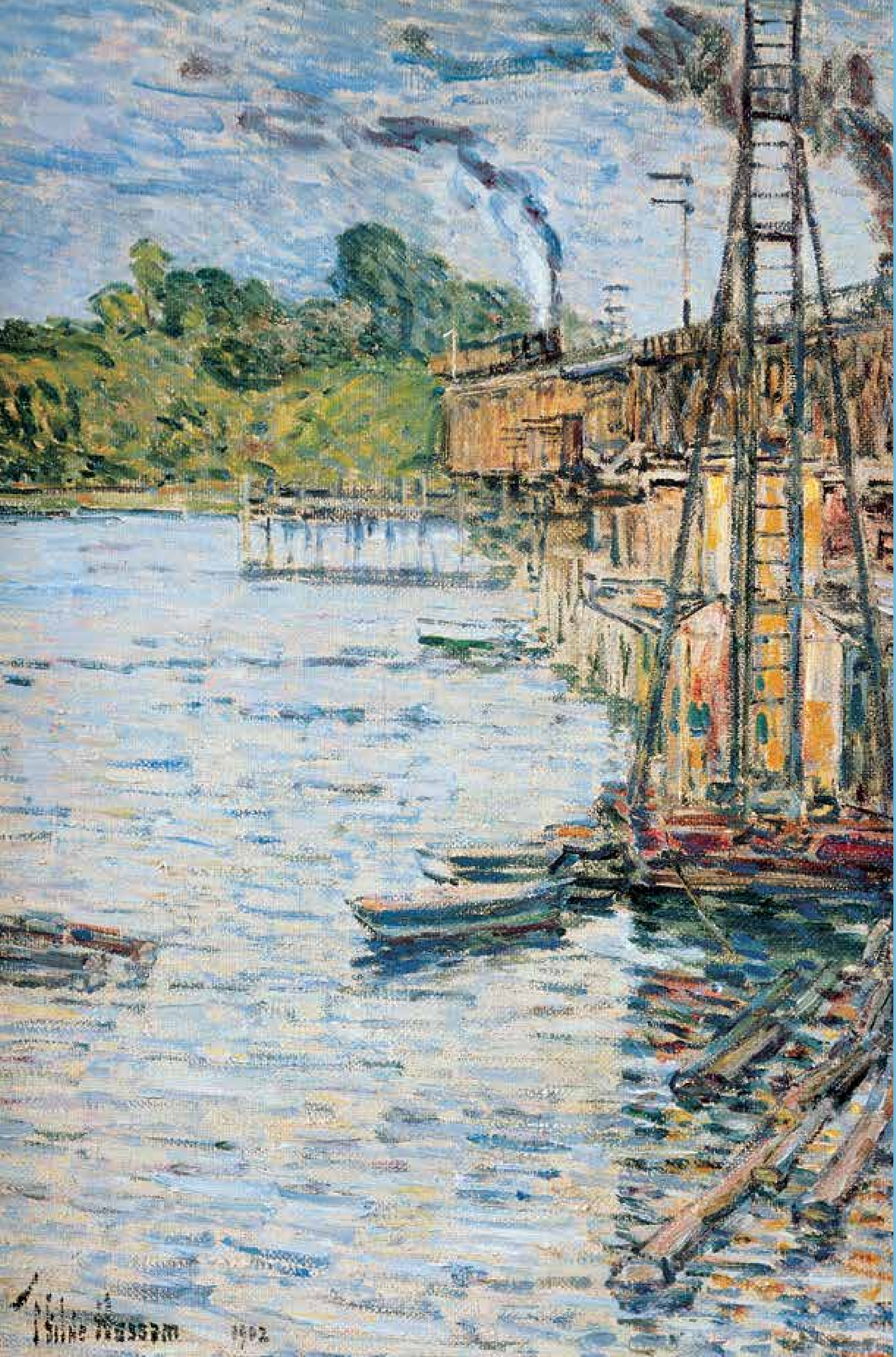

LONG ISLAND SOUND

PROSPECTS FOR THE URBAN SEA

AN EXECUTIVE SUMMARY

EDITORS: JAMES S. LATIMER · MARK A. TEDESCO
R. LAWRENCE SWANSON · CHARLES YARISH
PAUL E. STACEY · COREY GARZA

TESTIMONIALS

"This massive, multidisciplinary synthesis is a welcome contribution to the understanding of Long Island Sound, providing not only new knowledge, but important information relevant to managers of coastal ecosystems. It will provide an extremely valuable resource for Long Island Sound for many years to come."

—**Gene E. Likens**, Founding Director and President Emeritus
Cary Institute of Ecosystem Studies, Millbrook, NY

"*Long Island Sound: Prospects for the Urban Sea* is a major new and timely contribution to the literature on one of the nation's most important estuaries. Prospects for all our estuaries are changing, primarily as a result of coastal development and effects associated with climate change, particularly sea level rise and increased power of storm surges, rising temperatures, and ocean acidification. This book provides valuable insights into understanding these impacts and into how to improve the prospects for the qualities and uses of Long Island Sound most important to society and to creating and maintaining a healthy, productive ecosystem. Many of the lessons are transferrable to other estuaries and coastal systems."

—**Jerry R. Schubel**, President and CEO
Aquarium of the Pacific, Long Beach, CA

PURCHASE INFORMATION

The book is part of Springer's Series on Environment and Management. It is available in e-book either in its entirety or by individual chapter on the publisher's website at **www.springer.com.** The hardcover version can be ordered on the Springer website or those of other booksellers.

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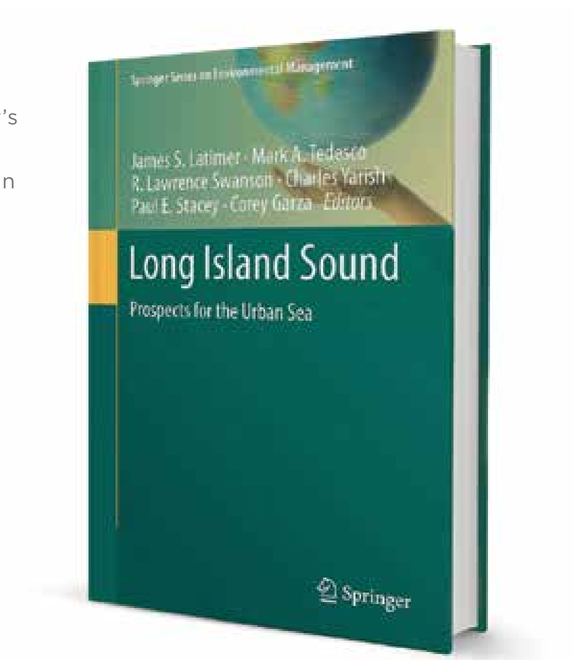


LETTER FROM THE EDITORS

Long Island Sound: Prospects For The Urban Sea is the first synthesis of the science of Long Island Sound in more than 35 years. The Long Island Sound, described by Daniel Webster as the American Mediterranean, has experienced over four centuries of human habitation and use. As a result, it is undergoing many changes, and similar changes can be seen in other estuaries throughout the country. Now subject to coordinated restoration efforts, the fate of Long Island Sound is a harbinger of coastal waters everywhere.

The practical genesis of this book can be traced back to a workshop sponsored by the Science and Technical Advisory Committee of the Long Island Sound Study (LISS). The LISS, part of the National Estuary Program and charged with protecting and restoring Long Island Sound, had already developed a Comprehensive Conservation and Management Plan, formally approved in 1994 in accordance with Clean Water Act requirements. The plan was bolstered by an infusion of new monitoring and research, but the management lexicon of the time was evolving and didn't even include climate change. Since that time, the National Estuary Program's faint whispers of ecosystem-based management using the best science in collaborative efforts that incorporate society and the economy had become bold calls embraced by scientists and adopted by policymakers.

The need for scientific synthesis is acute. Consider the ever increasing amount of specialized data and information about coastal and estuarine systems; the complexity of new and enduring challenges such as climate change, coastal development and use conflicts, emerging contaminants, fisheries management, invasive species, and nutrient pollution. Also consider the increased demand by policy makers and the public to translate science so that it is understandable and applied effectively to address these challenges in a world of diminishing public resources.

An up-to-date comprehensive reference volume synthesizing the body of research that had been conducted in and around Long Island Sound had not been readily available to the local research and management community. At long last, this volume brings together a body of environmental data collected by researchers from the academic and agency communities as it applies to understanding the environmental dynamics of Long Island Sound. Throughout this synthesis, the emphasis is on summarizing our current knowledge of the physical and biological processes in a format that will serve as a primary reference volume for scientists conducting research in Long Island Sound and beyond. In addition to the data summaries, chapters discuss recommendations for synthesizing this body of knowledge into a comprehensive ecosystem-based management strategy for Long Island Sound, as well as the potential impacts of climate change on this ecosystem.

Six technical chapters summarize our knowledge about the human history, geology, physical oceanography, geochemistry, pollutant history, and biology and ecology of Long Island Sound. The last chapter identifies the linkages between science and environmental management, drawing extensively from hard-learned lessons on identifying threats and implementing strategies to confront them. This synthesis book will be of interest to anyone engaged in research, conservation, and restoration of coastal ecosystems: scientists, students, managers, planners, and environmentalists. It will help guide both research and management activities of Long Island Sound and other urban estuaries around the world.

This Executive Summary will provide you with an overview of key findings detailed in the book. We hope you find this insightful and thought-provoking.

EDITORS: JAMES S. LATIMER, MARK A. TEDESCO, R. LAWRENCE SWANSON, CHARLES YARISH, PAUL E. STACEY, AND COREY GARZA

CHAPTER 1

LONG ISLAND SOUND: A SOCIOECONOMIC PERSPECTIVE

Authors: Marilyn E. Weigold and Elizabeth Pillsbury

Long Island Sound and its watershed have been subject to development pressures throughout their histories.

- Throughout history and even today, Long Island Sound (LIS) has been a resource for inhabitants on both sides of the waterway.
- A nautical highway for native peoples and European settlers, LIS was traversed by ferries beginning in the 1700s and steamboats from the 1800s through the 1930s.
- Population increases in the 19th century, together with mainland industrialization, posed challenges in the form of sewage and industrial wastes.
- Parkways, plus bridges spanning the upper East River, spurred 20th century suburbanization; interstate highways of the post-World War II period led to the development of exurban areas.
- The 20th century challenge of providing electrical power was met, in part, by the construction of the Millstone Nuclear Power Plant in Connecticut, but massive protests and the lack of an adequate evacuation plan led to the dismantling of Long Island's Shoreham nuclear power plant.
- Despite the challenges facing LIS, recreational and commercial fishing have persisted. Whether setting sail on whaling voyages in the 1800s or seeking menhaden, or finfish and shellfish for human consumption, fishermen experienced both good and lean years including the 1990s when a lobster die-off decimated that fishery.
- In the 1970s and 1990s, federal-state studies of LIS explored challenges facing the waterway and its aquatic life, and the LIS Restoration Act of 2000 codified federal support for interstate cooperative efforts.

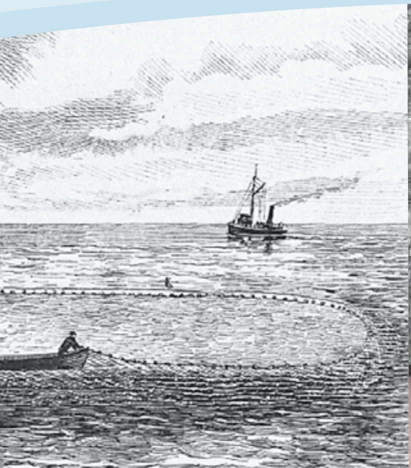
CHAPTER 2

THE GEOLOGY OF LONG ISLAND SOUND

Author: Ralph Lewis

Geologic forces that have shaped LIS and its watershed constitute the backdrop from which its physical and biological distinctiveness is derived.

- Northern portions of the LIS Basin are underlain by a south-dipping bedrock surface that extends beneath eroded remnants of Coastal Plain strata to the south. These units are overlain by deposits of Glacial Lake Connecticut. Their thickness and extent indicate that the last glacier (there were at least four) did more to fill in the Basin than it did to carve it out.
- Evidence of the draining of Glacial Lake Connecticut, subsequent sea level rise, and active modern sediment transport is found in post-glacial stream, estuarine, and marine deposits.
- The north shore of the Basin (i.e., the coast of Westchester County, NY and Connecticut) is dominated by glacially-smoothed, north-south-trending bedrock promontories flanking glacially-modified, bedrock valleys filled with glacial melt-water deposits and the beaches and marshes that have developed on them. This is the longest stretch of low-energy, bedrock-dominated shoreline on the US east coast.
- The east-west orientation of Long Island and Fishers Island is a reflection of the assorted sediments that were glacially emplaced over Coastal Plain strata along the southern flank of the Basin. The resulting shorelines are more mobile and permeable, and less able to resist the long-term effects of tides, storms, and sea level rise than the bedrock-dominated north shore.
- Contrasting land use, sediment transport and erosion/deposition patterns, and ratios/delivery paths for ground and surface water inputs to the Sound are directly related to the physical character of the Basin's shorelines.




CHAPTER 3

THE PHYSICAL OCEANOGRAPHY OF LONG ISLAND SOUND

Authors: James O'Donnell, Robert E. Wilson, Kamazima Lwiza, Michael Whitney, W. Frank Bohlen, Daniel Codiga, Diane B. Fribance, Todd Fake, Malcolm Bowman, and Johan C. Varekamp

Physical forces underpin the spatial and temporal characteristics of the waters of LIS.

- Much has been learned about the pattern of circulation and sea level variations in Long Island Sound since 1990, using a combination of ship- and buoy-based observations and numerical models. The spatial structure of the tides and the long term mean flow is now more firmly established, and the predictability of the distribution and variability of temperature, salinity, light, and major nutrients has substantially improved.
- Understanding of sea level fluctuations driven by storms is advanced, and storm level predictions are already valuable. However, higher resolution models are needed to help better predict flooding of towns, cities, and natural areas, such as marshes.
- Statistical calculations of wave action in the middle of LIS appear to be consistent with theories based on fetch limitation; however, data are still relatively sparse.
- Vertical mixing plays an important role in the distribution of heat, salt, and dissolved oxygen in LIS. Models and observations suggest that rates are spatially variable and unsteady. More critical evaluations are essential to enhance the predictability of ecosystem structure and function.
- There is strong evidence of decadal scale variations in river flow, temperature, salinity, wind, and insolation, such that these must be linked to regional climatic variations.
- Humans have changed the shape of the shoreline of LIS and the hydrology of its watershed with consequences for LIS water characteristics. For example, the dredging of the East River and the development of water distribution systems may have led to changes in the salinity of the western LIS.

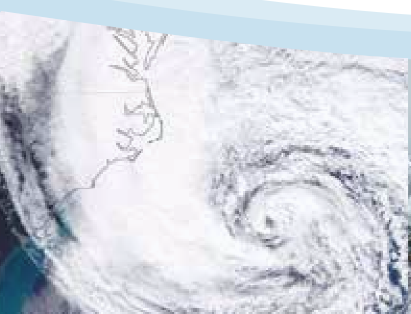
CHAPTER 4

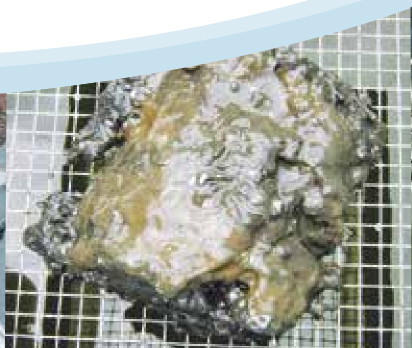
GEOCHEMISTRY OF THE LONG ISLAND SOUND ESTUARY

Authors: Carmela Cuomo, J. Kirk Cochran, and Karl K. Turekian

Geochemical processes shape the characteristics of LIS sediments with consequences for overlying water quality.

- LIS sediments are home to a complex interconnected biogeochemical system involving organisms, geologic particles, and chemical species all of which interact with bottom waters whose movements are tightly constrained by the geography of the Sound.
- Fine-grained sub-tidal sediments of western LIS and most harbors, inlets, and bays within LIS are dominated by low-oxygen conditions in the absence of large benthic populations. Coarse sediments of eastern LIS and elsewhere are dominated by oxygen-rich processes in the absence of large inputs of organic carbon. Central LIS sediments exist in a dynamic balance between anoxic and oxic conditions, moving continuously between these states.
- The primary source of organic carbon input to LIS sediments is phytoplankton, but evidence of a terrestrial carbon component can be found near Norwalk Shoals and within Smithtown Bay.
- The distribution of redox-sensitive metals in LIS sediments correlates with organic carbon content, grain size, and sediment oxidation state. Generally, highest metal inventories occur in western and central LIS.
- Isotope tracers have proved useful in studying sediment-associated processes in LIS. Isotopic inventories vary spatially, suggesting lateral exchange and transport of particles within the Sound and a strong dependence of the inventories on the rate and depth of particle mixing.





CHAPTER 5

METALS, ORGANIC COMPOUNDS, AND NUTRIENTS IN LONG ISLAND SOUND: SOURCES, MAGNITUDES, TRENDS, AND IMPACTS

Authors: Johan C. Varekamp, Anne E. McElroy, John R. Mullaney, and Vincent T. Breslin

The magnitude and dynamics of pollutant inputs to LIS reflect the activities on its watershed and are observed in the biota, sediments, and waters of LIS.

- LIS is a relatively shallow estuary with an average depth of 20 meters (65 feet), and it has a unique hydrology and history of pollutant loading. In particular, problems arise from contaminants in LIS's muddy sediments and aquatic life, and the buildup of nutrients in the water column.
- Dated sediment cores provide records of eutrophication and metal contamination reaching back hundreds of years.
- LIS sediments are contaminated with toxic compounds and elements related to past and present wastewater discharges and runoff, including nonpoint source and stormwater runoff and groundwater discharges. Legacy pollutants such as mercury, copper, and zinc will remain a problem for LIS despite the fact that the active source industries no longer exist.
- Major impacts to LIS have resulted from the abundant amounts of nutrients discharged into LIS through atmospheric deposition, domestic and industrial wastewater flows, fertilizer releases, and urban runoff. These sources and their effects are the result of human presence and activities in the watershed, and the severity of pollutant loadings and their impacts correlate with the total population in the surrounding watersheds.
- Enacted environmental legislation since the mid-to-late 1900s (e.g., Clean Air Act, Clean Water Act) has had a beneficial effect on LIS. Contaminant loadings for many toxic organic and inorganic chemicals have decreased over the last few decades.
- Major strides have been made in reducing the input of nutrients into LIS, but cultural eutrophication is still an ongoing problem and efforts to control nutrients will need to continue.

CHAPTER 6

BIOLOGY AND ECOLOGY OF LONG ISLAND SOUND

Authors: Glenn Lopez, Drew Carey, James T. Carlton, Robert Cerrato, Hans Dam, Rob DiGiovanni, Chris Elphick, Michael Frisk, Christopher Gobler, Lyndie Hice, Penny Howell, Adrian Jordaan, Senjie Lin, Sheng Liu, Darcy Lonsdale, Maryann McEnroe, Kim McKown, George McManus, Rick Orson, Bradley Peterson, Chris Pickerell, Ron Rozsa, Sandra E. Shumway, Amy Siuda, Kelly Streich, Stephanie Talmage, Gordon Taylor, Ellen Thomas, Margaret Van Patten, Jamie Vaudrey, Charles Yarish, Gary Wikfors, and Roman Zajac

Biological communities in LIS are profoundly affected by the environments in which they live.

- Biological communities in LIS reflect the environments in which they are found, such as the intertidal, shallow, subtidal, and open water regions. Alterations in physical, chemical, and biological construct of these habitats, both natural and human-caused, can impact their survival.
- The understanding of the biology of LIS is based on decades of research combined with sustained monitoring efforts measuring the physical, chemical, and biological parameters. For example, fish surveys have shown long-term changes in the relative and absolute abundance of different fish species, with cold-water species declining and warm-water species increasing. However, understanding the underlying causes of this phenomenon is difficult as many fish species are migratory.
- The ecological challenges to the biota of LIS include cultural eutrophication, hypoxia, biological invasions, climate change, and the collapse of commercially-important populations.
- The biological consequences of the challenges facing LIS are dramatic, with strong longitudinal gradients in plankton productivity and changes in critical habitats such as tidal marshes. There have also been dramatic declines in important species such as eelgrass, lobster, and winter flounder, while seafloor-dwelling organisms have been affected by periodic hypoxia.




CHAPTER 7

SYNTHESIS FOR MANAGEMENT

Authors: Mark A, Tedesco, R. Lawrence Swanson, Paul E. Stacey, James S. Latimer, Charles Yarish, and Corey Garza

The management of LIS and its watershed is dependent upon our understanding of the factors that affect it.

- Long Island Sound has been the site of seminal research on coastal marine ecosystems. For example, its importance for navigation and trade placed some of the earliest surveys conducted in the US of water depth, tides and currents, and later of groundbreaking work in coastal oceanography and sediment geochemistry within its waters.
- Changing environmental conditions in the "Urban Sea" over the past 400 years can be linked to alterations in the 16,000 square miles of land that drain into it, a primary driver of water quality degradation and habitat loss. Fostered by a growing environmental ethic and increasingly stringent state and federal laws, noticeable improvements in recent decades in some measures have been observed.
- The effects of climate change are already apparent, including warmer waters, an earlier spring freshet, altered wind patterns, and changes in the biological community, including a decline in high-value resources such as lobsters. The potential acceleration of climate change must be integrated into planning, adaptation, and restoration efforts.
- Significant progress has been made in curbing nutrient pollution, especially from point sources, but keeping pace with failing and outdated infrastructure, the growing and pervasive impact of new development, and compromised positive biological feedback loops in critical eelgrass, shellfish, and wetland systems that promote ecosystem health and resilience remain challenges.
- Sound science and cross-jurisdictional governance that are inclusive, adaptive, innovative, and accountable are needed to further and sustainably protect and restore Long Island Sound.

IMAGE CREDITS

ON THE COVER

Childe Frederick Hassam (1859–1935). The Mill Pond, Cos Cob, 1902; Oil on canvas, 26 1/4 x 18 1/4 in. Collection of the Bruce Museum, Greenwich, CT, Anonymous Gift, 94.25

CHAPTERS 1–4, FROM LEFT TO RIGHT

Menhaden fishery–school of menhaden surrounded by purse-seine. Sketch by Capt. B. F. Conklin. Credit: NOAA National Marine Fisheries Service

CT schist rock that contributes garnets to coastal beaches. Photo by Judy Preston

Folded and fractured bedrock is characteristic of many of the outcrops along the Connecticut River, such as this along the banks of Selden Creek in Lyme, CT. Photo by Judy Preston

Fishers Island, NY coastline. Photo by Patrick Comins

A NASA satellite image shows the eye of Hurricane Sandy on October 28, 2012 approaching the coast about 575 miles from LIS. Photo by Jesse Allen, NASA Earth Observatory

Aerial assessment of damage caused along the CT shoreline by Hurricane Sandy. Photo by the Connecticut National Guard

A sediment core collected with an Eckman box core sampler from Cold Spring Harbor, NY. Photo by Charles Yarish

Students from the laboratory of University of Massachusetts Professor Mark Altabet deploy a rosette sampler as part of a LISS-funded project to learn more about what causes summertime hypoxia in the western LIS. Photo by Mark Altabet

CHAPTERS 5–7, FROM LEFT TO RIGHT

Sediment flow from Hurricane Irene, August 2011. Photo by Larissa Graham

A juvenile eastern painted turtle from Pratt Cove in Deep River, a freshwater tidal marsh. Photo by Judy Preston

Three chicks and two adult osprey in a nest at Milford Point, CT. Photo by Sibel Güner

Ribbed mussels and seaweed in their natural marsh habitat. Photo by Mark Dixon, NOAA Milford Laboratory

Project Limulus horseshoe crab tagging. Photo by Judy Preston

Stratford, CT sewage treatment plant aeration tank under construction. The tank will help remove nitrogen from sewage. Photo by CT DEEP

Wooden decoys in use to encourage Least Terns to nest. Photo by Sibel Güner

Volunteers lend a helping hand planting 10,000 dune grass shoots and 400 native shrubs at the Brides Brook in Connecticut's Rocky Neck State Park. Photo by Save the Sound




USEFUL CONTACTS

EPA LIS Office
Stamford Government Center
888 Washington Blvd.
Stamford, CT 06904-2152
Phone: (203) 977-1541
Fax: (203) 977-8102

New York Sea Grant
146 Suffolk Hall
Stony Brook University
Stony Brook, NY 11794-5002
Phone: (631) 632-9216
Fax: (631) 632-8216

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EDITORS

James S. Latimer
Office of Research and Development
US Environmental Protection Agency
Narragansett, RI 02882 USA

Mark A. Tedesco
Long Island Sound Office
US Environmental Protection Agency
Stamford, CT 06904 USA

R. Lawrence Swanson
School of Marine and Atmospheric Sciences
Stony Brook University
Stony Brook, NY 11794 USA

Charles Yarish
Department of Ecology and Evolutionary Biology
University of Connecticut
Stamford, CT 06901 USA

Paul E. Stacey
Great Bay National Estuarine Research Reserve
New Hampshire Fish and Game Department
Durham, NH 03840 USA

Corey Garza
Division of Science and Environmental Policy
California State University
Monterey Bay, Seaside, CA 93955 USA

Long Island Sound Study
c/o New York Sea Grant
146 Suffolk Hall
Stony Brook University
Stony Brook, NY 11794-5002

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