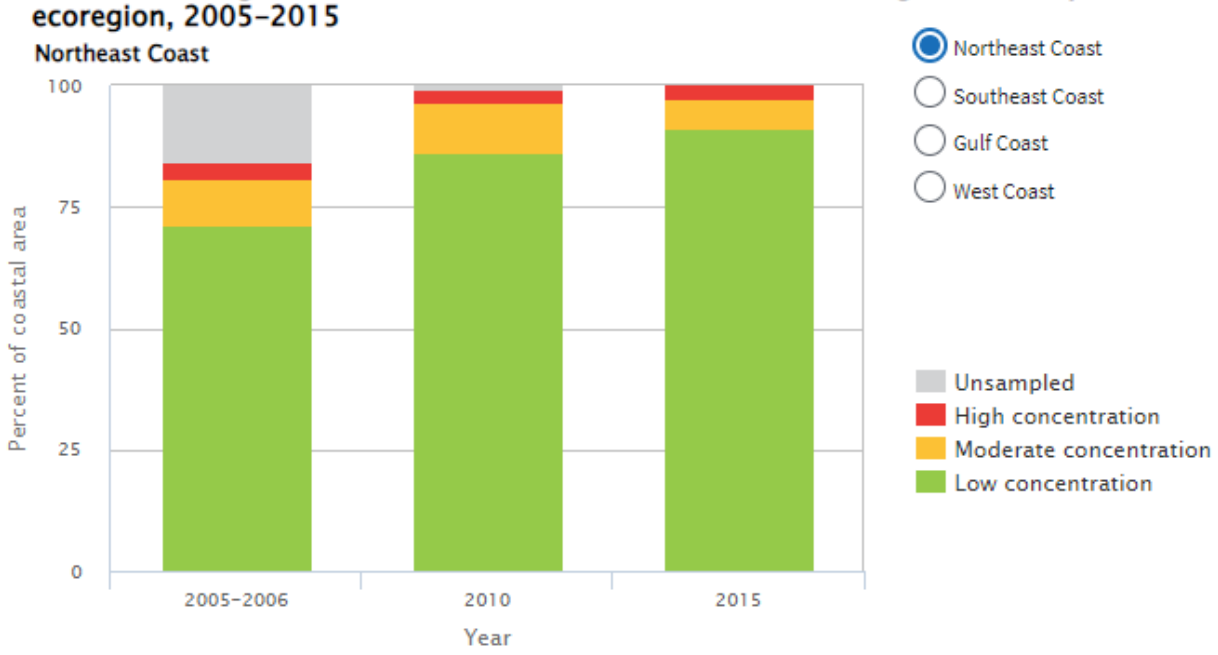
See text for definitions of categories.

Analysis shows that the increase in high water quality in Northeast coastal waters is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical document for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 2. Nitrogen concentrations in coastal waters of the contiguous U.S. by ecoregion, 2005–2015



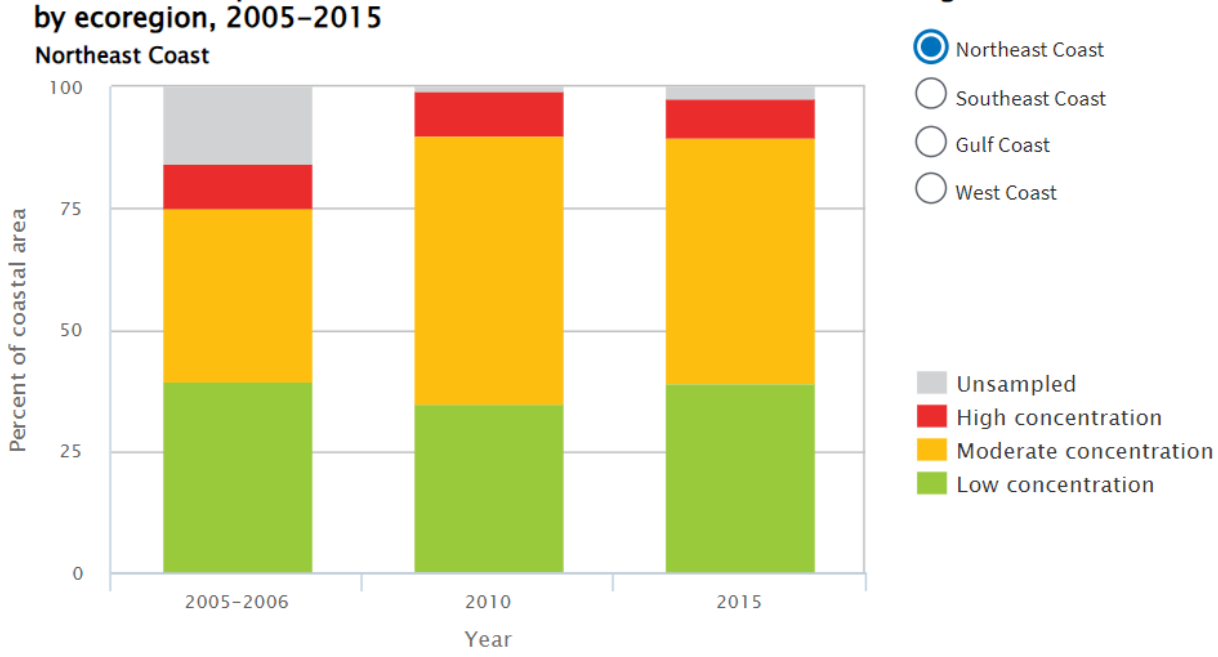
This indicator measures dissolved inorganic nitrogen (DIN), which is the sum of nitrate, nitrite, and ammonia. See text for definitions of categories.

Analysis shows that the increase in low concentrations in Northeast coastal waters is statstically signficant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 3. Phosphorus concentrations in coastal waters of the contiguous U.S. by ecoregion, 2005–2015



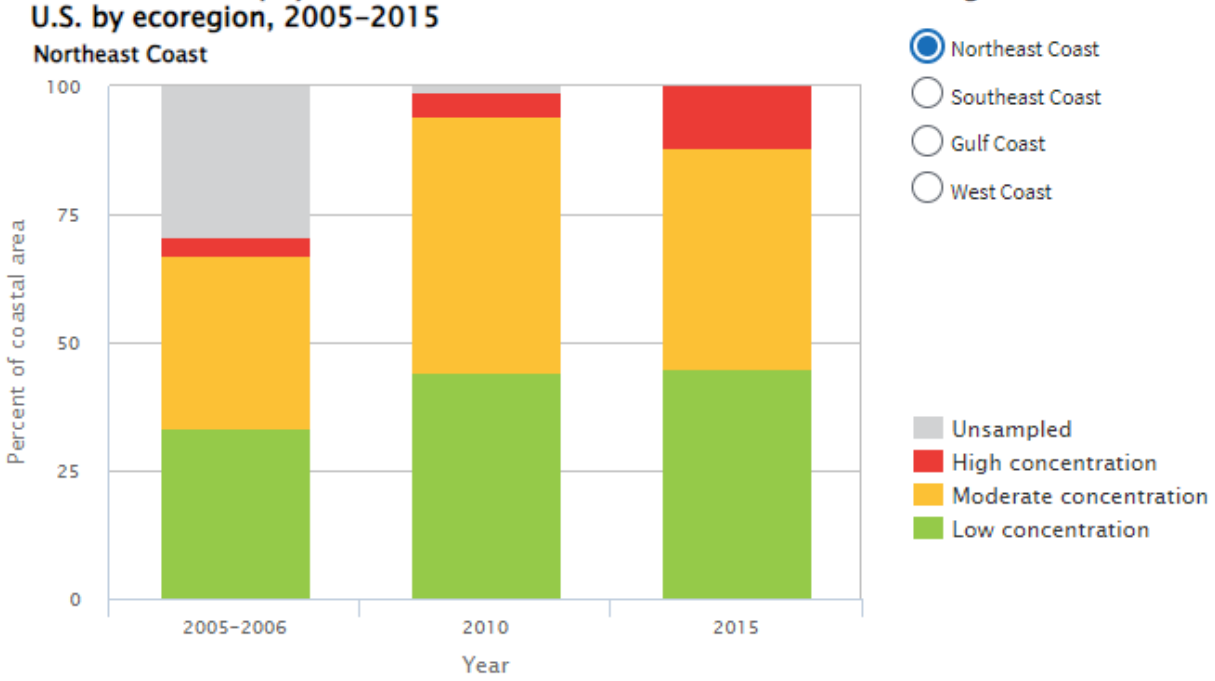
This indicator measures dissolved inorganic phosphorus (DIP), which equals orthophosphate. See text for definition of categories.

Analysis shows that the increase in moderate concentrations in Northeast coastal waters is statistically significant. For more information about the uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 4. Chlorophyll-*a* concentrations in coastal waters of the contiguous U.S. by ecoregion, 2005–2015



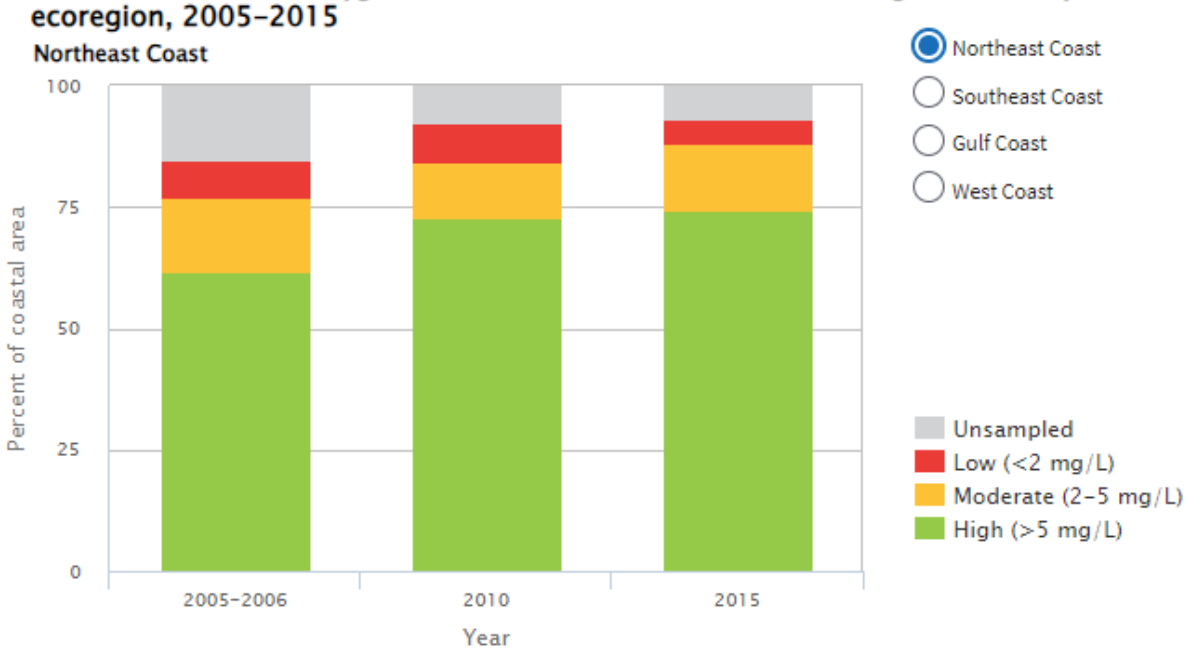
See text for definitions of categories.

Analysis shows that the increases in low, moderate, and high concentrations in Northeast coastal waters are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 5. Dissolved oxygen levels in coastal waters of the contiguous U.S. by ecoregion, 2005–2015



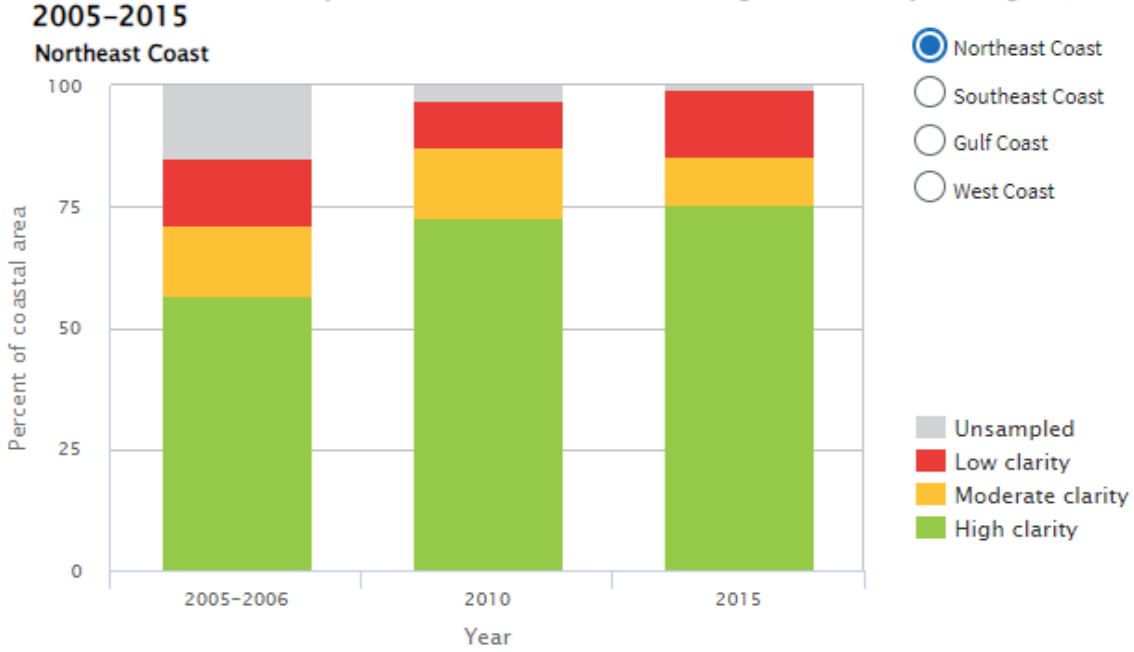
This indicator measures bottom or near-bottom water dissolved oxygen. See text for definitions of categories.

Analysis shows that the increase in high dissolved oxygen in Northeast coastal waters is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 6. Water clarity in coastal waters of the contiguous U.S. by ecoregion, 2005–2015



See text for definitions of categories.

Analysis shows that the increase in high clarity in Northeast coastal waters is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2021

Visit https://www.epa.gov/roe to see the full exhibit.