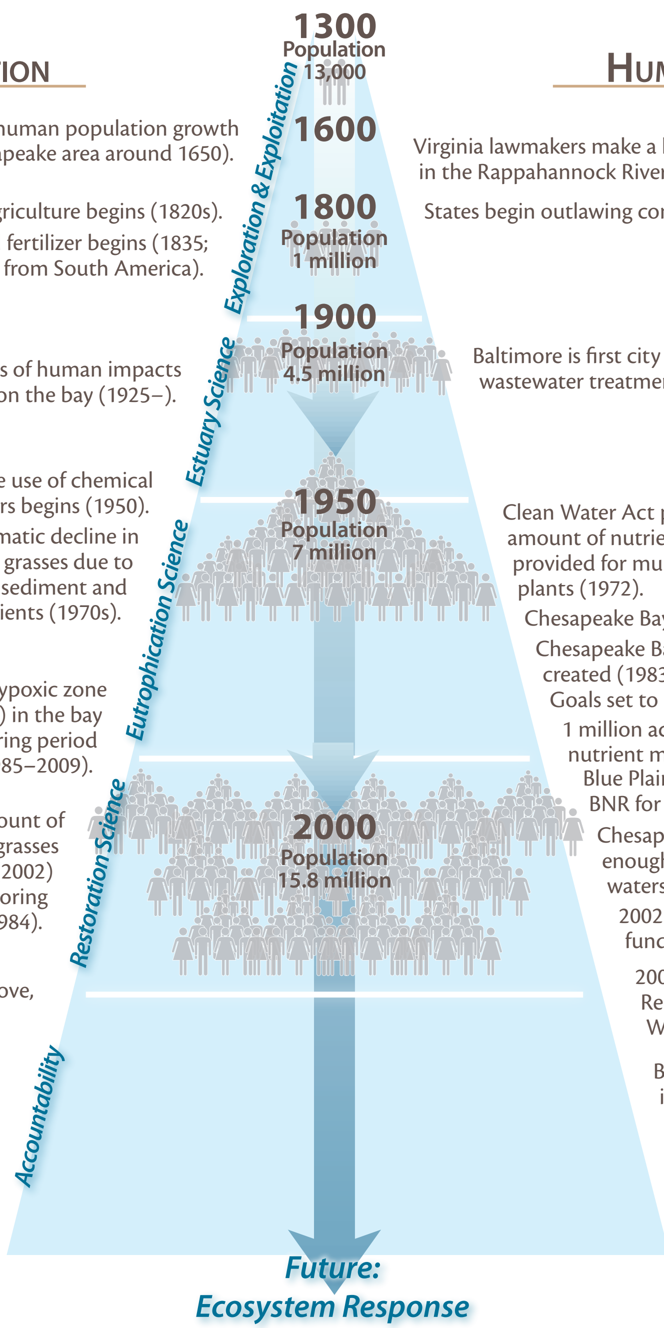
NITROGEN IN THE CHESAPEAKE BAY: A RETROSPECTIVE

Nitrogen pollution has been a primary cause of a degraded Chesapeake Bay ecosystem for over a century. However, resource management response to excess nitrogen only began in the 1970s with the Clean Water Act. Since then, Bay monitoring programs have measured the amount of nitrogen coming from human activities on land (urban, suburban, rural, and industrial) and from natural cycling in the water column. This newsletter summarizes monitoring data and describes nitrogen trends in both the non-tidal and tidal areas of the Chesapeake Bay.

Human response to nitrogen loading in the Chesapeake Bay: How far have we come?



Bay eutrophication

Degradation begins from early human population growth (Europeans settle in the Chesapeake area around 1650).

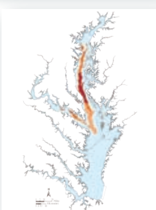
Large-scale land clearing for timber and agriculture begins (1820s).

Extensive use of natural fertilizer begins (1835; (using bird guano from South America).

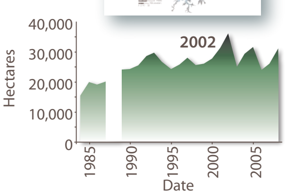
Increasing scientific studies of human impacts on the bay (1925–).

Extensive use of chemical fertilizers begins (1950).

Dramatic decline in aquatic grasses due to excess sediment and nutrients (1970s).



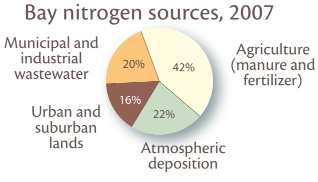
Largest hypoxic zone (1993) in the bay mainstem during period of record (1985–2009).



Largest amount of aquatic grasses recorded (2002) since monitoring began (1984).

While nitrogen trends in the bay improve, water clarity remains poor.

Bay nitrogen sources, 2007



Resurgence of aquatic grasses in low salinity zones of the bay is correlated with decreasing nutrient loads (2010).

Human responses

Virginia lawmakers make a law in order to prevent overfishing in the Rappahannock River (1680).

States begin outlawing commercial hunting (1820s).

Baltimore is first city in U.S. to use wastewater treatment facility (1920).

Clean Water Act passed, limiting the type and amount of nutrients to the Bay. It also provided for municipal sewage treatment plants (1972).

Chesapeake Bay Commission created (1980).

Chesapeake Bay Program created (1983).

Goals set to reduce nitrogen (1987).

1 million acres of farmland are under nutrient management plans (1994).

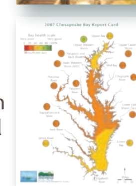
Blue Plains WWTP (biggest in watershed) begins BNR for half of its flow (1996).

Chesapeake 2000 sets goal of reducing pollution enough to take the bay off the EPA's impaired waters list.

2002 Farm Bill passed, funding agricultural subsidies.

2004 Chesapeake Bay Restoration Fund (MD) for WWTP upgrades to ENR.

Bay-wide report card introduced (2006).



EPA proposes draft nitrogen Total Maximum Daily Load (TMDL) for Chesapeake Bay (2010).

BNR = biological nutrient removal
ENR = enhanced nutrient removal
WWTP = wastewater treatment plant

Figure 1. Tracking Chesapeake Bay ecosystem health in relation to nitrogen and human milestones over time documents some resource management success, in spite of the continued challenge of population growth. Blue text represents phases for Chesapeake Bay science.

Connecting nitrogen trends in the Bay and its watershed

TRENDS IN THE WATERSHED

The US Geological Survey (USGS), US EPA Chesapeake Bay Program, and state agencies measure nitrogen and streamflow at many locations in the Chesapeake Bay watershed. This information is used to evaluate management actions for nutrient reduction. Nitrogen concentration varies each year due to both human-related and natural factors. Human activities include agricultural and suburban fertilizer application as well as implementation of management practices. Natural factors include variation in weather (precipitation) and transportation times of nitrogen in streams and groundwater.

Nitrogen concentration at individual locations varies within years mostly due to rainfall and resulting streamflow, as seen at a Potomac River site near Washington DC (Figure 2). Results for the same Potomac site over a 24-year period show a slight decrease in nitrogen from 1984 to 2007 (Figure 3). Of the 34 sites tested for trends in the non-tidal network, the majority have statistically significant improving or no significant trends in non-flow-adjusted total nitrogen concentrations (Figure 4). It should be noted that while the improving trends are statistically significant, in many cases, the amount of change has not been enough to meet nutrient reduction goals. This is not surprising considering only 50% of the sites show improving trends. As a result, there is still a large amount of nitrogen making its way into the Chesapeake Bay.

Dept of Nat. Resources; Laura Fabian

Water quality is collected by automatic data logger platforms and researchers throughout the Chesapeake Bay watershed. Water samples are taken back to the lab for nitrogen analysis.

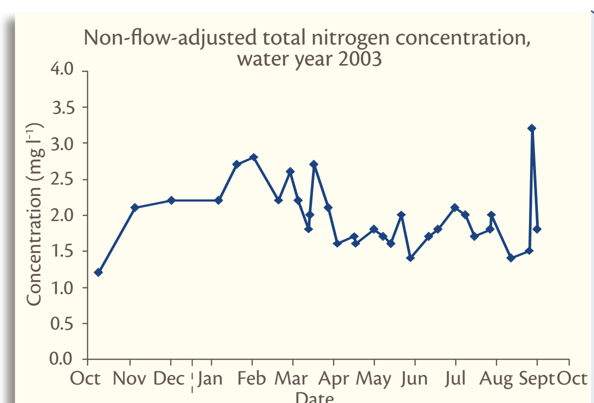


Figure 2. Non-flow-adjusted nitrogen concentrations on the Potomac River at Great Falls, MD, shows variability from month to month.

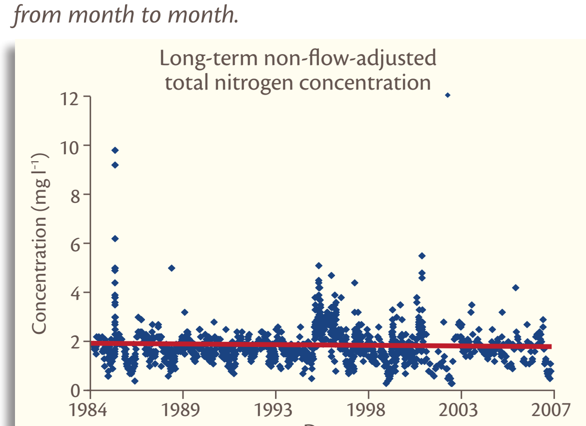


Figure 3. The long-term, non-flow-adjusted concentration data for the same site show a slight decrease in nitrogen from 1984 to 2007.

Total nitrogen concentrations in non-tidal Chesapeake Bay (rivers and streams)

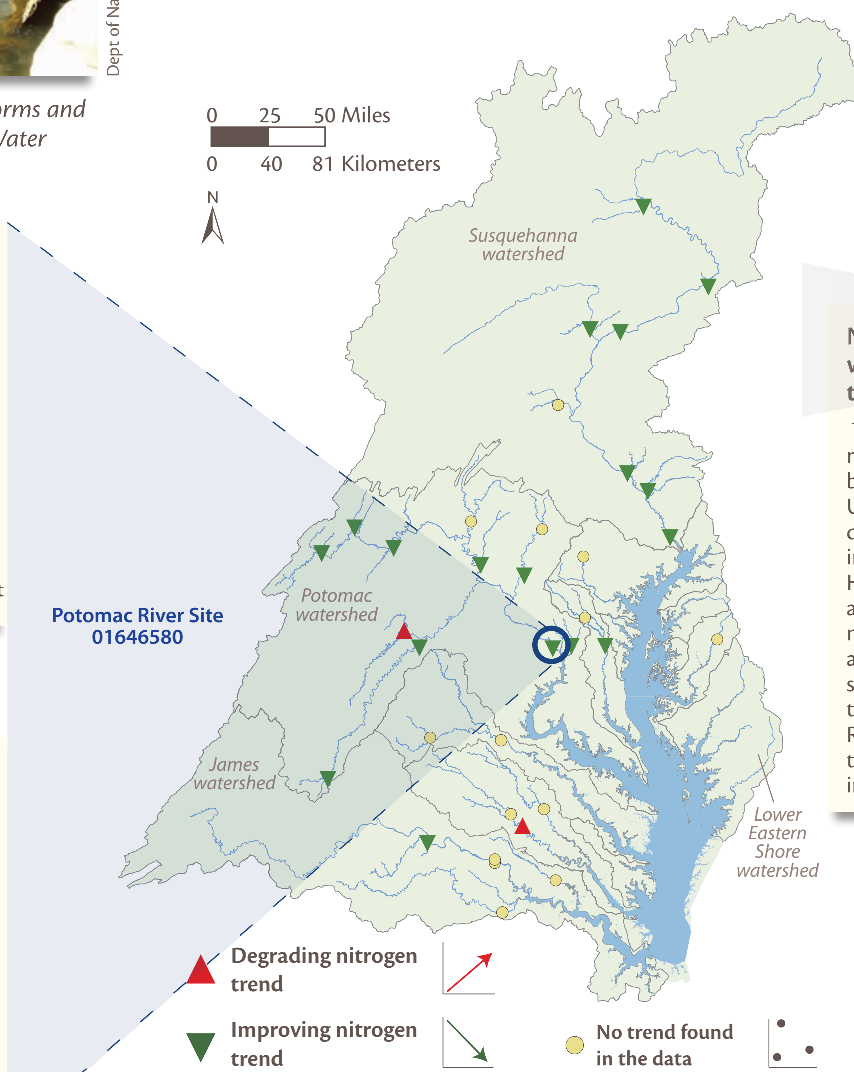


Figure 4. Map of non-flow-adjusted total nitrogen concentration trends in the non-tidal Chesapeake Bay watershed. Approximately half of the sites are shown to be improving.

Nitrogen is declining in the Bay where nitrogen is declining in the watershed

The mainstem Bay shows decreasing nitrogen concentrations (indicated by the green arrows and inverted U shapes), which coincide to decreasing nitrogen concentrations in the Susquehanna River watershed. However, the shape of the trend, as an inverted U, indicates that nitrogen has just started to decrease after either increasing, or staying the same, for many years. The trends in the tidal Rappahannock and York River follow the degrading or no trend nitrogen concentrations seen in the watershed.

TRENDS IN THE BAY

Significant nitrogen concentration trends are present for most of the Chesapeake Bay mainstem since monitoring began in the mid-1980s, except in the Upper Bay (Figure 5). There are some signs of improving nitrogen trends in the middle and lower mainstem, although many of these trends show a switch from degrading or no nitrogen concentration trends to improving nitrogen concentration trends (Figures 6 and 7).

A closer look at data from specific tributary and mainstem locations reveals both improving and degrading nitrogen concentration trends. In the upper tidal Potomac River, a resurgence in aquatic grasses may be related to improving nitrogen concentrations, as well as decreased point source nitrogen loads by a recently upgraded wastewater treatment plant. Most monitoring stations in the lower Chesapeake Bay mainstem show improving nitrogen trends, although the source of these trends is unclear, since the tributaries flowing into the lower Bay have degrading or no trends in nitrogen concentrations. It could be the influence of ocean water coming into the Bay and mixing with Bay waters.

At other stations across the tidal portion of the Bay, monitoring reveals degrading total nitrogen trends. Nitrogen concentrations are degrading in the upper Patuxent River (since the early to mid 2000s). Additional degrading trends are found in the middle of Virginia's Rappahannock River, and at most of the monitoring stations in the lower York River, perhaps due to increasing total nitrogen point source loads. These degrading nitrogen concentrations may reflect increasing or additional pressures from human activities or biological processes.

C. Wicks

A researcher measures water quality parameters on the tidal portion of the Rhode River.

Total nitrogen concentration trends in tidal Chesapeake Bay

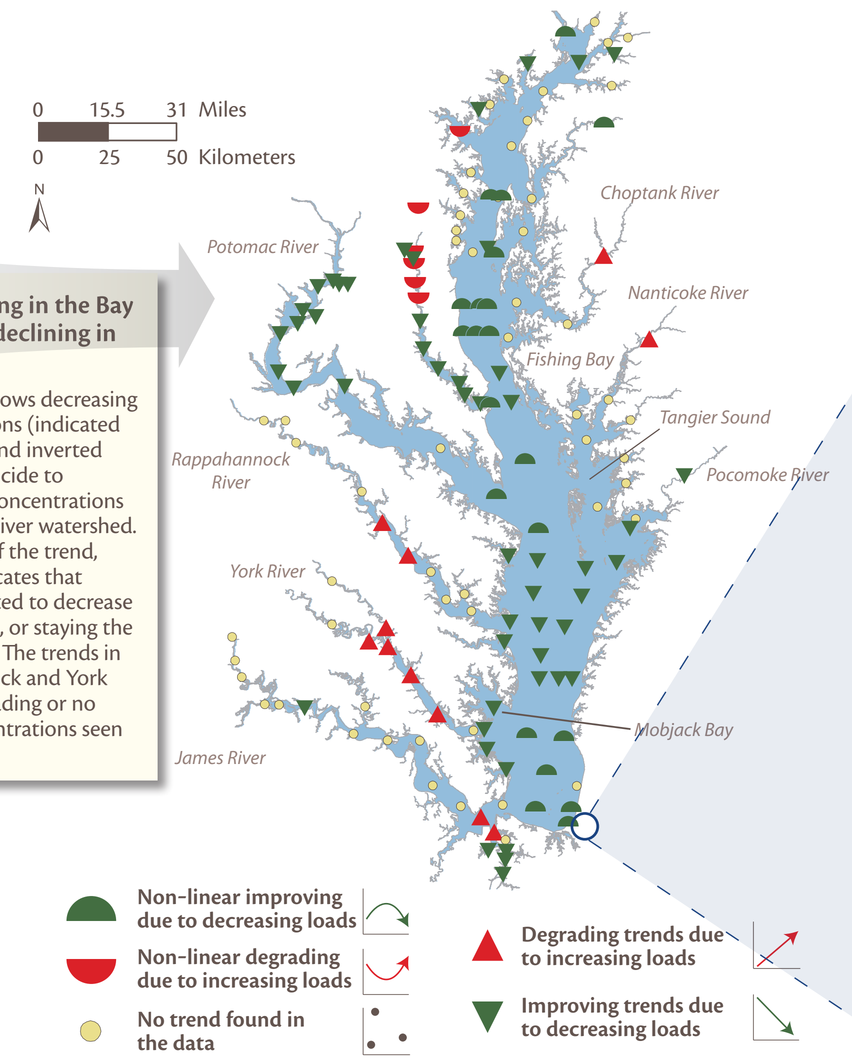


Figure 5. Total nitrogen concentration trends in the tidal portions of Chesapeake Bay. MD and VA tributaries data are from 1985 through 2009 while the VA mainstem Bay data are from 1988 through 2009. The difference in date ranges may have influenced the observed trends. Note: No non-linear trends available for VA tributaries.

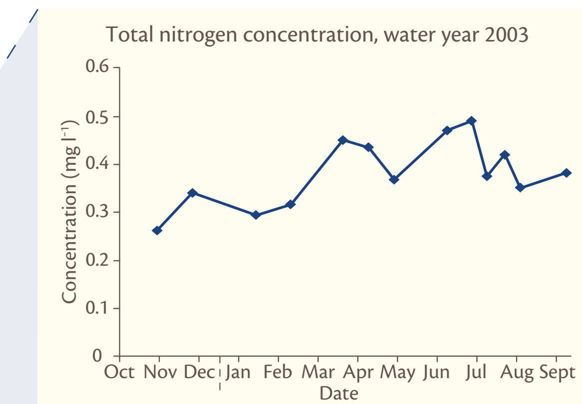


Figure 6. Monthly averages for the mainstem tidal site, CB7.4, for the 2003 water year. One year of data is not enough to see a trend due to the variability in the data.

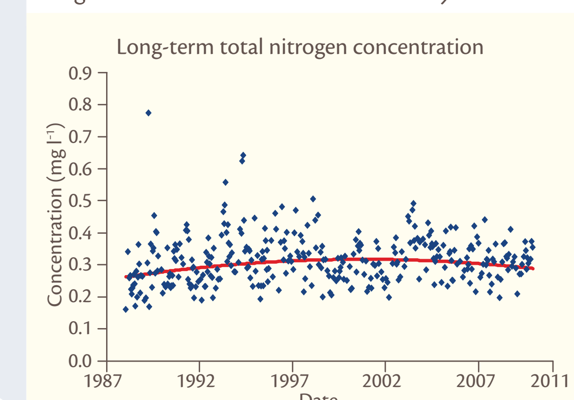


Figure 7. The data for tidal site, CB7.4, over the entire period of record show an initial increase in nitrogen followed by a reversal of this trend.

Point source nitrogen = Managed pollution

Over the last 25 years, the model of the annual load of total nitrogen to the Bay shows a decrease (Figure 8). However, the model of point source nitrogen shows a continued contribution of about 20% of the nitrogen that ends up in the Chesapeake Bay.

Wastewater treatment plants are an example of point source pollution. In the late 1980s, technological advancements for "cleaning" the water of nitrogen before it enters local waters were introduced. The latest improvements, called Enhanced Nutrient Removal (ENR), remove more than 90% of pollutants and reduce nitrogen concentrations to 3 mg L^{-1} (ppm).

Although advanced methods for controlling nitrogen inputs to the bay are well understood, there is a lag time between the development of the technology and its implementation at wastewater treatment plants due to the time required for implementation and at least in part to a lack of public funding. As a result, many such facilities are still waiting to be upgraded, which may partly explain the increase in total nitrogen in Figure 9.

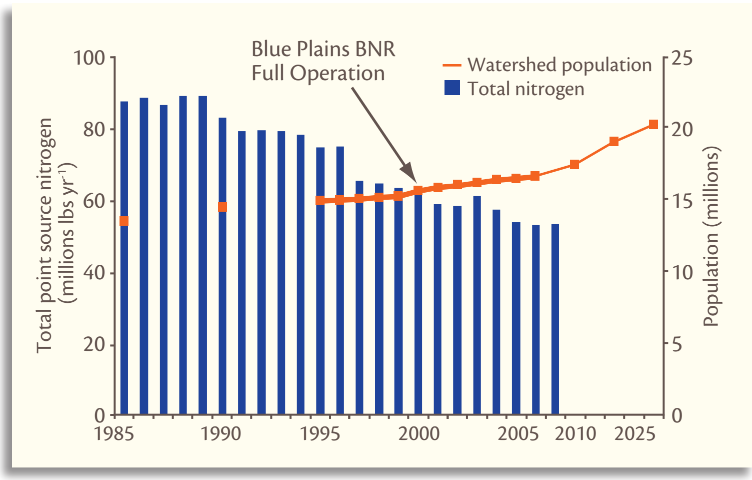


Figure 8. Total nitrogen loads delivered per year to Chesapeake Bay (modeled) and projected population growth. BNR=Biological Nitrogen Removal; Data: Chesapeake Bay Program.

DCWASA

Employees adjust machinery (left) and test nitrification tanks (right) at wastewater treatment plants.

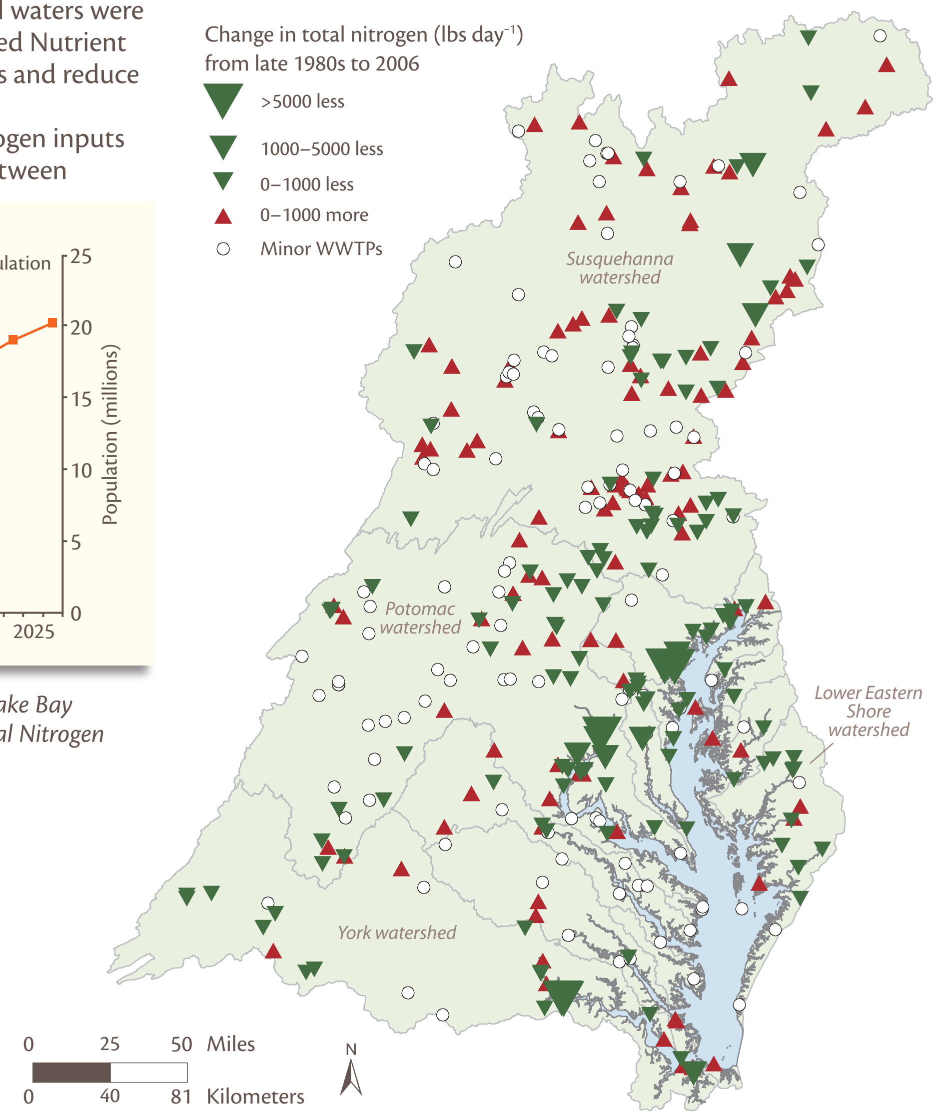


Figure 9. This map shows the modeled change in total nitrogen at major wastewater treatment plants (WWTPs) in the Chesapeake Bay. There is an overall decrease in nitrogen from WWTPs to local waters but many facilities can still be improved.

Newsletter design and layout:
Emily Nauman, EcoCheck
Jane Hawkey, IAN-UMCES
Heath Kelsey, EcoCheck
Caroline Wicks, EcoCheck

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For more information: http://www.chesapeakebay.net/nutr1.htm

www.eco-check.org

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