Springer Series on Environmental Management

James S. Latimer · Mark A. Tedesco
R. Lawrence Swanson · Charles Yarish
Paul E. Stacey · Corey Garza *Editors*

Long Island Sound

Prospects for the Urban Sea

Springer

Springer Series on Environmental Management

For further volumes:
http://www.springer.com/series/412

James S. Latimer · Mark A. Tedesco
R. Lawrence Swanson · Charles Yarish
Paul E. Stacey · Corey Garza
Editors

Long Island Sound

Prospects for the Urban Sea

Springer

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

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

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

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

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

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

ISSN 0172-6161
ISBN 978-1-4614-6125-8 ISBN 978-1-4614-6126-5 (eBook)
DOI 10.1007/978-1-4614-6126-5
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013951776

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Dedication

To Gerard M. Capriulo

While this book was being written, it was with deep regret that we learned that Gerard M. Capriulo, the Fletcher Jones Professor of Marine Biology, and chairman of the Biology Department at Saint Mary's College of California, died suddenly and unexpectedly on November 14, 2009. He was 56. Gerry, as he was known to his friends and colleagues, was an active scientist engaged in many activities involved in the biological oceanography of Long Island Sound and was one of the key chapter authors of the biology and ecology of the Sound.

Gerry was born in Brooklyn, New York, and was introduced to marine science as a student intern at the New York Aquarium. He graduated, magna cum laude, with his Bachelor of Sciences Degree in Biology from St. John's University where he developed a keen interest in microzooplankton, in particular, tintinnid ciliates. He received his Masters and Doctoral Degrees from Stony Brook University and accepted his initial academic appointment at Purchase College (SUNY) in 1983. It was at Purchase College where he developed an active teaching and research program dealing with Long Island Sound. He moved through the academic ranks at Purchase College, ultimately earning his professorship and was the chair of the environmental science program until his departure to Saint Mary's College in 1997.

Gerry was an activist and an enthusiast for his science. He was fervently devoted to his students and gave them unreserved attention. Gerry supervised more than 60 undergraduate research theses and was an active member of graduate student committees at the University of Connecticut. On the day of his passing, he had taken his students on a trip to the Pacific Ocean! While at Purchase College, Gerry was actively involved in many institutions and organizations around Long Island Sound including: Westchester County's Long Island Sound Advisory Committee; The Science and Technical Advisory Committee of the Long Island Sound Study; The Science Advisory Committee of the Connecticut Audubon Society; he served on the Board of Directors and the Executive Committee of Sound Waters; he was a member of the Board of Trustees of Save the Sound Inc. (formerly Long Island Sound Taskforce of the Oceanic Society); and he was a member of the Education, Program, and Science Committee of the Board of

Directors for the Maritime Aquarium at Norwalk. He was also a visiting scientist at The Bermuda Biological Station, a research scientist at the Department of Marine Sciences at The University of Connecticut and a member of the summer core faculty at the Shoals Marine Laboratory, Cornell University, and University of New Hampshire. In 1988, Gerry was a session chairman and keynote speaker for a NATO Advanced Study Institute held in England on protozoan ecology. After he relocated to California, he joined the Board of Directors of the Aquarium of the Pacific's Marine Conservation Research Institute.

Gerry's scholarship was as varied as his personal interests. He authored numerous scientific publications dealing with Long Island Sound. Gerry was the lead proponent that there was an alteration of the planktonic food web structure of Long Island Sound due to eutrophication via the paradigm of the microbial loop. In 2002, he was the lead author of a major treatise on the biological oceanography of Long Island Sound entitled "The Planktonic Food Web Structure of a Temperate Zone Estuary, and Its Alteration Due to Eutrophication" (Hydrobiologia). In 1990, Gerry published *The Ecology of Marine Protozoa* (Oxford University Press), and in 2003, he published a nonfiction book on the role of symbiosis in the origin of the universe, life, and the development of ecosystems entitled *The Golden Braid: The Symbiotic Nature of the Universe* (Global Outlook Publishing). At the time of his death, he was particularly interested in the role of symbiosis in the structuring of marine ecological interactions. He was focusing his research on the relationship between the aggregating sea anemone, *Anthopleura elegantissima (Brandt)* and its zooxanthellae. He was also writing a very popular newspaper column called *ECOfocus* for Clayton Pioneer newspapers (Clayton, California). Gerry was truly a very talented and gifted writer, who was able to communicate with his colleagues as well as the general public.

The loss of Gerry Capriulo is widely and deeply felt, most certainly by his family including his sister, parents-in-law, his daughters Lauren and Rebecca, and his wife Amelia. We are all so fortunate that through Gerry's insights we have a better understanding of the structure and functioning of Long Island Sound's estuarine and coastal ecosystems and food webs. Although we are all greatly saddened by the abrupt and untimely end of a very productive colleague, we should find a degree of solace in knowing that some of Gerry Capriulo's scientific thought and inspiration has passed to his students and colleagues. The editors wish to dedicate this volume to the memory of Prof. Gerard M. Capriulo. His spirit will be a guiding force for researchers and students interested in the Long Island Sound ecosystem for years to come.

Charles Yarish

Preface

Endeavoring to synthesize the estuarine science of Long Island Sound (LIS) from the perspective of public policy and management is not new. Published more than 35 years ago, *The Urban Sea: Long Island Sound* (Koppelman et al. 1976) and *Long Island Sound: An Atlas of Natural Resources* (CTDEP 1977) provided cross-disciplinary perspectives with an eye toward laying a foundation for still developing coastal management programs. Contemporaneous to these efforts, though not directly linked, was the development of comprehensive, interdisciplinary regional management plans, either centered around LIS (New England River Basin Commission 1975), or directed at portions of the watershed (e.g., Nassau-Suffolk Regional Planning Board 1978). Reflecting perhaps both the optimism and level of resources available at the time, those planning efforts were ambitious in scope and remarkable for the breadth of federal, state, local, and public involvement in their development. Even today they are instructive reading.

Yet the need for synthesis remains and has, if anything, grown stronger (Carpenter et al. 2009). Consider the ever increasing amount of specialized data and information about coastal and estuarine systems (Valiela and Martinetto 2005). Consider 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. And also consider the increased demand by policy makers and the public to translate science, so that it is understood and applied more efficiently and effectively to address these challenges in a world of limited public resources.

But the challenges to synthesis for management are formidable. Resolving discrete environmental problems with directed management in isolation from other social and economic needs may no longer be feasible. The scale of human pressures on the ecosystem is shifting from local land modification and resource harvest to global pollutant deposition and climate change. Understandably, the consequent interaction of cause and effect has become blurred despite improving science, fueling debates about probable outcomes of action and the compromises of cost. The future variability of natural systems such as stream flow or storm intensity may no longer be predictable from historical conditions due to anthropogenic changes in the Earth's climate (Milly et al. 2008). If so, management models will need to account for those structural changes and integrate them more fully with human societal and economical needs. Failure to adapt management approaches accordingly could threaten or slow the progress achieved in the 40 years since enactment of the Clean Water Act.

These factors and trends are evident in the continuing management of LIS. The practical genesis of this book can be traced back to a 2007 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 LIS, had already developed a Comprehensive Conservation and Management Plan, formally approved in 1994 under requirements laid out in the Clean Water Act. But the science upon which the plan was based was approaching 20 years old and the management lexicon of the time didn't even include climate change. Much new research had been conducted, and 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 (McLeod et al. 2005) and adopted by policymakers (National Ocean Council 2012, New York Ocean and Great Lakes Ecosystem Conservation Act 2006).

Hobbie (2000) described synthesis as "the bringing together of existing information in order to discover patterns, mechanisms, and interactions that lead to new concepts and models." Kemp and Boynton (2012) defined synthesis as "the inferential process whereby new models are developed from analysis of multiple data sets to explain observed patterns across a range of time and space scales." They further emphasized the key need to "improve mutually supporting linkages between synthesis research and coastal management."

The purpose of this book then is to bring together existing information about LIS, to take stock of what we know, in order to help discover and explain its patterns and mechanisms. Six technical chapters sum our knowledge about its human history, geology, physical oceanography, geochemistry, pollutant history, and biology and ecology. It is expected that a more synthetic knowledge of the science of LIS will provide a firmer foundation for improving ecosystem-based management—particularly as we confront climate change. To test this, the last chapter attempts to identify the linkages between the scientific synthesis of LIS and environmental management.

While the book is largely targeted to a technical, scientific audience, it is our belief that science is too important to be left exclusively to scientists, planning too important to be left exclusively to planners, and environmental management too important to be left exclusively to managers. Successful ecosystem-based management of LIS will require that if the old walls between these fields must remain, they should at least have larger windows.

References

Carpenter et al (2009) Bioscience 59(8):699–701

Connecticut Department of Environmental Protection (1977) Long Island Sound: an atlas of natural resources. Hartford

Kemp WM, Boynton WR (2012) Synthesis in estuarine and coastal ecological research: What is it, why is it important, and how do we teach it? Estuaries Coasts 35:1–22

Koppelman LL, Weyl PK, Gross MG (1976) The urban sea: Long Island Sound. Praeger, New York, p 223

Hobbie JE (2000) Estuarine science: the key to process in coastal ecological research. In Hobbie JE (ed) Estuarine science: a synthetic approach to research and practice. Island Press, Washington, pp 1–16

McLeod KL, Lubchenko J, Palumbi SR et al (2005) Scientific consensus statement on marine ecosystem-based management. http://www.compassonline.org/sites/all/files/document_files/EBM_Consensus_Statement_v12.pdf. Accessed 18 Feb 2011

Milly PCD, Betancourt J, Falkenmark M et al (2008) Stationarity is dead: wither water management? Sci 319:573–574

Nassau-Suffolk Regional Planning Board (1978) The Long Island comprehensive waste treatment management plan. vol 1: Summary Plan

National Ocean Council (2012) Draft National Ocean Policy Implementation Plan. http://www.whitehouse.gov/sites/default/files/microsites/ceq/national_ocean_policy_draft_implementation_plan_01-12-12.pdf. Accessed 22 Feb 2012

New England River Basins Commission (1975) Final report of the Long Island Sound regional study. vol 1 Summary, Vol 2 Supplement

New York Ocean and Great Lakes Ecosystem Conservation Act (2006) Environmental Conservation Law. Article 14. http://www.oglecc.ny.gov/media/ECL_Article%2014.pdf. Accessed 22 Mar 2012

Valiela I, Martinetto P (2005) The relative ineffectiveness of bibliographic search engines. Biosci 55(8) pp 688–692

Acknowledgments

This project received support from the US Environmental Protection Agency under Cooperative Agreements LI-97183601 and LI-97186501 with the Connecticut Sea Grant College Program, University of Connecticut, and Cooperative Agreement LI-97241708 with the New York Sea Grant College Program, Research Foundation of SUNY. We wish to heartily acknowledge the support and perseverance of the following people and organizations. Without their help, this project would never have been accomplished.

Thomas Bianchi	External Peer Review	Texas A&M University
Jon C. Boothroyd	External Peer Review	University of Rhode Island
Robert Christian	External Peer Review	Eastern Carolina University
Sylvain DeGuise	Funding Logistics	CT Sea Grant
William Dennison	External Peer Review	University of Maryland
Johanna Hunter	Funding Logistics	EPA New England
Virge A. Kask	Scientific Illustration	UCONN Biology Central Services
Jason Krumholz	Special Editing	NOAA NMFS
Jim Kuwabara	External Peer Review	US Geological Survey
Natalie A. Naylor	External Peer Review	Hofstra University
Edna Nolfi	Special Editing	EPA Long Island Sound Office
Cornelia Schlenk	Funding Logistics	NY Sea Grant
Bonnie W. Stephens	Technical Editor	Stony Brook University
Kuo Wong	External Peer Review	University of Delaware

Contents

Contributors

W. Frank Bohlen Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Malcolm Bowman School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Vincent T. Breslin Science Education and Environmental Studies, Southern Connecticut State University, New Haven, CT 06511, USA

Drew Carey Coastal Vision, Newport, RI 02840, USA

James T. Carlton Williams-Mystic Maritime Studies Program, Williams College, Stonington, CT 06355, USA

Robert Cerrato School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

J. Kirk Cochran School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Daniel Codiga Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882, USA

Carmela Cuomo Department of Biology and Environmental Sciences, University of New Haven, West Haven, CT 06516, USA

Hans Dam Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Rob DiGiovanni Riverhead Foundation for Marine Research and Preservation, Riverhead, NY 11901, USA

Chris Elphick Department of Ecology and Evolutionary Biology, University of Connecticut, Groton, CT 06340, USA

Todd Fake Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Diane B. Fribance Department of Marine Science, Coastal Carolina University, Conway, SC 29528, USA

Michael Frisk School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

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

Christopher Gobler School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Lyndie Hice School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Penny Howell Marine Fisheries Division, Connecticut Department of Energy and Environmental Protection, Hartford, CT 06106, USA

Adrian Jordaan University of Massachusetts Amherst, Amherst, MA 01003, USA

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

Ralph Lewis Long Island Sound Resource Center, University of Connecticut, Groton, CT 06340, USA

Senjie Lin Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Sheng Liu Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Darcy Lonsdale School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Glenn Lopez School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Kamazima Lwiza School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Anne McElroy School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Maryann McEnroe School of Natural and Social Sciences, Purchase College, Purchase, NY 10577, USA

Kim McKown Bureau of Marine Resources, New York State Department of Environmental Conservation, East Setauket, NY 11733, USA

George McManus Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

John R. Mullaney US Geological Survey, East Hartford, CT 06108, USA

James O'Donnell Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Rick Orson Orson Ecological Consulting, Branford, CT 06405, USA

Bradley Peterson School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Chris Pickerell Cornell Cooperative Extension of Suffolk County, Riverhead, NY 11901, USA

Elizabeth Pillsbury Riverdale Country School, The Bronx, NY 10471, USA

Ron Rozsa Coastal Management Program, Connecticut Department of Energy and Environment Protection, Hartford, CT 06106, USA

Sandra E. Shumway Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Amy Siuda Sea Education Association, Falmouth, MA 02540, USA

Paul E. Stacey Great Bay National Estuarine Research Reserve, New Hampshire Fish and Game Department, Durham, NH 03824, USA

Kelly Streich Bureau of Water Management Planning and Standards, Connecticut Department of Energy and Environmental Protection, Hartford, CT 06106, USA

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

Stephanie Talmage School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

Gordon Taylor School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA

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

Ellen Thomas Department of Geology and Geophysics, Yale University, New Haven, CT 06511, USA

Karl K. Turekian Department of Geology and Geophysics, Yale University, New Haven, CT 06511, USA

Margaret Van Patten Connecticut Sea Grant, University of Connecticut, Groton, CT 06340, USA

Johan Varekamp Earth and Environmental Sciences, Wesleyan University, Middletown, CT 06459, USA

Jamie Vaudrey Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Marilyn E. Weigold Dyson College of Arts and Sciences, Pace University, Pleasantville, NY 10570, USA

Michael Whitney Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA

Gary Wikfors Northeast Fisheries Sciences Center, National Oceanic and Atmospheric Administration, Milford, CT 06460, USA

Robert E. Wilson 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, Groton, CT 06340, USA

Roman Zajac Department of Biology and Environmental Science, University of New Haven, New Haven, CT 06516, USA

Acronyms and Common Units

ADCP	Acoustic Doppler Current Profilers
ASP	Amnesic Shellfish Poisoning
ASR	Aquatic Surface Respiration
AVS	Acid-Volatile Sulfides
BBiom	Bacterial Biomass
BIS	Block Island Sound
BSi	Biogenic Silica
BNP	Bacterial Net Production
BOD	Biological Oxygen Demand
BTZ	Benthic Turbidity Zone
C&GS	Coast and Geodetic Survey
CB	Chesapeake Bay
CCE	Cornell Cooperative Extension of Suffolk County
CCMP	Comprehensive Conservation and Management Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Carbonate Fluorapatite
Chl *a*	Chlorophyll *a*
CLIS	Central Long Island Sound
cm	Centimeters
cm/s	Centimeters Per Second
CMSP	Coastal Marine Spatial Planning
C/N	Carbon to Nitrogen Ratio
COD	Chemical Oxygen Demand
CORGM	Marine Organic Carbon
CORGT	Terrestrial Carbon
CORGWW	CORG flux from WWTFs
CR	Connecticut River
CSO	Combined Sewer Overflows
CTD	Conductivity, Temperature, and Depth
CTDEP	Connecticut Department of Environmental Protection
CTDEEP	Connecticut Department of Energy and Environmental Protection (formerly CTDEP)

CTDEP MFIS	Connecticut Department of Environmental Protection Marine Fisheries Information System
CWA	Clean Water Act
DDA	Dark $DI^{14}C$ Assimilation
DDT	Dichlorodiphenyltrichloroethane
DIC	Dissolved Inorganic Carbon
DIN	Dissolved Inorganic Nitrogen
DNC	Dominion Nuclear Connecticut
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
dpm/L	Disintegrations Per Minute Per Liter
DSi	Dissolved Silica
EBM	Ecosystem-Based Management
EDC	Endocrine Disrupting Compounds
EF	Enrichment Factors
ELIS	Eastern Long Island Sound
EMAP	Environmental Monitoring and Assessment Program
EOBRT	Eastern Oyster Biological Review Team
EOC	Extracellular Organic Carbon
EOF	Empirical Orthogonal Function
ERL	Effects Range Low
ERM	Effects Range Median
ESG	Eastern Sound Gyre
ESI	Environmental Sensitivity Index
ESID	EcoSpatial Information Database
EXRK	Execution Rocks
FIS	Fishers Island Sound
FOAM	Friends of Anoxic Mud
FVCOM	Finite-Volume Coastal Ocean Model
$g/m^2/yr$	Grams Per Square Meter Per Year
g/mole	Grams Per Mole
GESAMP	The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIS	Geographic Information System
GNHS	Geological and Natural History Survey
GPP	Gross Primary Production
GSA	Gill Surface Area
gww	Grams Wet Weight
HAB	Harmful Algal Blooms
Hb	Blood Hemoglobin
HR	Housatonic River
I-95	Interstate 95
I-287	Interstate 287
JFM	January, February, and March
kg/d	Kilograms Per Day

kg/s	Kilograms Per Second
kg/m^3	Kilogram Per Meter Cubed
kg/ha/yr	Kilogram Per Hectare Per Year
kg/day	Kilograms Per Day
LIE	Long Island Expressway
LILCO	Long Island Lighting Company
LIPA	Long Island Power Authority
LIRR	Long Island Rail Road
LIS	Long Island Sound
LISICOS	Long Island Sound Integrated Coastal Observing System
LISS	Long Island Sound Study
LISTS	CTDEEP LIS Trawl Survey
LOI	Loss on Ignition
MAB	Middle Atlantic Bight
MFIS	Marine Fisheries Information System
m/Pa	Meters (sea level rise) Per Pascal (unit wind stress)
m/s	Meters Per Second
m/y	Meters Per Year
m/yr	Meters Per Year
m^3/d	Cubic Meters Per Day
m^3/s	Meters Cubed Per Second
m^3/yr	Meters Cubed Per Year
mg/l	Milligrams Per Liter
m/s^2	Meters Per Second Squared
MHW	Mean High Water
mg/kg	Milligrams Per Kilogram
mg/kgww	Milligrams Per Kilogram Wet Weight
mg/L	Milligrams Per Liter
microgram/g	Micrograms Per Gram
Mkg/yr	Million Kilograms Per Year
mm/yr	Millimeters Per Year
$mmol/m^2/day$	Millimoles Per Meter Squared Per Day
mol/L	Moles Per Liter
MOS	Margin of Safety
NADP	National Atmospheric Deposition Program
NAO	North Atlantic Oscillation
NASQAN	National Stream Quality Accounting Network
NAWQA	National Water Quality Assessment
NCA	National Coastal Assessment
NCE	Nitrogen Credit Exchange
NDBC	National Data Buoy Center
NEIWPCC	New England Interstate Water Pollution Control Commission
NEP	National Estuary Program
ng/g	Nanograms Per Gram
ng/gdw	Nanograms Per Gram Dry Weight

ng/gww	Nanograms Per Gram Wet Weight
NGVD	National Geodetic Vertical Data
NHANES	National Health and Nutrition Examination Survey
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPP	Net Primary Production
NRC	National Research Council
NS&T	National Status and Trends
NURC	National Undersea Research Center
NURTEC	Northeast Underwater Research Technology and Education Center
NWC	Northwest Control
NYCDEP	New York City Department of Environmental Protection
NYSDEC	New York State Department of Environmental Conservation
OHO	Oxyhydr(oxides)
OM	Organic Matter
OMZ	Oxygen Minimum Zones
P	Grazing Percentage
PAH	Polycyclic Aromatic Hydrocarbons
PBDE	Polychlorinated Dibenzodioxins and Furans and Polybrominated Diethyl Ethers
PCA	Principal Component Analysis
PCBs	Polychlorinated Biphenyls
PE	Peconic Estuary
PFC	Perfluorinated Compounds
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane Sulfonate
P-I	Oxygen-Based Photosynthesis-Irradiance
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
PPCPs	Pharmaceuticals and Personal Care Products
psu	Practical Salinity Units
QAC	Quaternary Ammonium Compounds
RCRA	Resource Conservation and Recovery Act
REMOTS	Remote Ecological Monitoring of the Seafloor
RFMRP	Riverhead Foundation for Marine Research and Preservation
ROV	Remotely Operated Vehicle
RPD	Redox Potential Discontinuity
S	Salinity
SPI	Sediment Profile Imaging
SoMAS	School of Marine and Atmospheric Sciences
SQUID	Sediment Quality Information Database
SSER	South Shore Estuary Reserve
SWEM	Systemwide Eutrophication Model

T	Temperature
TBT	Tributyltin
TDI	Total Dissolved Inorganic Nitrogen
TDIP	Total Dissolved Inorganic Phosphorus
TDML	Total Maximum Daily Load
TOC	Total Organic Carbon
TIN	Total Inorganic Nitrogen
TRS	Total Reduced Sulfides
μg/g	Micrograms Per Gram
μg/gdw	Micrograms Per Gram Dry Weight
μg/gww	Micrograms Per Gram Wet Weight
μg/L	Micrograms Per Liter
USACE	US Army Corps of Engineers
USGS	United States Geological Survey
WLIS	Western Long Island Sound
WWTF	Wastewater Treatment Facilities

Childe Frederick Hassam (1859 -1935). The Mill Pond, Cos Cob, 1902; Oil on canvas, 26 ¼ x 18 ¼ in. Collection of the Bruce Museum, Greenwich, CT, Anonymous Gift, 94.25

William Sidney Mount (1807-1868). Crane Neck Across the Marsh, 1841. Oil on panel, 12.875 x 17". The Long Island Museum of American Art, History & Carriages. Gift of Mr. and Mrs. Carl Heyser, Jr., 1961

Chapter 1
Long Island Sound: A Socioeconomic Perspective

Marilyn E. Weigold and Elizabeth Pillsbury

1.1 Discovery and Early Settlements

Four centuries ago Captain Adriaen Block, a Dutch merchant, undertook multiple voyages to the New York area to engage in the fur trade. In the course of one of his three or four trips, he discovered the waterway that nineteenth century statesman Senator Daniel Webster called the "American Mediterranean." According to most accounts, the discovery was made in 1614 when Block and his crew, whose ship the *TIGER* was destroyed by fire, constructed a new vessel in Manhattan (Hart 1959) and sailed it up the East River through the swirling torrents of Hell Gate, and out into the open Sound (Stokes 1967). Some sources suggest that the discovery of the Sound occurred during the 1612 voyage Block made on another ship, the *FORTUYN,* or the 1612–1613 journey to New Netherland undertaken on the same ship. During that trip, Block may have sailed from east to west in Long Island Sound (LIS) in 1613 (Stokes 1967). Sailing the opposite way in 1614, Captain Block explored the Connecticut coastline, as well as the Connecticut River, landed at Montauk and possibly on Block Island (Varekamp 2006).

A decade later, the Dutch established a permanent settlement on Manhattan Island and a short-lived settlement consisting of only a few families near the mouth of the Connecticut River. The latter venture lasted only 2 years but Dutch traders continued to visit the area to secure furs from the native inhabitants. They were displaced, however, by the English who built Fort Saybrook at the mouth of the Connecticut River (Cave 1996). English settlement of the Sound shore of Connecticut proceeded rapidly after the Pequot War of 1637, which decimated the native peoples of eastern Connecticut (Eisler 2001). In 1638, the New Haven Colony was founded and within a few years

M. E. Weigold (✉)
Dyson College of Arts and Sciences, Pace University, Pleasantville, NY 10570, USA
e-mail: mweigold@pace.edu

E. Pillsbury
Riverdale Country School, Bronx, NY 10471, USA
e-mail: epillsbury@riverdale.edu

J. S. Latimer et al. (eds.), *Long Island Sound*, Springer Series on Environmental Management, DOI: 10.1007/978-1-4614-6126-5_1,

it spawned settlements in Branford, Guilford, and Stamford on the Connecticut coast and across the Sound in Southold on the North Fork of Long Island. By the mid-1600s, English settlers from Massachusetts and Connecticut moved to Huntington and other places along the Island's north shore, including the area from Oyster Bay west through Queens, a region originally included in the New Netherland Colony.

1.2 Transportation

1.2.1 The Sound as a Nautical Highway

Whether they dwelled on the mainland or on Long Island, inhabitants of the Sound area used the waterway as a nautical highway to transport locally produced foodstuffs to the markets of New York City and Boston. In the first half of the seventeenth century, the settlers of eastern Connecticut and eastern Long Island established strong ties with Boston, not only because of their proximity to the Puritan metropolis but because of the New Netherland colony's onerous trade regulations. Once the British assumed control, renaming the colony New York, Manhattan became a popular destination for trading vessels departing from ports up and down the Sound. Some ships venturing forth from LIS harbors participated in the coast-wide trade while others transported dried fish, lumber, and other items to the West Indies and brought back sugar and spices (Decker 1986). The harbor of Black Rock, a thriving maritime center long before the community was absorbed by neighboring Bridgeport, was home port for vessels engaged in the West Indian trade. Farther east on the mainland coast, New London assured its prominence in the West Indian trade by building sizable vessels capable of transporting considerable cargo. In recognition of both its location at the eastern end of the Sound and its growing trade, a customs commissioner was appointed for New London in the mid-seventeenth century (Caulkins 1852). In 1756, a customs house for the western part of the Sound was established in New Haven. Three decades later, with its thriving maritime activity centered around Long Wharf, New Haven was a major seaport on LIS (Maynard 2004). In addition to its trade with the Far East, Europe, and the West Indies, in the nineteenth century New Haven generated income from sealing and whaling. Although New London was Connecticut's premier whaling port, Mystic, Stonington, Bridgeport, East Haddam, and Norwich sent out whaling vessels, as did Cold Spring Harbor on the north shore of Long Island.

1.2.2 Overland Travel

Although trips to faraway places, whether on whaling ships or trading vessels, could be very lucrative, most inhabitants of the Sound shore area did not venture far from home. But they did have to stay connected with the outside world.

Consequently, as settlements expanded from the immediate coastline to the hinterland of the Sound, roads were needed to connect the interior with the wharves that were a key element in trade. The inhabitants of areas of Connecticut located on rivers flowing into the Sound could transport their farm products by boat downriver to coastal ports, but mainland colonists who were not so well situated had to rely upon roads, some of which were merely enhanced versions of Indian trails. Given Long Island's paucity of rivers, roads, such as they were, constituted the only viable way to get to the coast. In contrast, with the limited north/south roads leading to the Sound was the east/west North Country Road (Newsday 1998). While it extended from the western end of Long Island all the way out to Suffolk County, a trip on the road was something to be endured rather than enjoyed. A keen-eyed rider on horseback may have been able to spot and avoid the inevitable ruts in the road, but a fully loaded coach was not so maneuverable. Its passengers were jostled as the vehicle swayed from side to side and if it touched down in a crater, even momentarily, its human cargo could literally hit the ceiling.

Travelers on the mainland side of the Sound were no less immune to these hazards. The Boston Post Road, portions of which were laid out in the 1670s, could be challenging (Baird 1974). Frigid temperatures and snow in winter made for slow going and during the spring thaw the ribbon of highway linking the Sound shore communities turned into a sea of mud. Even in good weather, coaches leaving lower Manhattan for the long trip to Boston often journeyed no farther than Rye the first day. A libation from the tap room of Haviland's Inn, a good meal, and a night's rest, such as it was given the fact that colonial regulations stipulated that five men could occupy a bed, prepared the weary travelers for the next day's adventure on the Post Road. At different times, John Adams and George Washington passed this way and stayed at the widow Haviland's Inn (Baird 1974). Earlier in the eighteenth century Sarah Kemble Knight, an Englishwoman traveling between Boston and New York on horseback, forded streams, rode over rickety wooden bridges, and stayed at inns that were, in her view, mostly inferior. Now and again, such as in New Rochelle, she was pleased with her accommodations (Knight 1935). No matter how comfortable the lodgings along the way, getting to one's destination by traveling overland remained an ordeal. All of this changed in the early nineteenth century, however, with the introduction of steamboats on LIS.

1.2.3 The Era of Steam Navigation

The age of steam had commenced in 1807 with the successful voyage of Robert Fulton's *CLERMONT* on the Hudson River. The War of 1812 delayed the introduction of steamboats on the Sound but the year after the conflict ended, Captain Elihu Bunker piloted the aptly named steamboat *FULTON* 75 miles between New York City and New Haven in 11 h. The return trip stretched out to 15 h because of rough seas. This was, nevertheless, quite an achievement. Within a year, Captain Bunker had a new ship, *COMMONWEALTH*. All white, except for its vivid green trim, the vessel was anything but understated. But this was all to the good because the eye-catching *COMMONWEALTH* stimulated interest in steam navigation. By 1817, regular service between New York and New Haven was instituted and quickly increased from two trips per week to three. For a time, the all-water route was suspended because the New York State legislature had granted a monopoly to Robert Fulton's company. As the exclusive legal provider of steamboat service on the state's waterways, the Fulton interests were able to prevent others from plying New York waters. This led to a makeshift arrangement whereby Connecticut captains steamed down to Greenwich, on the New York border, where passengers boarded stagecoaches for the remainder of their journey to Manhattan (Baird 1974). To the delight of captains and travelers, this considerable inconvenience ended in 1824 when the Supreme Court of the United States, in the case of Gibbons v. Ogden, ruled the Fulton monopoly unconstitutional. This decision inaugurated an era of unfettered competition among steamboat companies as they vied with one another to attract customers by offering more comfortable ships, bargain fares, and faster trips.

To reach their destination in the shortest possible time, some captains did not stop to refuel but instead were supplied with fresh wood, the fuel used by the first generation of steamboats, by sloops near Fishers Island in the eastern Sound. In the 1830s, coal was substituted for wood. Steamboats were able to carry enough of it to make non-stop trips, even if excess coal was required to plough through heavy seas or to challenge a rival boat to a race. Some of these contests had disastrous results because a great deal of steam pressure was required to achieve maximum speed and this could lead to explosions. Following a race between the *PROVIDENCE* and the *NEW ENGLAND* in 1833, the latter vessel exploded when it reached its destination, Essex on the Connecticut River upstream from the Sound (Daily Herald 1833). Such accidents engendered fear in the traveling public but steamboat designers came up with a solution, namely to elevate steamship boilers by placing them above the deck. Passengers were relegated to the lower deck, which was deemed safer in the event of an explosion. The famous British author Charles Dickens traveled throughout the Sound on a boat of this design on an American tour in 1842 and found the vessel disagreeable from an aesthetic standpoint. More pleasing in appearance were traditionally designed steamboats, most of which operated quite safely. Now and again, however, there were horrific accidents and they were not always the result of racing.

Although the *LEXINGTON*, which had been built for Commodore Cornelius Vanderbilt, had engaged in a famous race with the *JOHN W. RICHMOND*, racing had nothing to do with the loss of the *Lexington*. Instead, it was improper placement of cargo on the top deck of the ship that set off a dreadful chain reaction on a frigid night in January 1840. Since the hold of the ship was already full, bales of cotton being shipped to New England textile factories were placed on the upper deck next to the smokestacks. Given the extremely cold weather and ice floes in the Sound, the ship's boilers were working overtime to propel the vessel through the angry waters. As the *LEXINGTON* made its way east, sparks from the smokestacks ignited the cotton. With the ship engulfed in flames, Captain George Child pointed the vessel toward the Eaton's Neck lighthouse off Huntington, but the tiller ropes burned and he was unable to steer. At that point, the lifeboats were launched, but only one made it to the north shore of Long Island. It was empty, but four people did survive by clinging to unburned bales of cotton. One person drifted 40 miles east, scaled the bluffs at Baiting Hollow, and walked nearly a mile to a house whose inhabitants took him in. In the aftermath of the sinking of the *LEXINGTON*, unscrupulous opportunists who had read accounts of the disaster in New York City newspapers converged upon the beaches of the north shore to peel through the wreckage in hopes of finding hard currency carried by businessmen traveling on the ship that night. This prompted New York State to dispatch guards to patrol a fifteen mile stretch of the north shore to safeguard bodies, baggage, and anything else that washed up in the aftermath of a disaster that claimed 120 lives (McAdam 1957).

A predictable but temporary falloff in steamboat travel occurred following the sinking of the *LEXINGTON,* but the introduction of larger, beautifully appointed vessels helped overcome passenger apprehension. The ships of the Fall River Line, founded in 1847, were especially popular (Covell 1947). The Narragansett Steamship Company, established by financiers Jay Gould and Jim Fisk in the 1860s, competed with the Fall River Line by offering beautiful décor and personnel outfitted in natty uniforms (Covell 1947). Accurate charts of LI waters produced by the US Coast Survey beginning in the 1830s contributed to a safe passage through the Sound. The Coast Survey's charts and LI maps were the federal government's "first major venture in scientific cartography" (Allen 1997). A half century after the first charts were produced, steamboats and other vessels plying the waters of LIS experienced an easier passage through Hell Gate, a treacherous stretch of swirling water in the vicinity of today's Robert F. Kennedy Bridge (Triborough Bridge), after the US Army Corps of Engineers used dynamite to eliminate underwater rocks in 1876. The blast was the world's largest up to that time (Jackson 1995). LIS steamboats were not the only vessels to benefit from this. Ships coming into New York Harbor from the Atlantic had to cross a sand bar at Sandy Hook. Ships drawing more than 23 feet of water could not navigate this obstacle and, as a result, New York Harbor's future was limited unless the federal government appropriated sufficient funds to rectify the problem. Absent a huge Congressional appropriation, the solution was to enhance the Hell Gate passage, enabling large ships to transit from the Atlantic to LIS and down to New York Harbor (Klawonn 1977).

In addition to vessels that passed through Hell Gate and plied the whole length of LIS linking New York with Boston and other New England destinations, there were vessels that transported New Yorkers to seaside resorts in Connecticut and Long Island. Some of these ships were owned by the Montauk Steamboat Company, which became a subsidiary of the Long Island Rail Road (LIRR) in 1899 (NYT, May 14, 1899, 3).

The LIRR had been conceived in the 1830s by Brooklyn business interests who spied an opportunity to make a fortune by transporting people between New York and Boston by way of Long Island. Absent a direct rail link between those two cities on the mainland, and gambling on the likelihood of none materializing in the near future because of the cost of bridging the rivers flowing into the Sound, the LIRR's investors funded the creation of a line from the western end of the Island, which was easily reached by ferry from Manhattan, to Greenport on the North Fork (Ziel 1965). There, Boston bound passengers took a steamboat across to Stonington, CT where they boarded a train for the remainder of the 11.5-h trip to Boston. When the LIRR made its debut as a major regional carrier in 1844, there was a gigantic celebration at the Greenport railroad station. But the merriment so evident on that occasion gave way to gloom and doom just 4 years later when the New York, New Haven, and Hartford Railroad completed a line from New York to New Haven where it linked up with an existing line running inland to Hartford and Springfield and across to Boston. This all-rail route soon became the preferred way to travel between Manhattan and New England, and the LIRR was reduced to being a local line serving an area whose population would be insufficient to support a railroad until the next century. Following bankruptcy in 1850, the LIRR gradually recovered and built feeder lines running to north shore communities that started to grow thanks to tourism and, in the twentieth century, suburbanization. In 1891, the LIRR attempted to revive its cross-Sound service by transporting railroad cars on the Oyster Bay line to Wilson Point in Norwalk, CT on special ferries. The cars were then connected to trains heading to different points in New England. It was a novel idea but it did not attract the anticipated ridership.

Far more popular were excursion and commuter steamboats. They did a lively business in the summer by transporting people on day trips to picnic groves along the Sound and by delivering New Yorkers to their summer residences. One of the most popular commuter vessels was the *SEAWANHAKA,* which remained a favorite of its regular passengers even after losing an exciting race in 1867 to the *JOHN ROMER* of the Greenwich and Rye Steamboat Company, whose president was William Marcy Tweed, the notorious boss of New York City's corrupt Tammany Hall political machine. More than a dozen years later, on a June day in 1880, the *SEAWANHAKA* caught fire as it headed up the East River en route to its regular stops in Roslyn and Sea Cliff on the north shore of Nassau County. The ship's quick-thinking captain, Charles Smith, beached the vessel on a shoal, enabling most of the passengers to escape. Despite the encroaching flames, he did not let go of the wheel until the boat came to rest (NYT, June 30, 1880, 1). Not far from where the *SEAWANHAKA* met its fate, the excursion steamer *GENERAL SLOCUM* burned and sank with the loss of over a thousand lives in June 1904 as it headed out to the Sound on a church-sponsored excursion. Three years later, the steamer *LARCHMONT* of the Joy Line went down off Watch Hill, RI with the loss of at least 189 lives. A final determination of the number who perished could not be made because the passenger list was aboard the sunken ship (NYT, Feb. 13, 1907, 2). There were four casualties in January 1935 when the *LEXINGTON* of the Colonial Line went down in the East River (NYT, Jan. 4, 1935, 44). That same year the Fall River Line, which had been acquired by the New Haven Railroad in an effort to regulate competition between land and sea transport, suspended its New London service. Other service suspensions followed, as did a strike. Combined with the line's growing deficit during the Great Depression, the work stoppage proved to be the final blow. The Fall River Line was phased out by the New Haven Railroad in 1937 and its famous sidewheel steamboats, the *COMMONWEALTH*, the *PRISCILLA*, the *PLYMOUTH,* and the *PROVIDENCE* were sold for scrap. Six years earlier steamboat service from Hartford to New York via the Connecticut River and LIS had been terminated (Delaney 1983).

1.2.4 Ferries

Just as it had been a factor in the demise of the steamboat business on LIS, the Great Depression curtailed but did not totally eliminate cross-Sound ferry service. One line that did vanish during the 1930s, the Rye-Oyster Bay ferry, had existed since 1739. In the colonial era, the ferry was an important economic stimulus. A store that was part of the ferry complex in Rye stocked an array of goods, including textiles, foodstuffs, guns, gunpowder, and rum (New York Mercury, April 30, 1759, Supplement, 2). A retail establishment of this type was able to thrive because its customers included not only residents who lived nearby but countless ferry travelers, including Westchester Quakers who during the summer months traveled to Long Island to worship with brethren at the Matinecock Friends Meeting House in Glen Cove (Fox 1919). Some people who traveled on the ferry moved permanently to the opposite side of the Sound and transported their farm implements and household possessions with them. The original price list for the Rye-Oyster Bay ferry noted the cost of transporting such items as beds, bedding, and tables (Weigold 1975). Besides the Rye ferry, in the eighteenth century there was cross-Sound service from New Rochelle to Hempstead and from New London to Orient Point.

Although colonial era ferries served an important purpose, they were utilitarian sailing vessels that simply transported people from one side of LIS to the other. The ferries of the early twentieth century, in contrast, were, in a sense, pleasure craft because their patrons often boarded, with or without automobiles, with the thought of a nautical outing, perhaps combined with a picnic on the other side of the waterway. This was especially so during the 1920s, which was the golden era of ferries on the Sound. During that decade, it was possible to cross the waterway at numerous points. At the western end of the Sound, there was a ferry linking Clauson Point in the Bronx with College Point in Queens. Moving a bit eastward, there was service between New Rochelle and Sands Point, Rye and Sea Cliff, and Rye and Oyster Bay. The ferries originating in Rye were operated by the same company that linked Greenwich and Oyster Bay. The Long Island terminus for these vessels was actually Bayville, in the Town of Oyster Bay.

The Greenwich-Oyster Bay service supposedly originated upon the recommendation of industrialist Andrew Carnegie, who at one point had to get from the mainland to Long Island without delay. The trip for Mr. Carnegie and his carriage cost $250. Theodore Roosevelt paid considerably less in 1917 when