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(Testimony on the Barnegat Bay-Little Egg Harbor Estuary)

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Introduction

My name is Michael J. Kennish. I am a Research Professor in the Institute of Marine and Coastal Sciences at Rutgers University. I am also a member of the Deep-Sea Ecology and Biotechnology Center and the Climate Institute at Rutgers. In addition, I am affiliated with the Ecology and Evolution Graduate Program at the University. Furthermore, I serve as the director of the research and monitoring program of the Jacques Cousteau National Estuarine Research Reserve in Tuckerton. As a marine ecosystem scientist at Rutgers, I conduct basic and applied research on the structure and function of estuarine and coastal marine environments, most notably those in New Jersey. This research forms the scientific foundation and platform for ecosystem-based management. I have extensive experience conducting research and monitoring on the Barnegat Bay-Little Egg Harbor (BB-LEH) Estuary, as well as other coastal systems in New Jersey.[1-18] Most of this research has focused on the effects of human activities on these environments.

State of the Estuary

BB-LEH is a highly eutrophic, ecologically impacted, and impaired coastal lagoon. Because it is bounded by a nearly continuous barrier island complex (Island Beach and Long Beach Island) and an extensively developed watershed, BB-LEH is susceptible to pollution inputs as well as other human and natural stressors. Its poor flushing and protracted water residence times result in retention of pollutants in the estuary and their recycling among abiotic (nonliving) and biotic (living) system components. These characteristics increase the probability of pollution impacts and ecological damage. The system has undergone significant ecological decline as documented by a series of recent peer-reviewed, scientific publications.[7,13,19-22]

BB-LEH is most seriously impacted by eutrophication, a process defined as nutrient enrichment and increase in the rate of organic matter input in a waterbody leading to an array of cascading changes in ecosystem structure and function such as decreased dissolved oxygen levels, increased microalgal and macroalgal abundance, occurrence of harmful algal blooms (HABs), loss of seagrass habitat, reduced biodiversity, declining fisheries, imbalanced food webs, altered biogeochemical cycling, and diminished ecosystem services.[14] Eutrophication poses the most serious threat to the long-term health of BB-LEH by altering its ecosystem structure and function.[6,7,19-20] The net effect of eutrophication is potentially permanent alteration of biotic communities, extensive loss of living resources and habitats, and greater ecosystem-level impacts. Eutrophication of BB-LEH has accelerated during the past two decades, and it is now impacting the uses that we, as a society, make of the system.

Studies of coastal lagoonal systems indicate that environmental impacts escalate as population growth, development, and the amount of impervious cover increase in surrounding watersheds. A watershed impact threshold, where degradation of water quality is observed, is exceeded when the amount of impervious surface cover surpasses 10%.[23] Impervious land cover in the BB-LEH Watershed is greater than 10%, and it is projected to exceed 12% at buildout. The watershed is now nearly 35% developed (Center for Remote Sensing and Spatial Analysis, Rutgers University).

The population growth in Ocean County increased from 108,241 in 1960 to 576,567 in 2010 at the last census (Table 1). Between 1980 and 2010, the population in the county increased by more than 66%. During the summer months, the population in Ocean County increases to ~1,500,000 people as noted by the Ocean County Planning Board in 2011, and the eutrophication problems in the estuary escalate. Dramatic land use and land cover changes have occurred in the watershed concurrently with population growth over the past three decades. Therefore, it should come as no surprise that serious ecological problems are now occurring in the BB-LEH Estuary. Ecological impacts are expected to increase with ongoing land alteration.[4,24]

I want to briefly recount important details on the eutrophication problems that currently impact BB-LEH. The estuary condition has escalated from moderately eutrophic, first identified in the early 1990s, to highly eutrophic over the past decade.[7,28] Nitrogen is the most problematic nutrient element responsible for this deterioration, although phosphorus also plays a role during certain time periods and must be considered as well. Wieben and Baker[25] reported that nitrogen enters the estuary via the following pathways: ~66% of the load (i.e., the amount of nitrogen entering the bay) derives from watershed surface water inflow, ~22% from atmospheric deposition, and ~12% from direct groundwater discharges. In 2007, Bowen et al.[26] estimated that the fertilizer nitrogen load from the watershed to the estuary comprised 29.3% of the total nitrogen load from the watershed. The total nitrogen pollution load is expected to increase as development and accompanying land use and land cover changes (the conversion of forests and open spaces to development) increase in the watershed. Baker et al.[27] reported highest total surface water loads (baseflow plus runoff) of nitrogen and phosphorus for the BB-LEH Watershed in 2010, amounting to ~857,000 kg TN (1,889,362 lbs TN) and ~32,000 kg TP (70,548 lbs TP), respectively.

To understand the slow deterioration of BB-LEH, it is instructive to review key characteristics that render the estuary vulnerable to environmental impacts. First, both nonpoint and point sources of pollution affect BB-LEH; these are often thought of as "stressors." Of the various environmental problems arising from these stressors, eutrophication poses the most serious threat because it creates the potential for ecosystem-wide decline, affecting the long-term health and function of the entire system from Bay Head to Tuckerton, impacting living resources, essential habitat (e.g., seagrass and shellfish beds), and human uses throughout.[7,10] These effects are now apparent in BB-LEH, and the estuary has been ranked among the most eutrophic systems in the U.S.[28]

Depending on the physicochemical and biotic conditions, the consequences of eutrophication in a waterbody are numerous and varied and include low dissolved oxygen, harmful algal blooms (HABs), loss of essential habitat (e.g., seagrass and shellfish beds), lower biodiversity, reduced harvestable fisheries, imbalanced trophic food webs, declining system stability and resilience, diminished ecosystem services, and impacted human use. Most of these eutrophic effects have been documented in the BB-LEH Estuary.[4,7,10,29] The eutrophic condition can worsen. The long-term effect of eutrophication is potentially permanent alteration or loss of biotic communities and habitats, and great ecosystem-level degradation.[14]

The eutrophication process disrupts the ecological interrelationships and functioning of coastal waterbodies like BB-LEH. Nutrient enrichment, notably nitrogen and phosphorus inputs, stimulates algal production and sets into motion changes in the ecosystem from the bottom-up, literally altering the foundations of the way the estuary works. As algal populations bloom, die off, and then sink to the floor of the estuary, they undergo microbial decomposition which uses up oxygen causing stress and loss of living resources there.

Species composition, abundance, distribution, and diversity of organisms often change considerably in such eutrophied systems, including top-down feeding groups that regulate algal populations, keeping them in check. Opportunists and nuisance organisms (e.g., macroalgae, *Enteromorpha* spp. and *Ulva* spp.) frequently dominate these systems, outcompeting and replacing more desirable and stable forms, notably seagrass. A positive correlation exists between nutrient loading and algal production and biomass. The accumulation of large amounts of decaying algae on the estuarine floor not only leads to hypoxic conditions but also the production of sulfides in bottom sediments mediated by microbial activity that can be extremely toxic to bottom-dwelling communities. Extensive phytoplankton and macroalgae blooms, epiphytic overgrowth, and suspended particulates also create unfavorable shading conditions for seagrass that can cause dieback and elimination of this essential bottom habitat for shellfish and finfish.

Additional biotic impacts associated with nutrient enrichment include changes from filter-feeding to deposit-feeding benthic (bottom dwelling) organisms. There is frequently a progressive change from larger, long-lived benthic organisms (e.g., hard clams, *Mercenaria mercenaria*) to smaller, rapidly growing, but shorter lived forms. The loss of larger, filter-feeding shellfish species is well documented in BB-LEH,[4] which can reduce bottom-up control and regulation of phytoplankton populations. In such an environment of less top-down control, toxic phytoplankton blooms also commonly occur (e.g., brown tide, *Aureococcus anophagefferens*). The potential for permanent alteration of biotic communities and habitats exists in this type of impacted system, and its stability and resilience are likely compromised.

Eutrophication Report

Rutgers scientists, in collaboration with investigators from the U.S. Geological Survey, conducted a comprehensive four-year eutrophication study of BB-LEH (2009-2013) that culminated in the completion of a detailed report on the eutrophic condition of the estuary.[29] Completed in April 2013, this eutrophication report clearly characterizes and quantifies the biotic and habitat responses occurring in BB-LEH to nutrient loading from the watershed in an effort to delineate cause-and-effect relationships involving nutrient enrichment. An analytical method used in this study provides an accurate assessment of eutrophic condition in BB-LEH and quantifies the status and trends of the estuary in response to nutrient loading. The assessment tool (i.e., Index of Eutrophication) quantifies the eutrophic condition of the estuary over a protracted period of time (1989-2010) and identifies the condition of, and relationships between, ecosystem pressures, ecosystem state, and biotic responses by integrating over 74,400 observations among 85 variables for ~20 indicators. It therefore offers one of the most comprehensive and holistic assessments of the BB-LEH ecosystem condition to date. Subsequently, the results of this eutrophication study were published in the peer-reviewed scientific literature,[20] and in an extensively reviewed U.S. Geological Survey scientific investigations report.[27]

A major goal of this ecosystem-based study has been to provide databases useful for developing nutrient loading criteria in support of nutrient management planning. Generating nitrogen and phosphorus water quality standards for the estuary and establishing Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus are two ways of managing and mitigating the eutrophication problems. The eutrophication report provides quantitative limits on nitrogen and phosphorus loading from the watershed that can be used to establish numeric standards and TMDLs for nitrogen and phosphorus for the BB-LEH Estuary. That is, once loading increases above 2,000 kg TN km^{-2} yr^{-1} or 100 kg TP km^{-2} yr^{-1} (4,409 lbs TN km^{-2} yr^{-1} or 220 lbs TP km^{-2} yr^{-1}), as is the case of the north segment of the estuary, eutrophication condition reaches a new, lower steady state of poor condition. Therefore, an upper limit on nitrogen and phosphorus loading to the estuary of 1,500 kg TN km^{-2} yr^{-1} and 75 kg TP km^{-2} yr^{-1} (3,307 lbs TN km^{-2} yr^{-1} and 165 lbs TP km^{-2} yr^{-1}) can be used as nutrient targets to effectively manage eutrophication in the system.[29]

Major findings of the eutrophication report on the BB-LEH Estuary are as follows:[29]

- BB-LEH is an estuary that has undergone significant ecological decline through time. The strong positive relationship between nutrient loading from the watershed and estuarine nutrient concentrations, the degradation of an array of biotic indicators, and the relationship between nutrient loading and the Index of Eutrophication supports this finding.
- BB-LEH has generally experienced declining environmental conditions since the early 1990s as documented by Index of Eutrophication scores for the system using a suite of ~20 water quality, biotic, and habitat indicators.
- Over the 1989-2010 period, BB-LEH experienced low dissolved oxygen (82 times ≤4 mg L^{-1}), high total suspended solids (max >200 mg L^{-1}) and chlorophyll *a* (max >40 µg L^{-1}), harmful algal blooms (≥200,000 cells mL^{-1}), epiphytic loading (mean values up to 38.3% cover of seagrass), macroalgae blooms (80-100% bottom cover 36 times, 70-80% bottom cover 19 times, 60-70% bottom cover 10 times), habitat loss, >67% fewer clams, and degraded seagrass biomass (to 2.7±8.0 g m^{-2} aboveground; 17.9±37.5 g m^{-2} belowground).[29]
- The condition of BB-LEH has progressively worsened over the past two decades for both nitrogen and phosphorus, and there is an overall poorer condition for nutrient loading.
- Nutrient loading – both total nitrogen loading and total phosphorus loading – clearly results in substantial degradation and eutrophication of BB-LEH. The poor condition of nutrients in the estuary over the study period is directly related to nutrient loading from the watershed.
- Total nitrogen loading and total phosphorus loading scores were more degraded during 2003-2010 than during previous years.
- BB-LEH is particularly sensitive to even relatively small increases in nutrient loading due to its extreme enclosure and a watershed to estuary areal ratio of 6.5:1.
- Nutrient loading to the estuary has increased with watershed development. Urban land development and increasing impervious cover are responsible for nutrient levels that are elevated above background levels.
- Nitrogen loads from turf areas of the watershed are about twice those from non-turf areas. Phosphorus loads from turf areas are about eight times those from non-turf areas.[27]

- From 1989 to 2011, the annual total nitrogen loads from the watershed (surface water loads) to the estuary ranged from about 455,000 to 857,000 kg TN yr^{-1} (1,003,103 to 1,889,362 lbs TN yr^{-1}). The lowest levels were recorded in 1995, and the highest levels, in 2010. The north segment accounted for about 66% of the annual total nitrogen load to the estuary.[27]
- From 1989 to 2011, the annual total phosphorus loads from the watershed (surface water loads) to the estuary ranged from about 17,000 to 32,000 kg TP yr^{-1} (37,479 lbs TP yr^{-1} to 70,548 lbs TP yr^{-1}). The lowest levels were recorded in 1995, and the highest levels, in 2010. The north segment accounted for about 63% of the annual total phosphorus load to the estuary.[27]
- The north segment of the estuary experienced the most severe eutrophication and degradation over the 1989-2010 study period.
- The central and south segments of the estuary are currently undergoing eutrophication and are in a state of decline based on calculations of the Index of Eutrophication.
- The north segment of BB-LEH is designated as impaired for dissolved oxygen (DO) and remains on the Clean Water Act 303d list for impairment. However, greater numbers of low DO occurrences ($\leq$ 4 mg L^{-1}) were recorded in the central and south segments of the estuary than in the north segment, over the 1989-2010 study period.
- There were 82 occurrences of DO levels $\leq$ 4 mg L^{-1} (the surface water quality criterion for DO is 4 mg L^{-1}) recorded in the estuary and tributary systems at multiple sampling sites between 1989 and 2010. Most of these low DO levels occurred in the south segment of the estuary (N = 63), with far fewer in the central segment (N = 13) and the north segment (N = 6).[29]
- DO measurements in the estuary during the 1989-2010 period represent only one DO measurement taken quarterly (grab samples) at multiple sampling stations and mainly during the morning to afternoon daylight hours. No grab samples were collected at night when DO levels would generally be lowest in the estuary. Hence, these DO data likely underestimate the actual number of low DO occurrences that occurred in the estuary during this period.
- Nutrient enrichment has caused an array of biotic and habitat impacts in the estuary as noted below.
- Seagrass condition is highly degraded, having declined substantially through time. In 2010, the lowest eelgrass biomass values were recorded for the estuary (aboveground biomass = 2.7 g dry wt m^{-2}; belowground biomass = 17.9 g dry wt m^{-2}).[19] Low eelgrass biomass continued through 2011. The decline of seagrass beds is a serious concern in the estuary because of their multiple ecosystem services, notably major sources of primary production, food for waterfowl, essential habitat and nursery areas for numerous fish and invertebrates, filters of chemical substances, agents in

biogeochemical cycling, and buffers against wave and current action as well as sediment erosion.

- Macroalgal blooms (e.g., *Ulva lactuca, Enteromorpha intestinalis*, and *Gracilaria tikvahiae*) appeared frequently in the estuary in response to nutrient enrichment. The number of macroalgal blooms increased through time, being statistically significantly greater during the 2008-2010 period than during the 2004-2006 period.[30]

- Epiphytic cover of seagrass blades, which can impair photosynthesis, was significant in 2009, 2010, and 2011, reaching a maximum mean value >48%.

- Harmful algal blooms (HABs) (i.e., brown tide, *Aureococcus anophagefferens*) occurred repeatedly between 1995 and 2002 (no monitoring of brown tide was conducted after 2004). The highest *A. anophagefferens* abundances $\geq 1.5 \times 10^6$ cells mL^{-1} occurred in 1995 and 1999-2002. *A. anophagefferens* occurred in the estuary during 2010 at densities up to 5,300 cells ml^{-2}.

- Nuisance summer phytoplankton blooms commonly occur in the estuary often caused by small picoplanktonic microalgal species such as the chlorophyte *Nannochloris atomus* and the cyanobacterium *Synechococcus* sp. These blooms can be detrimental to hard clams (*Mercenaria mercenaria*) in the estuary.[31]

- Hard clam abundance decreased markedly compared with abundance in the mid-1980s. An estimated total of 64,803,910 hard clams was recorded in Little Egg Harbor in 2001 compared with an estimated total of 201,476,066 hard clams in 1986/87.[32] A State hard clam survey conducted in 2011, however, showed an increase in abundance to an estimated 85,745,065 hard clams, although this represents a decline in abundance of 57% compared with hard clam abundance in 1986/87. In addition, most of the increase in 2011 was ascribed only to a few sampling stations, with 25% of the total stock found at only 5 of the 196 stations sampled. Furthermore, the median hard clam abundance actually decreased by 11% in 2011 compared with 2001.[33]

- Hard clam harvest recorded in the estuary decreased by more than 98% between 1975 (636,364 kg; 1,402,942 lbs) and 2005 (6,820 kg; 15,036 lbs).[34] The number of commercial clam licenses for the system has declined significantly through time due to low clam abundance.[35]

- Abundance of the sea nettle (*Chrysaora quinquecirrha*) increased dramatically over the past decade, with blooms commonly observed in the north segment of the estuary since 2004.[29] Large numbers of sea nettles have posed a hazard to human use of some estuarine areas. Sea nettles also consume large quantities of zooplankton and thus may shorten the food chain, potentially altering energy flow and impacting fish and other higher-trophic-level organisms in the estuary.

- About 45% of the estuarine shoreline is now bulkheaded, including most of the north segment. Nektonic biodiversity is ~25% lower along bulkheaded shorelines than along natural shorelines.[36]

Impairment

The State's List of Water Quality Limited Waters (i.e., Section 303(d) of the Clean Water Act) includes the north segment of BB-LEH which is now designated as impaired for dissolved oxygen due to low DO measurements. The central and south segments of the estuary had more occurrences of DO levels ≤ 4 mg L^{-1} (the surface water quality criterion for DO is 4 mg L^{-1}) between 1989 and 2010 than did the north segment.

No numeric nutrient criteria exist for BB-LEH that would provide more rigorous water quality standards for the estuary. Action item 7 of the Governor's 10-point Action Plan (Table 2) is to "Adopt More Rigorous Water Quality Standards." Based on results of the eutrophication study of BB-LEH, numeric nutrient criteria can now be established for the estuary. Once loading increases above 2,000 kg TN km^{-2} yr^{-1} or 100 kg TP km^{-2} yr^{-1} (4,409 lbs TN km^{-2} yr^{-1} or 220 lbs TP km^{-2} yr^{-1}), as in the case of the north segment of the estuary, eutrophication condition reaches a new, lower steady state of poor condition. Therefore, an upper limit on nitrogen and phosphorus loading to the estuary of 1,500 kg TN km^{-2} yr^{-1} and 75 kg TP km^{-2} yr^{-1} (3,307 lbs TN km^{-2} yr^{-1} and 165 lbs TP km^{-2} yr^{-1}) can be used as nutrient targets to manage eutrophication in the system.[29] These numeric values can be used to establish TMDLs for nitrogen and phosphorus for BB-LEH.

The New Jersey Department of Environmental Protection has adopted rules establishing narrative nutrient criteria for BB-LEH that are certainly constructive. It is important to stress here, however, that documented impacts in the estuary noted above appear to violate the State's Narrative Nutrient Standard (NJAC 7B-1.14(d)4.i.), which states that:

"Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses due to objectionable algal densities, nuisance aquatic vegetation, diurnal fluctuations in dissolved oxygen or pH indicative of excessive photosynthetic activity, detrimental changes to the composition of aquatic ecosystems, or other indicators of use impairment caused by nutrients."

Other System Impacts

The detrimental effects of eutrophication are exacerbated by other factors. Superstorm Sandy had a significant impact on estuarine habitats due to overwash events and sedimentation which caused shoaling problems. Storm surge caused erosion of benthic habitats in some areas as well, altering the sediment composition and potentially impacting seagrass beds and other benthic organisms. In addition, beach, dune, and salt marsh habitats were impacted.

Salt marshes in the BB-LEH Watershed are vulnerable to perimeter shoreline erosion, sea-level rise linked to climate change, extreme weather events, storm surge, and coastal subsidence. Coastal marsh stability requires sufficient sediment accretion on the salt marsh surface to maintain elevation. Recent studies by Drexel University indicate that sedimentation in salt marshes of the BB-LEH Watershed may not be adequate in areas, making them more susceptible to inundation and flooding. Studies of the Tuckerton Peninsula salt marsh system at the southern margin of Little Egg Harbor have revealed a high rate of salt marsh habitat loss along the eastern and southern shorelines amounting to 1.6 m yr^{-1} between 1995 and 2008.[37] Coastal marshes play a vital role in filtering or sequestering nutrients from upland areas and the atmosphere. Thus, the ongoing loss of marsh area surrounding BB-LEH is a major concern since marsh habitat can reduce nutrient loading to the estuary.

Loss of natural habitat due to bulkheading, dredging, ditching, and lagoon construction continues in some areas of the system. Human activities in watershed areas, notably deforestation and infrastructure development, partition and disrupt habitats while also degrading water quality and altering biotic communities. Ongoing land surface alteration raises turbidity and siltation levels in tributaries of the estuary, which can create benthic shading problems. We still do not know what overall effect boat and jet-ski use has had on biotic communities and habitat in the estuary. However, a benthic imaging study conducted by the Center of Remote Sensing and Spatial Analysis at Rutgers University in 2009 revealed more than 25 linear miles of boat scars damaging seagrass beds.[29]

BB-LEH has experienced reduced freshwater inputs in the estuary related to operation of centralized wastewater treatment facilities (>50 million gal/day discharged to the coastal ocean) and increased freshwater withdrawals for domestic use (~78 million gal/day).[29] Reduced freshwater inflow has a marked influence on water residence time and the accumulation of nutrients in estuarine system components. Reduction of freshwater inputs may significantly affect physical-chemical processes and biotic responses.

Impingement, entrainment, thermal discharges, and biocidal releases of the Oyster Creek Nuclear Generating Station (OCNGS) cause significant mortality of estuarine and marine organisms in Barnegat Bay.[2] OCNGS is scheduled to close in 2019.

More biotic species are invading the estuary from subtropical or even tropical waters as climate change proceeds, which can alter biotic community structure. It is important to track the effects of climate change on the estuary to formulate effective sustainable management plans for the future.

Land Use Change

Human activities in the BB-LEH Watershed linked to declining environmental conditions in the estuary are largely land use and land cover issues – or how we use land in the watershed. Of particular impact is the continued development of the open spaces and forests of the watershed that require effective land use planning and management decisions for remediation. With population growth in the watershed expected to increase from more than 575,000 year-round residents (~1,500,000 people during the summer tourist season) to ~850,000 people at buildout (~50% increase in year-round residents), aquatic environmental pressures will continue to occur, particularly as impervious cover and other land surface alteration in the watershed increase, leading to greater input of nutrients and other pollutants to the estuary.[29] The watershed surface will continue to be partitioned and natural habitats altered. The challenges will be formidable to develop and apply the appropriate measures to remediate the future impacts on the estuary.

Urban land use in the BB-LEH Watershed has increased dramatically over the past four decades. In 1972, the watershed-developed area amounted to ~19%, but it increased to 25% in 1995, 30% in 2006, and ~34% at present. By 2010, the watershed had 111,560 acres of urban land area. Agricultural land area amounted to 4,965 acres in 2010, down from 6,314 acres in 1995. Upland forest area in turn decreased from 158,147 acres in 1995 to 139,915 acres in 2010.[38] The BB-LEH Watershed now has (>20 times) more urban land cover than agricultural land cover, and the trend is increasing.[39] Cumulative changes in the watershed land surface are leading to greater impervious cover and runoff to area streams and rivers discharging to BB-LEH, thereby promoting nutrient enrichment and other pollutant discharges to the estuary.[29] One acre of pavement, for example, results in 27,000 gallons of runoff per inch of rainwater.[40]

Remedial Measures

A well-coordinated, holistic, long-term management plan is important for improving the ecological condition and resources of BB-LEH. In other estuaries such as Chesapeake Bay, the following remedial strategies have been pursued: upgrades of stormwater controls, greater open space preservation, accelerated soil restoration, best land use management practices (e.g., improved management of turf areas), TMDLs for nutrients, and support of education programs that explain to the public how and why these strategies are important and necessary for the protection of BB-LEH. Management strategies in the coastal watersheds of these impacted estuaries have also addressed ways to minimize the creation of impervious surfaces, compacted soils, and sprawl, while concurrently preserving natural vegetation and landscapes.

For BB-LEH, the fertilizer law that went into effect in 2012 and targets reduction of fertilizer nitrogen and phosphorus loading to BB-LEH is certainly constructive. Compacted soil remediation will reduce stormwater runoff as well. Establishing numeric standards and TMDLs for nitrogen and phosphorus for the BB-LEH system would provide additional measures to manage eutrophication.

Summary

The eutrophication report completed in 2013 indicates that BB-LEH is seriously impacted by nutrient enrichment (i.e., nitrogen and phosphorus).[29] A holistic environmental management approach is therefore critical to reduce nutrient loading and eutrophication of the estuary. This includes in part upgrading stormwater controls (only 10 of ~2700 stormwater basins are currently being restored), mandating land use best management practices in the BB-LEH Watershed, preserving open space, and educating the public as to how and why these strategies are important and necessary for protecting the BB-LEH system. It is also important to examine population growth and development rates in Ocean County that represent drivers of change that cause substantive land use and land cover changes and resulting ecological impacts in the estuary.[29] Generating nitrogen and phosphorus numeric standards for the estuary and establishing Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus are two ways of managing and mitigating the eutrophication problems. An upper limit on nitrogen and phosphorus loading to the estuary of 1500 kg TN km^{-2} yr^{-1} and 75 kg TP km^{-2} yr^{-1} (3,307 lbs TN km^{-2} yr^{-1} and 165 lbs TP km^{-2} yr^{-1}) can be used as nutrient targets to manage eutrophication problems in the system.[29] A sustained, well-coordinated, and holistic management plan is critical to improving the ecological condition and resources of the estuary.

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Table 1. Population Growth in Ocean County from 1950 to 2010.

Year	Number of People
1950	56,622
1960	108,241
1970	208,470
1980	346,038
1990	433,203
2000	510,916
2010	576,567

Data Sources: Ocean County Cultural and Heritage Commission;
U.S. Census

Table 2. Governor Christie's Ten Point Action Plan to Restore the Ecological Health of Barnegat Bay-Little Egg Harbor.

Close the Oyster Creek Nuclear Generating Station
Fund Stormwater Runoff Mitigation Projects
Reduce Nutrient Pollution from Fertilizer
Require Post-Construction Soil Restoration
Acquire Land in the Watershed
Establish a Special Area Management Plan
Adopt More Rigorous Water Quality Standards
Educate the Public
Fill in the Gaps on Research
Reduce Water Craft Impacts

The comments in this document are solely those of the author based on extensive research, technical reports, and scientific publications on the Barnegat Bay-Little Egg Harbor Estuary.