Stony Brook University
School *of* Marine and
Atmospheric Sciences

The effects of excessive nitrogen delivery and mitigating such delivery on Long Island's coastal ecosystems

Christopher J. Gobler, Ph.D.

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Long Island is crowded. With three million people packed into Nassau and Suffolk County, there are only a handful of nations in the world that are more densely populated. In Suffolk County, most of these people dwell in homes without a modern waste disposal system (e.g. sewers) and thus the nitrogenous waste from more than one million Suffolk residences is leaching out of septic tanks and cesspools and into the groundwater beneath our feet. This unplanned experiment is proceeding quickly, as the recently released Suffolk County Comprehensive Water Resources Management Plan reported rapid and large changes (40 and 200% increase) in the levels of nitrogen in Suffolk County's groundwater between 1987 and 2005, with measurements in 2013 showing even higher levels of nitrogen and models indicating nitrogen levels will continue to rise for several decades. The majority of nitrogen in groundwater in Suffolk County and unsewered parts of Nassau County originates from septic tanks and cesspools. Household and agricultural fertilizer are the second largest sources of nitrogen. Nitrogen rich groundwater continually seeps from land into our bays, harbors, and estuaries where it is exacting an unwanted toll.

Salt marshes are the marine habitats closest to land, serve as an important habitat for a variety of animals and, as we learned from Hurricane Sandy, serve as a critical first line of defense against coastal storm surge and waves. Unfortunately, according to NYSDEC, excessive nitrogen loading has contributed to the loss of up to 80% of Long Island's coastal salt marshes since the 1970s across Long Island's north shore, south shore, and east end.

Excessive nitrogen seepage is also stimulating the growth of multiple strains of harmful and toxic algal blooms such as brown tides, red tides, mahogany tides, rust tides, and blue-green algal blooms. These occurrences are new, being unknown to Long Island three decades ago, but

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now recurring annually all over Long Island. These algae are having a cascading negative impacts on our coastal ecosystems and in some cases can be a human health threat. For example, red tides caused by *Alexandrium* produce the potent neurotoxin, saxitoxin, that can contaminate shellfish with the toxin and lead to paralytic shellfish poisoning (PSP) in humans consuming such shellfish. There have been more than a dozen PSP-induced shellfish bed closures on Long Island in recent years and people have can die of PSP in parts of the world without proper monitoring. In freshwater, dozens of sites across Long Island have experienced blue-green algal blooms during the past decade. These algae can synthesize potent neurotoxins and gastrointestinal toxins that have been responsible for dog illnesses and deaths on eastern Long Island in recent years. Other harmful algal blooms on Long Island including brown tides caused by *Aureococcus* and rust tides caused by *Cochlodinium* are harmless to humans and pets, but secrete compounds that cause mortality in bivalve shellfish and finfish.

Eelgrass meadows are a critical benthic habitat that sustain our most important shellfish and finfish which use these regions as a nursery. Estuaries with lush eelgrass meadows on Long Island have robust fisheries. Eelgrass, however, is highly sensitive to nitrogen loading and shading by algae that grow dense due to excessive nitrogen loading. As nitrogen levels in groundwater have increased, 90% of Long Island's eelgrass has vanished and Suffolk County has recently predicted these grasses will be extinct on Long Island in two decades if current nitrogen loading trends continue.

Algal blooms stimulated by excessive nitrogen loading can also starve coastal waters of oxygen and make them more acidic, two conditions that are also detrimental to fish and shellfish. For all of these reasons, Long Island fisheries have been on the ropes. In the 1970s, the bay scallop fishery on eastern Long Island and the hard clam fishery on the south shore were the two largest fisheries for these mollusks on the US east coast. Since that time, landings of hard clams and bay scallops on Long Island have diminished more than 90% due to a combination of the woes brought about by excessive wastewater nitrogen outlined above: Algal blooms, seagrass loss, low oxygen, and lower pH. In the end, these trends could directly affect every Long Islander as billions of dollars of our economy are wrapped up in fisheries and tourism and home values have been shown to trend with coastal water quality.

Importantly, during the past several decades, we have witnessed efforts to reduce nitrogen loading that have yielded clear ecological success on and around Long Island. For example, across Long Island Sound in Groton, CT, lies Mumford Cove. From ~1945 through 1987, a sewage treatment plant discharged into the middle of the Cove and the ecosystem became degraded. It became fully covered by the macroalgae, *Ulva*, and was one of the only locations in CT to ever experience a toxic PSP event. In 1987, sewage discharge was diverted out of the Cove and the ecosystem began to rapidly recover. Inorganic nitrogen levels plummeted to nearly undetectable levels and *Ulva* coverage simultaneously declined by 90% in one year and eelgrass returned to Mumford Cove. By 2002, only 15 years later, eelgrass coverage had reached 50% of the Cove bottom. To this day, PSP has never returned to Mumford Cove since the sewage discharge and nitrogen loading decreased.

This process played out on a larger scale on Long Island's south shore at the end of the last century. The Bergen Point sewage treatment plant in West Babylon was built in the 1970s and originally discharged sewage directly into Great South Bay. In 1981, an outfall pipe that discharged to a location three miles into the Atlantic Ocean was completed. Following the connection of the Bergen Point plant to the ocean outfall, the region of Great South Bay where the plant had been discharging and where nitrogen-enriched groundwater had been flowing prior to the construction of the sewage treatment plant began to change. The level of dissolved inorganic nitrogen in the regions of Great South Bay nearest the plant declined dramatically. More importantly, between 1978, before the ocean outfall and 2002, 20 years after the outfall, nearly 3,000 acres of seagrass re-grew within the regions of Great South Bay surrounding the plant. For perspective, during the same time, every other region of Long Island lost eelgrass. In eastern Great South Bay, where homes with cesspools continued to leach their contents into groundwater, more than 5,000 acres of seagrass was lost between 1978 and 2002. This contrast proves that seagrasses recover when nitrogen loads are mitigated, a finding consistent with other studies around the world.

Four years ago, Northport Harbor had arguably the worst water quality on Long Island. It annually experienced the largest PSP-based shellfish bed closures on Long Island between 2006 and 2012 and the largest red tides ever documented on Long Island. Its nearby beaches were permanently closed to extremely high levels of bacteria indicative of fecal contamination. The major source of contamination to Northport Harbor had been the Northport Harbor sewage treatment plant which discharged directly to the back of the harbor, a region that had been the epicenter of PSP and red tide in this system. In 2013, an upgrade to the sewage treatment was completed that cut the nitrogen load to the Harbor by 50%. At the same time, all of the pipes leading to the plant that had been suspected of leaking had been inspected and fix. As a consequence, red tides have all but vanished from Northport and the region and levels of fecal coliform bacteria have declined to very low levels. In addition, the neighboring Centerport Beach re-opened after a seven-year closure.

The largest effort ever to reduce nitrogen loading to Long Island waters came from the Long Island Sound Study which in 1994 set out to reduce nitrogen loading to Long Island Sound by 58.5% by 2014. This goal was set to reduce the size and severity of the 'Dead Zone' or low oxygen zone in Long Island Sound that was lethal to marine life. The goal was largely met by upgrading sewage treatment plants to release less nitrogen into the Sound. The results have been clear and, to some extent, more impressive than anticipated. Since 2002, the size of the Dead Zone in Long Island Sound has progressively gotten smaller. In 2015, there was no region in Long Island Sound that had oxygen levels below 2 mg/L. To the best knowledge of the scientific community, this had no happened since the start of the 20th century. Consequently, marine life not seen for decades has begun to return to Long Island Sound including humpback whales.

Collectively, these findings indicate that excessive nitrogen loading leads to a cascading series of negative outcomes that are damaging to Long Island's fisheries and economy. Findings further indicate that efforts to reduce nitrogen loading on Long Island and in the region have led to the recovery of marine resources and improvement in water quality.