H.R. 1674:
LONG ISLAND SOUND RESTORATION AND STEWARDSHIP ACT

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H.R. 1674: Long Island Sound Restoration and Stewardship Act

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Cover Photo by Jerry Monkman, from the Long Island Sound Study Comprehensive Conservation and Management Plan

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Table of Contents

Executive Summary

As a regional hub of industry and commerce, the Long Island Sound and its watershed have long experienced anthropogenic environmental damage. This damage, which researchers first documented in the 1950s, contributed to the 1972 passage of the Federal Water Pollution Control Act (Clean Water Act). Efforts to protect the Sound have included amendments to the Clean Water Act, the creation of the Long Island Sound Study (the Study) as a governance structure, and the publication of numerous plans and advisory documents. This project focuses on H.R. 1674, the Long Island Sound Restoration and Stewardship Act, which was introduced by Connecticut Representative Rosa DeLauro in 2017. The legislative purpose of the bill is to require the U.S. Environmental Protection Agency's (EPA) Long Island Sound Office to conduct further studies on the environmental impacts to the Sound, develop strategies to educate the public, monitor progress, and report bi-annually to Congress. The bill also reauthorizes funding for these activities through 2023.

Despite these efforts, the watershed continues to face environmental challenges. This report focuses primarily on water quality and nitrogen pollution, habitat degradation, and climate change, although the Long Island Sound Study also addresses other environmental components. In focusing on these subject areas, we study both technical and community-oriented solutions to the Sound's environmental problems. Examples include: upgrading wastewater treatment facilities and Combined Sewer Overflow systems ("CSOs"), conducting nutrient bioextraction, restoring eelgrass and tidal wetlands, fostering local government partnerships, and increasing public involvement.

We then evaluate future management challenges, which in this report are limited to: 1) intergovernmental coordination between the U.S. EPA's Long Island Sound Office and the governments of New York State and Connecticut; and 2) sustainable development pressures. After evaluating potential challenges, we analyze how the bill's goals can be measured. Finally, we propose areas of further study that would assist in improving the overall health of the watershed, particularly in regard to tracking and assessing public engagement. Continuing progress requires diligence to ensure that the chosen measurements accurately describe the state of the Sound. If approved and implemented properly, the bill will advance the improvements that have already been made.

Section 1

Background and Context

Historical Context

The history of the Long Island Sound and the Northeastern United States are fundamentally intertwined. The industrialization, commercialization, and development that enabled New York and the Atlantic coast to become economic powerhouses has caused profound changes in the ecology of the region's waters.

The Long Island Sound stands out as a significantly degraded ecosystem. Given its proximity to several major cities, it has served as the center of maritime industry in the region and contains many shipping channels. Though human activity in the Sound has led to environmental damage since the earliest days of industrialization, urbanization in the postwar period magnified the effects of human activity on habitats, native species, and economic output. The first comprehensive study of water quality in the Sound was conducted in the 1950s and suggested widespread human impacts on dissolved oxygen concentrations. By the 1970s, these low oxygen levels resulted in major fish kills throughout the Sound, which along with other water pollution incidents, led to the 1972 Federal Water Pollution Control Act, commonly

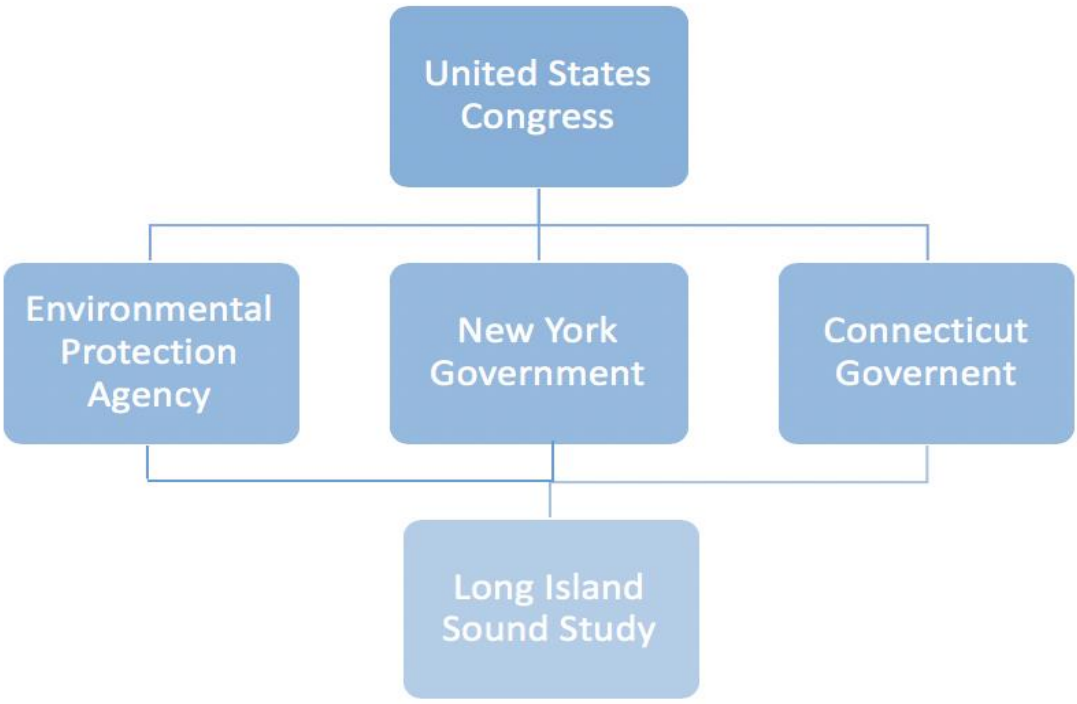

Figure 1: Hierarchy of agencies involved in the Long Island Sound Study

known as the Clean Water Act (Long Island Sound Study, 2017a).

In 1985, Congress passed an amendment to the Clean Water Act that created the Long Island Sound Study: a partnership among New York, Connecticut, and the US EPA, with input from concerned organizations and individuals around the Sound. Since its founding, the Study has established guidelines and standards for the protection and management of the Sound, with mixed success in improving the overall ecosystem. H.R. 1674, the Long Island Sound Restoration and Stewardship Act, reauthorizes the Management Conference of the Long Island Sound Study through 2023. It also directs the EPA Long Island Sound Office to conduct further studies to help meet the outlined goals and schedules of the existing plan (DeLauro, 2017).

In 2015, the Long Island Sound Study released an updated version of the Comprehensive Conservation and Management Plan (CCMP), a document that outlines and guides the restoration actions of the Study. The most recent iteration of the CCMP groups solutions into four themes:

1. Clean Waters and Healthy Watersheds
2. Thriving Habitats and Abundant Wildlife
3. Sustainable and Resilient Communities
4. Sound Science and Inclusive Management

Within these broad categories, the CCMP identifies specific ecosystem targets that serve as the basis for these goals. The management strategies outlined in this proposal each fit into one of these categories.

This improvement indicates the Long Island Sound Study's efficacy in actualizing change in a dynamic and complex watershed.

The State of the Sound

Since its founding, the actions of the Long Island Sound Study have generated steady progress. According to Eco Report Cards, an independent non-profit organization that produces health rankings for water ecosystems around the world, the average water quality in the Sound has improved from a grade of C in 2013 to a grade of C+ three years later. This improvement indicates the Study's efficacy in actualizing change in a dynamic and complex watershed. We describe this progress in greater detail in the "Measuring Success" section.

Figure 2: Map of the Long Island Sound showing water quality grades. Image from: Ecohealth Report Cards

Year	Historical Context
1950's	Large-scale urbanization, suburbanization, and regional population growth
	First water quality study of the Long Island Sound conducted, revealing evidence of human impacts on oxygen levels in the Sound
1970's	Low oxygen levels result in fish kills in the Western Sound
1972	Federal Water Pollution Control Act passed by Congress
1985	Long Island Sound Study established by Congress
1994	Comprehensive Conservation and Management Plan adopted by the Long Island Sound Study
2003	Long Island Sound Agreement adopted, establishing targets for the Sound's restoration
2006	Long Island Sound Stewardship Act passed
2008	Sentinel Monitoring Work Group established by the Long Island Sound Study to assess potential impacts of climate change on the Sound
2015	Comprehensive Conservation and Management Plan revised to continue to build upon restoration progress made
2017	H.R. 1674 introduced by Representative Rosa DeLauro of Connecticut

Figure 3: Timeline and Historical Context of the Long Island Sound

Section 2

Management Challenges

The Long Island Sound Study's ongoing research efforts help us understand the problems facing the Sound. The Sound is the terminus of its watershed, which means that environmental problems throughout the region are magnified downstream. Pollutants that are released into the watershed upstream ultimately make their way to the Sound where they impact water quality. Pollution and regional development have degraded coastal habitats and led to the decline in habitat connectivity throughout the watershed.

Nitrogen Pollution & Water Quality

The Long Island Sound watershed is a highly interconnected ecosystem. Streams, rivers, lakes, aquifers, rain, and snowmelt that flow or fall within the watershed eventually reach the Sound (Long Island Sound Study, n.d.-f). Nitrogen pollution originates from both point and nonpoint sources. Point sources are polluting entities that can be traced to a specific origin, such as wastewater treatment facilities and industrial plants, while nonpoint sources are diffused throughout a measurable area and can be difficult to trace. Septic systems, storm water, and agricultural runoff are examples of nonpoint source pollution (Long Island Sound Study, 2017c).

Figure 4: Streaks of red tide in Cutchogue Harbor run along the western side of Nassau Point on Long Island's north fork. Image from: NY Sea Grant

As development encroaches on natural lands, the increasing prevalence of impervious surfaces reduces the natural filtration capabilities of the soil (Center for Land Use Education and Research, 2013). When this natural filtration capacity is diminished, pollutants move through the watershed and enter the Sound, where they can cause denitrification, or the production of atmospheric nitrogen by microbes. As a result of the reduced filtration capability of the soil, excess nitrogen enters the Sound and is consumed by algae, causing the growth of algal blooms. Some algal blooms release toxins that make humans and other species sick and can sometimes be fatal. Additionally, decomposition of algae by microbial decomposers consumes oxygen to the point of depletion, creating hypoxic conditions commonly referred to as "dead zones" (The Nature Conservancy, 2018). Hypoxic areas can

kill sessile and slow-moving species, such as lobsters or young and underdeveloped fish, and impact the local economy, which is heavily dependent on fish and shellfish harvesting. For example, the harvest of hard clams in the Sound has fallen 90 percent since 1980, affecting thousands of jobs in the region (Foderaro, 2017).

Habitat Degradation and Fragmentation

The Long Island Sound contains twelve unique habitats, each of which is important for connectivity within the watershed. Habitat continuity, the continuity of the preferred environment of an organism, is important to the overall health of ecosystems. The Comprehensive Conservation and Management Plan has identified the extent of coastal habitat, and in particular eelgrass and tidal wetlands, as primary areas of attention. Eelgrass meadows are one of the most biodiverse habitats in the Sound, given their role as critical habitat for many species of fish and shellfish during their developmental stages (Pickerell, 2017). Eelgrass meadows are particularly important to local communities as they lessen erosion along the shore and decrease water turbidity (cloudiness) by settling suspended sediments from the water column. Habitat connectivity links the Sound's different habitats and allows the movement of species and resources which is important for maintaining biodiversity. Connectivity allows individuals to move and breed across populations, which increases genetic diversity and enables populations to adapt to changing environments (Long Island Sound Study, 2015).

Invasive species also pose a threat to biodiversity. A species is considered invasive when it is non-native to the ecosystem and its introduction causes harm to the economy, environment, and human health. These species, which are usually introduced unintentionally by humans, may prey on native species, outcompete them for resources, or carry diseases (Balcom, 2012).

Figure 5: The Asian Shore Crab (Hemigrapsus sanguineus) originated in the western part of the Pacific Ocean and is now an invasive species in the Sound, competing for similar habitat to native blue crab, rock crab, and lobster. Image from: Cornell Cooperative Extension

Invasive species have broad diets and tolerance to a variety of environmental conditions, enabling them to survive in new habitats fairly easily. The Asian Shore Crab, an invasive species in the Sound, eats a variety of food sources and can disrupt the food web by altering the amount of resources available to species that have more limited diets. These characteristics, along with the absence of natural predators, give invasive species like the Asian Shore Crab the ability to alter the abundance and distribution of species

diversity within an ecosystem (U.S. Geological Survey, 2018). Other invasive species found in the Long Island Sound include sea squirts, *Phragmites* (the common reed), and perennial pepperweed (Balcom, 2012).

Climate Change

Climate change is leading to rising sea levels and more frequent, extreme, and unpredictable storms (U.S. Global Change Research Program, 2017). While climate models are helpful in demonstrating the potential effects of climate change, their estimates can vary (Thorpe, 2005). The uncertainty over future climate makes it difficult for municipalities throughout the Long Island Sound watershed to determine appropriate resilience strategies. Options must be evaluated based on economic cost, visual appeal, and effectiveness. Moreover, while some of these measures may protect against intermittent storms, they do little to combat permanent sea level rise (Regional Plan Association, 2016).

Connecticut's coastal communities are particularly vulnerable to increased storms and rising sea levels. Roads along the shoreline face both intermittent and permanent flooding, and municipalities face tough decisions regarding infrastructure improvements (Ofgang, Lee-Murphy, & Yuravich, 2017). Municipalities must determine how much to raise a road, if at all, to avoid either scenario, and conflicting sea level rise estimates make this decision even more difficult. Raising a road is expensive, and municipalities must weigh the costs and benefits of building a structure that has a longer lifetime. Similarly, railroads are at risk of flooding as many of them run parallel to the coastline. Officials debate whether it is possible to move sections of the track and if it is acceptable to delay station improvements in order to incorporate climate adaptation measures (Spiegel, 2015).

The uncertainty over future climate changes makes it difficult for municipalities to conduct cost-benefit analyses to determine appropriate resilience strategies.

Eelgrass Habitat Restoration

Eelgrass is a rooted, underwater grass found in bays, estuaries, and beaches. It is important to wetland ecosystems as it provides foraging areas, collects sediments, reduces wave energy, improves water quality, and protects coastal areas from erosion. The growth and persistence of eelgrass are good indicators of water quality, as the presence of excessive nutrients like nitrogen and phosphorous increase phytoplankton concentrations, leading to algal blooms and preventing sunlight for eelgrass growth and survival.

Researchers at The Cornell Cooperative Extension developed rock transplant methods to allow for successful establishment of eelgrass shoots. This project was also partially funded by the Long Island Sound Futures Fund. Donor meadows included Mulford Point, Fisheries Island, and Orient Point. Test planting was began in 2005 and intensive plantings were conducted from 2006 to 2008. Currently, the plantings have exceeded the natural eelgrass beds and are thriving. (Cornell Cooperative Extension 2017).

Cornell Cooperative Extension; Long Island Sound Study

Section 3

Technical Solutions

The Comprehensive Conservation and Management Plan proposes several solutions for improving the health of the Sound. These solutions include physical strategies, such as improving water quality and preserving and restoring habitat, as well as increasing community engagement through education and awareness. This section investigates the proposed technical solutions and evaluates their effectiveness in helping the Long Island Sound Study achieve its restoration goals.

Upgrading Wastewater Treatment Plants

Proper collection and treatment of wastewater is essential to protecting public health and local waterways. New York City's wastewater is processed at 14 different wastewater treatment plants, about half of which discharge into local waterways connecting to the Sound. Wastewater is treated according to both state water quality standards and federal Clean Water Act requirements. Nitrogen discharge is not directly harmful to human health, and wastewater treatment plants were not originally designed to remove nitrogen from treated water. Over time, however, researchers found that nitrogen overload from inadequate wastewater treatment leads to algal blooms and hypoxia, and has damaged the Sound. In response, the U.S. EPA and state environmental agencies in New York and Connecticut jointly developed the "Nitrogen Reduction Strategy." The Nitrogen Reduction Strategy addresses hypoxia by significantly reducing the amount of nitrogen entering the Sound from wastewater treatment plants. It restores them to the 2000 Total Maximum Daily Load agreement between Connecticut and New York State. To meet this standard, the New York City Department of Environmental Protection has spent over $1 billion on upgrades to four wastewater treatment plants, which has successfully decreased nitrogen discharges by 60% relative to a 1994 baseline, representing a significant decrease from the baseline level of 59,000 trade equalized pounds per day (NYC Department of Environmental Protection, 2017). Additionally,

Figure 6: The Hunts Point Wastewater Treatment Plant (WWTP) is one of the largest of New York City's 14 water pollution control plants. This is one of the plants that New York Department of Environmental Protection spent over $1 billion on nitrogen removal upgrades. Image from: NYC Department of Environmental Protection

Connecticut has spent more than $450 million on nitrogen removal technologies that convert organic nitrogen present in wastewater into inert nitrogen gas that is released harmlessly into the atmosphere (Connecticut Department of Energy and Environmental Protection, 2016b). While effective, these upgrades require significant and ongoing infrastructure modifications.

The New York City Department of Environmental Protection has spent over $1 billion on upgrades to four wastewater treatment plants, which has successfully decreased nitrogen discharges by 60%.

Upgrading Combined Sewer Systems

Combined sewer systems collect storm water runoff and domestic sewage within the same drainage system. During heavy rainfall events, these sewer systems become inundated by a higher volume of water than normal, and release untreated wastewater into local waterways, including the Sound. These events are called Combined Sewer Overflows (CSOs). To reduce the occurrence of these events, the New York City Department of Environmental Protection has expanded storm sewers and constructed several large CSO retention tanks. These infrastructure developments have increased CSO capture rates from roughly 30% in 1980 to more than 80% today (NYC Department of Environmental Protection, 2018). Additional methods to reduce strain on combined sewers include implementation of green infrastructure projects such as green space in urban areas, right-of-way bioswales and storm water greenstreets. These work to control the capture and release of storm water runoff, thereby reducing the need for end-of-pipe storm water storage and treatment systems (NYC Department of Environmental Protection, 2018).

Nutrient Bioextraction

Nutrient bioextraction is the practice of farming shellfish and seaweed for the purpose of removing nitrogen and other excess nutrients from natural water bodies. This solution complements source control programs while restoring natural ecosystem services. Bioextraction can increase the assimilative capacity of aquatic ecosystems, and make them more resilient to nutrient loading. Nutrient bioextraction is currently the only method available to remove nitrogen after it has entered the Sound. The 2011 “Ribbed Mussel Farming Pilot Study” installed a raft with ropes in the Bronx River to catch and grow ribbed mussels, which feed on the decomposing plankton that contribute to hypoxia.

Figure 7: An Atlantic ribbed mussel used for nutrient bioextraction. Photo: Environmental Science and Engineering Magazine

As the mussels grow, they incorporate excess nutrients into their bodies and are then harvested for other uses such as conversion into fish food pellets (Rose, n.d.).

Eelgrass and Tidal Wetland Restoration

Coastal habitats of the Long Island Sound, such as tidal wetlands, are important ecological transitional zones between land and water. However, tidal wetlands in the Sound have largely been dredged or filled, and poor water quality has negatively impacted the Sound's eelgrass beds. As such, the Long Island Sound Study has identified eelgrass and tidal wetland restoration as a priority management issue.

Tidal wetlands are areas dominated by rooted plants that are flooded by the tide. They help trap sediments, store flood water, and reduce wave energy during storms, addressing a number of issues that threaten the Sound's ecosystem and coastal communities. Two thirds of all marine species depend on tidal wetlands for a portion of their life cycle.

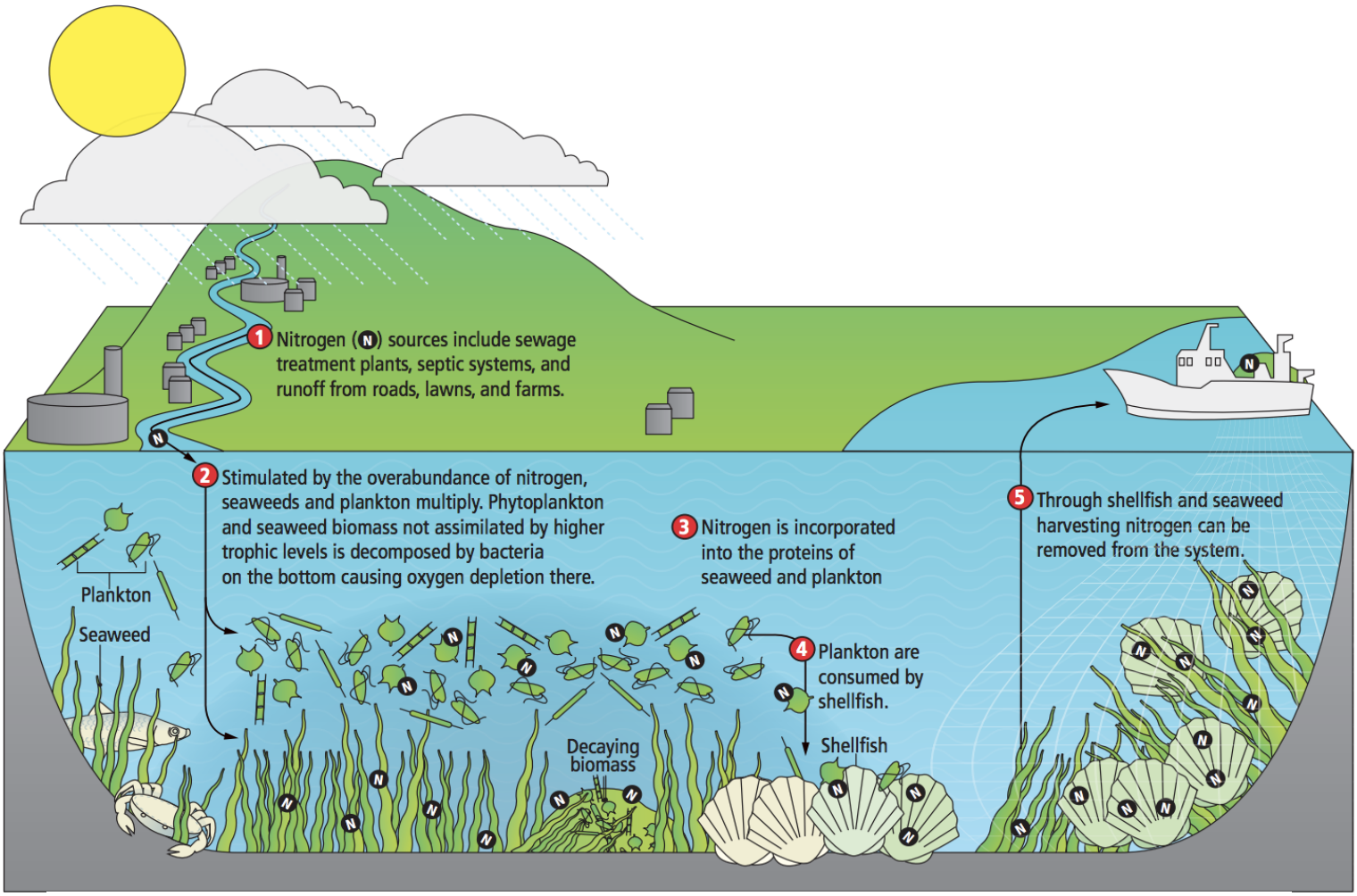

Figure 8: Nutrient Bioextraction is the process of farming and harvesting shellfish (mussels) and seaweed to remove nitrogen and other harmful nutrients from the water.

To restore tidal wetlands, engineering activities focus on restoring tidal flow through the removal of tide gates, installation of large culverts, and removal of fill. One goal of the Study is to restore "an additional 515 acres of tidal wetlands by 2035 from a 2014 baseline" (Long Island Sound Study, n.d.-e).

Another goal of the Study is to "restore and maintain an additional 2,000 acres of eelgrass by 2035 from a 2012 baseline of 2,061." The Study intends to achieve this target through water quality protection and replanting efforts. Successful restoration has been found through hand-planting by SCUBA divers, as well as seed-scattering methods (Long Island Sound Study, n.d.-e).

Barn Island Wildlife Management Area

Barn Island is a success story for conservation efforts of tidal marshes in the Long Island Sound. As a designated 1,024 acre Wildlife Management Area in Connecticut, this island is ecologically important. It is home to 25 federal or state listed endangered and threatened species. However, this was not always the case. In the 1930s, residents drained the marsh to get rid of the mosquitoes that bred in its stagnant waters. This led to a decrease in biodiversity and loss of birds using the area. By 1978 the Connecticut Department of Energy and Environmental Protection installed culverts for standing water to restore the natural tidal flow through the area. Once the marsh returned to its natural flow, native wildlife and plants began to return to the site.

The National Audubon Society has determined Barn Island a "Globally Significant Important Bird Area." Today, Barn Island's restoration is used as a model for other salt marsh restoration and stewardship projects (Long Island Sound Study 2012).

Peter Marteka / Hartford Courant

Section 4

Community-Oriented Solutions

The Long Island Sound is affected by industrialization and urbanization, but the actions of individuals living within the watershed can also harm the ecology of the Sound. Accordingly, the Long Island Sound Study develops and implements strategies to increase public education and awareness with respect to the ecological health and water quality of the Sound.

These awareness and engagement campaigns, along with other community-oriented solutions, engage local governments and communities, increase local participation in Sound remediation, and encourage best management practices for upstream industry and agriculture.

Local Government Partnerships

The 2015 Long Island Sound Nitrogen Reduction Strategy provides a framework for reaching targets to remove nutrient loads within the Sound and larger watershed network. The path to implementing this plan relies heavily on partnerships between the Long Island Sound Study and local governments throughout the Sound's area. In the present iteration of the Comprehensive Conservation and Management Plan, the Study credits this close alliance with multiple levels of government for much of their success in improving water quality in the Sound over the last 20 years (Long Island Sound Study, 2015).

In particular, the Study required local government participation to update at-risk infrastructure and to develop resiliency plans to protect against potential damage from climate change and the Sound's degradation. The development of these resiliency plans involved changes to zoning, housing, transportation, and local laws and regulations (Long Island Sound Study, 2015). These changes would have been impossible–and the goals unattainable–without strong partnerships between towns, cities, states and the Long Island Sound Study.

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Public Awareness

Throughout the Comprehensive Conservation and Management Plan, the Long Island Sound Study promotes increasing public engagement through education and outreach campaigns that raise awareness regarding how individuals and their actions can impact the Sound. Currently, the Study promotes a social media campaign called "#DontTrashLISound," which emphasizes how even seemingly inconsequential individual choices about lawn fertilization, motor oil, and pet waste can affect the water quality of the Sound. The Study also encourages volunteers to help with citizen science, the collection and analysis of data relating to the Sound by members of the general public (Thomas, 2011).

Figure 9: Tidal wetlands are important to the Long Island Sound because they act to improve water quality, trap sediment, protect coasts from erosion, reduce wave energy, and store flood waters. Image from: Long Island Sound Study

#DontTrashLISound

#DontTrashLISound is a public awareness campaign hosted by the Long Island Sound Study that raises awareness within the community on how individual actions impact the Sound. Particular emphasis is placed on how community members can make better choices regarding the management of lawn fertilization and motor oil waste, and how pet waste affects water quality. It also encourages volunteers to get involved with citizen science projects.

The first campaign achieved such a success that a second one was launched on August 2, 2018 through the Long Island Sound Study's Facebook and Twitter pages. This year's focus will be on breaking the "single-use plastic habit." The campaign will be followed up four weeks later with a community volunteer beach cleanup event on International Coastal Cleanup day on September 15th.

Section 5

Future Management Challenges

Many factors in the Long Island Sound region can complicate the implementation of proposed solutions. To achieve long-term success, the EPA Long Island Sound Office, New York, and Connecticut must develop strategies for continued cooperation.

Intergovernmental Coordination

The U.S. EPA, New York, and Connecticut have worked together to protect and restore the Sound since its designation as an Estuary of National Significance in 1988. While the Sound's health is affected by other upstream states, New York and Connecticut are the primary decision makers regarding the Sound's management (Long Island Sound Study, 2016).

To achieve long-term success, the EPA, New York, and Connecticut must develop strategies to adapt to a changing climate, balance conservation and development needs, and strive for continued cooperation.

Cooperation between the two states is essential: roughly half of the Sound is designated Connecticut waters, the other half New York waters (NYS Department of Environmental Conservation, n.d.). The health of the Sound impacts the local economies and the environments of coastal communities in both states, but their different geographic locations and individual economies cause each state to view the Sound differently. Their varied uses can complicate intergovernmental coordination.

Development Pressures

The vitality of the Long Island Sound region depends on balancing conservation and development. While conservation is important to protect natural resources, development is necessary for economic growth. These interests, however, often conflict: designating a piece of land as a protected area often prevents its development. On the other hand, developing an area can lead to habitat loss. A current example involves the sale of Plum Island, New York in the Eastern Sound. The island, the site of a federal research center, has remained closed to the public for decades. The island's isolation allowed it to become an important preserve for many diverse species. In 2009, the government put the island up for sale. Developers see the island as a possible future resort or other commercial enterprise, while conservationists want the island to be preserved as a national park. The sale of Plum Island is representative of frequent scenarios at the local level when lands are converted from natural habitat for residential or commercial development (Ofgang, 2018).

Section 6

Measuring Success

Metrics are used to measure the success of restoration efforts as well as assess progress towards goals and develop future objectives. The Comprehensive Conservation Management Plan has an extensive research and monitoring program that tracks and assesses multiple ecosystem targets and indicators of ecosystem health related to the overarching restoration themes. Each target is assessed and assigned one of the following designations:

- Data Unavailable
- Behind Schedule
- On Track
- Ahead of Schedule
- Met Goal

Ecosystem targets are performance measures. Targets have supporting indicators, which are meant to further assess ecosystem health, but unlike targets, these indicators do not have set goals.

Water Quality Targets

Nitrogen pollution was one of the first metrics tracked in the Sound (Long Island Sound Study, 2017a). Under the CCMP, the Study monitors nitrogen loading and runoff into the Sound to combat hypoxia. This target is designated ahead of schedule, and the Study has added additional sensors around the Sound for nitrate, phosphate, and ammonium (Long Island Sound Study, 2017b). The Study also seeks to increase vegetation in riparian buffers along waterways to 75% by 2035. Riparian zones which are vegetated with native flora allow runoff to permeate into the soil, which traps pollutants, prevents erosion, and mitigates the effects of impervious surfaces (Long Island Sound Study, n.d.-c). Current data on this target is not yet available, but a study that compares the 2015 data to the 2010 baseline using satellite imagery will be released later this year.

Habitat Restoration Targets

The Study aims to restore and preserve the ecological diversity and abundance of the Sound, and it assesses progress toward this goal by measuring habitat connectivity and extent. The Study has a goal of increasing habitat connectivity by 2035, but is currently in the process of identifying and refining existing data tools that can be used to establish metrics for this target (Long Island Sound Study, n.d.-a).

Habitat extent represents a related but distinct metric to habitat connectivity. Measuring habitat extent focuses on the breadth of tidal wetlands and eelgrass. Two-thirds of all marine species found in the Sound depend on tidal wetlands for some portion of their lifecycle and 75% of all restored coastal habitats in the Sound are tidal wetlands. Since 2015, the Study has helped to restore approximately 21.9 acres per

year, however the goal is still behind schedule. The Study is currently analyzing eelgrass data for a final report, scheduled to be released in 2018. Successful restoration of eelgrass beds will depend on an analysis of the extent of annual eelgrass bed data, which is currently being undertaken by the Study (Long Island Sound Study, n.d.-e).

Public Engagement Targets

The Study is actively invested in increasing public participation in Sound restoration. The Study measures progress towards this target in two ways: the percentage of coastal residents participating in activities within the Sound and public perception that individual behavior can change the Sound's water quality. In response to invasive species, the Study has instituted the

Project Limulus and the Role of Citizen Science

Horseshoe crabs use the Sound's shoreline to mate and spawn during high tide new moons from mid-May to end of June. They play an important role in the Sound's ecosystem as an indicator species in determining the health and productivity of the Sound. Migratory birds and other species depend on horseshoe crab egg deposits as a food source, and several fish species depend on juvenile crabs as part of their diet. Community members, school groups, and citizen scientists are contributing important new life history and population data for research (Long Island Sound Study 2010).

Project Limulus is a collaboration between Sacred Heart University, U.S. Fish and Wildlife Service, the Long Island Sound Study, and community members to gather data on horseshoe crabs (*Limulus polyphemus*) in the Sound. Since its start in 1998, Project Limulus has relied on citizen science to collect data, conduct surveys, and tag horseshoe crabs. Over twenty years of data collection from citizen scientists has resulted in 88,000 tagged horseshoe crabs, with 22,000 individuals re-sighted, and 1,800 spawning surveys (Skahill, 2014).

U.S. Fish & Wildlife Service

Clean Vessel Program to engage the boating community in preventing further introductions. A simple metric for tracking engagement is through volunteer participation in coastal cleanups and other events. Public surveys have been conducted in coastal areas related to recreational use of the Sound (boating, kayaking, and other activities), but further metrics need to be developed in order to track public engagement more efficiently (Long Island Sound Study, n.d.-b). For example, tracking citizen science involvement would be an effective measure of success as many citizen science programs already exist in and around the Sound.

Areas for Further Study

While the Study already tracks a wide variety of measures, some can be enhanced or added in order to better assess progress. For example, there is no effort to track the abundance of invasive species found in the Sound. Currently, Connecticut's Department of Energy and Environmental Protection conducts an annual trawl survey in the Sound for all species, and inevitably finds invasive species, like the Asian Shore Crab discussed earlier (Connecticut Department of Energy and Environmental Protection, 2016a). More data regarding abundance and distribution of invasive species are needed in order to develop ecosystem targets in this area.

Additionally, the Study tracks climate change indicators (e.g. water temperature and sea level), but does not have measurable goals for climate change resilience. The Climate Change and Sentinel Monitoring Program analyzes climate change impacts to the Sound and provides regulators with necessary information to enact adaptation strategies. The program developed pilot-scale monitoring to measure indicators of change in the Sound's ecosystems; these indicators include hypoxia, acidification, finfish abundance, and water turbidity. While this program focuses on the impacts of climate change, it has yet to set these impacts. These could be developed in the future once baselines are established. Some measures of resilience may be similar to existing targets (Long Island Sound Study, n.d.-d). Figure 10 below provides additional information regarding water quality, habitat quality, and community awareness metrics.

More concrete abundance and distribution data are needed in order to develop ecosystem targets in this area.

Fig. 10: Measures of ecosystem target success, grouped by category.

	Ecosystem Target	Supporting Indicators	Baseline Measure	Goal	Status	Data Source
Water Quality	Nitrogen Loading	Duration of Hypoxia; Area of Anoxia/Severe Hypoxia; Water Quality Index	59,000 pounds per day (2000 Total Maximum Daily Load from wastewater treatment plant point sources)	60% reduction by 2017	Goal Met	Connecticut Department of Energy and Environmental Protection (CTDEEP); New York State Department of Environmental Conservation (NYSDEC)
	Extent of Hypoxia	Duration of Hypoxia; Area of Anoxia/Severe Hypoxia; Water Quality Index	208 squre miles of area of bottom waters with dissolved oxygen ≤ 3 mg/L (pre-200 Total Maximum Daily Load average)	28% reduction by 2035	Ahead of Schedule	CTDEEP; Interstate Environmental Commission for Western Long Island Sound; Long Island Sound Coastal Observatory
	Riparian Buffers	Watershed Population; Population within 50 Mile Buffer; Changes in Forest Cover	65% of New York and Connecticut's riparian zones (defined as within 300 feet of any stream or lake) are vegetated (2010 baseline)	75% vegetated by 2035 (total of 1,030 square miles of naturally vegetated area)	Data Unavailable (report coming 2018)	University of Connecticut Center for Land Use Education and Research (CLEAR)
Habitat Quality	Habitat Connectivity	n/a	n/a	Increase connectivity of coastal habitat by 2035 by restoring and/or protecting habitat patches	Data Unavailable	GIS databases
	Eelgrass Extent	Water Quality Index	2,061 acres (2012 baseline)	Restore an additional 2,000 acres habitat by 2035	Data Unavailable (report coming 2018)	CTDEEP; EPA; U.S. Fish and Wildlife Service; U.S. Geological Survey
	Tidal Wetland Extent	n/a	990 acres (2014 baseline)	Restore an additional 525 acres by 2035	Behind Schedule	CTDEEP; NYSDEC; Long Island Sound Study Partners
Community Awareness	Public Engagement and Knowledge	Volunteers at Coastal Cleanups	n/a	Increase the knowledge and engagement of the public in the protection and/or restoration of the Sound	Data Unavailable	Stony Brook University

Conclusion

The Long Island Sound has long been a center of industry and commerce since the acceleration of development following the end of World War II, causing extensive ecosystem damage. After the passage of the Clean Water Act in 1972, the state of the Long Island Sound became a government focus. The Long Island Sound Study was established as an amendment to the Clean Water Act and U.S. EPA and State managers were assigned to manage the Study's activities.

The recent 2015 Comprehensive Conservation and Management plan focused on the following primary areas: clean waters and healthy watersheds; thriving habitats and abundant wildlife; sustainable and resilient communities; and sound science and inclusive management. At this time, the main threats to the Sound are nitrogen pollution and degraded water quality, habitat degradation and fragmentation, and climate change. Through the efforts of the Study, the EPA, and state management, effective technology has been implemented. Upgrades to wastewater treatment plants have reduced nitrogen levels and limited hypoxia events and algal blooms. Combined sewer systems have been upgraded throughout New York City, allowing for an increase in sewage capture rates from 30% to 80%. New methods including nutrient bioextraction and eelgrass and tidal wetland restoration are also being employed as a means of reducing nutrient levels and restoring coastal ecosystems, which is critical to improving biodiversity and protecting shorelines from storm damage and flooding.

The Study prioritizes community involvement in Long Island Sound restoration and management, recognizing that restoration efforts cannot be successful without the cooperation of the community. Additionally, government coordination must be maintained due to the large size of the Long Island Sound watershed, as New York, Connecticut, Massachusetts, Rhode Island, and Vermont are all subject to H.R. 1674. On a smaller scale, local governments and residents are involved with the activities of the Study and the implementation of H.R. 1674.

Measurement of success is critical, but data challenges persist and still much data remains difficult to obtain and evaluate. However, the Study continues to work to address gaps in data and is currently in the process of analyzing new data. Nitrogen cycling continues to be a top priority as a means of preventing hypoxia and algal blooms. The Study plans to increase vegetation buffers by 75% by 2035 as well as increase habitat connectivity. Increasing the number of community members directly participating in restoration activities is also a primary goal.

The Long Island Sound Study has demonstrated success in restoring the health of the Sound but there is still work to be done, particularly in regard to water quality near urban areas like New York City. Through continued work, and with the benefit of additional data and studies, these efforts can improve the health of the Sound for all of its residents.

References

Balcom, N. (2012). Aquatic Invasions. *Newsletter of the Long Island Sound Study*.

Center for Land Use Education and Research. (2013). Impervious Surfaces: Long Island Sound Regional Impervious Surface Study. Retrieved July 24, 2018, from http://clear.uconn.edu/projects/imperviouslis/index.htm

Christopher H. Pickerell. (2017, September 6). Eelgrass Restoration and Monitoring. Retrieved July 24, 2018, from http://ccesuffolk.org/marine/habitat/eelgrass-restoration-and-monitoring

Connecticut Department of Energy and Environmental Protection. (2016a). *Long Island Sound Trawl Survey*. Retrieved from http://www.ct.gov/deep/lib/deep/fishing/publications/2016_long_island_sound_trawl_survey.pdf

Connecticut Department of Energy and Environmental Protection. (2016b, December 16). Tidal Wetland Restoration. Retrieved July 25, 2018, from http://www.ct.gov/DEep/cwp/view.asp?a=2705&q=323828&deepNav_GID=1654

DeLauro, R. (2017, March 29). H.R.1674 - 115th Congress (2017-2018): Long Island Sound Restoration and Stewardship Act [webpage]. Retrieved July 28, 2018, from https://www.congress.gov/bill/115th-congress/house-bill/1674

Foderaro, L. W. (2017, December 22). 'Dead Rivers, Closed Beaches': A Water Crisis on Long Island. *The New York Times*. Retrieved from https://www.nytimes.com/2017/05/08/nyregion/dead-rivers-closed-beaches-an-acute-water-crisis-on-long-island.html

Long Island Sound Study. (2015). *Long Island Sound Comprehensive Conservation and Management Plan 2015*.

Long Island Sound Study. (2016). Introduction to the Summary of the Plan. Retrieved July 26, 2018, from http://longislandsoundstudy.net/about/our-mission/management-plan/introduction/

Long Island Sound Study. (2017a). History. Retrieved July 24, 2018, from http://longislandsoundstudy.net/about-the-sound/history/

Long Island Sound Study. (2017b). *Long Island Sound Study's Year in Review: 2016* (Newsletter). New York, NY: Stony Brook University.

Long Island Sound Study. (2017c). Nitrogen Loading. Retrieved July 24, 2018, from http://longislandsoundstudy.net/ecosystem-target-indicators/nitrogen-loading/

Long Island Sound Study. (n.d.-a). Habitat Connectivity. Retrieved July 27, 2018, from http://longislandsoundstudy.net/ecosystem-target-indicators/habitat-connectivity/

Long Island Sound Study. (n.d.-b). Public Engagement and Knowledge. Retrieved July 27, 2018, from http://longislandsoundstudy.net/ecosystem-target-indicators/public-engagement-and-knowledge/

Long Island Sound Study. (n.d.-c). Riparian Buffer Extent. Retrieved July 27, 2018, from http://longislandsoundstudy.net/ecosystem-target-indicators/riparian-buffer-extent/

Long Island Sound Study. (n.d.-d). Sentinel Monitoring for Climate Change. Retrieved July 28, 2018, from http://longislandsoundstudy.net/research-monitoring/sentinel-monitoring/

Long Island Sound Study. (n.d.-e). Tidal Wetland Extent. Retrieved July 27, 2018, from http://longislandsoundstudy.net/ecosystem-target-indicators/tidal-wetland-extent/

Long Island Sound Study. (n.d.-f). Watershed Projects. Retrieved July 24, 2018, from http://longislandsoundstudy.net/our-vision-and-plan/clean-waters-and-healthy-watersheds/long-island-sound-watershed-projects/

NYC Department of Environmental Protection. (2017, January 5). $1 Billion Nitrogen Reduction Project Improves the Health of the East River and Long Island Sound. Retrieved July 25, 2018, from http://www.nyc.gov/html/dep/html/press_releases/17-001pr.shtml#.W0N_i9hKhAY

NYC Department of Environmental Protection (n.d.). Map of Plant Locations and Capacities. Retrieved August 8, 2018, from http://www.nyc.gov/html/dep/html/wastewater/wwsystem-plantlocations_wide.shtml

NYC Department of Environmental Protection. (2018). Combined Sewer Overflows (CSOs). Retrieved July 25, 2018, from http://www.nyc.gov/html/dep/html/stormwater/combined_sewer_overflow.shtml

NYS Department of Environmental Conservation. (n.d.). New York's Marine & Coastal District Waters. Retrieved July 26, 2018, from https://www.dec.ny.gov/permits/95483.html

Ofgang, E., Lee-Murphy, M., & Yuravich, A. (2017, March 28). Connecticut's Rising Seas: Are Towns and Cities Ready? Retrieved July 24, 2018, from http://www.connecticutmag.com/health-and-science/connecticut-s-rising-seas-are-towns-and-cities-ready/article_e97a46de-0a74-11e7-a2f8-172f13eecce2.html

Ofgang, E. (2018, February 19). The Battle to Preserve Plum Island. *Connecticut Magazine.* Retrieved August 7, 2018, from connecticutmag.com/the-connecticut-story/the-battle-to-preserve-plum-island/article_dbae0b00-158e-11e8-b36d-3b028acdc036.html.

Regional Plan Association. (2016). *Under Water: How Sea Level Rise Threatens the Tri-State Area*. New York, NY: Regional Plan Association.

Rose, J. (n.d.). Nutrient Bioextraction. Retrieved July 12, 2018 from http://longislandsoundstudy.net/wp-content/uploads/2011/08/Bioextraction_factsheet.pdf

Spiegel, J. (2015). Climate Change Threatens Connecticut's Vital Shoreline Rail. Retrieved July 24, 2018, from https://ctmirror.org/2015/07/15/rail-1-staging/

The Nature Conservancy. (2018). The Problem. Retrieved July 24, 2018, from https://www.liswaterquality.org/the-problem/

Thomas, E. (2011, September). *How Watershed Protection on the Local Level Benefits Water Quality of Long Island Sound*. Powerpoint presented at the Niantic River State of the Watershed.

Thorpe, A. (2005). Climate Change Prediction: A Challenging Scientific Problem. *The Institute of Physics*.

U.S. Geological Survey. (2018, July 10). Asian shore crab (Hemigrapsus sanguineus) - Species Profile. Retrieved July 24, 2018, from https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=183

U.S. Global Change Research Program. (2017). Climate Science Special Report: Fourth National Climate Assessment. In D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, & T. K. Maycock (Eds.) (p. 570). Washington, DC, USA. Retrieved from https://science2017.globalchange.gov/